EVALUATION OF WATER HARVESTING REBATE PROGRAMS IN TUCSON, AZ

by

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1: Introduction

As freshwater continues to become scarce around the world, alternative water management solutions will be necessary. Current over pumping practices, aided by long droughts, cause wells to dry up in the western United States, and a brutal drought in East Africa puts the whole region at risk of famine as crops fail and animals die. In the face of such massive problems, people search for new solutions and review old solutions to utilize every drop of water.

Harvesting rainwater and stormwater has long been used to make more of the resource in areas where it is scarce. The practice may have first been developed in 4500 BCE (Li et al. 2000). The basic design behind rainwater harvesting has not changed since its inception; basically, runoff from surfaces is directed and channeled into a storage area. Stormwater harvesting is also used to redirect excess water to prevent erosion and other damaging runoff. Graywater is the untreated wastewater produced by washing clothes, bathing areas, and sinks (Ghaitidak and Yadav 2013). There are many methods to harvest water, ranging from simple to complex methods. On the simpler side, harvesting water involves well-placed dirt berms or hoses to redirect water. On the more complex side, harvesting water may involve more expensive storage tanks, diverter valves, and other plumbing infrastructure. Much of the focus of water harvesting has been on semi-arid and arid environments, but the use of water harvesting strategies has not been limited to any one application.

Many water providers are looking for ways to encourage conservation. One of those ways is subsidizing conservation measures, which include rebates or tax breaks for low-flow toilets and fixtures, high-efficiency washing machines, graywater systems, and rainwater harvesting systems. In Arizona, Tucson Water has used these measures to promote water conservation and indicated an interest in delving further into measuring the impacts of their water harvesting incentive programs (City of Tucson 2017e). These include houses that have received graywater and rainwater rebates and incentives.

A 2016 National Academy of Sciences report on graywater identifies several areas of needed research, including assessing regulatory innovations to increase onsite water use, understanding how water harvesting systems affect water use behavior, assessing user knowledge of water harvesting systems, and further understanding the extent that best management practices are implemented (National Academies of Sciences, Engineering, and Medicine 2016). Furthermore, maintenance costs, techniques, and ideal schedules for maximum system productivity are relatively unknown for water harvesting infrastructure (Desert Water Harvesting Initiative 2013a). This study is designed to provide insights into water harvesting, water use behavior, the extent of user knowledge, the extent of the best management practices, and maintenance requirements of the systems.

This thesis investigates three research questions regarding the water harvesting rebate program implemented by Tucson Water. The first two questions are about the water harvesting system maintenance. In particular, they are about the maintenance requirements for the systems and the practices implemented by water harvesters in Tucson. Two hypotheses are offered based on these questions: (1) The results will indicate that preventative maintenance is required for continuous operation of the systems. (2) The most common maintenance practice is repairing broken pipes. These hypotheses are based on the fact that many outdoor watering systems require preventative maintenance, and it is not uncommon for pipes to break in the weather. The third question is whether water harvesting systems increase the vegetation on parcels where they are installed. The hypothesis related to this question is that the properties of the water harvesting rebate recipients will have significantly more vegetation (greenness) after the system was installed compared to the properties that did not receive a rebate. This hypothesis is formulated because adding an additional source of no cost irrigation water might push people to irrigate more than before the water was available. A survey was conducted to examine the first two questions. Remote sensing was used to compare the Normalized Difference Vegetation Index (NDVI) values of the properties before and after the rebate program was implemented to answer the second question.

2: Background

Tucson is a city in Pima County in Southern Arizona with a total population of 531,641 in 2015. Pima County's population was approximately 1 million in 2015 (US Census Bureau 2016). According to the 2010 United States Geological Survey (USGS) water census, Pima County withdraws 305.43 million gallons per day (mgd) of freshwater from all sources. The City of Tucson's water utility, Tucson Water, delivers water to 722,700 people, one-third of which reside outside the city limits. In 2016, the utility delivered 118 gallons of water per capita per day (GPCD) to all users, although the delivery to residential customers was 82 GPCD. The general per capita deliveries include commercial and industrial users, whereas the residential per capita value does not (City of Tucson 2017a). Tucson has 144,191 acre-feet of the Colorado River water allocated through the Central Arizona Project (CAP) (Central Arizona Project 2015). The CAP water has the lowest priority on the river, meaning that it is the first one to face cuts to its yearly allocation if the water level in Lake Mead falls below 1,075 ft above sea level and a shortage is declared pursuant to the 2007 Interim Guidelines for Lower Basin Shortages and Coordinated Operations for Lake Powell and Lake Mead (Bureau of Reclamation 2015). There are also priority levels within the CAP system, in which Tucson has a municipal and industrial priority. High priority means that water deliveries to Tucson will not be cut until all excess deliveries and non-Indian agriculture deliveries have been cut (Central Arizona Project 2016).

The western United States is known for its aridity and difficulties surrounding water are increasingly becoming widespread and pertinent. How water should be used or reused is often debated; utilities promote conservation by encouraging their customers to harvest and reuse water from various sources among other activities. Water conservation is defined as “any beneficial reduction in water use or water loss” (Baumann et al. 1984). In the literature, water conservation is rarely explicitly defined, instead is used colloquially to indicate demand-side management strategies (e.g. Abdel-Rahman and Abdel-Magid 1993; Otaki et al. 2017; Brelsford and Abbott 2017). Demand-side management strategies focus on demand reductions as opposed to the supply-side management strategies, which focus on water source expansion (Kanta and Berglund 2015). Water harvesting is considered both a demand-side and a supply-side strategy (Brooks 2006) and Tucson Water refers to the rebates given for rainwater and graywater harvesting as “Water Conservation Rebates” (City of Tucson 2017e).

There is a wide variety of rainwater and graywater harvesting systems. On the graywater side, systems range from a bucket in a sink to a complex multi-thousand-dollar diversion and treatment system. In Arizona, the Administrative Code lays out graywater rules in Title 18, Chapter 9, section 711 and 719. It defines graywater as wastewater from sinks (except the kitchen sink), bathing areas, and washing machines. The code was changed in 2001 to make legal graywater use more straightforward and simplify the role of the state. Tucson has had several iterations of graywater ordinances over the years that have mandated various levels of graywater integration into new developments (City of Tucson 2008). Tucson Water, the largest water utility in the Tucson area, started a graywater harvesting rebate program in 2012. In order to qualify for the full $1,000 incentive, the system had to be installed after January 1, 2013 and the recipient must take a designated class about graywater (City of Tucson 2017b). Other areas in the United States (US) that offer financial incentives for graywater systems include San Diego, CA; Santa Clara, CA; Santa Rosa, CA; and Tempe, AZ (Gauley et al. 2015)

On the rainwater side, Tucson Ordinance 10597 has started to require that commercial development use harvested rainwater for at least 50% of landscaping needs since June 2010 (Garrison et al. 2011). Rainwater harvesting rebates were first offered to the customers of Tucson Water in 2012.The program was updated in 2015 to include curb cuts that allow stormwater to enter the right-of-way from the street and water rain gardens in street-side basins. The level of complexity in these systems can vary significantly. Rebates are given for passive systems that add berms, swales, and basins to direct water through a landscape. They also cover more complex and expensive active systems including tanks that capture and store water for future use. The program covers up to 50% of the materials, not to exceed $500 for passive systems and up to $1 per gal of tank size, not to exceed $2,000 for active systems. A single customer is not eligible for more than $2,000 in a combined rainwater harvesting system rebate. Very large systems, the ones over 5,000 gal, require a permit but systems under that do not as long as certain requirements are met. In order to qualify, the recipient must attend one three-hour workshop and submit a project plan (City of Tucson 2017d).

Other areas in the US that provide financial incentives for some form of rainwater harvesting are San Diego, CA; Santa Rosa, CA; Kitsap County, WA; Santa Monica, CA; Palo Alto, CA; Prescott, AZ; Flagstaff, AZ; Allen, TX; Austin, TX; Sunset Valley, TX; and Albuquerque, NM. Some of these incentives are based on the amount of water stored, but most are for some sort of infrastructure (Meehan and Moore 2014). For those areas interested in implementing and promoting water harvesting, the Desert Water Harvesting Initiative, an effort by the University of Arizona Water Resources Research Center "to enhance outreach and communication between utilities, practitioners of water harvesting, academics, and interested citizens" (Desert Water Harvesting Initiative 2017), identified five policy options that will help with this goal: 1) Installation of Demonstration Sites and Pilot Projects, 2) Removal of Code Barriers, 3) Creation of Stormwater Utility/Fees, 4) Provision of Incentives, and 5) Development of Regulation (Desert Water Harvesting Initiative 2013b).

3: Objectives

The objectives of this research are two-fold. The first is to present a more complete picture of the maintenance requirements for water harvesting systems. This is accomplished by conducting a survey of residents who received water harvesting rebates from Tucson Water. The second objective is to measure the changes in the Normalized Difference Vegetation Index (NDVI) of the properties that received a rebate before and after the program was initiated. NDVI is a measure of plant productivity (greenness). A higher NDVI value indicates more plant productivity and therefore more greenness. The NDVI values will be compared to the changes in NDVI of the properties that did not receive a rebate over the same time period. NDVI is used as a proxy for residential irrigation practices (Halper et al. 2012); thus, a change in NDVI indicates a change in irrigation practices. Using this method, the irrigation practices of water harvesters are compared to those who have not received a water harvesting rebate. More irrigation would lead to higher plant productivity and greenness. There are three possible outcomes of this comparison: 1) Water harvesters can have a similar change in greenness to those who did not receive a rebate. This might occur if harvested water is used in lieu of municipal water and the amount of water used for irrigation remains the same. 2) Water harvesters can have more positive changes in NDVI. A positive change would indicate a higher degree of greenness after the systems were installed than before. This might happen if water harvesters expand their irrigated areas or plant more densely. 3) Water harvesters can have a larger negative change in NDVI. A negative change would indicate a lower degree of greenness after the systems were installed than before. This might occur if water harvesters irrigate less after installing a system or remove vegetation.

4: Literature Review

4.1: Rainwater harvesting

4.1.1: General Information

There is evidence of rainwater harvesting as early as the 4th century BC. Experiments done on large stone mounds in the Negev Desert in Israel demonstrate that these structures would have been very effective at harvesting water at the rain events that are typical of the area (Lavee et al. 1997). Rainwater harvesting can cover a wide range of activities. In rural areas, small catch dams can be constructed across washes to collect rainwater for irrigation and livestock watering. Fields or other parcels of land can have berms, swales, and ditches constructed in such a way to direct rainwater to allow plants to harvest a greater amount of water than they could in a natural state. This type of rainwater harvesting is called passive rainwater harvesting (Figures 1–4). Rainwater can also be collected from rooftops and other impermeable surfaces and directed to other places or collected in tanks or catch basins to be distributed later. These types of systems are called active rainwater harvesting systems (Figure 5) (Kinkade-Levario 2007). These definitions are also used by Tucson Water (City of Tucson 2017c). The University of Arizona Cooperative Extension occasionally uses different terminology for active and passive systems. They have used the term “complex” for “active” and “simple” for “passive” (Waterfall 2006). In other documents, they use the term “passive system” in the same way as Tucson Water (Daily and Wilkins 2012).

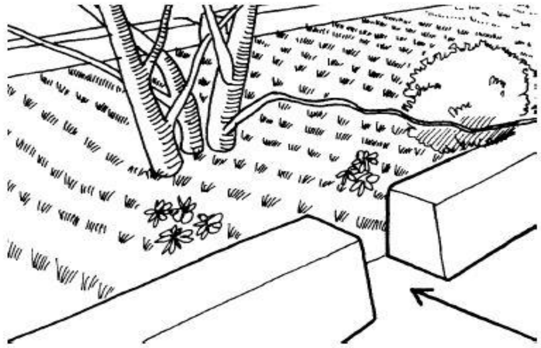
Brad Lancaster has been a driving force of the innovation behind water harvesting and an advocate for many years. His books and reports on water harvesting are highly regarded and include detailed information about assessing resources, choosing a system, integrated design, erosion control, soil fertility, water quality, and much more (Lancaster 2013; Lancaster and Marshall 2013). He has identified "Eight Universal Principles of Successful Water Harvesting" (Lancaster 2007, 2013):

1. Long and thoughtful observation to assess site resources and challenges.
2. Start at the highpoint of the watershed and work down to take advantage of lower volumes and flow velocities.
3. Start small and simple because scaling up is better than being overwhelmed, plus numerous small earthworks distribute water better than few large ones.
4. Slow and spread the flow of water to reduce erosions and encourage infiltration.
5. Plan an overflow route and use the overflowed water as a resource.
6. Maximize living and organic groundcover, which increases the sponge-like quality of the soil.
7. "Stack functions" such as designing cisterns that collect water while controlling the stormwater and placing vegetation and cisterns so that they can shade buildings in the summer.
8. Continually reassess the system to increase efficiency.

Examples of Passive Systems:

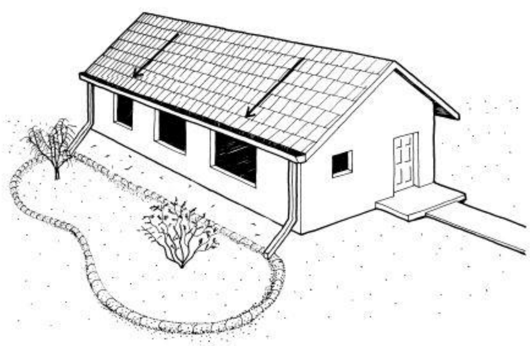
Simple system — Roof catchment, channel and planted landscape holding area.

Figure 1: Example of passive system 1. Source: "Harvesting Rainwater" (Waterfall 2006)



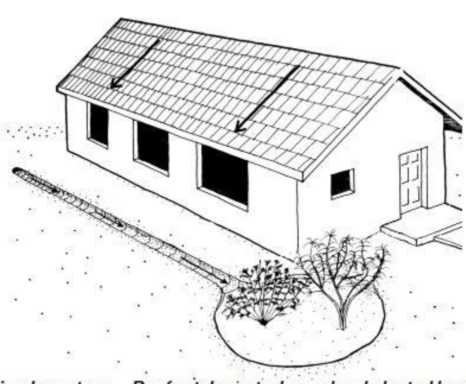
Parking lot curb cutout directing water into planted area.

Figure 2: Example of passive system 2. Source: "Harvesting Rainwater" (Waterfall 2006)



Simple system — Roof catchment, gutters, downspouts and bermed landscape holding area.

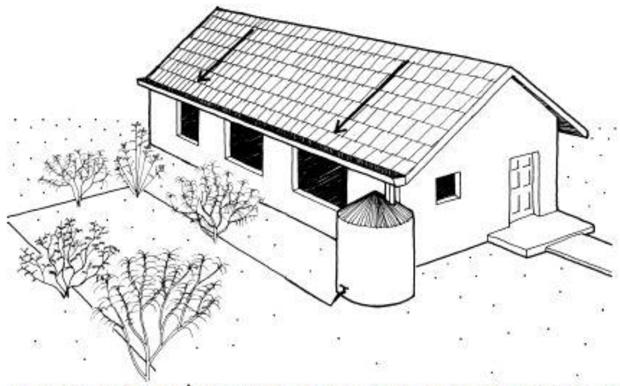
Figure 3: Example of passive system 3. Source: "Harvesting Rainwater" (Waterfall 2006)



Simple system — Roof catchment, channel and planted landscape holding area.

Figure 4: Example of passive system 4. Source: "Passive Water Harvesting" (Daily and Wilkins 2012)

Example of Active System:



Complex water harvesting system with roof catchment, gutter, downspout, storage, & drip irrigation distribution system.

Figure 5: Example of active system. Source: "Harvesting Rainwater" (Waterfall 2006)

4.1.2: Maintenance

Passive systems require little maintenance at minimum or no cost. Active systems may require more maintenance due to the increased number and complexity of components, which largely depend on the intended use of the harvested water (US Environmental Protection Agency 2013). Common maintenance requirements for rainwater harvesting include keeping the holding areas free of debris; controlling and preventing erosion; cleaning and repairing the channels, dikes, berms and moats; keeping gutters and downspouts free of debris; flushing debris from the bottom of storage containers; cleaning and maintaining filters; and expanding the areas of water concentration as plants grow (Waterfall 2006). The most common of these requirements is debris removal and filter cleaning. In systems with tanks, inspecting the tank regularly is recommended and pump maintenance depends on the type and set up of the pump (US Environmental Protection Agency 2013). The frequency of these requirements varies and is summarized in Table 1. The tasks in Table 1 represent the best practices but very few states or cities have codified maintenance for rainwater harvesting systems (US Environmental Protection Agency 2013).The Water Environment Research Foundation estimated the cost of maintenance requirements including inspection, reporting, cleaning roof and filters, sediment removal, and pump replacement at $1,068/yr (Water Environment Research Foundation 2009).

Table 1: Suggested Maintenance. Source: Virginia DCR Stormwater Design Specification No. 6 – Rainwater harvesting (Virginia Department of Conservation and Recreation 2013)

Suggested Maintenance Procedures for Rainwater Harvesting Systems	
Activity	**Frequency**
Keep gutters and downspouts free of leaves and other debris	Twice a year

Inspect and clean pre-screening, inlet filtration devices, and first flush diverters	Four times a year
Inspect and clean storage tank lids, paying special attention to vents and screens on inflow and outflow spigots. Check mosquito screens and patch holes or gaps immediately	Once a year
Inspect condition of overflow pipes, overflow filter path, and/or secondary runoff reduction practices	Once a year
Inspect tanks for sediment buildup	Every third year
Clear overhanging vegetation and trees over roof surface	Every third year
Check integrity of backflow preventer (unless required more frequently by state or local regulations)	Every third year
Inspect structural integrity of tank, pump, pipe, and electrical system	Every third year
Replace damaged or defective system components	Every third year

4.1.3: Agriculture

The adoption of rainwater harvesting techniques in agriculture is dependent on a multitude of factors. Socio-economic factors are especially important in less developed areas of the world. Since passive rainwater harvesting techniques are virtually cost free, studies have investigated what factors make a farmer more or less likely to adopt some of these techniques. The number of years in school is a strong predictor of the adoption of rainwater harvesting techniques (Recha et al. 2015). Other factors include the availability of labor to do the work required for more complex techniques and the amount of land owned (Recha et al. 2015).

Research done in China has shown some promise of using rainwater harvesting as a way to improve production of rainfed crops as well as prevent soil erosion in semi-arid regions. China has a long history of collecting rainwater for survival and some of these traditional techniques are being adopted to work with modern agriculture. The impetus for the research in some areas of China is not only the cost of large-scale water collection facilities but also the unavailability of surface water and the brackishness of groundwater. Furthermore, the landscape is not conducive to irrigation development as it is hilly, which contributes to high production costs and potentially prices the water out of the realm of usability for growers in these areas (Li et al. 2000).

Another advantage of rainwater harvesting in agriculture can be erosion prevention. In sandy soils of the parts of China where much of this technology has been developed, erosion is commonplace. Farmers have been forced to grow crops on sandy hillslopes to achieve sufficient yield. After rainwater harvesting systems were put in place, farmers were able to meet practical needs while only farming on flatter areas (Li et al. 2000).

Cropping patterns are also important in taking full advantage of rainwater harvesting in rainfed agriculture (Akhtar et al. 2016), which may also help mitigate some of the effects of climate change especially in areas where irrigation is not an option (e.g., sub-Saharan Africa). Lebel et al. (2015) provide a look at much of the African continent and its potential to benefit from rainwater harvesting under changing climate. To summarize, much of the continent will continue to benefit from rainwater harvesting until the 2050s under climate change with increased radiative forcing.

In agricultural practice, external and in situ water harvesting systems are part of rainwater management strategies. In situ water harvesting, in particular, is part of a broader agricultural practice called conservation agriculture, which also involves specific tillage and soil conservation practices. Conservation agriculture, in some form, is practiced on 40% of the rainfed farmland in the Unites States (Rockström et al. 2010). This practice goes well beyond rainwater harvesting techniques and has been well documented in the literature as a whole, but not explicitly as rainwater harvesting. Knowler and Bradshaw (2007) provide a synthesis of the recent research on conservation agriculture.

4.1.4: Domestic/Urban

There is a long history of rainwater harvesting at the household level. Ancient civilizations harvested water for domestic use and this practice continues to this day in many parts of the world. Developed countries moved away from harvesting water and focused on centralized water distribution systems, especially in urban areas. Recently, as water conservation has become a more recognized practice, more attention has been paid to rainwater harvesting in developed areas of the world. In these areas, rather than being driven by necessity, voluntary adoption of rainwater systems is more often driven by a desire to be environmentally friendly and/or a desire to feel self-reliant (Sharma et al. 2016). While using rainwater for drinking water has become less popular in more developed countries, developing countries continue to use rainwater harvesting as a source of drinking water. This is because groundwater is often unattainable due to the poor pumping technology and high costs, and surface water may be highly polluted (Helmreich and Horn 2009).

In developed countries, water harvesting is frequently driven by a desire to control stormwater runoff (Sharma et al. 2016). Semi-arid cities such as those in the southwestern United States have a higher stormwater management potential than regions with greater than 762 mm of annual precipitation (Steffen et al. 2013). Water harvesting systems are subsidized in some countries such as Germany to increase the amount of impervious surfaces not connected to the sewer system. This is often a cheaper alternative than improving sewers to have a higher carrying capacity. (Sharma et al. 2016).

Cities with greater than 762 mm of annual precipitation have the potential to reduce urban water use by about 50%, while semi-arid cities may only be able to reduce urban water use by up to

30%. Semi-arid cities have more potential for high rooftop yield, which is the runoff volume captured by the cistern divided by the total rooftop runoff volume. This is driven by cistern size, water use patterns, and precipitation patterns (Steffen et al. 2013). While a city such as Tucson may only be able to reduce urban water use by 30% using rainwater harvesting, a large portion of the rain that falls can be captured. A European Union Directive encourages urban water savings by rainwater harvesting and other methods, but the level of encouragement in each country varies. France does not have much rainwater harvesting adoption; the UK encourages it, but does not have any subsidy programs; and Sweden is installing harvesting systems in large housing complexes (Sharma et al. 2016).

Australia is an outlier in rainwater harvesting among developed countries. The 1990s saw a paradigm shift towards sustainable urban development. During this time, several model projects that incorporated rainwater harvesting were developed. These projects were well publicized and the use of rainwater as an additional source of water in these projects was successful. Following these demonstration projects, there was an extended drought in much of Australia in the 2000s. Reservoir levels fell and there was a real possibility of major cities running out of water. This prompted action to bring alternative water sources online as quickly as possible. Along with wastewater reuse and desalination, rainwater harvesting was heavily invested in. Rebates and other incentives allowed for rapid expansion of rainwater harvesting systems for non-potable uses including toilet flushing and garden irrigation. Long-term strategic planning documents now reflect the idea that rainwater harvesting can be a critical part of a city's water supply and demand balance (Sharma et al. 2016).

In many countries around the world, developed and undeveloped, surveys have been used to assess various aspects of rainwater harvesting. In Nigeria, a survey was used to assess the physical makeup of rainwater harvesting systems, practices of harvesters, and the rainwater harvesting maintenance culture. Most harvesters had similar rainwater harvesting systems; all of them used rainwater for washing; some of them had some sort of first flush device; and some cleaned their tanks at least once a year (Igbinosa and Osemwengie 2016). A survey was also implemented in Bangladesh to assess the physical characteristics of rainwater harvesting systems and the best practices of the population. The construction of the harvesting systems varies quite a bit and harvesters use the collected water for drinking and washing for a part of the year. For the remainder of the year, they drink arsenic-contaminated groundwater or untreated surface water (Karim 2010). Another survey was conducted in the UK to measure the receptivity of water users' to rainwater harvesting. Maintenance and cost were found to be the largest limitations of receptivity to rainwater harvesting but overall, respondents were open to the idea (Ward et al. 2013).

4.1.5: Industrial/Commercial

Studies of industrial or commercial rainwater harvesting often focus on return on investment (ROI). Some studies find ROI for rainwater harvesting systems to be negative, while others show the opposite. A review by Wang and Zimmerman (2015) demonstrates that the ROI of water harvesting systems depends on a multitude of factors. One factor is the stormwater fee. The higher the stormwater fee is, the more likely a system that captures a chunk of the stormwater will pay off. Another major factor is the design of the system. It is critical that tanks are sized properly for the catchment area and are placed in such a way that reduces pumping costs. Pumping costs are often overlooked in analyses but play a big role in large distribution systems. Tanks that are placed in such a way as to allow for gravity-fed distribution have the ability to greatly reduce pumping costs and thus the lifetime cost of the system (Wang and Zimmerman 2015).

At the commercial scale, the concentration of the population served by the system is also an important factor. A warehouse with a large collection system and only a few toilets that can be flushed with collected rainwater is less likely to have a positive ROI than a large office building with multiple toilets and other non-potable uses. The potable water savings are strongly correlated with the precipitation patterns in various locations. Arid areas have less potential for water savings but have a greater potential to increase the control of stormwater. Arid areas are drier but tend to have higher-intensity precipitation events that lead to more intense runoff from impervious surfaces. Higher stormwater fees in these areas greatly increase the likelihood of receiving a positive ROI on a rainwater system (Wang and Zimmerman 2015).

Rainwater harvesting models are relatively common but empirical studies are not conducted very often. A study by Ward et al. (2012) continuously tracked the use of water by a rainwater harvesting system in an office building in the UK for almost a year. The efficiency of water savings was calculated by dividing the volume of rainwater consumed by the system and then used to estimate the payback period. There were some maintenance issues with the system, which caused the system to stop working for some time. When this time period was excluded, the efficiency of water savings was calculated to be 97% (Ward et al. 2012) but excluding that time period seems unrealistic as it is not uncommon that there are maintenance and plumbing issues with any water delivery system. Having the backup of city water may have contributed to the delayed repair because it may have lowered the sense of urgency in repairing the system. Furthermore, as the authors pointed out, high efficiency was partly due to the building being under-occupied while the rainwater harvesting system was designed for full occupancy. The building was only about one-third full; thus, it was not surprising that the rainwater harvesting system was able to meet the full demand most of the time. Further studies that track long-term usage will be necessary to better calculate the feasibility and desirability of commercial-scale rainwater harvesting systems.

4.1.6: Additional Considerations

There are multiple considerations to consider before installing rainwater harvesting systems. The first is the cost efficiency. Rebates are often used to offset these costs but in areas where there are no rebates, it may not be cost efficient to install rainwater harvesting systems. A study by Farreny et al. (2011) looked at the cost effectiveness of rainwater harvesting in large housing complexes linked together as a single harvesting unit. The study looks at several different scenarios and determines that rainwater harvesting systems do not make sense economically unless water prices are raised to the levels recommended by the European Union and if the buildings are analyzed separately. At the neighborhood scale and with higher prices, the payback period was calculated as 27 yr (Farreny et al. 2011). Despite what the Australian case demonstrates in section 4.1.4, the economics are quickly overshadowed by the prospect of running out of water looming large.

Another important aspect to consider is the long-term supply of rainwater. Compared to the large dams with high evaporative losses and costs coupled with uncertain precipitation and the costs and benefits of smaller scale, localized rainwater harvesting systems become increasingly popular (Edmunds and Cardona 2006). A number of modeling tools have been developed to assess the long-term supply of rainwater. These models use data on historical rainfall, roof catchment area, rainfall loss factor, tank volume, and water demand to optimize and estimate the long-term yield of the system. Tank storage size can also be optimized using models such as this one. It is important to have a properly sized tank so as not to misuse the resources on a tank too large or run out of storage with a tank too small. Many of these models assume multiple water uses such as toilets, washing machines, and garden irrigation (Sharma et al. 2016).

Economic factors are not the only the ones to consider in analyzing rainwater harvesting systems; environmental impacts are also important. Decentralized systems are by their nature more material intensive than centralized systems; however, large dams require five to ten times the money per cubic meter of water storage compared to the local rainwater management schemes (Edmunds and Cardona 2006). The extra material required for decentralized systems supports the idea that it is critical to size tanks appropriately to reduce wasted materials (Wang and Zimmerman 2015; Ward et al. 2012). These systems do help control stormwater, which can reduce eutrophication and non-point source pollution. Again, energy for pumping also has an environmental impact and is often more than that of the established water systems but this can be mitigated by wisely locating the tanks (Ward et al. 2012). Environmental factors are essential to performing a robust viability assessment of the rainwater harvesting systems.

4.1.7: Southern Arizona

Rainwater harvesting has been studied, experimented with, and engineered in and around Tucson since the mid-1970s when a computer program to design a water harvesting system was developed (Cluff 1984). The City of Tucson considers water harvesting a way to manage water demand (Tucson Water 2004). A study by Lancaster (2007) estimated that 70% of the water used by an average user in Tucson can be supplied by direct rainfall. Microbial and metal concentrations of harvested rainwater in Tucson has been documented in the literature (Jordan et al. 2008) but there are few peer-reviewed articles on the other aspects of water harvesting in Tucson.

In Sierra Vista, AZ and the surrounding communities, the grants for rainwater harvesting systems were available for a period of five years, but are no longer. Ongoing pilot and demonstration projects educate and inform the community about rainwater harvesting (Daily 2012; The Cochise Water Project 2012). While there are no published reports available about the outcomes of these programs, the Administrative Director of the Cochise Water Project in Sierra Vista, Tim Cervantes, has drawn some preliminary conclusions. First, [complex] water harvesting systems are not considered as water conservation methods because while they might reduce municipal water use, the water savings come at a high cost of $0.60/gal compared to $0.02/gal for water-saving toilets and $0.0002/gal for smart irrigation systems. Second, if the goal is to promote a conservation ethic, then large "in your face" water tanks in public places raise awareness more effectively than tanks hidden in residential yards. The Cochise Water Project has received a lot of positive feedback about the large public systems that it supports (Cervantes 2017).

The impediments to and the motivators of rainwater harvesting in the Sierra Vista area were studied by using background geographic data and several surveys. There was a high degree of interest in using rainwater harvesting and the largest impediment to expanding current systems was the lack of funds. Very few survey respondents who currently harvest rainwater had a negative view of their harvesting systems. The survey also investigated the user perception of municipal water use after harvesting began (Daily 2012).

4.2: Graywater Harvesting

In the United States, graywater is produced from washing machines, bathing areas, and sinks (Ghaitidak and Yadav 2013). In less developed areas of the world, reusing graywater is one option to overcome the decreasing per capita water availability due to rapid growth in population (Mandal et al. 2011). Graywater quality is a valid concern and is covered extensively in the literature. However, since graywater quality is beyond the scope of this paper, it will not be covered in this literature review. For an exhaustive compilation of graywater quality research, see Gross et al. (2015).

4.2.1: Around the World

Graywater reuse around the world is growing despite it being illegal in some areas. Allen et al. (2010) provides a thorough overview of graywater harvesting regulations around the world. To summarize, in the Middle East and Northern Africa, graywater regulations are often ill-defined or its use is illegal. Two exceptions are Israel and Jordan (Allen et al. 2010). Israel allows limited graywater use. It can only be used in non-residential buildings by professional personnel and must be brought to a very high quality. It is forbidden in single-family homes (Gross et al. 2015). Australia has very well-defined graywater policies at the state level and actively encourages the graywater use. Rebates are offered for installing graywater systems (Gross et al. 2015; Allen et al. 2010). Japan has mandatory graywater systems for buildings over 30,000 m^2. In Europe, Germany is a leader in graywater use (Allen et al. 2010; Gross et al. 2015). Graywater use is legal in Britain, but is not commonplace. Sweden and Norway have installed systems in some student housing developments and are studying them as a form of ecological sanitation. Most of South America and Africa have no formal regulations (Allen et al. 2010).

There is some concern that graywater use would lead to sewer blockages as peak flows decrease but studies indicate that the chances of blockages are minimal (Friedler and Penn 2011) and reductions in volume increase the infrastructure capacity for new users (US EPA 2016).

There are no known empirical studies of graywater systems other than the water quality, so the following sections of the literature review mainly focus on studies involving surveys. A survey was conducted in Deir Alla, Jordan to characterize the views of the population on water and wastewater, as well as “their motivation, practices, and concerns” related to two aspects of graywater reuse: treating the graywater and using the treated graywater for agricultural irrigation. The scarcity of water primarily determines which households are willing to use graywater (Ghrair et al. 2015). Surveys were also conducted to assess the public sentiment against various aspects of graywater in Australia (Christova-Boal 1995; Pinto and Maheshwari 2010) and Kenya (Raude et al. 2009).

4.2.2: The United States

The United States has no national graywater policies but approximately 30 states have some form of graywater regulations of their own (Sheikh 2010; Gross et al. 2015). Graywater is often used in rural areas, even in states that do not have regulations or that prohibit graywater use (Sheikh 2010). California has graywater use regulations but the use of graywater tends to follow drought occurrences. Some cities in California encourage the use of graywater. The California Plumbing Code has gone through several iterations regarding graywater over the years. The most recent iteration was passed in 2009 and states that a system that only uses one fixture does not require a permit. These users must meet 12 conditions formalized in the code (Sheikh 2010; Gross et al. 2015). These conditions are very similar to those in Arizona (below).

Florida has graywater regulations but most sewer companies do not allow graywater systems. There is a concern that there would be insufficient flow in the pipes to carry the waste to the plant and a concern about reduced water for reclaiming. Florida's regulations specify how long graywater can be stored and require all pipes be labeled and all graywater be dyed with a food-grade dye before it is sent to toilets. For residential uses, each occupant is allowed 25 gal/d for bathing areas and 15 gal/d for washing machines (Sheikh 2010).

Oregon has a complex permitting process for graywater use. All graywater users must have a permit for any use of graywater with one exception being Hughie sinks, which are the sink inserts that allow for people to collect water while using the kitchen sink. This exception was made based on the proposed research involving Hughie sinks. Since permitting each sink would have been prohibitively expensive, Oregon allows the use of kitchen sink water but only if it is used in a compost pile; it cannot be used on vegetation (Jarvis 2016). Graywater permits have three tiers depending on the size of the facility and the amount of graywater it will produce. Tier 1 is for a house with four bedrooms or less that produces less than 300 gal of graywater per day. Tier 2 is for facilities that produce less than 1,200 gal of graywater per day, and Tier 3 is for facilities that do not belong to the other tiers (Oregon Department of Environmental Quality 2016).

Nevada has a deliberately complex permitting process. All graywater use in the state must be permitted through the state health department. A special health district in Southern Nevada can technically issue permits, but does so very rarely (Bennett 2016). In Las Vegas, where most of the population resides, the concern is for return credits to the Colorado River. Las Vegas is also concerned about the efficiency of water use and there is a perception that all but the most informed customers would use graywater more inefficiently than the city (Bennett 2016).

Texas has regulations for graywater use for domestic, industrial, institutional, and irrigational purposes. A formal permit is not required for domestic use of less than 400 gal/d. North Carolina allows for permitted graywater for specific purposes, if treated to certain standards. New Mexico has a similar plan to Arizona's in that 250 gal of graywater per day may be used without a permit. Utah, Massachusetts, Oklahoma, and New York also have graywater regulations (Sheikh 2010).

In Colorado, graywater is not practical for most homeowners because it is regulated under individual sewage/disposal system guidelines. Although the Colorado Department of Public Health and Environment does not separate graywater from black water in these regulations, in rural areas where homeowners are already served by an individual sewage system, it is *possible* to install a graywater system, but it requires a significant amount of permitting and has very strict requirements (Waskom and Kallenberger 2012)

4.2.3: Arizona

Allen et al. (2010) and Gross et al. (2015) identify Arizona as a leader in graywater promotion and use. This state has simple guidelines for residential graywater users and does not require any formal permit for residential graywater use. There are only two rules pertaining to graywater in Arizona's Administrative Code, R18-9-711 and R18-9-719. The administrative code was changed in 2001 to make the graywater permitting program easier for people to participate while also simplifying the responsibilities of the state and to recognize the reality that many people were already operating graywater irrigation systems. An estimated 13% of Tucson residents were operating graywater systems by 1999 (Gross et al. 2015). The state has the best management practices that any graywater user has to follow to comply with the rules. These include:

1) Avoiding human contact with graywater,
2) Preventing graywater from running off the property,
3) Not irrigating food producing plants other than trees,
4) Prohibiting spraying of graywater,
5) Keeping it out of any wash or drainage,
6) Using in places where groundwater is five feet below the surface,
7) Labeling pipes that contain graywater under pressure,
8) Covering and sealing storage tanks that have hazardous chemicals,
9) Washing diapers and other infectious garments in the sewer system,
10) Keeping surface accumulation minimal,
11) Disposing of any backups in the normal sewer system, and

12) Ensuring that graywater use does not interfere with a private waste disposal system design requirements (Arizona Department of Environmental Quality 2016).

These practices are similar to the guidelines to reduce exposure and manage risk associated with graywater use (Gross et al. 2015). If residential users comply with these rules, then they may use up to 400 gal of graywater per day and are considered a permitted user of graywater. Producing more than 400 gal or non-residential use requires a formal permit. This permit is very “unwieldy” according to Chuck Graf, which means that there are probably many unpermitted users around the state (Graf 2016).

If the best management practices are not followed, then the state relies on a complaint system to find the violators. A graywater user would have to violate the regulations to a great enough extent to attract the attention of their neighbors or someone else to be reprimanded for breaking the rules. Therefore, there are quite possibly many people violating the rules, which means that the rules are not very effective in protecting public health (Graf 2016). This may not be an issue because before the revisions to the code in 2001, there were between 100,000 and 200,000 illegal graywater users in Arizona (Graf 2016). Furthermore, the Arizona Department of Environmental Quality (ADEQ) is not aware of any reported illnesses linked to the graywater use (Crook and Rimer 2009).

Tucson, AZ has an ordinance that requires graywater “stub-outs” in many new residential houses. Ordinance 10579 was initially passed in 2008 and required all new residential housing have a graywater diverter valve or a separate multi-pipe outlet on washer hook-ups as well as an outdoor “stub-out” to allow for direct irrigation. It also required separate drains on bathroom sinks, showers, and bathtubs that need to be able to be connected outside to a future “distributed graywater system” (City of Tucson 2008). In 2013, the ordinance was updated via ordinance 11089 due to the high cost of compliance of ordinance 10579. The updated ordinance requires that “All new residential dwelling units shall include piping to allow separate discharge of graywater for direct irrigation in accordance with Table 2601.2. Feasible graywater discharge piping shall be installed to allow for gravity distribution.” Table 2601.2 makes the requirements contingent upon the size of the “distribution area” or yard. For a house with a yard under 200 sq. ft., graywater attachments are optional. For yards between 200 and 400 sq. ft., one fixture is required, and for yards over 400 sq. ft. one fixture is required plus all bathing and washing machine fixtures must be above grade (City of Tucson 2008).

The original ordinance claims that a graywater system can save a typical household 13,000 gal of potable water a year, but no studies have been done to assess if there have been any water savings, or to what extent, in new homes equipped with these features.

In Arizona, information about graywater on state or city websites is plentiful. A simple search engine query of "Arizona graywater" yields multiple sources of information from official departments about graywater, including the Arizona Department of Water Resources and the Arizona Department of Environmental Quality. This information includes what graywater is, how it is used, and the regulations in Arizona as well as some of the potential dangers of using graywater inappropriately. Sheikh (2010) offers a robust chart with basic information about graywater in each state and where the regulations are found in the administrative code (pp. 49).

4.3: Remote Sensing to Measure/Evaluate Water Harvesting

Remote sensing and Geographic Imaging Systems (GIS) have been used to measure several effects of rainwater harvesting using a number of different methods. GIS has become a very useful tool in measuring these effects, which can be broken into three broad categories: identifying the suitability of rainwater harvesting; predicting the effectiveness of future rainwater harvesting projects while considering the potential changes in climate; and analyzing the effectiveness of existing rainwater harvesting locations.

4.3.1: Suitability

Suitability maps seem to be the most common way GIS is used for rainwater harvesting applications. This process has become fairly standardized in the literature. First, data are gathered and maps are created based on the criteria that are deemed essential for designating suitability. Since these criteria tend to be in different units, for example millimeter of rain and degrees of a slope, the criteria maps are classified into suitability classes. Each criterion is given a weight, which in some cases is equal for all maps and in other cases is not. The weighted maps are then combined to create an overall suitability map (Mahmoud and Alazba 2015; Mwenge Kahinda and Taigbenu 2011; Al-Shamiri and Ziadat 2012).

4.3.2: Evaluating Future Effectiveness

Using GIS to predict future effectiveness of rainwater harvesting is similar to creating suitability maps, but slightly more complicated. The basic concept is the same. First, the characteristics of areas that are conducive to rainwater harvesting are found and then, maps based on those characteristics are created, weighted, and combined to create a map of locations that would be effective under current climate conditions. The next step can be very complicated depending on the complexity of the model. The same characteristics chosen above must be altered based on at least one future climate prediction.

The complicated part is knowing how those characteristics will change as the climate changes (Lebel et al. 2015).

There is some good science behind the “basic” changes such as precipitation and temperature for various areas around the world but how they will affect the other natural systems is the subject of current research. The end result in models of this nature is to make assumptions that will account for a range of changes. Model coefficients can be altered to account for a variety of factors such as precipitation variability and vegetation response but the calculations of these coefficients can get very complicated. After the model is complete, the same steps for creating a suitability map can be used with the model-adjusted factors (Lebel et al. 2015).

4.3.3: Evaluating Existing Water Harvesting Systems

There is only one study that evaluates an existing rainwater harvesting system in an urban area and uses runoff prevention as a metric. The study performed in Tucson, AZ develops a method to measure the effectiveness of rainwater harvesting interventions. GIS is used to measure the capacity of rainwater catchments, which are then used as a metric in determining the reduction in runoff. This sort of process could be scaled up and applied to other rainwater harvesting methods using Remote Sensing and GIS to analyze the effect of rainwater harvesting at a larger scale (Psillas 2015).

While GIS and remote sensing are often used to assess rainwater harvesting potential at different scales, they have not been used to specifically assess how domestic rainwater harvesting affects small-scale landscape changes.

5: Methodology

This study has two parts: a survey about water harvesting system maintenance and remote sensing analysis. Both parts were designed in an informal partnership with Tucson Water to meet the research interests of the author and fulfill the monitoring requirements of the utility. Both parts require the same first step, which is to identify the residents that have received water harvesting rebates from Tucson Water. This was done using the records provided by Tucson Water. The identities of the rebate recipients were not disclosed to anyone outside Tucson Water, including the author. There were a total of 1,585 rebates given; 1,463 were rainwater harvesting rebates and 122 were graywater rebates.

5.1: Survey

User perception and practice about water harvesting systems are often assessed by conducting surveys (Karim 2010; Daily 2012; Raude et al. 2009; Al-Mashaqbeh et al. 2012; Igbinosa and

Osemwengie 2016; Ward et al. 2013; Pinto and Maheshwari 2010). The survey used for this study was developed by the author in consultation with an employee of Tucson Water (Candice Rupprecht, Water Conservation Program Manager) based on reviewing similar surveys and the employee's professional experience. The survey was reviewed by another Tucson Water employee, a water harvesting expert at the Watershed Management Group, a non-profit organization that provides "knowledge, skills, and resources for sustainable livelihoods" (Watershed Management Group n.d.) (including water harvesting). The survey was also reviewed by a survey design expert at the University of Arizona; however, it was not tested. Tucson Water was interested in the survey because evaluating all aspects of their current rebate programs is critical to improving future programs. Maintenance is one aspect of their rebate programs for which they did not have any information.

The survey was designed to take no more than 20 min to complete. It consisted of 17 questions about water harvesting systems and their maintenance (Table 2). See Appendix A for the complete survey.

Table 2: List of Survey Questions

Number	**Question**
Q1	What kind of water harvesting system(s) do you have? Select all that apply.
Q2	Please describe your water harvesting system(s).
Q3	Have any of the following issues with your system(s) occurred? Select all that apply.
Q4	If you've experienced maintenance issues with your system, were these issues expected? Please explain.
Q5	What preventative maintenance has been done on your water harvesting system(s) since installation? Select all that apply.
Q6	What repairs have been done on your water harvesting system(s) since installation? Select all that apply.
Q7	Of those maintenance actions selected in questions 5 and 6, please rank the top 3 most frequently done maintenance requirements. (1 being most frequent)
Q8	Of those maintenance actions selected in questions 5 and 6, which maintenance requirement is the greatest concern? Please indicate why your selection is the greatest concern.
Q9	How much do you spend on maintenance annually?
Q10	Of those maintenance actions selected in questions 5 and 6, what maintenance is performed on your water harvesting system(s) at the intervals below?

Q11	To what degree do maintenance requirements currently prevent you from using your system(s)?
Q12	If you indicated problems in the previous question, please indicate how long your system(s) has/have not been working as designed.
Q13	If part of your harvesting system(s) breaks or degrades, do you have the ability to repair it?
Q14	About how much time is spent managing your system(s) each time maintenance is performed?
Q15	Have maintenance issues affected the quality of your harvested water? If yes, please explain.
Q16	Based on your experience, would you install the same or similar water harvesting system again? Why or why not?
Q17	Is there other information you would have liked in advance of installing your water harvesting system? If so, please describe.

Since the survey involved human subjects, the University of Arizona Institutional Review Board (IRB) approval was necessary. The survey was approved on November 30, 2016 but deemed exempt from a comprehensive IRB review due to the lack of risk to the respondents. See Appendix D for IRB Approval Letter.

The survey was created in the online software Qualtrics and was sent by Tucson Water to the recipients of water harvesting rebates on December 16, 2016 using an anonymous link. The survey was left open until January 15, 2017 at which point all the open surveys were closed and the responses were collected.

Responses were counted and percentages were calculated. For the open-ended questions, the program Nvivo (QSR International, Australia, 2015) was used to calculate the word frequencies in the responses to each question using the "Word Frequency" query and the "root words" option in that the root of each word was created and all of the iterations of that word were counted together as opposed to in separate categories. For example, "tank" and "tanks" were counted together instead of one count being calculated for "tank" and one for "tanks." The "Word Tree" function was used to put the most frequent words in context. Common words such as "water" were removed from the analysis. Each question had different words removed. For example, the word "tank" may be a critical word in a question asking the respondent to describe their water harvesting system but not a useful indicator of a response to a question asking about tank damage. The most frequent words were used to identify the themes in open-ended responses.

5.2: NDVI Differencing

This study utilized the National Agriculture Imagery Program (NAIP) data provided through the United States Department of Agriculture Farm Service Agency to calculate the differences in NDVI between 2010 and 2015. The year 2010 was before the water harvesting rebate program was implemented and the year 2015 was three years into the program. The data are composed of georeferenced orthophotos with a spatial resolution of one meter. The spectral resolution is four bands: red, green, blue, and near infrared (NIR) and the temporal resolution is 3 yr. They are in a projected coordinate system of NAD 1983 UTM Zone 12N. The NAIP imagery was taken in the first two weeks of June for both the respective years. NDVI differencing is often used to assess land use/land cover changes as it relates to vegetation in which the change thresholds are set based on the standard deviation (Mancino et al. 2014; Hu, De Jong, and Sluiter 2004; Jensen 2016; Coppin et al. 2004; Singh 1989).

The digital numbers of the pixels provided with the NAIP data were converted into reflectance values using the United States government's Landsat 8 reflectance values provided through USGS Earth Explorer. The Landsat 8 platform collects data in 11 bands ranging from ultra blue to thermal infrared. The two bands used to convert the NAIP data were Band 5 (NIR) and Band 4 (Red), which both have a spatial resolution of 30 m. The Landsat reflectance values of one invariant light pixel and one invariant dark pixel were recorded for the red and NIR bands for 2010 and 2015. A light-colored patch of ground south of Tucson that did not change between 2010 and 2015 was used for the light reflectance value and a lake was used for the dark reflectance value. The Landsat reflectance values for both locations were different by two units or less between 2010 and 2015. At the invariant locations, the corresponding digital number value in the NAIP images was also recorded. Using the dark and light pixels, a simple linear equation was created to convert the digital numbers to the reflectance values for the red and NIR bands for both years of data (Jensen 2016).

Second, NDVI was calculated using the standard NDVI equation: NDVI= (NIR-Red)/(NIR+Red). Using Raster Calculator in ArcMAP, the 2010 NDVI image was subtracted from the 2015 NDVI image. All of the Pima County land parcels were provided by the Pima County Association of Governments (PAG). These parcels were clipped to the boundary of the Tucson Water service area and the pixel statistics for each parcel were calculated using the Zonal Statistics tool.

Third, a threshold for the change was calculated based on the standard deviation NDVI difference values of the parcels in the Tucson Water service area. The threshold is typically set between one and two standard deviations (Mas 1999). Each parcel had a mean value for the change in NDVI but since each parcel represented a different area, this value had to be normalized. Each mean parcel value was multiplied by the area of the parcel and then divided by the sum of all parcel areas. This value was then multiplied by 10^6 to make the values more manageable in ArcMap. Very small values were rounded to "0" in the software and multiplying by 10^6 was a simple and quick fix to this.

$$\Delta NDVI_{norm\,(i)} = \left(\frac{\overline{\Delta NDVI_i} * Area_i}{\sum_1^j Area}\right) * 10^6$$

In the above equation, (i) is the parcel of interest and (j) is the last parcel in the series. The mean and standard deviation of these normalized values were calculated and the upper and lower change thresholds were calculated as $\mu \pm n \cdot \sigma$; where μ is the mean normalized ΔNDVI value and σ is the normalized ΔNDVI value standard deviation. The value of n is identified by the "trial and test method" (Mancino et al. 2014).

The data were divided based on this threshold, which was first set using one standard deviation. All parcels with a ΔNDVI value above the upper threshold would have a significant positive change in NDVI and all the parcels below the lower threshold would have a significant negative change in NDVI. Experimenting with more standard deviations was deemed unnecessary due to the low number of parcels that had significant changes in NDVI.

The 719 parcels that received a water harvesting rebate between January 1, 2012 and December 31, 2014 were selected and the change thresholds calculated in the previous paragraphs were applied. These dates were used to allow for at least one full growing season to elapse before the imagery was taken in June 2015. This time frame allows for normal property green up, although it may not be able to account for behavioral changes in irrigation practices, i.e. people may not immediately alter irrigation patterns. If this is the case, the results would show a different amount of NDVI change for later rebates compared to the earlier rebates. In this case, the process would have been repeated with a different time frame. Next, twice the number of parcels that received a rebate was randomly selected. Parcels that received a rebate were excluded from this selection and the change thresholds were applied. The percentage of the parcels that exhibited significant changes for both the rebate and the random parcels was calculated.

Three areas of desert were selected using Google Earth on the outskirts of Tucson with natural desert land cover. One was selected to the east, one was selected to the south, and one was selected to the west of Tucson. These areas were selected because they are unirrigated and remain relatively unchanged (i.e. are not developed or visibly altered) in a five-year time period as confirmed by Google Earth time series images. Using Landsat 8, NDVI values were provided through USGS Earth Explorer and

NDVI differencing between 2015 and 2010 was completed for these areas. The USGS scales the NDVI values calculated from Landsat 8 data by a factor of 10,000, which results in a valid NDVI range of -10,000 to 10,000 (USGS 2016). The image for 2010 was taken on June 15, 2010 and the image for 2015 was taken on June 15, 2015. First, the 2010 image was subtracted from the 2015 image. Statistics of the individual pixel values were calculated. Using the method above, the upper and lower change thresholds were calculated based on the standard deviation and the mean. The percentage of pixels that exhibit significant changes in these natural areas was calculated (Jensen 2016) and this value was compared to the percentage of parcels that experienced significant changes in the random selection of parcels and the parcels that received a water harvesting rebate.

In NDVI studies investigating the effects of irrigation, it is necessary to control for precipitation (Halper et al. 2012). To account for the effect precipitation might have on NDVI in 2010 and 2015, rainfall data were downloaded from NOAA's National Centers for Environmental Information database. The daily precipitation at 36 weather stations in Tucson was recorded from May 1 to June1, 2010 and 2015. This time period was selected because greenness responds to the changes in precipitation with a delay of several weeks to a month (Castro et al. 2009). The NAIP imagery was collected during the first two weeks of June for both years; thus, precipitation that occurred during May could potentially affect NDVI in June. The average precipitation for this time period was calculated for each station. Using the coordinates of each station, the average precipitation in Tucson between May 1 and June 1 was interpolated using kriging (Biau et al. 1999) (Figures 6-8).

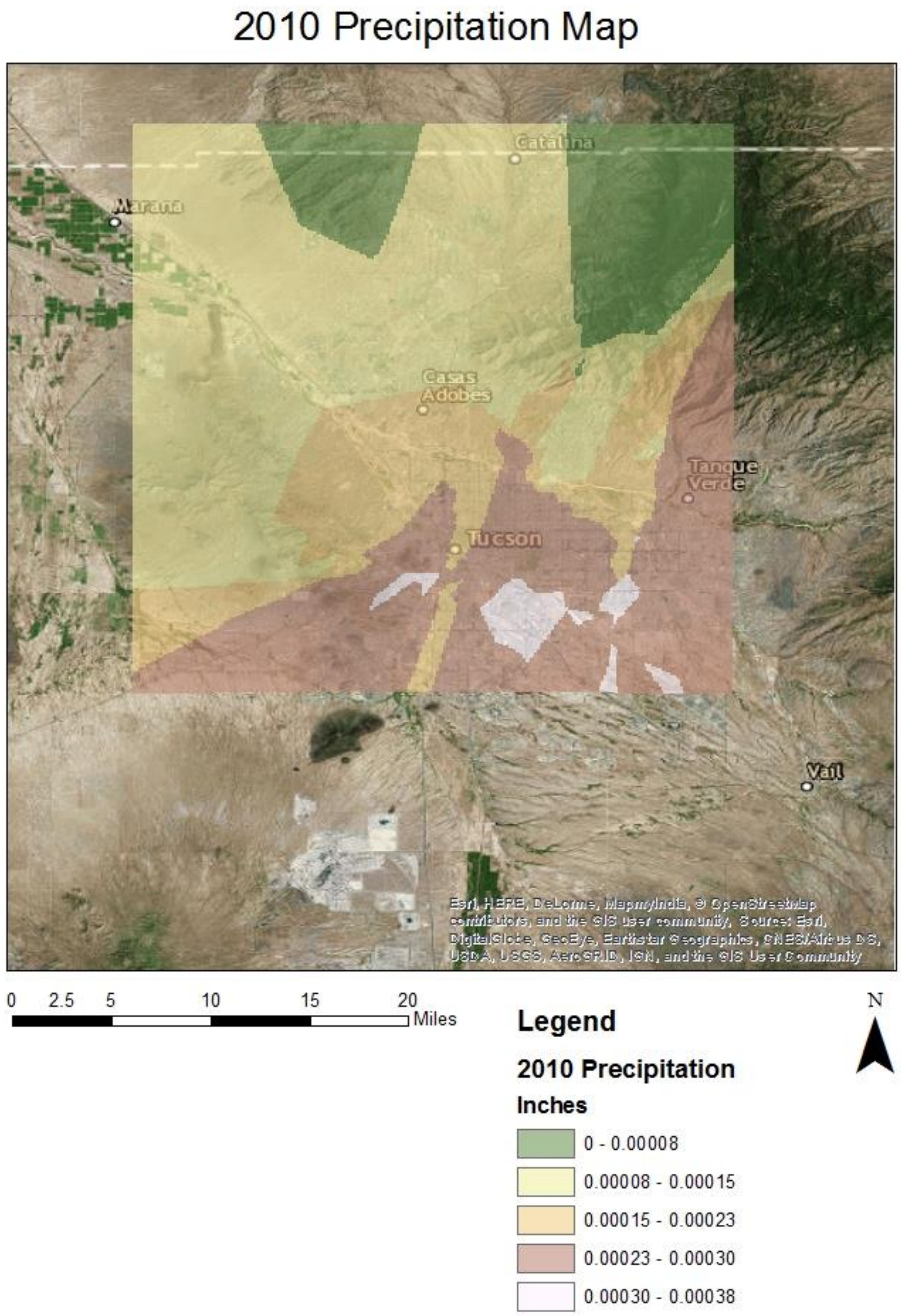


Figure 6: Interpolated Precipitation Surface for 2010 using Kriging

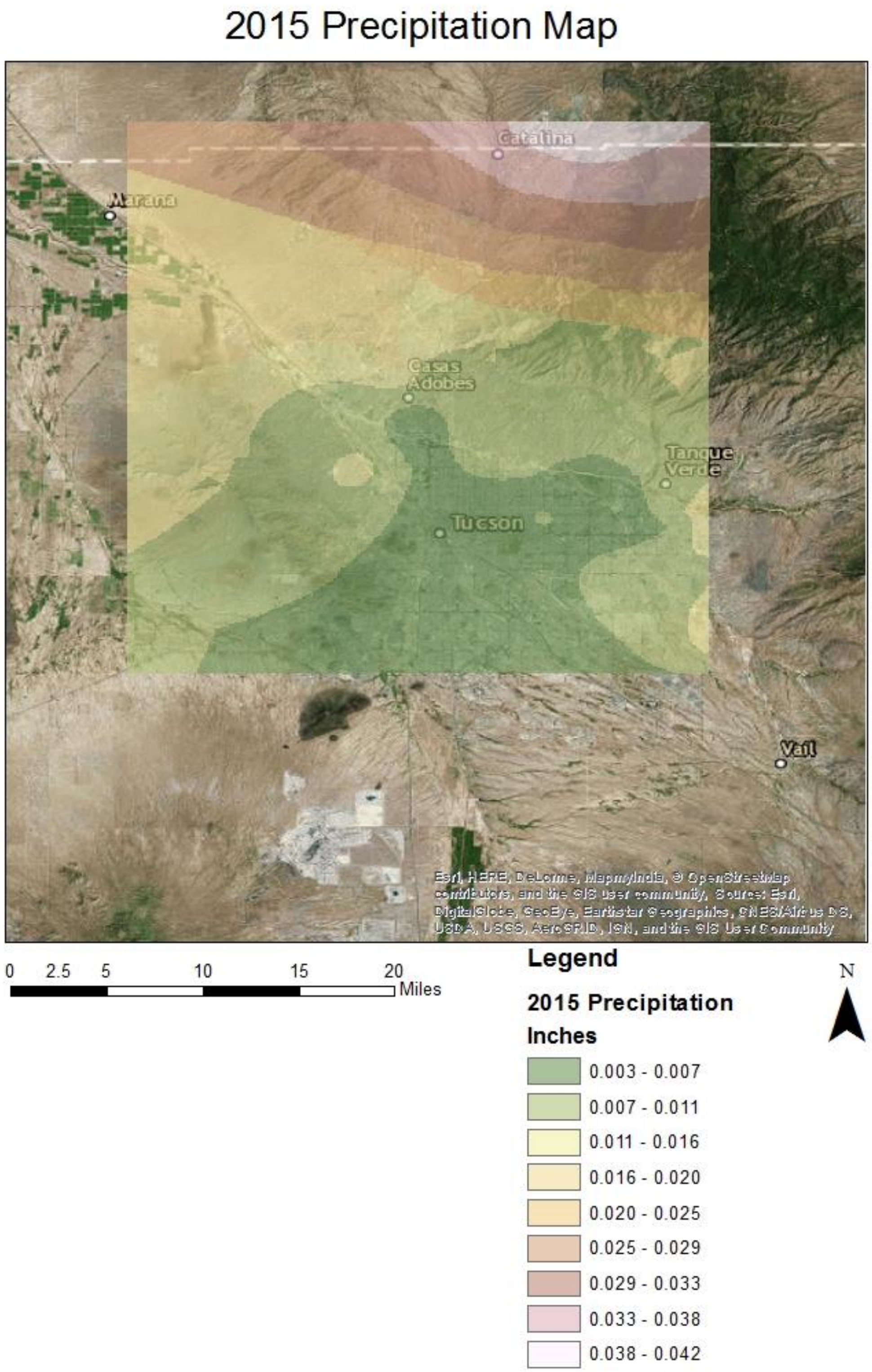


Figure 7: Interpolated Precipitation Surface for 2015 using Kriging

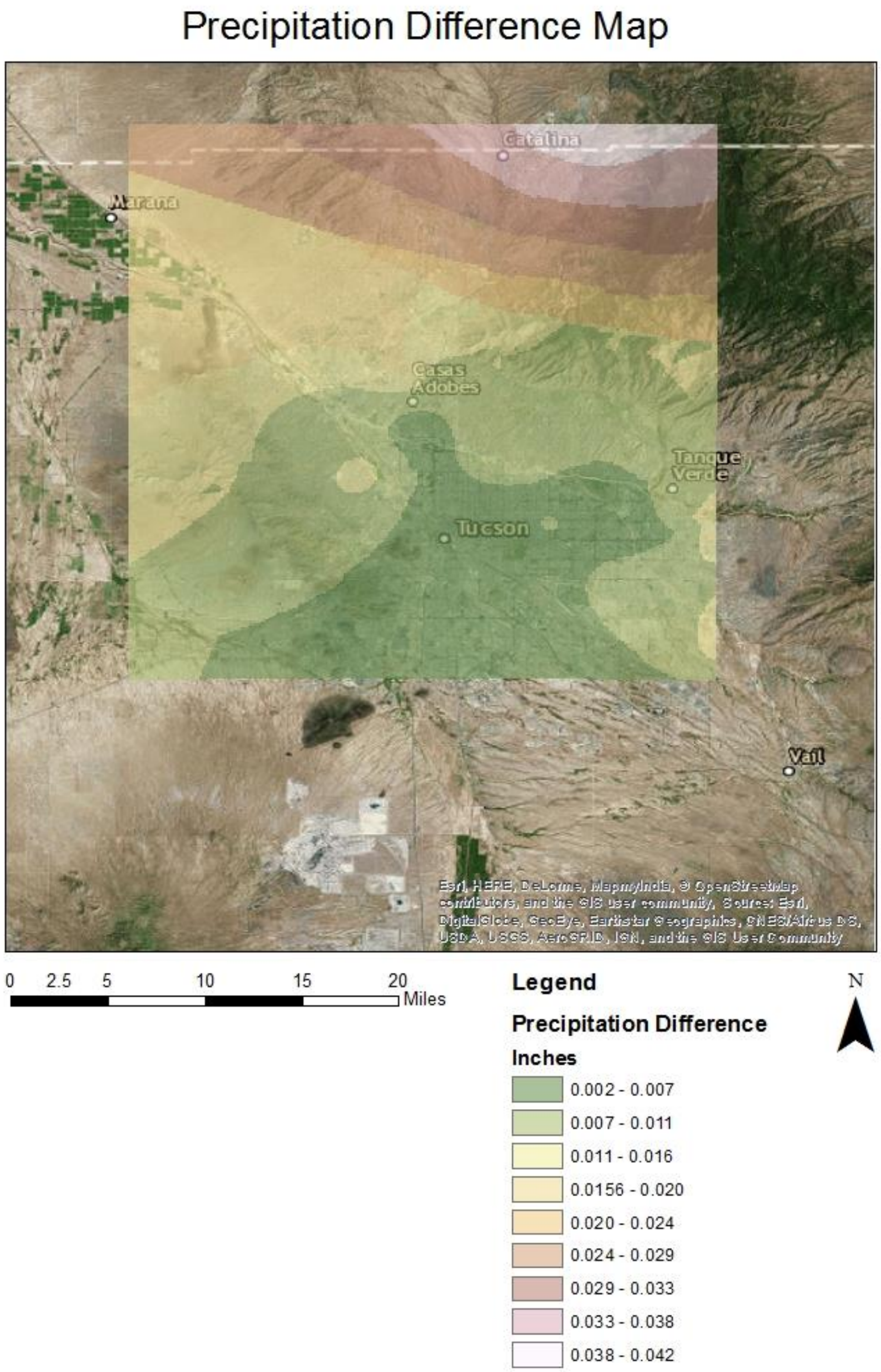


Figure 8: Interpolated Precipitation Surface for 2010 subtracted from 2015

Next, zonal statistics for precipitation were calculated using the parcels as zones and the precipitation surface for input data (Figure 8). The precipitation data were normalized in the same way as the NDVI data by multiplying the mean value of each parcel by the area of the parcel, dividing it by the sum of the area of all parcels, and then multiplying by 10^6.

$$\Delta Precip_{norm\,(i)} = \left(\frac{\overline{\Delta Precip_i} * Area_i}{\sum_1^j Area}\right) * 10^6$$

Zonal precipitation statistics were calculated for 2010 and 2015, and the 2010 value was subtracted from the 2015 value. Zonal statistics based on the parcels were also calculated for the NAIP NDVI values for 2010 and 2015, separately. A regression analysis was completed for precipitation and NDVI for 2010, 2015, and the difference between 2010 and 2015.

6: Results

6.1: Maintenance Survey

This section describes the selected findings of the survey. These findings were selected based on their relevance to the maintenance requirements and practices. The results not included here add to the overall maintenance picture but are not directly related to the research questions. The full survey results are provided in Appendix B. The survey had a response rate of 47% with 566 responses out of a total survey population of 1,194. The survey results showed that 90% of the respondents have an active system with storage tanks and/or cisterns, 52% have a passive system, 21% have a washing machine collection system, 8% have a shower collection system, 3% have a bathroom collection system, 1% has a full house graywater collection system, and 5% have some other form of graywater collection. Of the 28 respondents who indicated they have another form of graywater collection, 32% (nine respondents) have a kitchen sink collection system, 21% (six respondents) have a bucket in the shower/bath, 2% (six respondents) have an outdoor sink or shower, 7% (two respondents) have a "washing machine," and 4% (one respondent) has a dishwater system. There was also one respondent for each of the following systems: "a garage sink," "infiltration," "roof rainwater," and "gutters" (Figure 9).

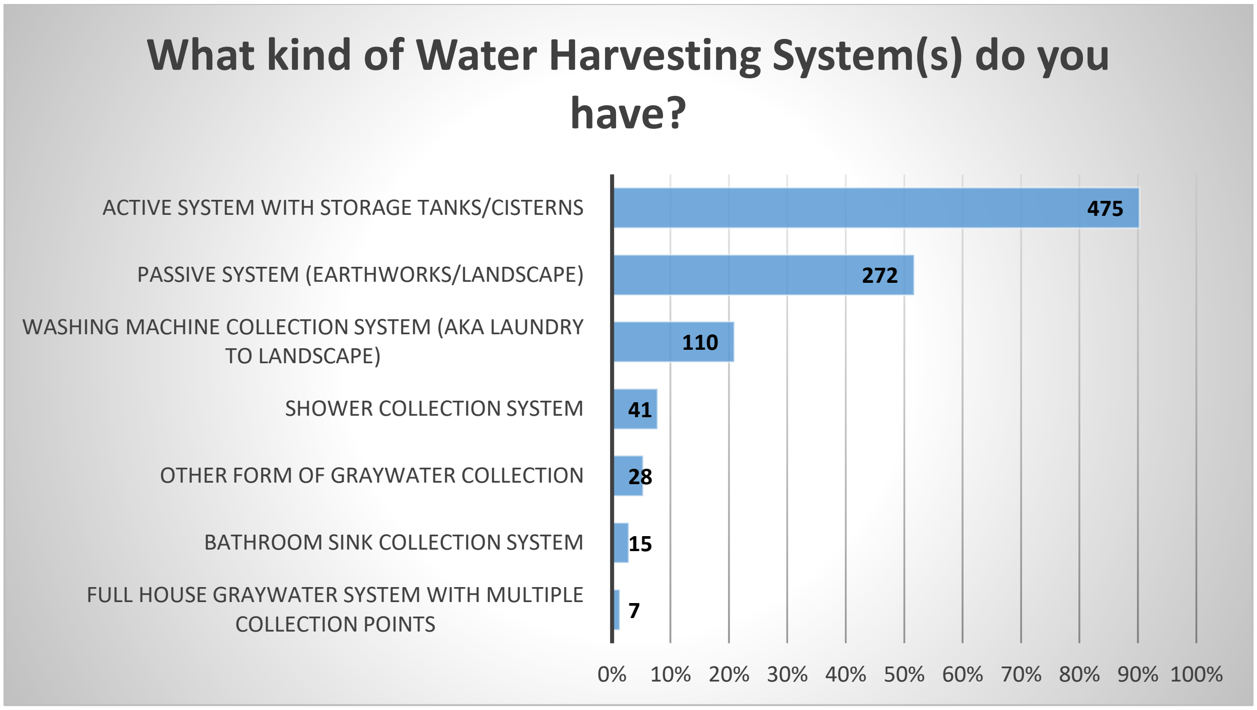


Figure 9: Water Harvesting Systems (N=526)

The most common issue with the water harvesting systems was “gutters have overflowed” for 17% of respondents although a greater number of respondents (33%) indicated there have been no issues with their harvesting systems. The next common issue was “debris filter has overrun /failed /allowed mosquito access” at 8%, followed by some “other” problem at 7%, “algae in the tank” at 6%, “basins silted up or clogged” and “tank has overflowed from somewhere other than designated overflow pipe” both with 5% of respondents. “Earthworks have overflowed in unintended area” and “system has an unpleasant odor” were indicated as issues by 4% of respondents. “Tank has leaked” received a 3% response rate followed by “tank foundation has eroded,” “tank had to be drained due to mosquitos or contamination,” and “water has ponded in basins for more than 24 h” each with a 2% response rate. “Graywater system has backed up/failed,” “tank emptied due to broken parts,” and “tank has remained empty” were each marked by 1% of the respondents (Figure 10).

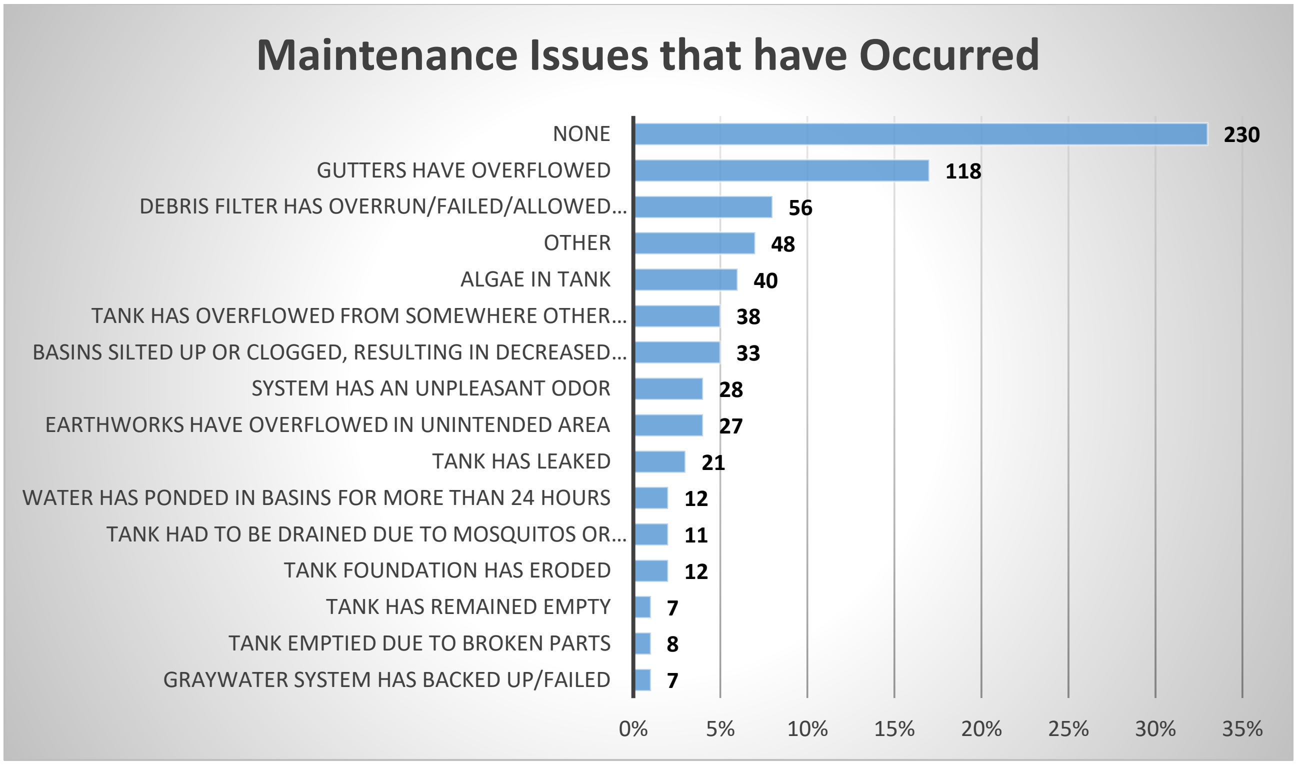


Figure 10: Maintenance Issues that have occurred (N=696)

The respondents were asked to elaborate on the issues they reported. While responses varied, five main themes emerged: mosquitos, clogged gutters, clogged filters, leaking parts, and insufficient pressure. The following responses demonstrate the examples of these themes.

Mosquitos: “Doing all we can and followed instructions but still see some mosquitoes coming out of the tank or the overflow, during the high water months. Also, the collection point at the gutters, point in which all the water is collected, often overflows and cascades violently outside, causing ground erosion and water proximity to the house, which is exactly what we didn't want in the first place.”

Clogged gutters: “The strainers on the discharge from the gutters are not adequate size and need to be cleaned frequently of clumped piles of leaves. I have subsequently made on new strainer of my own design which is more effective but need to make several more. The strainers on the market are not adequate.”

Clogged filters: “[A contractor] installed the tanks, the one on the south side is installed in such a way that it is impossible to adequately clean out the debris filter on top of the tank that the gutter flows into, resulting in 50–75% water loss for that tank...rain overflows around the screen, run down by the side of the tank, and puddles at the base of tank. Have called SARG a few times, they came out, but each fix only made it worse.”

Leaking parts: “Some seals were leaking a little bit and needed a more sealant”. “Small leaks where there are threads for hose connector”.

Insufficient pressure: “Everything I need watered is at the waist level or in pots about 18 in. high”. When the level drops in the tanks, the flow is too slow or even non-existent. I will have to buy pumps”.

Respondents were asked if the issues they experienced were expected. They were given the option to select “no issues”, which 55% of all respondents selected. Of the respondents who indicated they had experienced issues, 62% indicated the issues were expected and 38% indicated they were not expected (N=501).

The respondents were asked about the preventative maintenance that they have done. “Clean gutters” was selected by 68% of the respondents. “Clean first flush filters” was selected by 33%, some “other” form of preventative maintenance and no preventative maintenance by 18%, “reinforce the basins with rock to prevent erosion” by 16%, “paint storage tanks” by 8%, “clean storage tanks” by 7%, “lint cleanout in the graywater system” by 5%, “repainted inflow/overflow plumbing” by 5%, and “cleaning soap buildup in graywater basins” by 3% (Figure 11). The responses of those who selected “other” can be summarized in eight categories: 1) debris screen replacement/cleaning, 2) Installing some other screen for pests, 3) Mosquito repellants, 4) Caulking/paint, 5) Dig basins/berms, 6) Clean gutters, 7) Replace pipe, 8) Cover various parts to protect against sun/freeze.

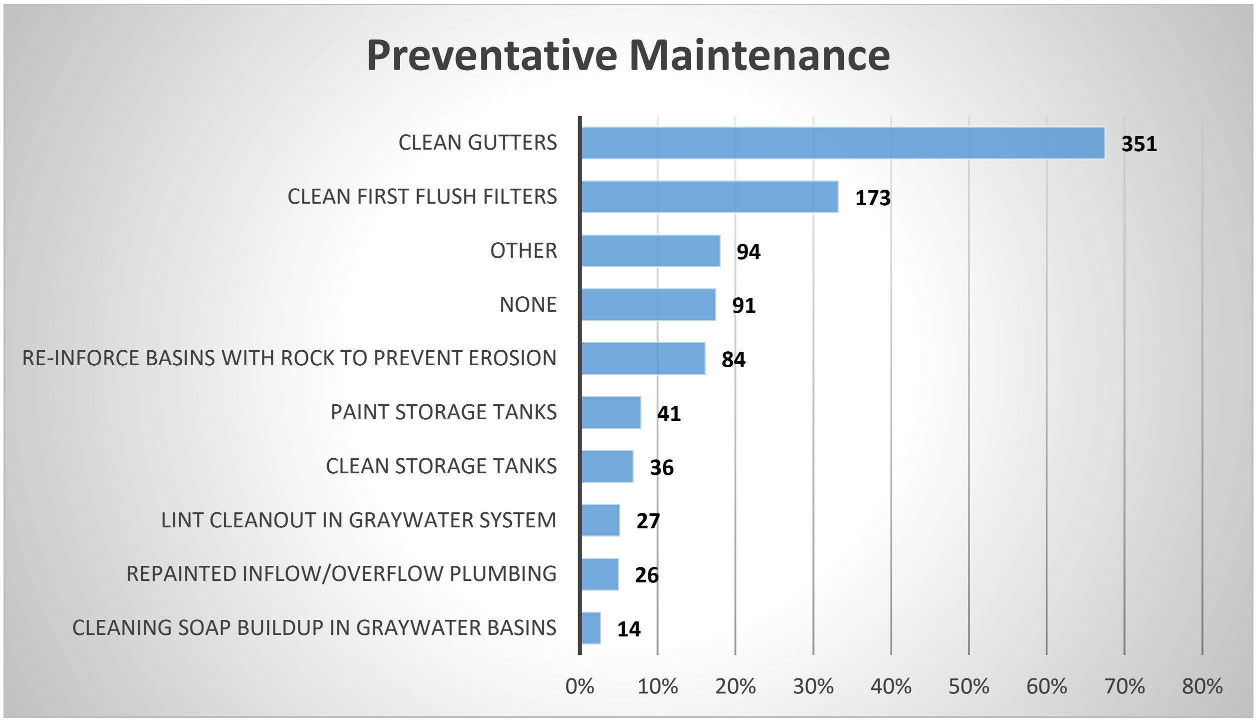


Figure 11: Preventative Maintenance (N=520)

The survey also asked about the repairs that the respondents have done. A majority (59%) indicated they have done no repairs. Some "other" repair was done by 13% (Figure 12). The "other" responses can be summarized in four categories: 1) Add/change filters, 2) Modify gutters, 3) Install additional pipes, and 4) Berm modification.

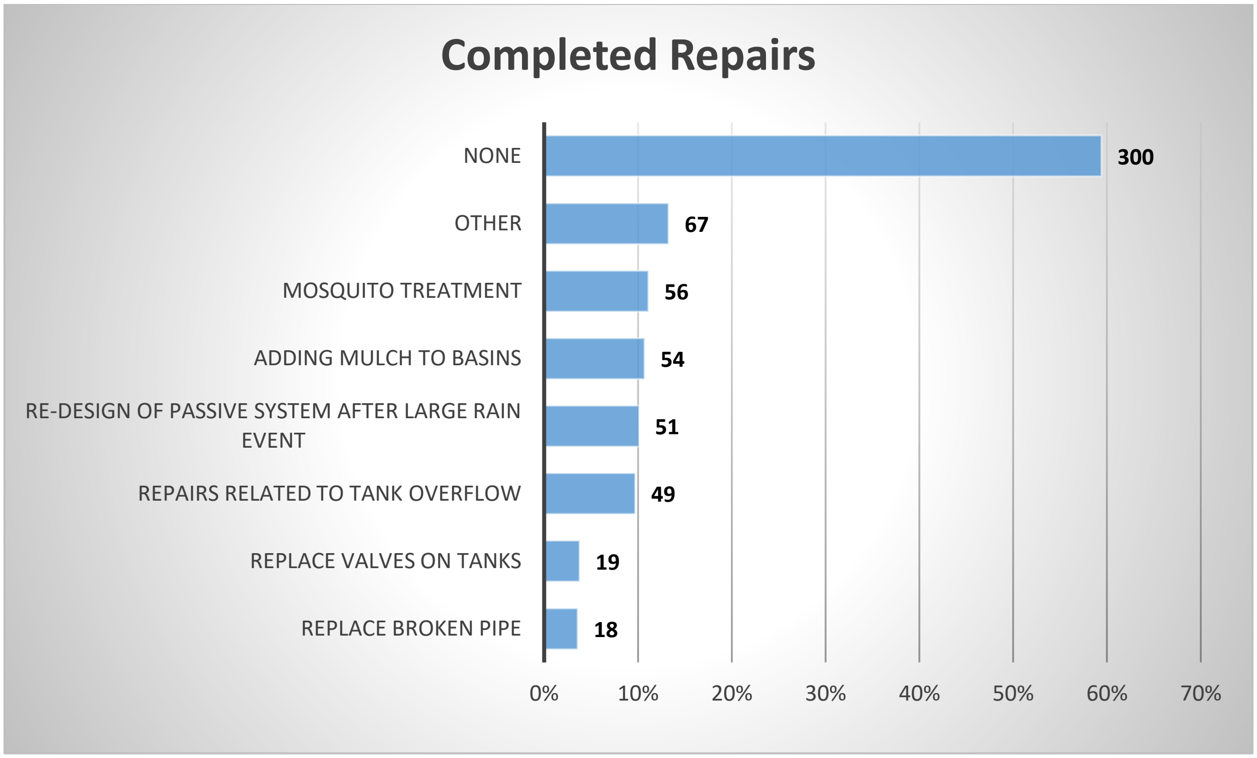


Figure 12: Completed Repairs (N=505)

Respondents were asked to rank their top three maintenance requirements. The most ranked one was "clean gutters", selected 298 times. The second most ranked was "clean first flush filters", selected 143 times, and the third was "the other from question 5" (regarding the preventative maintenance), selected 72 times. Figure 13 summarizes these findings.

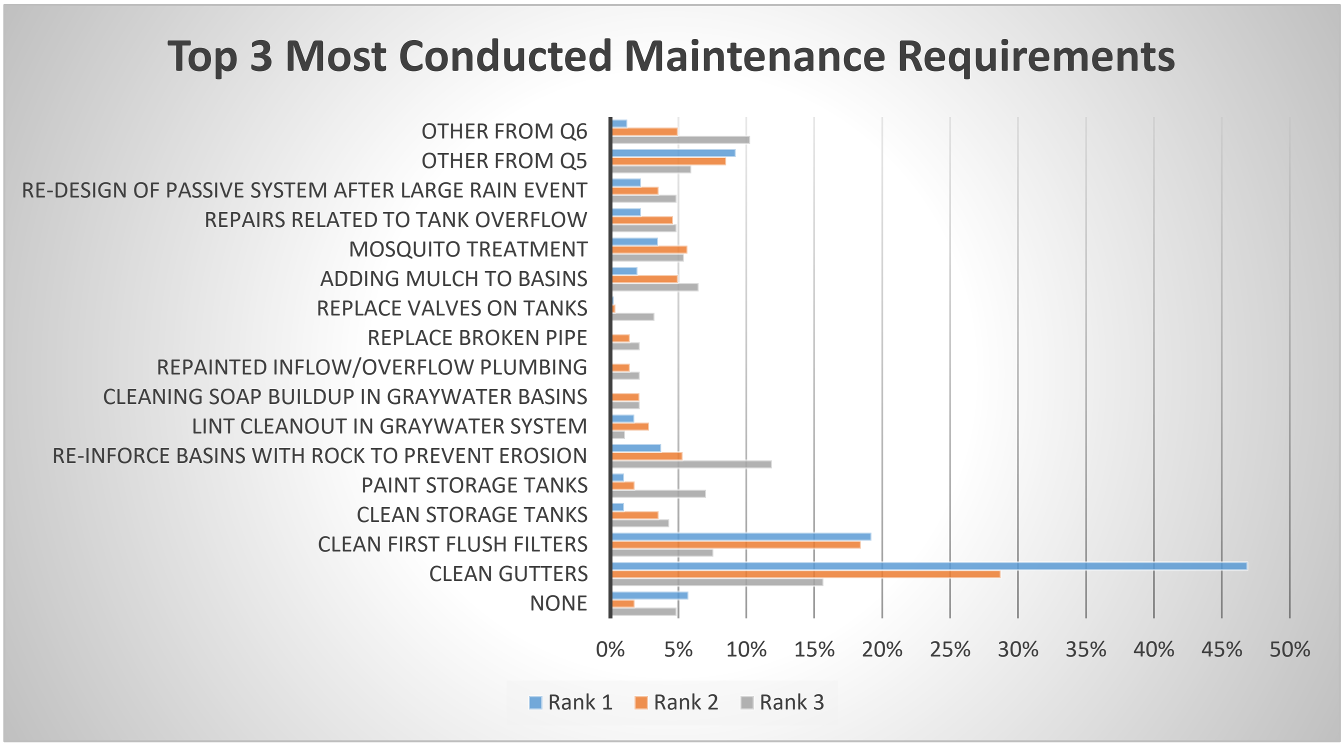


Figure 13: Maintenance requirements ranked by frequency (N=300)

Respondents were also asked to select the maintenance requirements that they are most concerned with. "None" was the most selected answer by 32% of the respondents followed by "clean gutters" by 29%. "Clean first flush filters" was selected by 8% of the respondents, the selection referencing what the respondent wrote in for Q5 (other from Q5) was selected by 8%, "mosquito treatment" was by 5%, "repairs related to tank overflow" was selected by 4%, "other from Q6" was selected by 3%, "clean storage tanks" was selected by 3%, and the remaining were selected by under 3% of respondents (Figure 14).

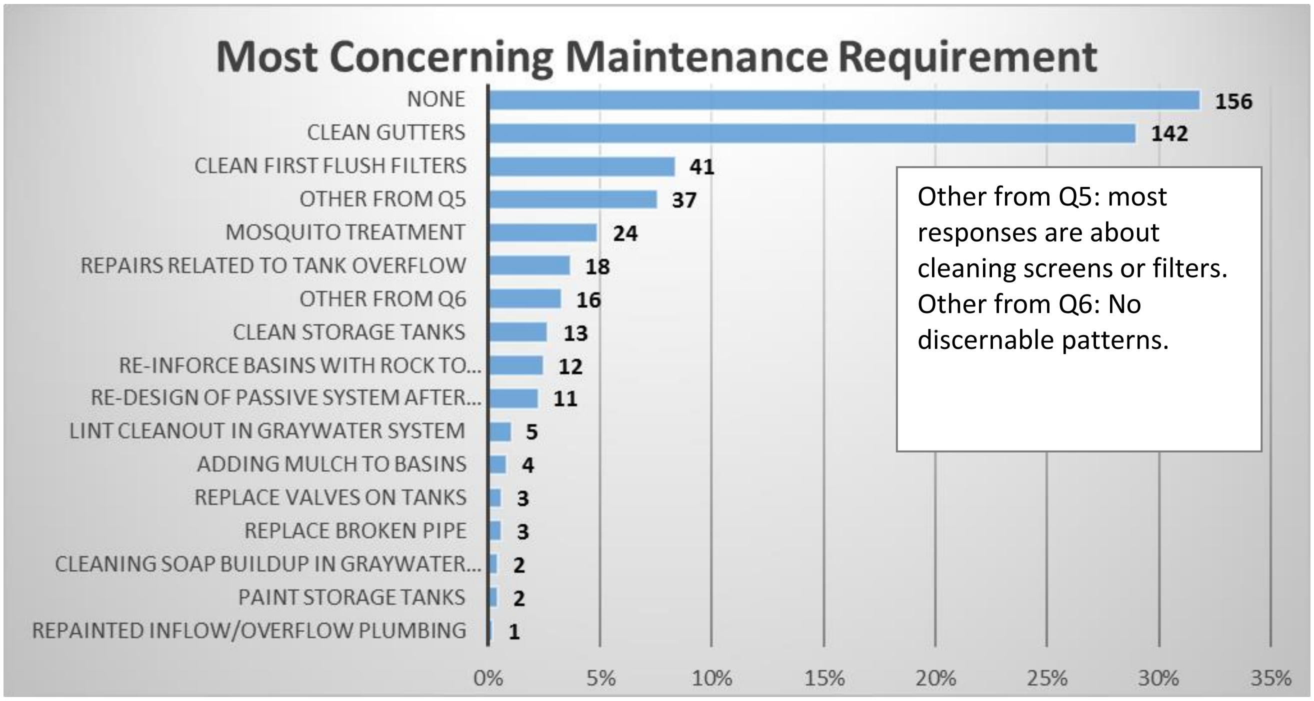


Figure 14: Most conducted maintenance (N=490)

Respondents were asked about the amount they spend on maintenance annually. The responses to this question varied significantly and the question did not specify a unit of spending. Some wrote in a dollar amount, which is what the designers of the survey wanted, and others responded in time units. The majority of people (54%) indicated that maintenance cost them nothing annually. The second largest group of respondents (24%) responded in time units or indicated that they did not have any information about the annual cost. The question was open-ended but the values were grouped into the following categories: "less than $50," "$50 to $100", "$101 to $500," and "over $500." The "Less than $50" category received 13% of the responses, "$50 to $100" received 5%, "$101 to $500" received 3%, and "over $500" received 1%. Some who answered "a very high maintenance cost" indicated that that amount included the installation cost (Figure 15).

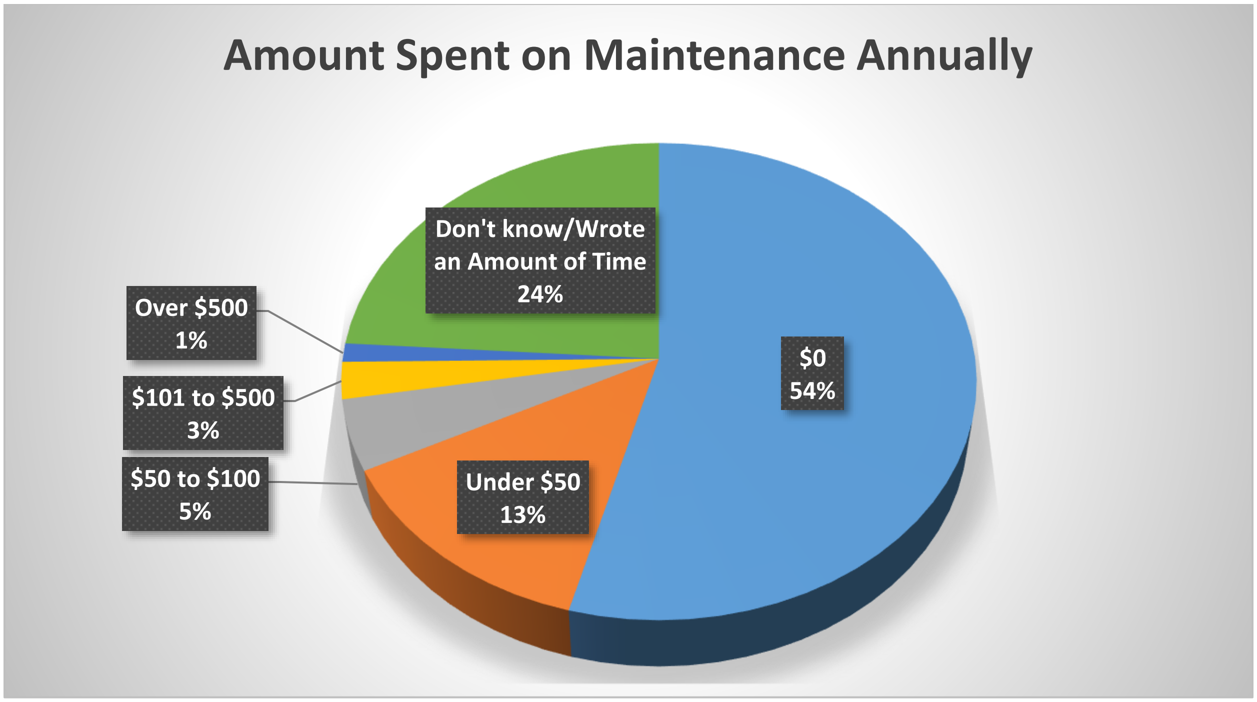


Figure 15: Annual Maintenance Spending (N=373)

Respondents were asked about the maintenance frequency. They were given the choices of "weekly," "monthly," "quarterly," "yearly," "only once," and "after a large rain event" for each of their original maintenance requirement selections (Figure 16). The most common weekly task was "none," followed by "clean gutters." The most common monthly, quarterly, and yearly task was "clean gutters." The most common selection for "only done once" was "other from Q6." The most common task done only "after a large rain event" was "clean first flush filters."

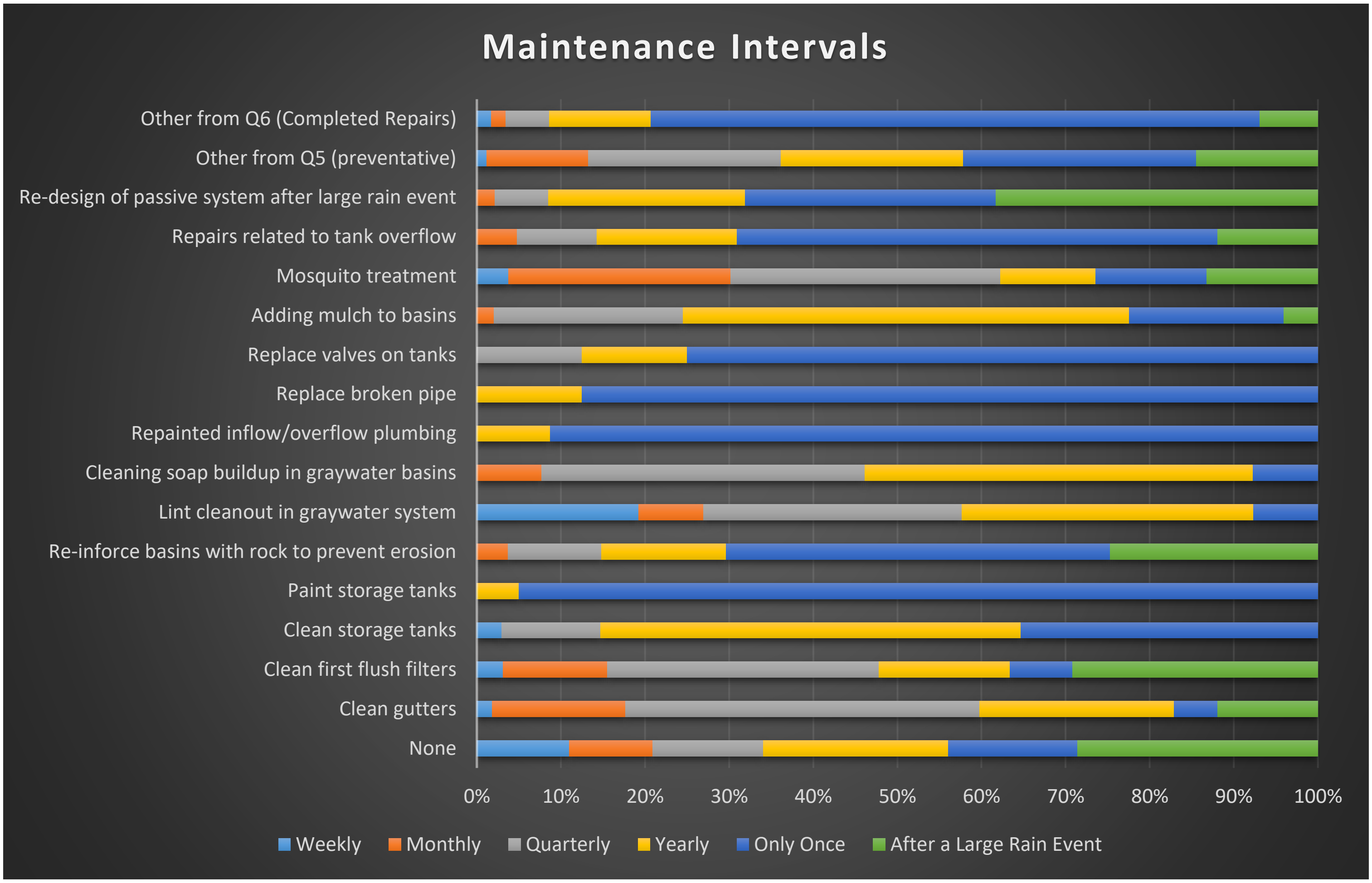


Figure 16: Maintenance intervals for each task

To follow up on the effort and time the maintenance requires, the respondents were asked how much time each maintenance action takes. In this question, they were given the categories of time and 72% indicated that each maintenance effort takes less than one hour. The next most common answer was “one to two hours” (23%) followed by “half a day” (3%) and “full day” (1%) (Figure 17).

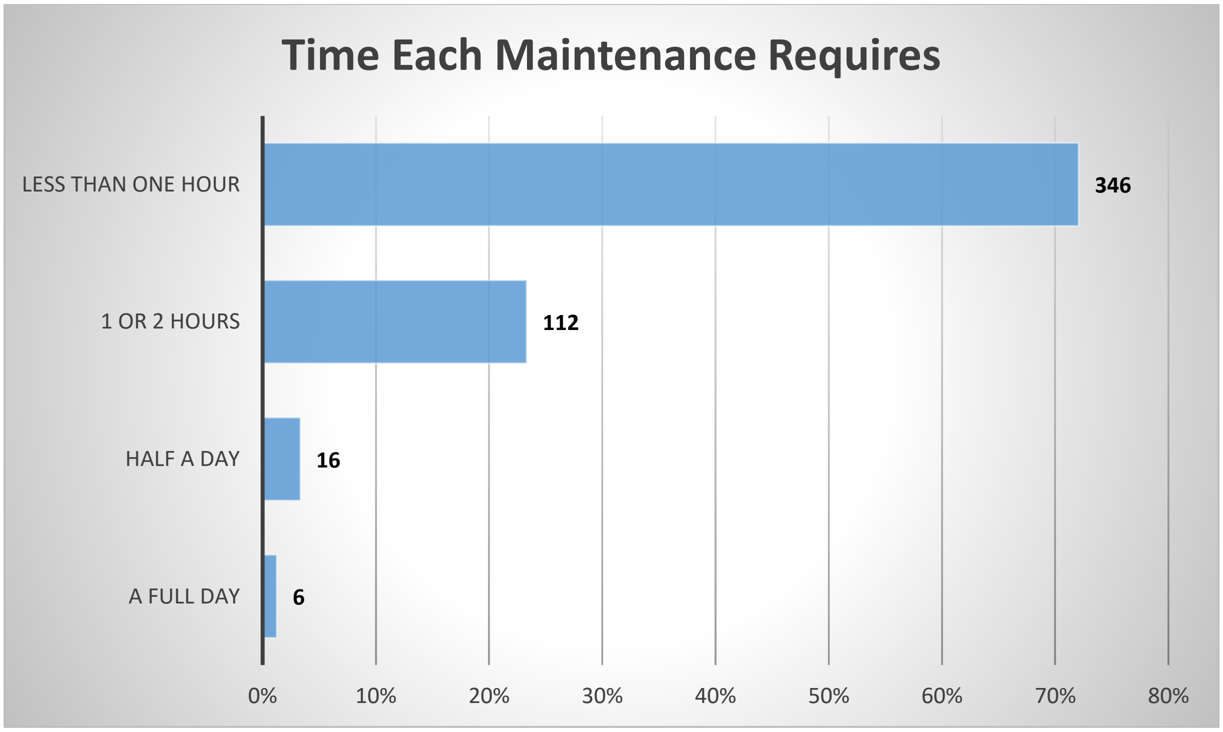


Figure 17: The amount of time taken when maintenance is required (N=480)

The respondents were also asked whether they would install the same system again. The majority (93%) indicated they would install the same system again and 7% said they would not. The explanations of these responses varied but mainly included adding more capacity, better and/or different filters, putting in a passive system, installing a pump and fixing pressure issues, and removing the pump in graywater systems. "More capacity" was mentioned twice, "larger tanks" was mentioned three times, "pump" was mentioned three times and additionally two more times in conjunction with "remove", "pressure" was mentioned twice, "filter" was mentioned twice, and "passive" was mentioned twice in the context of installing a passive system.

The last question was open-ended and asked if there is anything the harvesters wished they had known before installing their system. The answers were extremely varied and mainly included the following:

1) Classes were sufficient (mentioned 11 times),
2) Help with design (mentioned 7 times),
3) Help selecting good installers (mentioned 6 times),
4) Information on building materials (mentioned 6 times),
5) More about pressure limitations (mentioned 5 times),

6) How to deal with mosquitos (mentioned 4 times),
7) How to position system/use for irrigation (mentioned 2 times), and
8) Information on water quality (mentioned 2 times).

These main ideas were selected using Nvivo to identify the most common words and then analyzing those words in context. For example, “class” was used 19 times, but only 11 of those were about the helpfulness of the class. See Appendix C for full open-ended responses.

Overall, gutters and filters play a large role in water harvesting maintenance. They are the two most common responses to the past issues, preventative maintenance, repairs, and maintenance. Reported costs of maintenance are low and the time required for maintenance is minimal.

6.2: NDVI Differencing

The initial NAIP NDVI differencing produced values between -2 and 2 NDVI units since each image contained values between -1 and 1 NDVI units. Low values indicate less vegetation (greenness). After the mean values for each parcel were normalized for the area, the NDVI ranged from -1,154 to 70 NDVI units. The mean of the normalized values was -0.42066 and the standard deviation was 5.82. The upper and lower change thresholds ($\mu \pm n \cdot \sigma = -0.42 \pm 1 \cdot 5.82$) were 5.40 and -6.24, respectively. When these thresholds were applied to the 719 parcels that received a water harvesting rebate from Tucson Water, there were zero parcels with normalized mean values within the negative or positive change threshold. When the thresholds were applied to the 1,438 parcels randomly selected in the Tucson Water service area, there were nine parcels (0.6%) with normalized mean values within the negative change threshold and zero parcels within the positive change threshold. Values within the negative threshold have significantly less vegetation and values within the positive threshold have significantly more vegetation. The thresholds were also applied to all 270,495 parcels in the Tucson Water service area. There were 2,123 (0.8%) parcels that exhibited a negative change and 74 (0.03%) parcels that exhibited a positive change (Figure 18).

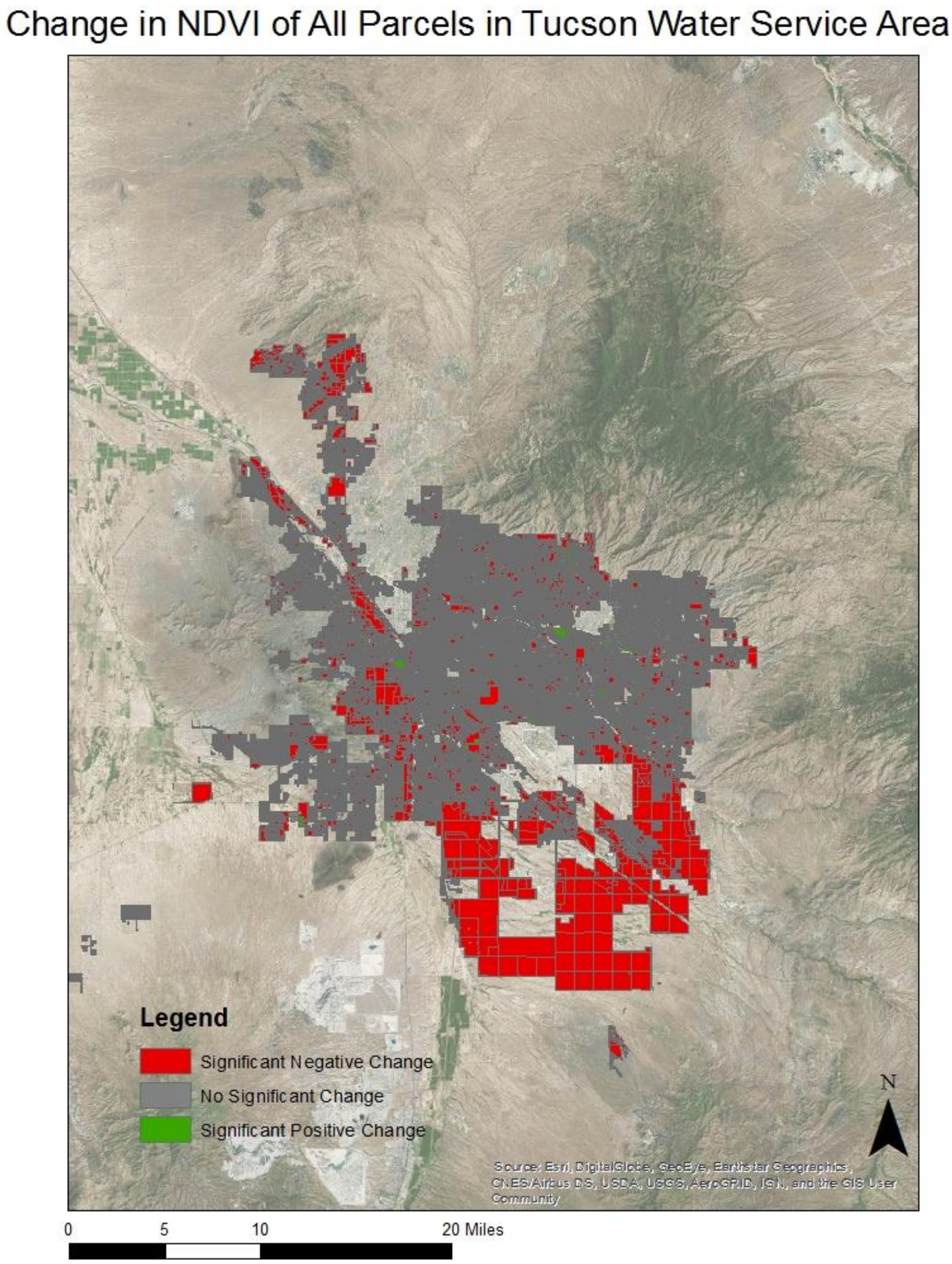


Figure 18: Parcel level change in NDVI from 2010 to 2015

The areas of desert outside Tucson were not irrigated and did not experience any development between 2010 and 2015. The NDVI values for these areas ranged from -1,518 to 366. The mean was -177.17 and the standard deviation was 275.77. The upper and lower thresholds were 98.6 and -452.9, respectively. When these thresholds were applied to the desert areas, 8.5% of the area had a significant positive change in NDVI and 17% of the area had a significant negative change (Figure 19).

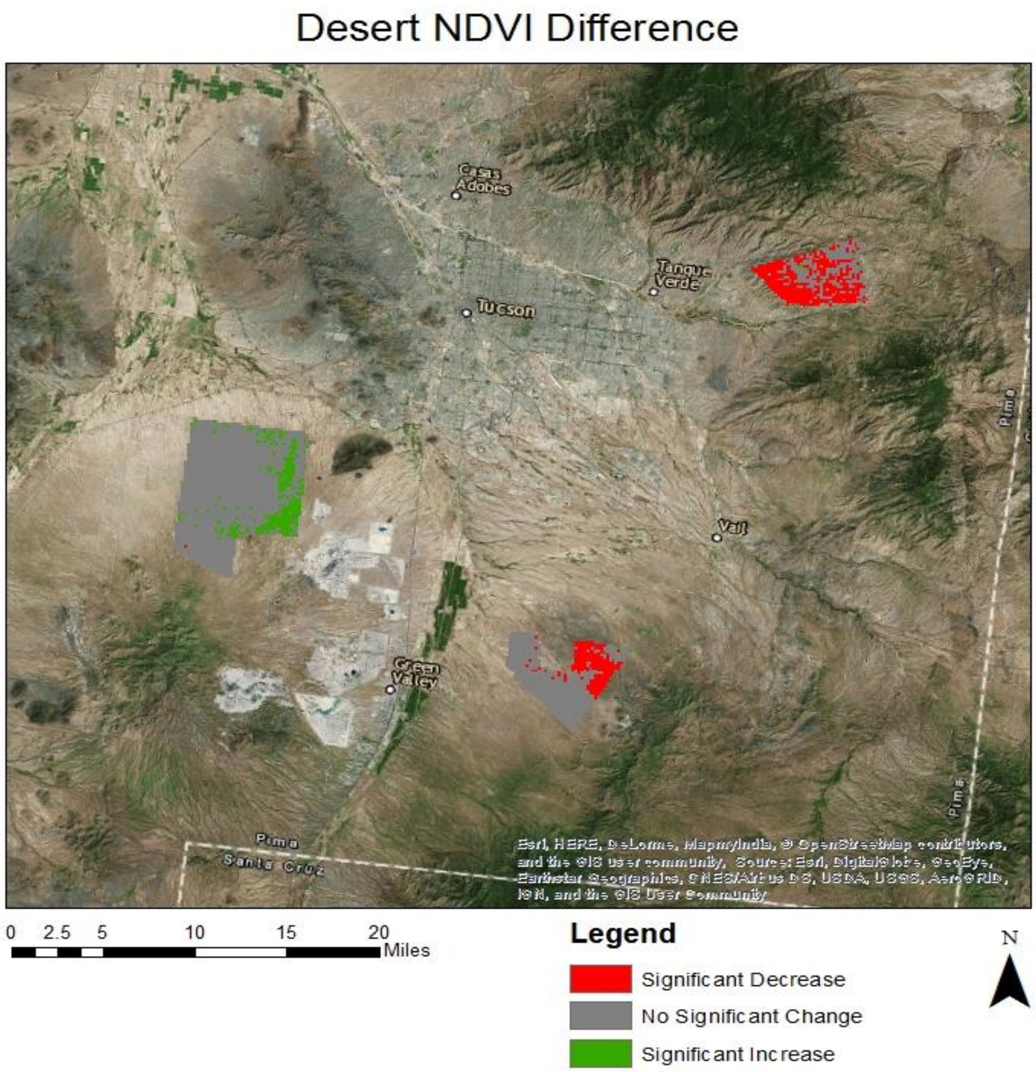


Figure 19: Areas of unirrigated, undeveloped land for which NDVI was calculated are within the gray polygons

To assess the impact of precipitation on NDVI values, a regression analysis was performed using a precipitation surface calculated by kriging (Gaussian process regression) and the NDVI values calculated from the NAIP data. There was very little precipitation in 2010 (Figure 7). The regression analysis for 2010 resulted in R^2=0.74, a significance of F=0, a P-value for the precipitation coefficient of 0, and P-value for the y-intercept of 8.8E-89. The regression analysis for 2015 resulted in R^2 =0.20, a significance of F=0, and a P-value for both the precipitation coefficient and y-intercept of 0. The regression analysis for the change in precipitation and in NDVI resulted in R^2=0.41, a significance of F=0, a P-value for the precipitation coefficient of 0, and P-value for the y-intercept of 3.41E-208. These results indicate no significant correlation between NDVI and precipitation (Table 3).

Table 3: Statistics for Precipitation/NDVI Regression Analysis

	Equation	R Square	Significance F	Coefficient P-value	Intercept P-value
2010	y = 549.1x + 0.0947	0.7417077	0	0	8.80606E-89
2015	y = 0.801x + 0.2407	0.2065558	0	0	0
Difference	y = -0.0753x + 0.0096	0.4139191	0	0	3.4106E-208

7: Discussion

7.1: Maintenance Survey

The aim in undertaking this survey was to evaluate an understudied aspect of the water harvesting rebate program: maintenance. This aspect of water harvesting has received little attention in the literature but discerning the upkeep requirements of water harvesting systems is a critical component of understanding how these systems might fit into the water supply system. Maintenance is part of any water system and insights into the costs after installation can help inform decisions. The survey provided valuable insights into the maintenance practices of people who received a rebate, the most common maintenance requirements, and the cost of maintaining the water harvesting systems. Most people who received a rebate installed an active system (90%), although some of those who indicated they would install a different system given the chance indicated they would like a passive system. About 68% of the respondents indicated that they clean the clogged gutters frequently but most people had little or no maintenance issues. Part of this may be due to the program being relatively new, having started in 2012. There may not have been enough time for the systems to malfunction. Clogged gutters can cause water to overflow and impede system performance. This aspect of water harvesting systems is a concern for the respondents (29% are most worried about this problem). Gutters were mostly cleaned on a quarterly basis, which is close to the recommendation of Virginia Department of Conservation and Recreation (DCR) to clean gutters twice a year and filters quarterly. This seems to be frequent enough to make it a major concern. Pests such as mosquitos were often cited as a problem by many respondents along with various filters. Mosquitos pose a public health threat and they like warm weather (Deichstetter 2017). Existing methods should be assessed to protect harvesters from an increased mosquito population on their property. Some of the referenced filters were to keep the pests out but most filters referred to the debris and first flush filters.

In favor of those who consider installing a harvesting system, the cost of maintenance in the first few years after the installation is relatively low (54% of the respondents reported no cost). Many people chose to answer the question about the cost in time units, indicating that they are not concerned about the cost in dollar amounts. The time spent on maintenance was also a major concern in a survey of the general attitude towards complex graywater systems in Australia (Christova-Boal 1995). Water harvesting rebates have been skewed to those with higher incomes because lower income households cannot afford the cost of the system, even with the rebate. These high-income households may be less concerned with the maintenance cost. To improve the distribution of water harvesting systems, Tucson started a water harvesting pilot program targeting low-income households in 2016. This program includes grant and/or loan programs as well as education and outreach materials in Spanish (City of Tucson 2016). Most respondents who responded in monetary units spend under $50 on maintenance annually. The cost of maintenance for the harvesting systems in Tucson is much lower than $1,068/yr estimated by the Water Environment Research Foundation (Water Environment Research Foundation 2009).

Generally, most people who received a water harvesting rebate from Tucson Water follow the recommended guidelines for maintenance; only a small number do not follow the guidelines. Wastewater from the kitchen sink is not often collected by the respondents but it is collected by some respondents despite it being specifically prohibited in the Arizona graywater code.

These results highlight four important considerations for Tucson Water when planning future rebate programs as well as provide information necessary to create a list of best maintenance practices for Tucson Water. First, overall maintenance is not a major issue among the recipients of any rebated water harvesting system. Second, although overall maintenance is not perceived as an important issue, preventative maintenance is *critical* to the sustainable operation of the system. Preventative maintenance does not need much money but it does take time. This point should be highlighted by Tucson Water or included in the required classes for rebate recipients. For active systems, an inspection and cleaning of gutters and all filters twice a year is particularly important to avoid damaging overflows, mosquitos, and bad odors. It may also be helpful to highlight in the informational and promotional materials that active rainwater harvesting systems require more maintenance than other types of harvesting systems. Based on the context of the qualitative analysis, mosquitos, overflows, and bad odors are associated with tanks or cisterns more often than other harvesting systems.

Third, the cost of maintenance is low, which is somewhat beneficial information for further promotion and economic analyses of water harvesting rebate programs. Based on the survey results, the average annual cost of maintenance in Tucson is $44; however, many respondents indicated they did not know about the costs or responded in time units instead. To elicit meaningful responses from more participants, this question could have been better designed. The study in Sierra Vista indicated that the largest impediment to rainwater harvesting was the lack of funds. The rebates in the Tucson area provide some cost relief for the up-front expenses to the cost of installing the system, and this survey demonstrates that yearly costs are low, which may help overcome the financial obstacles to installing more water harvesting systems.

Fourth, the information provided in the classes about the maintenance of water harvesting systems currently available to rebate recipients is sufficient. Most of those who have had maintenance issues indicated that the issues were expected. In the open-ended responses, there were no expressions of surprise related to the maintenance. Information on other aspects of the water harvesting systems could be improved, however. Some respondents did express surprise at the low pressure of water distributed from the tanks. Some respondents planned their landscaping with the impression that the tanks would have more pressure than they do. There was also a pattern of complaints about the installation services and information about reputable installation companies was requested. Moreover, some respondents requested information about how to design a system and water pressure limitations.

A Tucson-specific maintenance interval chart was created using the maintenance interval information garnered from the survey (Table 4).

Table 4: Suggested Maintenance Intervals

Maintenance Requirement	**Suggested Maintenance Interval**
Add mulch to basins	Quarterly
Clean soap buildup in graywater basins	Yearly
Lint cleanout of graywater system	Quarterly
Clean storage tanks	Yearly
Clean first flush filters	Quarterly
Clean gutters	Quarterly
Mosquito treatment	Quarterly

7.2: NDVI Differencing

The NDVI of the properties that received a water harvesting rebate was examined to assess if having a water harvesting system affects the vegetation of the properties. The greenness can be used as an indirect indicator of irrigation practices. A significant increase in NDVI between the two years might indicate that a larger property area was under irrigation in 2015 than in 2010. It could also indicate an increase in precipitation. Zero parcels that received a rebate had a significant change in NDVI and only nine of the randomly selected parcels had a significant change in NDVI. These parcels represent 0.6% of the sampled parcels and all exhibited a negative change. Overall, most parcels in the Tucson Water service area did not show significant changes in NDVI, indicating that vegetation does not change much in urban and suburban landscapes.

Precipitation was loosely correlated with NDVI in 2010 but not in 2015 or with the difference between 2010 and 2015. Precipitation did not likely play a significant role in NDVI changes in the Tucson Water Service Area between 2010 and 2015. Had there been stronger correlation between the two, it would have been difficult to say whether NDVI change was a result of irrigation or precipitation. Regardless, having access to relatively free water would increase the vegetation in a residence. Another way to account for the natural changes in NDVI was the inclusion of differences in NDVI for unirrigated, undeveloped areas near Tucson. These areas had significant NDVI changes compared to the Tucson Water Service Area, which provides additional evidence that any change in NDVI in the service area is not due to precipitation or other natural processes. Assessing the changes in natural areas is beyond the scope of this study; however, the fact that there was a significant change in natural landscape compared to city landscape suggests that the processes that drive vegetation growth in natural areas and in cities are decoupled. The relatively unchanged NDVI in the city landscape is likely due to consistent irrigation. Had there been similar patterns in the NDVI changes for both the Tucson Water Service Area and the natural area around it, the ability to draw conclusions about the relationship between irrigation and greenness would have been diminished. Taking this into account and considering all rebate receiving properties and most non-rebate receiving properties that did not show any significant changes in NDVI, receiving a water harvesting rebate does not affect irrigation practices, at least not to the extent to change NDVI.

These findings provide three pieces of information for Tucson Water. First, no significant positive changes in NDVI indicate that people have not significantly increased irrigation volume after installing harvested water systems, although it is possible that people are unable to increase irrigation volume using harvested water due to water volume limitations. It is also possible that harvesters have increased irrigation, but not at a level that is sufficient to change NDVI. A final possibility is that irrigation has increased, but plants added between 2010 and 2015 are not yet large enough to significantly change NDVI.

Second, since there was no significant negative change in NDVI, it is unlikely that people have significantly reduced irrigation volumes after receiving a water harvesting rebate. If they have, it was not enough to affect NDVI. It is possible that the landscape was changed to more water efficient plants, which may be capable of reducing the irrigation requirements while not affecting greenness.

Third, the threshold for NDVI changes established in the literature may not pick up the small changes to landscaping that might occur after installing a water harvesting system. The methods used in this study to establish significant NDVI changes are typically used for landscape-scale analyses. The threshold for NDVI changes at smaller scales may need to be defined differently than that for larger scale analyses. This has not been established in the literature. For instance, irrigating a small vegetable or flower garden is a common use for harvested water because other uses, such as in-home use, require it being treated to improve its quality (Li et al. 2010). While the addition of a small garden on a property may provide some value as a food source, it is unlikely to significantly change the NDVI. Further studies using information other than NDVI are needed to detect these small-scale changes such as pixel- or object-based classifications using very high-resolution data. Using highly accurate and detailed multispectral training data could potentially detect the changes in individual plants.

8: Conclusions

The objectives of this project were to evaluate the maintenance practices and requirements of water harvesting systems as well as calculate the effect of water harvesting systems on vegetation. These objectives were met by conducting a survey and by NDVI differencing using aerial photography. This research also highlights the potential for stakeholder partnerships such as the informal ones between a student at the University of Arizona and Tucson Water. In this partnership, the student was able to pursue the research interests in a practical way while Tucson Water received results of the research at no cost to them.

The first research hypothesis regarding the maintenance of the water harvesting systems is confirmed by the survey results. Preventative maintenance is necessary for continuous operation of the system. Neglecting the preventative measures leads to water overflows, odor and mosquito problems. The second hypothesis (repairing broken pipes is the most common maintenance practice) is not supported by the survey results that indicated that cleaning gutters is the most common maintenance practice. Additionally, cleaning gutters frequently is a significant concern for the respondents. The cost of maintenance is low and most people with water harvesting systems are not surprised about the maintenance requirements. Major problems with these systems are scarce.

There was not a single land parcel on which a water harvesting system was installed that had a significant change in NDVI between 2010 and 2015. This conclusion does not support the research hypothesis that the properties that received a water harvesting rebate would have significantly more vegetation after the system was installed than the properties that did not receive a rebate. This is also a strong indication that installing water harvesting systems does not significantly change the greenness of the properties in three years or less. There are multiple possibilities as to why this might be the case, but the data do not point to one possibility over another. Had there been properties experiencing significant changes in NDVI, it would have been possible to analyze the secondary data to determine the factors correlated with significant changes in NDVI.

Further studies about the Tucson Water's rebate program might help shed light on common practices and whether water harvesting affects the property landscape. To establish trends in maintenance requirements, a survey such as the one conducted in this study could be launched at regular intervals. Comparing the results would help track maintenance requirements as the systems age. Asking open-ended questions in a separate, in-depth interview style surveys would likely collect more usable information than a short, written response surveys. For example, harvesters could describe the ways they use the water on their property and why. It would also be helpful to ask for the date of installation to be able to search for the links between the age of the systems and maintenance requirements.

Another approach to measuring the effect of water harvesting on residential landscapes would be a land-cover change analysis. With high-resolution data available for the Tucson area, a parcel-scale land-cover classification could be accomplished. This would provide some insights into some of the unanswered questions raised by this study such as whether or not vegetation has been changed but not on a large enough scale to affect NDVI. This type of analysis, coupled with municipal water use trends for the parcels, could provide insights into how water harvesters use the harvested water. If Tucson Water continues to promote water harvesting, further studies would be helpful to improve the program.

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Appendix A: Maintenance Survey

[Note: Sections highlighted in blue below show survey logic. This was used in questions that reference previously answered questions. This ensured that only responses were previously selected were displayed.]

Hello,

We request your participation in a survey of water harvesting maintenance. We expect that this survey will take you 20 minutes to complete and respectfully request that you complete the survey by January 15, 2017. The benefit of this survey is that it will provide a better understanding of how maintenance requirements affect the use of water harvesting systems. There are no risks to participating in the survey. The project team is composed of Ethan Vimont, graduate student at the University of Arizona, Dr. Sharon B. Megdal, Director, University of Arizona Water Resources Research Center, and Candice Rupprecht, Water Conservation Specialist at Tucson Water. Please click the button below to continue to the survey. You have been selected for this survey because you received a water harvesting rebate from Tucson Water. Your participation is entirely voluntary, but we hope you will help us by completing this survey. Refusal to participate or discontinued participation will not result in any penalty or loss of benefits to which you are otherwise entitled. For questions about your rights as a participant in this study or to discuss other study-related concerns or complaints with someone who is not part of the research team, you may contact the Human Subjects Protection Program at 520-626-6721 or online at http://rgw.arizona.edu/compliance/human-subjects-protection-program. We will ask questions about your harvesting system, and about your experience with the maintenance of the system. If you choose to participate and click the continue button you may decline to answer any question at any point. You may also stop at any time and ask that the records of the survey be destroyed immediately by contacting Ethan Vimont at the email address listed below. You also have the option of saving your responses and returning to the survey at a later time. Remember that the information you give us as part of this study will be used only in combination with the information provided by other participants. Your participation is completely voluntary and confidential; data will be presented in aggregated form only, and your name will not appear anywhere in publications or presentations based on the study. Research data may be reviewed by the University of Arizona Institutional Review Board in addition to the research team. An ID number will be assigned to the information you provide and we will use only that number in the data sets analyzed in the study. Any person-identifiable records we have, such as your contact information, will be encrypted and available only to the research team during the length of the study. We will eventually archive the data set, but only code numbers will be included in the archive. The results of this investigation will be used to write scholarly articles and reports intended to inform policy. By participating in this interview you are agreeing to our use of the data for our research. If you have any questions or need clarification, you may contact the research team at the following address: Ethan Vimont Graduate Research Assistant Water Resources Research Center University of Arizona 350 N. Campbell Ave Tucson, AZ 85719 Tel: (520) 621-3795 Email: vimont@email.arizona.edu An Institutional Review Board responsible for human subjects research at The University of Arizona reviewed this research project and found it to be acceptable, according to applicable state and federal regulations and University policies designed to protect the rights and welfare of participants in research.

Q1 What kind of water harvesting system(s) do you have? Select all that apply.

- ❑ Passive system (earthworks/landscape) (1)
- ❑ Active system with storage tanks/cisterns (2)
- ❑ Full house graywater system with multiple collection points (3)
- ❑ Washing machine collection system (aka Laundry to Landscape) (4)
- ❑ Shower collection system (5)
- ❑ Bathroom sink collection system (6)
- ❑ Other form of graywater collection (please specify) (7) ____________________

Q2 Please describe your water harvesting system(s).

Q3 Have any of the following issues with your system(s) occurred? Select all that apply.

- ❑ None (1)
- ❑ Algae in tank (4)
- ❑ Basins silted up or clogged, resulting in decreased infiltration (5)
- ❑ Debris filter has overrun/failed/allowed mosquito access (6)
- ❑ Earthworks have overflowed in unintended area (7)
- ❑ Graywater system has backed up/failed (8)
- ❑ Gutters have overflowed (9)
- ❑ System has an unpleasant odor (10)
- ❑ Tank emptied due to broken parts (11)
- ❑ Tank foundation has eroded (12)
- ❑ Tank had to be drained due to mosquitos or contamination (13)
- ❑ Tank has leaked (14)
- ❑ Tank has overflowed from somewhere other than designated overflow pipe (15)
- ❑ Tank has remained empty (16)
- ❑ Water has ponded in basins for more than 24 hours (17)
- ❑ Other (19) ____________________
- ❑ Please elaborate on problems with your system (3) ____________________

Q4 If you've experienced maintenance issues with your system, were these issues expected? Please explain.

- ❑ No Issues (1)
- ❑ Yes (2) ____________________
- ❑ No (3) ____________________

Q5 What preventative maintenance has been done on your water harvesting system(s) since installation? Select all that apply.

- ❑ None (1)
- ❑ Clean gutters (2)
- ❑ Clean first flush filters (3)
- ❑ Clean storage tanks (4)
- ❑ Paint storage tanks (5)
- ❑ Re-inforce basins with rock to prevent erosion (6)
- ❑ Lint cleanout in graywater system (7)
- ❑ Cleaning soap buildup in graywater basins (8)
- ❑ Repainted inflow/overflow plumbing (9)
- ❑ Other (10) ____________________

Q6 What repairs have been done on your water harvesting system(s) since installation? Select all that apply.

- ❑ None (1)
- ❑ Replace broken pipe (2)
- ❑ Replace valves on tanks (3)
- ❑ Adding mulch to basins (4)
- ❑ Mosquito treatment (5)
- ❑ Repairs related to tank overflow (6)
- ❑ Re-design of passive system after large rain event (7)
- ❑ Other (8) ____________________

Q7 Of those maintenance actions selected in questions 5 and 6, please rank the top 3 most frequently done maintenance requirements. (1 being most frequent)

If What preventative maintenance has been done on your water harvesting system(s) since installation... None Is Selected Or What repairs have been done on your water harvesting system(s) since installation? Select all tha... None Is Selected

_______ None (1)

If What preventative maintenance has been done on your water harvesting system(s) since installation... Clean gutters Is Selected

_______ Clean gutters (2)

If What preventative maintenance has been done on your water harvesting system(s) since installation... Clean first flush filters Is Selected

_______ Clean first flush filters (3)

If What preventative maintenance has been done on your water harvesting system(s) since installation... Clean storage tanks Is Selected

_______ Clean storage tanks (4)

If What preventative maintenance has been done on your water harvesting system(s) since installation... Paint storage tanks Is Selected

_______ Paint storage tanks (5)

If What preventative maintenance has been done on your water harvesting system(s) since installation... Re-inforce basins with rock to prevent erosion Is Selected

_______ Re-inforce basins with rock to prevent erosion (6)

If What preventative maintenance has been done on your water harvesting system(s) since installation... Lint cleanout in graywater system Is Selected

_______ Lint cleanout in graywater system (7)

If What preventative maintenance has been done on your water harvesting system(s) since installation... Cleaning soap buildup in graywater basins Is Selected

_______ Cleaning soap buildup in graywater basins (8)

If What preventative maintenance has been done on your water harvesting system(s) since installation... Repainted inflow/overflow plumbing Is Selected

_______ Repainted inflow/overflow plumbing (9)

If What repairs have been done on your water harvesting system(s) since installation? Select all tha... Replace broken pipe Is Selected

_______ Replace broken pipe (10)

If What repairs have been done on your water harvesting system(s) since installation? Select all tha... Replace valves on tanks Is Selected

_______ Replace valves on tanks (11)

If What repairs have been done on your water harvesting system(s) since installation? Select all tha... Adding mulch to basins Is Selected

_______ Adding mulch to basins (12)

If What repairs have been done on your water harvesting system(s) since installation? Select all tha... Mosquito treatment Is Selected

_______ Mosquito treatment (13)

If What repairs have been done on your water harvesting system(s) since installation? Select all tha... Repairs related to tank overflow Is Selected

_______ Repairs related to tank overflow (14)

If What repairs have been done on your water harvesting system(s) since installation? Select all tha... Re-design of passive system after large rain event Is Selected

_______ Re-design of passive system after large rain event (15)

If What preventative maintenance has been done on your water harvesting system(s) since installation... Other Is Selected

_______ ${q://QID3/ChoiceTextEntryValue/10} (16)

If What repairs have been done on your water harvesting system(s) since installation? Select all tha... Other Is Selected

_______ ${q://QID4/ChoiceTextEntryValue/8} (17)

Q8 Of those maintenance actions selected in questions 5 and 6, which maintenance requirement is the greatest concern. Please indicate why your selection is the greatest concern.

If What preventative maintenance has been done on your water harvesting system(s) since installation... None Is Selected Or What repairs have been done on your water harvesting system(s) since installation? Select all tha... None Is Selected

- ❍ None (1)

If What preventative maintenance has been done on your water harvesting system(s) since installation... Clean gutters Is Selected

- ❍ Clean gutters (2) ____________________

If What preventative maintenance has been done on your water harvesting system(s) since installation... Clean first flush filters Is Selected

- ❍ Clean first flush filters (3) ____________________

If What preventative maintenance has been done on your water harvesting system(s) since installation... Clean storage tanks Is Selected

- ❍ Clean storage tanks (4) ____________________

If What preventative maintenance has been done on your water harvesting system(s) since installation... Paint storage tanks Is Selected

- ❍ Paint storage tanks (5) ____________________

If What preventative maintenance has been done on your water harvesting system(s) since installation... Re-inforce basins with rock to prevent erosion Is Selected

- ❍ Re-inforce basins with rock to prevent erosion (6) ____________________

If What preventative maintenance has been done on your water harvesting system(s) since installation... Lint cleanout in graywater system Is Selected

- ❍ Lint cleanout in graywater system (7) ____________________

If What preventative maintenance has been done on your water harvesting system(s) since installation... Cleaning soap buildup in graywater basins Is Selected

- ❍ Cleaning soap buildup in graywater basins (8) ____________________

If What preventative maintenance has been done on your water harvesting system(s) since installation... Repainted inflow/overflow plumbing Is Selected

- ❍ Repainted inflow/overflow plumbing (9) ____________________

If What repairs have been done on your water harvesting system(s) since installation? Select all tha... Replace broken pipe Is Selected

- ❍ Replace broken pipe (10) ____________________

If What repairs have been done on your water harvesting system(s) since installation? Select all tha... Replace valves on tanks Is Selected

- ❍ Replace valves on tanks (11) ____________________

If What repairs have been done on your water harvesting system(s) since installation? Select all tha... Adding mulch to basins Is Selected

- ❍ Adding mulch to basins (12) ____________________

If What repairs have been done on your water harvesting system(s) since installation? Select all tha... Mosquito treatment Is Selected

❍ Mosquito treatment (13) ____________________

If What repairs have been done on your water harvesting system(s) since installation? Select all tha... Repairs related to tank overflow Is Selected

❍ Repairs related to tank overflow (14) ____________________

If What repairs have been done on your water harvesting system(s) since installation? Select all tha... Re-design of passive system after large rain event Is Selected

❍ Re-design of passive system after large rain event (15) ____________________

If What preventative maintenance has been done on your water harvesting system(s) since installation... Other Is Selected

❍ ${q://QID3/ChoiceTextEntryValue/10} (16) ____________________

If What repairs have been done on your water harvesting system(s) since installation? Select all tha... Other Is Selected

❍ ${q://QID4/ChoiceTextEntryValue/8} (17) ____________________

Q9 How much do you spend on maintenance annually?

Q10 Of those maintenance actions selected in questions 5 and 6, what maintenance is performed on your water harvesting system(s) at the intervals below?

	Weekly (1)	Monthly (2)	Quarterly (3)	Yearly (4)	Only Once (5)	After a large rain event (6)
If What preventative maintenance has been done on your water harvesting system(s) since installation... None Is Selected Or What repairs have been done on your water harvesting system(s) since installation? Select all tha... None Is Selected None (1)	❍	❍	❍	❍	❍	❍
If What preventative maintenance has been done on your water harvesting system(s) since installation... Clean gutters Is Selected Clean gutters (2)	❍	❍	❍	❍	❍	❍
If What preventative maintenance has been done on your water harvesting system(s) since installation... Clean first flush filters Is Selected Clean first flush filters (3)	❍	❍	❍	❍	❍	❍
If What preventative maintenance has been done on your water harvesting system(s) since installation... Clean storage tanks Is Selected Clean storage tanks (4)	❍	❍	❍	❍	❍	❍
If What preventative maintenance has been done on your water harvesting system(s) since installation... Paint storage tanks Is Selected Paint storage tanks (5)	❍	❍	❍	❍	❍	❍
If What preventative maintenance has been done on your water harvesting system(s) since installation... Re-inforce basins with rock to prevent erosion Is Selected Re-inforce basins with rock to prevent erosion (6)	❍	❍	❍	❍	❍	❍

If What preventative maintenance has been done on your water harvesting system(s) since installation... Lint cleanout in graywater system Is Selected Lint cleanout in graywater system (7)	❍	❍	❍	❍	❍	❍
If What preventative maintenance has been done on your water harvesting system(s) since installation... Cleaning soap buildup in graywater basins Is Selected Cleaning soap buildup in graywater basins (8)	❍	❍	❍	❍	❍	❍
If What preventative maintenance has been done on your water harvesting system(s) since installation... Repainted inflow/overflow plumbing Is Selected Repainted inflow/overflow plumbing (9)	❍	❍	❍	❍	❍	❍
If What repairs have been done on your water harvesting system(s) since installation? Select all tha... Replace broken pipe Is Selected Replace broken pipe (10)	❍	❍	❍	❍	❍	❍
If What repairs have been done on your water harvesting system(s) since installation? Select all tha... Replace valves on tanks Is Selected Replace valves on tanks (11)	❍	❍	❍	❍	❍	❍
If What repairs have been done on your water harvesting system(s) since installation? Select all tha... Adding mulch to basins Is Selected Adding mulch to basins (12)	❍	❍	❍	❍	❍	❍
If What repairs have been done on your water harvesting system(s) since installation? Select all tha... Mosquito treatment Is Selected Mosquito treatment (13)	❍	❍	❍	❍	❍	❍

If What repairs have been done on your water harvesting system(s) since installation? Select all tha... Repairs related to tank overflow Is Selected Repairs related to tank overflow (14)	❍	❍	❍	❍	❍	❍
If What repairs have been done on your water harvesting system(s) since installation? Select all tha... Re-design of passive system after large rain event Is Selected Re-design of passive system after large rain event (15)	❍	❍	❍	❍	❍	❍
If What preventative maintenance has been done on your water harvesting system(s) since installation... Other Is Selected ${q://QID3/ChoiceTextEntryValue/10} (16)	❍	❍	❍	❍	❍	❍
If What repairs have been done on your water harvesting system(s) since installation? Select all tha... Other Is Selected ${q://QID4/ChoiceTextEntryValue/8} (17)	❍	❍	❍	❍	❍	❍

Q11 To what degree do maintenance requirements currently prevent you from using your system(s)?

❍ None, my system works fine (1)
❍ My system is working, but not as well as designed (2)
❍ My system is not working at all (3)

Q12 If you indicated problems in the previous question, please indicate how long your system(s) has/have not been working as designed.

Q13 If part of your harvesting system(s) breaks or degrades, do you have the ability to repair it?

❍ Yes (1)
❍ No (2)

Q14 About how much time is spent managing your system(s) each time maintenance is performed?

- Less than one hour (1)
- 1 or 2 hours (2)
- Half a day (3)
- A full day (4)

Q15 Have maintenance issues affected the quality of your harvested water? If yes, please explain.

- Yes (1) ____________________
- No (2)

Q16 Based on your experience, would you install the same or similar water harvesting system again? Why or why not?

- Yes (1) ____________________
- No (2) ____________________

Q17 Is there other information you would have liked in advance of installing your water harvesting system? If so, please describe.

Q18 If you would like to further participate in this study by being part of a more in depth interview about your water harvesting system(s), please put your name, phone number, and/or email below. (If you choose not to give your contact information, the survey will remain anonymous).

Appendix B: Full Survey Results

The survey had a response rate of 47% with 566 responses out of a total survey population of 1,194 people. The survey found that 90% of people have an active system with storage tanks and/or cisterns, 52% have a passive system, 21% have a washing machine collection system, 8% have a shower collection system, 3% have a bathroom collection system, 1% have a full house graywater collection system, and 5% have some other form of graywater collection. Of the 28 people who indicated they have another form of graywater collection, 32% (9 respondents) wrote in that they have a kitchen sink collection system, 21% (6 respondents) indicated they have a bucket in the shower/bath, 2% (6 respondents) indicated they have an outdoor sink or shower, 7% (2 respondents) wrote in "washing machine," and 4% (1 respondent) indicated they have a dishwater system. There was also 1 respondent for each of the following: "a garage sink," "infiltration," "roof rainwater," and "gutters." See Figure 6.

The descriptions of the system were in line with the responses to the first question with a large majority of the descriptions involving cisterns or some form of earthworks. Cisterns was mentioned 153 times, tank(s) was mentioned 385 times, basin(s) was mentioned 109 times, earthwork(s) was mentioned 29 times, swale(s) was mentioned 25 times, and berm(s) was mentioned 45 times. Roof(s) was mentioned 259 times, and gutter(s) was mentioned 212 times indicating that the roof a common collection surface. Some of the responses were very detailed:

> "We have two 860gal cisterns that collect rainwater from the roof, which then one of them is used to water a small vegetable garden along with the roof runoff from the separate garage roof. The other cistern is used to water 3 trees and four bushes. The trees also get street rainwater runoff using basins to collect the water. The water from front part of the roof is channeled to a citrus tree and an ironwood tree. These two trees also receive bath/shower water from the kids' bathroom. The graywater from the laundry waters three trees in the backyard- a quince, fig and an oak."
>
> Most responses were more succinct such as, "rain gutters that go into a tank."

The most common issue with the water harvesting systems was "gutters have overflowed" at 17% though more respondents (33%) indicated there have been no issues with their harvesting systems. The next most common was "debris filter has overrun/failed/allowed mosquito access" at 8%, then some "other" problem at 7%, then "algae in tank" at 6%, then "basins silted up or clogged" and "tank has overflowed from somewhere other than designated overflow pipe" both with 5% of respondents. "Earthworks have overflowed in unintended area" and "system has an unpleasant odor" were indicated as issues by 4% of respondents. "Tank has leaked" received a 3% response rate followed by "tank foundation has eroded," "tank had to be drained due to mosquitos or contamination," and "water has ponded in basins for more than 24 hours" each with a 2% response rate. "Graywater system has backed up/failed," "tank emptied due to broken parts," and "tank has remained empty" were each marked by 1% of the respondents. See Figure 1B.

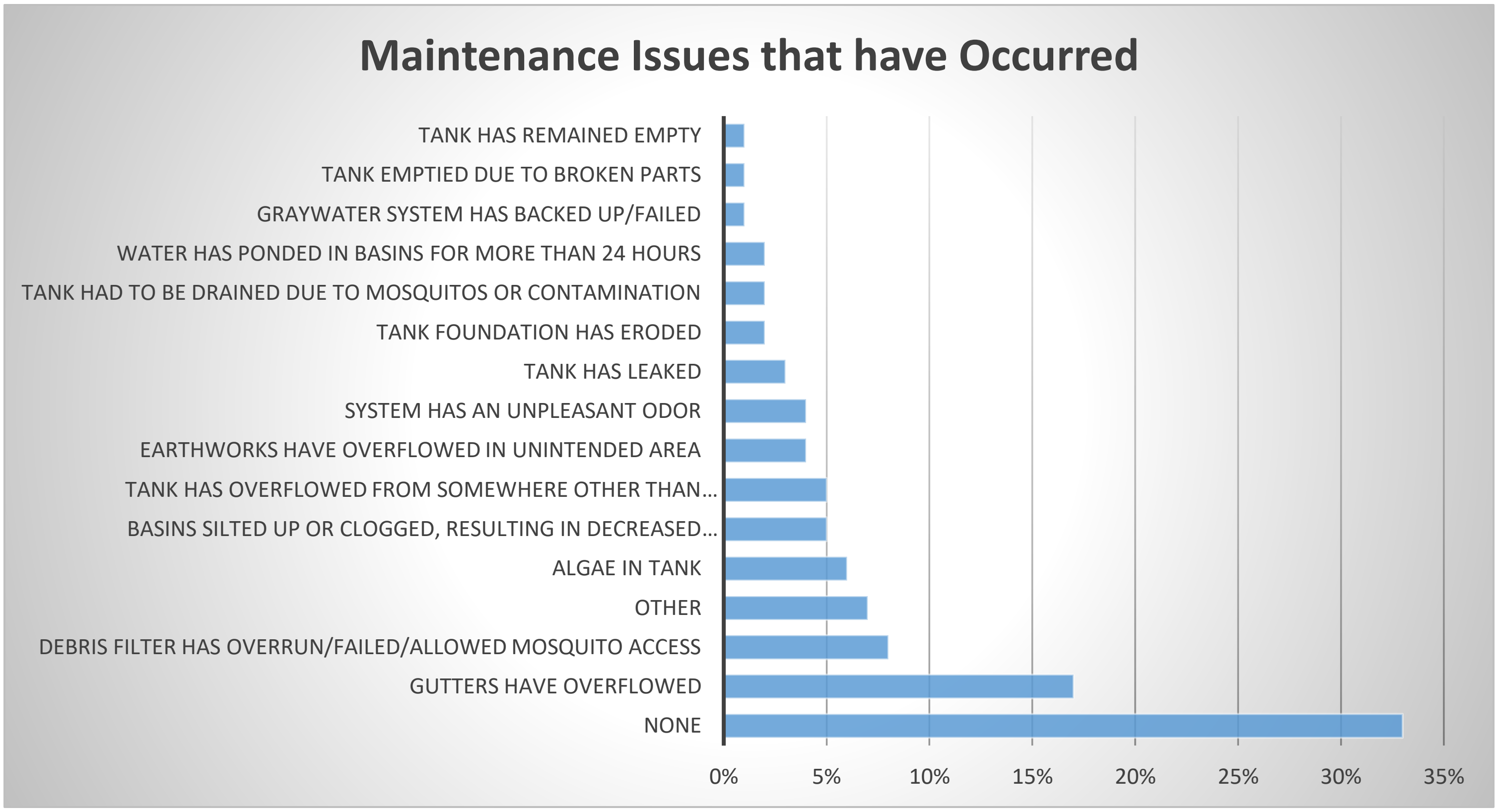

Figure 1B:: Maintenance Issues that have occurred

The respondents were asked to elaborate on the issues they indicated. While responses varied, five main themes emerged: mosquitos, clogged gutters, clogged filters, leaking parts, and insufficient pressure. The following responses demonstrate examples of these themes.

Mosquitos: “Doing all we can and followed instructions but still see some mosquitoes coming out of the tank or the overflow, during the high water months. Also the collection point at the gutters, point in which all the water collects, often overflows and cascades violently outside, causing ground erosion and water proximity to the house, which is exactly what we didn't want in the first place.”

Clogged gutters: “The strainers on the discharge from the gutters are not adequate size and need to be cleaned frequently of clumped piles of leaves. I have subsequently made on new strainer of my own design which is more effective but need to make several more. The strainers on the market are not adequate.”

Clogged filters: “SARG installed the tanks, the one on the south side is installed in such a way that it is impossible to adequately clean out the debris filter on top of the tank that the gutter flows into, resulting in 50-75% water loss for that tank...rain overflows around screen and run down side of tank, puddles at base of tank. Have called SARG a few times, they came out, but each fix only made it worse.”

Leaking parts: “Some seals were leaking a little bit and needed a little bit more sealant.” “Small leak where there are threads for hose connector.”

Insufficient pressure: “Every[th]ing I need watered is at waist level or in pots about 18 high. When the level drops in the tanks, the flow is too slow or even non-existant. I will have to buy pumps.”

Respondents were asked if the issues they experienced were expected. They were given the option to select “no issues,” which 55% of all respondents selected. Of the respondents who indicated they had experiences issues, 62% indicated they were expected and 38% indicated they were not expected. See Figure 2B. Respondents were also given the opportunity to explain their response. Many of the responses for people who expected the issues repeated the issue in place of an explanation. For example, “all of my cisterns at times are not large enough. water flows from the cistern over flow pipes.” Some did explain their response by indicating that they were aware of the issue before installing, or by writing that new systems often have issues in the beginning. One respondent said, “I was aware that as part of maintenance, it is important to clear debris and flush cistern occasionally.” Another wrote, “There are always minor bugs in systems when they are installed.”

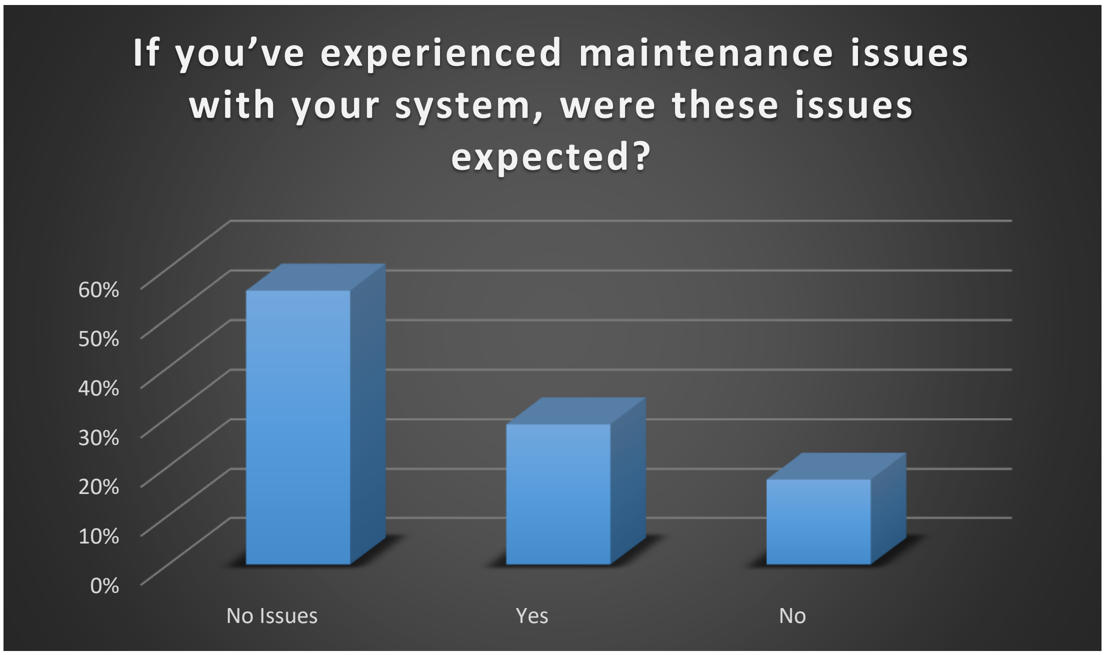

Figure2B: Maintenance issues expected or not

Similarly, in explaining why an issue was unexpected, many simply wrote that the problem was unexpected. “I did not expect the mosquito issue,” for example. Others indicated a design or installation flaw was to blame for the unexpected issue. “If it would have been installed correctly, there would have been no issues.” “Filter design failed. Got a replacement with new design.” Many also restated the problem: “Algae and mosquitos.”

The respondents were asked about the preventative maintenance that they have done. “Clean gutters” was selected by 68% of the respondents. “Clean first flush filters” was done by 33%, some “other” form of preventative maintenance and no preventative maintenance by 18%, “re-inforce basins with rock to prevent erosion” by 16%, “paint storage tanks” by 8%, “clean storage tanks” by 7%, “lint cleanout in graywater system” by 5%, “repainted inflow/overflow plumbing” by 5%, and “cleaning soap buildup in graywater basins” by 3%. See Figure 3B. The responses of those who selected “other” can be summarized in eight categories: 1) debris screen replacement/cleaning, 2) Installing some other screen for pests, 3) Mosquito repellants, 4) Caulking/paint, 5) Dig basins/berms, 6) Clean gutters, 7) Replace pipe, 8) Cover various parts to protect against sun/freeze.

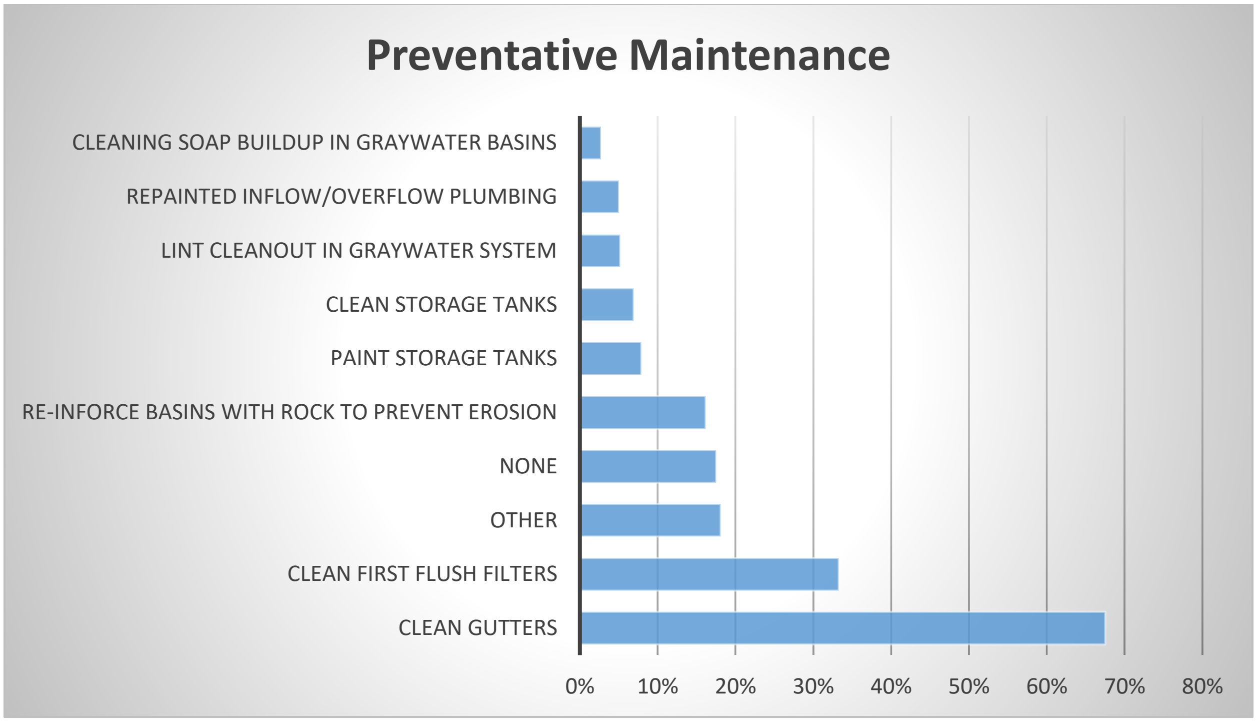

Figure3B: Preventative Maintenance

The survey also asked about repairs that the respondents have done. A majority (59%) indicated they have done no repairs. Some "other" repair was done by 13%, "mosquito treatment" and "adding mulch to basins" were done by 11%, "re-design of passive system after large rain event" and "repairs related to tank overflow" were done by 10%, and "replace valves on tanks" and "replace broken pipe" were each done by 4% of respondents. See figure 4B. The "other" responses can be summarized in four categories: 1) Add/change filters, 2) Modify gutters, 3) Install additional pipes, and 4) Berm modification.

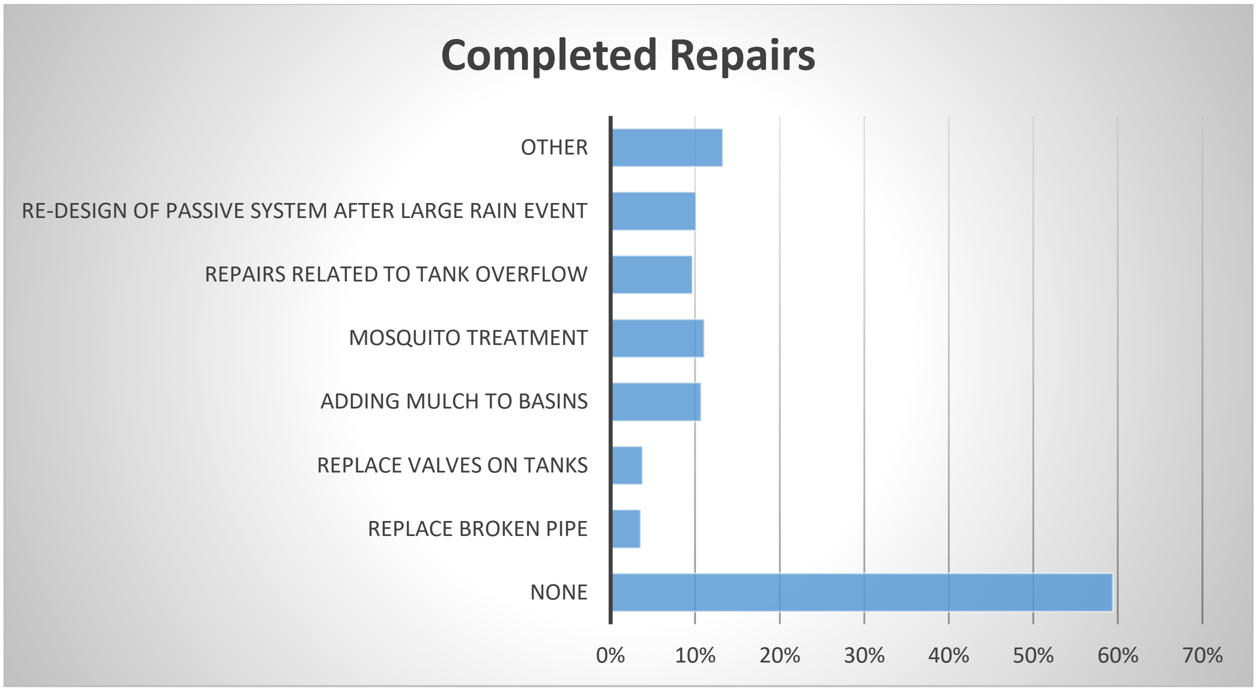

Figure4B: Completed Repairs

Respondents were asked to rank their top three maintenance requirements. The most ranked overall was "clean gutters;" it was selected 298 times. The second most ranked overall was "clean first

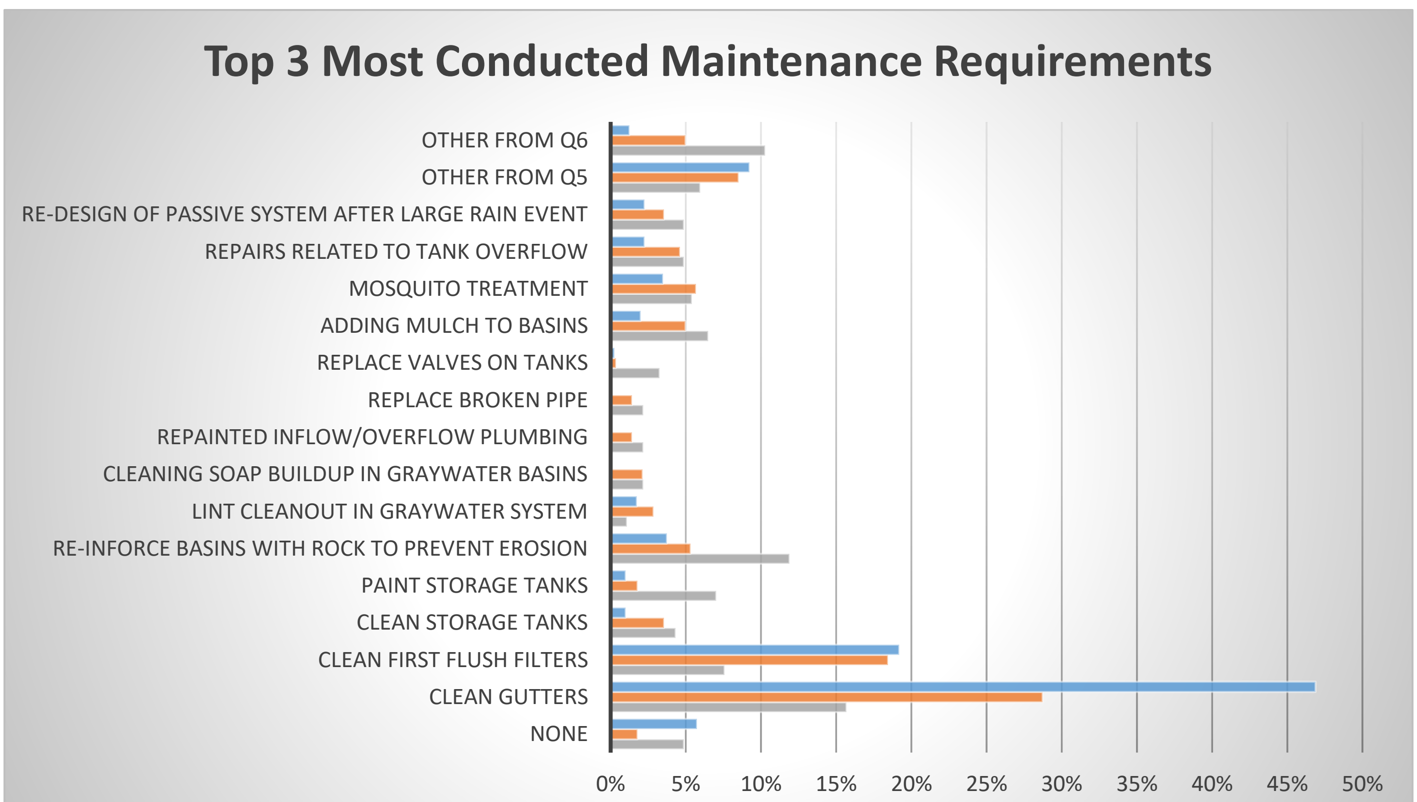

Figure5B: Maintenance requirements ranked by frequency flush filters;" it was selected 143 times. The third most ranked overall was "other from question 5" (regarding preventative maintenance); it was selected 72 times. Figure 5B summarizes the findings.

Respondents were also asked to select their most concerning maintenance requirement. "None" was the most selected with 156 selections followed by "clean gutters" with 142 selections. "Clean first flush filters" was selected 41 times, "other from Q5" was selected 37 times, "mosquito treatment" was selected 24 times, "repairs related to tank overflow" was selected 18 times, "other from Q6" was selected 16 times, "clean storage tanks" was selected 13 times, "re-inforce basins with rock to prevent erosion" was selected 12 times, "re-design of passive system after large rain event" was selected 11 times, "lint cleanout in graywater system" was selected 5 times, "adding mulch to basins" was selected 4 times, "replace broken pipe" and "replace valves on tanks" were selected 3 times, "paint storage tanks" and "cleaning soap buildup in graywater basins" was selected 2 times, and "repainted inflow/overflow plumbing" was selected 1 time. See Figure 6B.

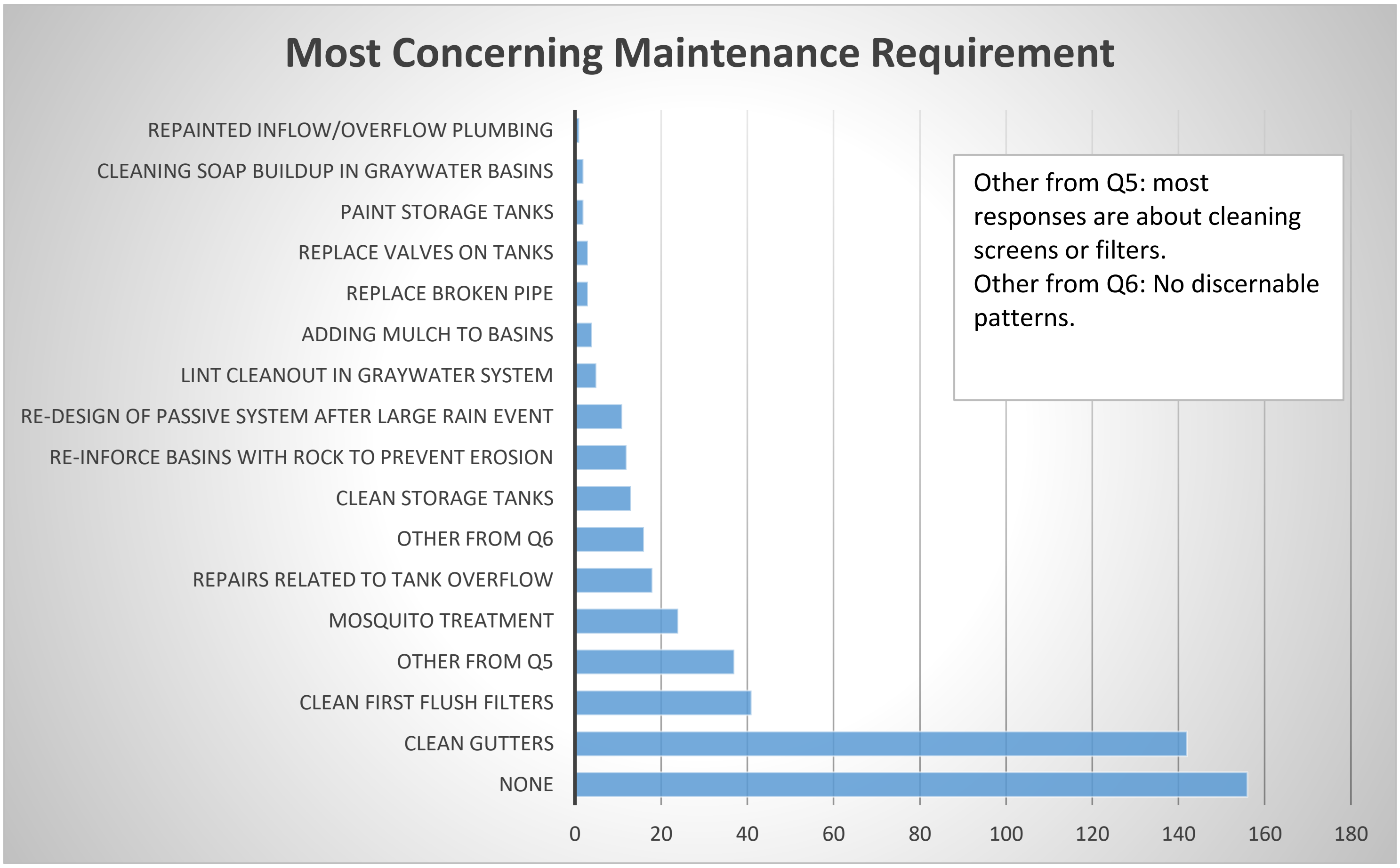

Figure6B: Most concerning maintenance

For those that selected "cleaning gutters" as the greatest concern, the reasons for this selection varied. Most didn't give reasons why it is concerning and instead gave responses like: "keeping the gutters clean keeps the cistern cleaner." The word clean(ed,ing) was mentioned 18 times. Others referenced the need for a ladder: "requires ladder." Ladder(s) was mentioned 5 times. Others stated the concern was mostly due to clogged gutters preventing proper operation of the system: "Debris in the gutters ultimately ends up in the filters and impacts collection efficiency." Debris was mentioned 13 times, clogged: 10 times, prevents was mentioned in the context of something preventing proper operation 9 times, and leaves were mentioned 11 times as a form of debris that causes problems.

The selection of "first flush filters" as the top concern was generally explained by a statement that clogged filters block water or that water odor had become undesirable. For example, "Cleaning out the first flush is imperative at this point to reduce the possibility of odor associated with standing water in the pipes." And "I don't want to hinder the flow of water to my storage tank." Clean(ing) was mentioned 8 times, and odor/stink(y) was mentioned 3 times. Ants were also mentioned 3 times as a source of clogged filters.

Nine respondents listed a reason as to why "cleaning tanks" was their greatest concern. The consensus of these is that this is a very labor intensive and physically difficult task. The words "time consuming," "cumbersome," "difficult," "inconvenient," "labor intensive," and "messy" were all used, which give a good impression of the mood surrounding this task. Only two respondents selected "paint tanks" as the most concerning. One wrote, "Ultraviolet sunlight is harmful to plastic," and the other "At least two coats because of our heat."

Respondents that indicated "re-inforce basins" as the greatest concern were primarily worried about soil erosion. For instance, "plants are affected by the erosion," and "Don't want to compromise the tank or plumbing."

"Mosquito treatment" was selected primarily because of concerns about safety and the ability to use the yard. The phrases "prevent use of outdoor patio," "don't like mosquitos," "bothersome," and "fear of West Nile Virus" were used, which represent the general sentiment of mosquitos more than the task. "Repair from tank overflow" was selected because of concerns about overflow affecting the house or erosion. "Foundation" and "erosion" were mentioned twice, and "house," the most commonly used word, was mentioned 4 times. Those who selected "re-design after rain" were concerned about the hard work to do this, and "other from Q5" most often were concerned about screens. Screen was the most used word, and was mentioned 8 times. It was accompanied by words like "clean," and "debris." "Lint cleanout," "soap buildup in graywater," "add mulch," and "other from Q6" had few responses respectively, and no discernable patterns in the responses.

Respondents were asked the amount they spend on maintenance annually. The responses to this question varied quite a bit, and it should be noted that the question did not specify a unit to spending. Some wrote in a dollar amount, which is what the designers had in mind, and others wrote in an amount of time. A majority of people (54%) indicated that maintenance cost them nothing annually. The second largest group of respondents wrote in a time or indicated that they did not know. This made up 24% of the responses. The question was open-ended, but the values were put into bins. These bins are "less than $50," "$50 to $100", "$101 to $500," and "over $500." "Less than $50" received 13% of the responses, "$50 to $100" received 5%, "$101 to $500" received 3%, and "over $500" received 1%. See Figure 7B.

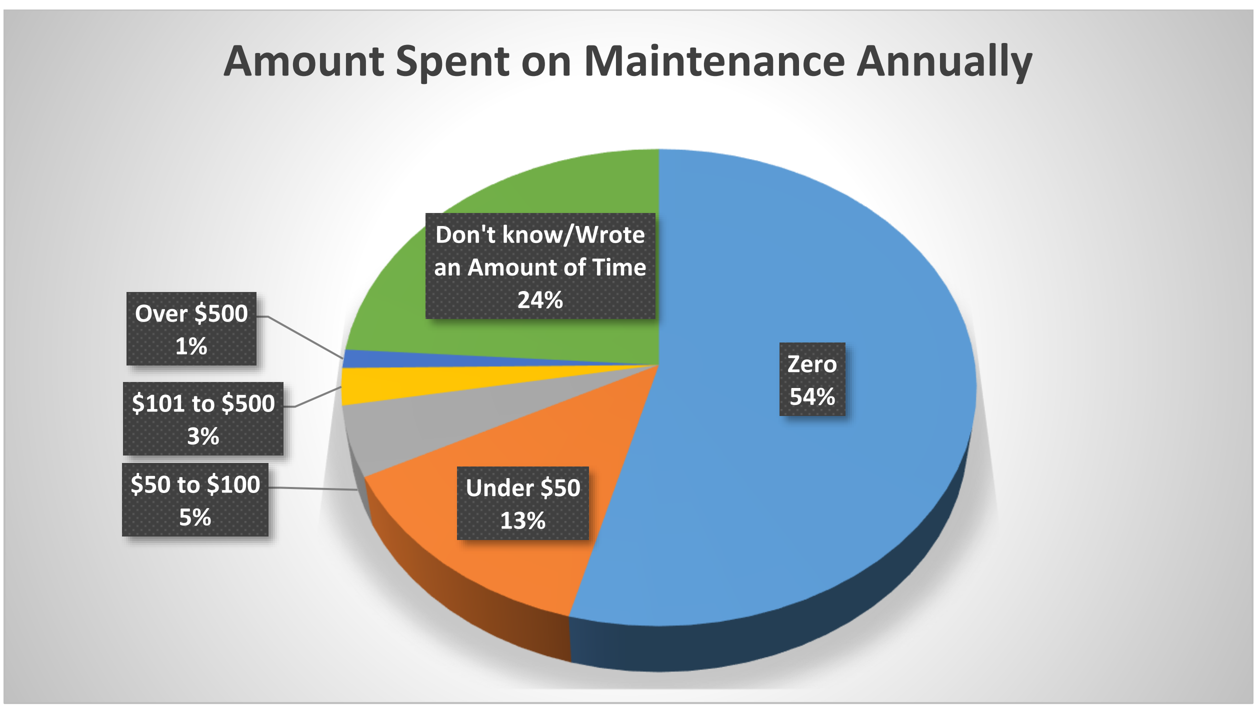

Figure 7B: Annual Maintenance Spending

Respondents were asked about how frequently they do the maintenance requirements they selected earlier in the survey. They were given their previous selections and the choices “weekly,” “monthly,” “quarterly,” “yearly,” “only once,” and “after a large rain event” for each of their selections. The most common weekly selection was “none,” followed by “clean gutters.” The most common monthly, quarterly, and yearly task was “clean gutters.” The most common selection for “only done once” was “other from Q6.” The most common task done only after a large rain event was “clean first flush filters.” Figure 8B displays the percentage of respondents that selected each task, broken out by the frequency they do the task.

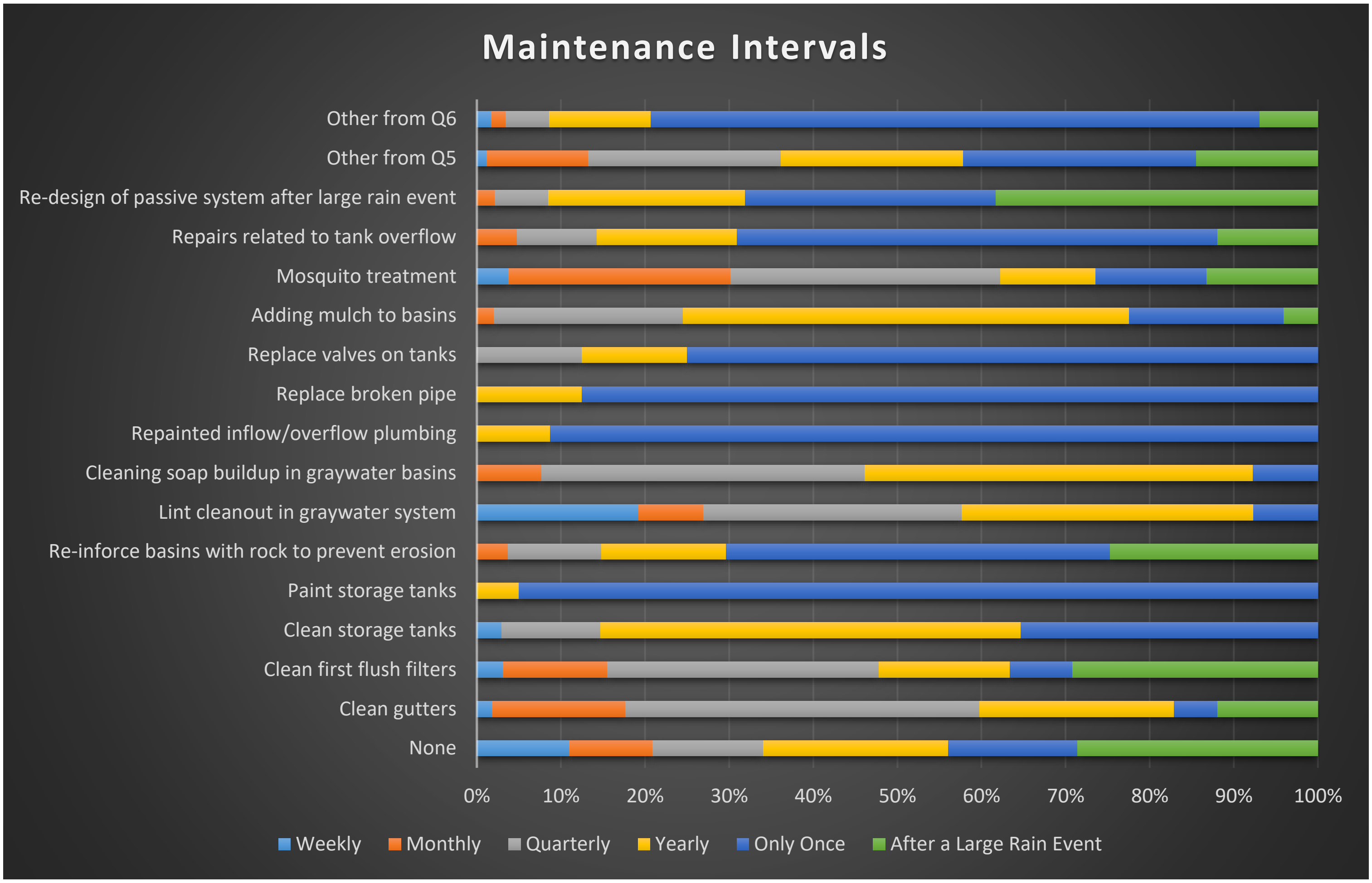

Figure 8B: Maintenance intervals for each task

It is possible that some of the survey respondent’s harvesting systems broke and have not been fixed. They were asked if maintenance requirements prevent use of their system. An overwhelming majority (91%) indicated that their system is working properly. Only 7% said that their system is working, but not as designed, and 1% indicated that their system is not working at all. See Figure 9B. To follow up on this, respondents were asked how long their system has not been working. Responses indicate that 20% of the broken systems have not worked properly since installation, and 3% have not worked for less than six months. There are 5% of systems that haven’t worked for six months, 3% haven’t worked for one year, 5% haven’t worked properly for two years, 2% haven’t worked properly for three years, and 2% haven’t worked properly for more than three years. The question was open-ended and 62% of respondents indicated the question was not applicable or wrote in some other piece of information. See Figure 10B.

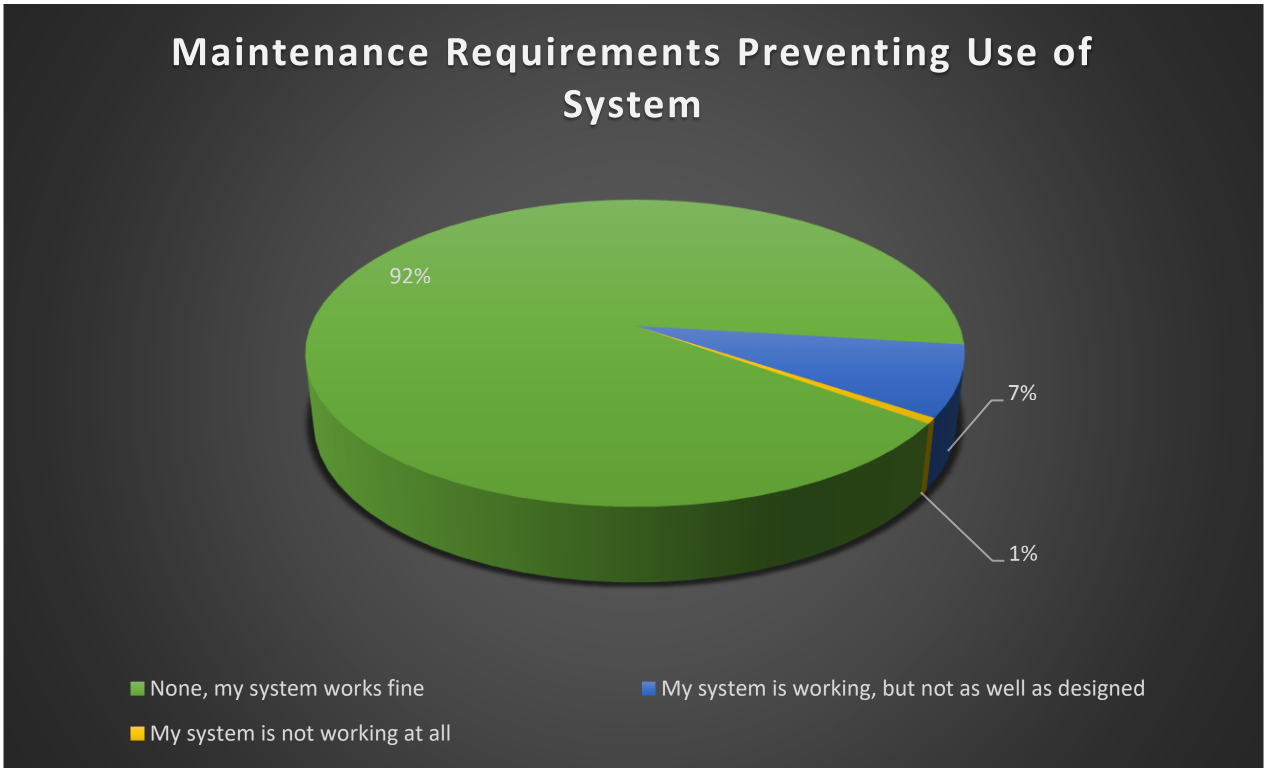

Figure 9B: The percentage of systems working or not working due to maintenance requirements

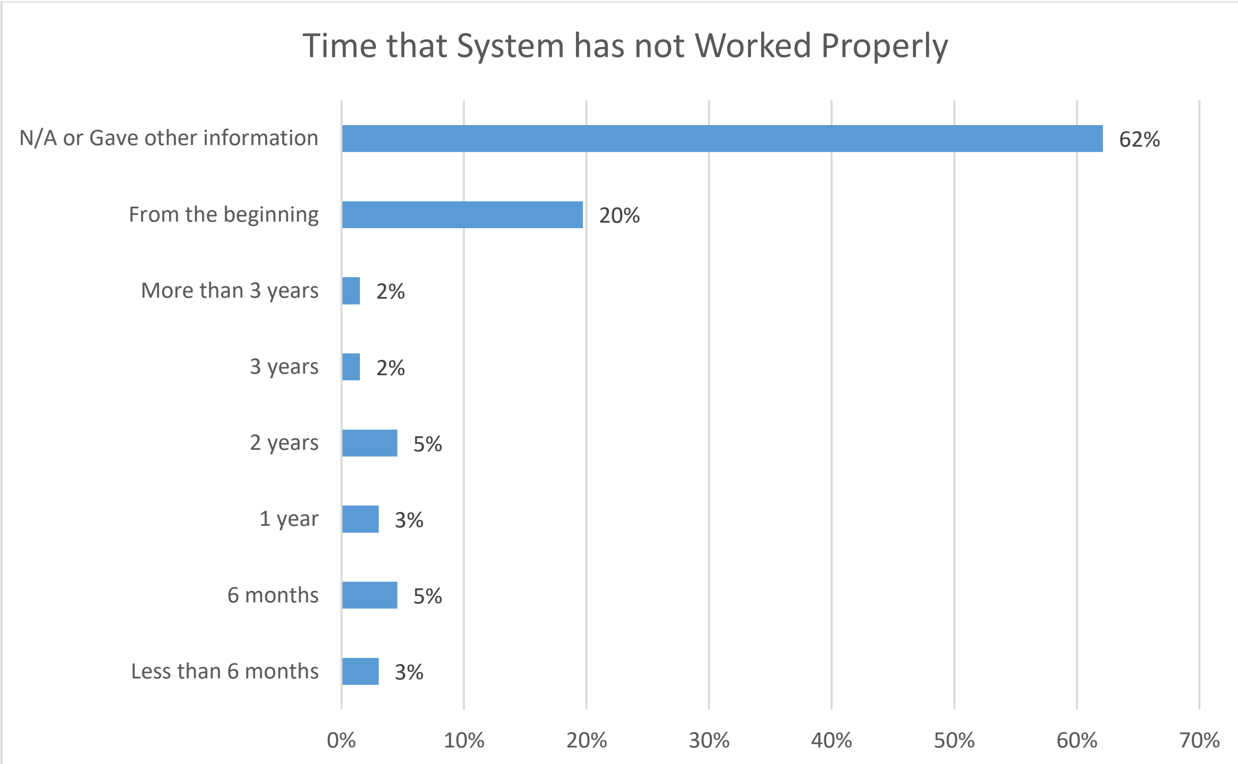

Figure 10B: Time that broken systems have not worked properly

The respondents were asked if they have the ability to repair their system if it breaks, and 82% indicated that they do have this ability while 18% indicated that they do not. See Figure 11B. To follow up on the effort and time maintenance requires, they were asked how much time each maintenance action requires. In this question they were given bins of time, and 72% indicated that each maintenance effort takes less than one hour. The next most common answer was one to two hours, which received 23% of the selections. "Half a day" was selected by 3%, and "a full day" was selected by 1% of the respondents. See Figure 12B.

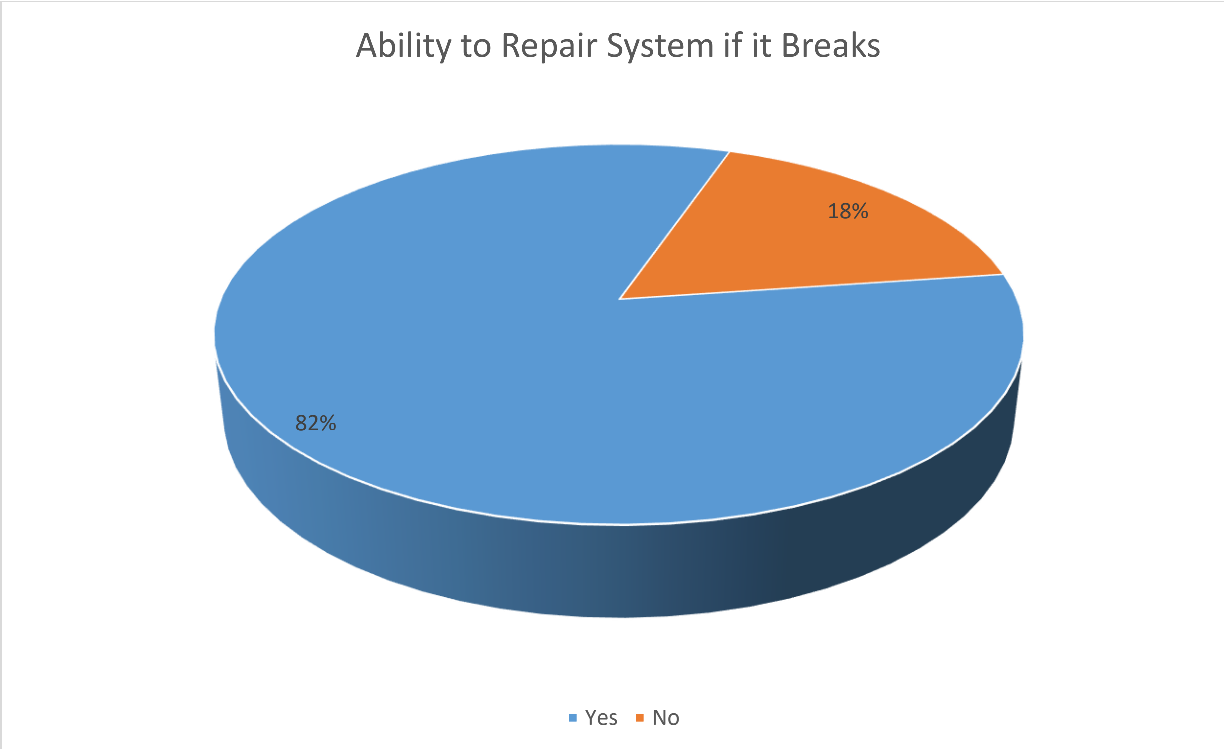

Figure 11B: Percentage of respondents with the ability to repair their system if it breaks.

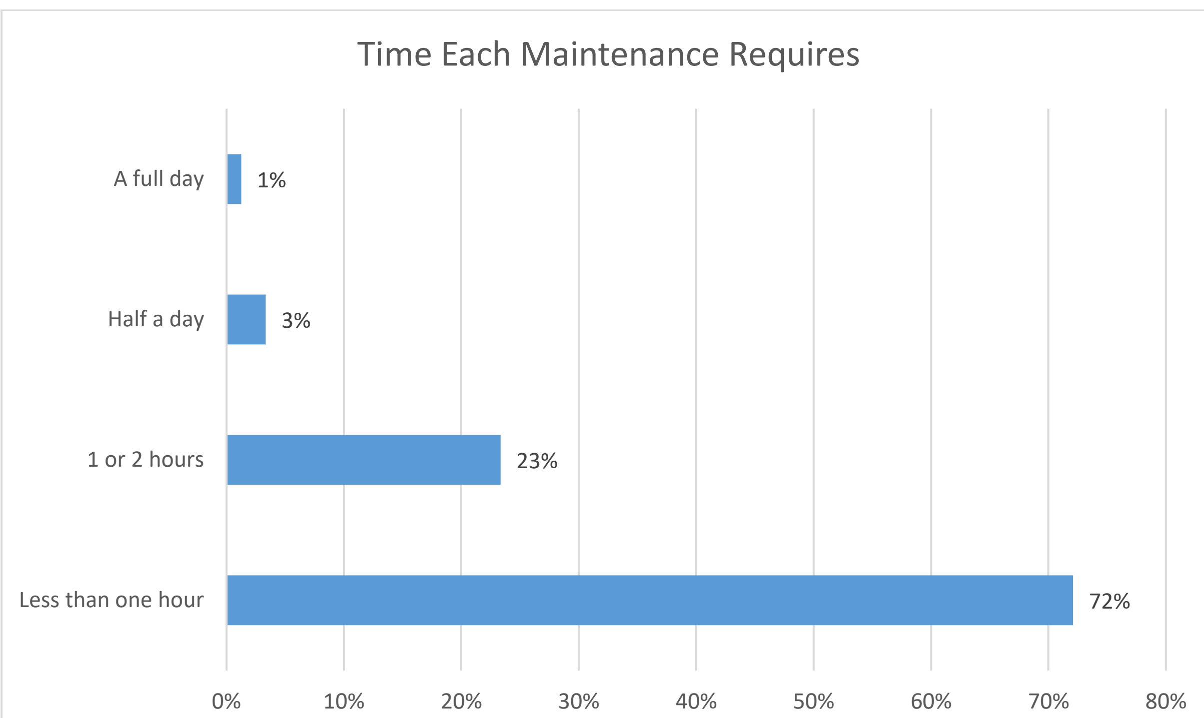

Figure 12B: The amount of time taken when maintenance is required.

Little is known about the water harvesters' perception of the quality of their harvested water. They were asked if maintenance requirements affect water quality and to explain. Most (94%) indicated that maintenance requirements have not affected the quality of water, and 6% indicated that they have. The explanations varied quite a bit. The most common themes in the responses are that an unfixed maintenance requirement has caused the system to produce an odor, the mosquito poison contaminates the water, and that some malfunction allows silt and dirt to build up in the system. "Odor" was mentioned three times, "smelly" once, "foul" in the context of smell was mentioned once, "mosquitos" were mentioned twice, "debris" was mentioned twice, and "impurities" was mentioned once. Many respondents also gave some other information, unrelated to the question such as, "I could have collected more."

The survey asked if respondents would install the same system again, and to explain. A large majority (93%) indicated they would install the same system again, and 7% said they would not. Again, explanations varied, but the main ideas included adding more capacity, better and/or different filters, putting in a passive system, installing a pump and fixing pressure issues, and to remove the pump in graywater systems. "More capacity" was mentioned twice, "larger tanks" was mentioned 3 times, "pump" was mentioned 3 times and it was mentioned two more times in conjunction with "remove," "pressure" was mentioned twice, "filter" was mentioned twice, and "passive" was mentioned twice in the context of installing a passive system.

The last question was open-ended and asked if there is anything the harvesters wished they had known before installing their system. These answers were extremely varied, and the main ideas are as follows: 1) None/classes were sufficient, 2) How to size gutters, 3) How to deal with mosquitos, 4) How to position system/use for irrigation, 5) Better classes, 6) More about pressure limitations, 7) Training on maintenance, 8) Help with design, 9) Help selecting good installers, 10) How to work with HOAs/give training, 11) Info on build materials, 12) Info on water quality, 13) Issues with/clarity about rule changes. These main ideas were selected by using Nvivo to find the most common words, and then looking at those words in context. For example, "class" was used 19 times, and some of those were to indicate the classes were sufficient, and some indicated that better classes were needed.

Appendix C: Full Text Responses

Q2: Please describe your water harvesting system(s).

Two cistern which harvest water from roof via gutters

Several earthworks to the rear and side of the house

2800 gallon plastic, above ground tank

Landscape basins, and laundry to landscape greywater system.

Gutters from roof feed two large tanks, one on each side of the house.

Dug basins in the front and back yard to collect rain water.

860 gallon tank

Mostly roof collection into three tanks.

Basic . About 150 ft of gutter draining into a 1320 bushman tank.

Roof and gutter get most of rain water from our house. Most goes into cisterns. Some floods some landscaping

2 tanks off of one roof

two water harvesting tanks on south and north of property and passive water systems for fruit and citrus trees on south and north of property.

2 750 gallon sisterns, with swale and basin permaculture...

We have two large tanks which are fed by gutters on our roof. we have drastically lower our irrigation and remove our grass lawn and front privy hedge and replace it with various cacti.

1300 gallon tank from approx. 1/2 of roof surface

850 gal tank fed by new gutters on roof. Overflow runs into earthworks area, dropped beds with desert perrenials. Rear of house has a 10-ft drop, ceated dry roch wall with basins. Second gutter feeds this area across open ground. Not quite finished... 850 gal tank is too small to provide water through late spring drought.

newly installed gutters (very expensive!) and three large tanks, some earthworks

2 800 gallon tanks hooked up to gutters that are used to water plants in both front and back yard

Gutters, downspouts, 2 cisterns, one infiltration basin.

Passive in front yard, gutters dump to 2 trees. In back yard gutters feed 1 865 gallon cistern. I should have 2 cisterns to maximize water collection, maybe in the coming year I will redo the back yard system.

Two 860 gallon cisterns connected in series to gutter downspout on one side of the house, and one 1320 gallon cistern connected to gutter downspout on other side of house. Downspout in front discharges to earthworks. We also have a laundry to landscape system that irrigates out landscaping vegetation.

Two 5' culvert cisterns, about 1900 gallons total. Gutters on about 2/3rd of our house, about 1000 square foot collection area. Also several basins in the backyard.

Water collection of of residential two car carport, both eves plumbed into one 1100 gallon tank. Passive is on entire 1 acre, feeding into tree wells with over flow spouts to protect well burns, overflow channeled to next downstream tree.

3 water harvesting tanks that catch water from the garage roof. Garage has single slope toward tanks. First tank fills then overflows into 2nd and 2nd overflows into 3rd. Also passive water harvesting of berms to direct water to plants and basins.

865- gallon PE cistern in the back of the house. Installation included adding gutters to a porch roof which had previously shed water onto the brick patio and stairs to our basement, with a questionable drain at the landing.

Most of our south-facing roof empties into gutters and an 865 gallon reservoir or cistern. This water is then used for the maintenance of the new trees/plants we have added to our backyard in the past year.

Multiple berms ,basins, curb cuts off the street

Full gutter system with half of the roof area going into storage tanks the other half going into underground leaching areas and retention areas around property

1200 gallon cistern collects from garage roof. It is a wet system. We have a bleed off for the wet system that feeds a small central portion of back yard. Overflow goes to passive system on one side of house and on to front yard. Yard - front, back and sides - have swails and retention basins. The house has a gutter on the back roof that goes to passive retention basins on side yards. The sides of the house roof is not guttered and feeds the passive retention basins on side yards.

1300 gallon tank. Some passive earthworks

1400gl cistern fed by three of five scuppers on the house. Earthworks.

850-gallon tank attached to roofline gutter

Runoff from hardscape to plants and water storage tanks from gutters off of roof.

1500 gallon tank, swales, retention basins

Two 865 gallon cisterns draining from house roof.

I have two large tanks--885 & 1100 gallons that collect rain water; a hose connected to washing machine that can be moved from tree to tree; and a passive system that flows down hill.

Two storage tanks -- approximately 900 gallons and 1130 gallons each.

2 rain tanks for the roof runoff. 1000 gallons and 1500 gallons.

I have a metal cistern in the back yard, and a plastic unit in front. My first WH project was digging a question-mark-shaped ditch off the street--a kind of fjord that waters a mesquite tree, a pomegranate, a fig, and a screw-bean.

Roof gutters that Supply 2 1350 gallon tanks

Burms, basins and ground scape with contours to divert run off from the street, roof and patios. Graywater to a tree line of shade trees.

Catch rain from roof into approx. 3000 tank and 300 gallon tank. Use water to water the many landscape and potted plants on the property

We have 3 850 gallon tanks installed in the back yard and some passive earthworks in the front for gutter runoff.

1--Swales and birms to slow runoff from my property

2--Three interconnected storage tanks linked to a drip irrigation system (still partly under construction/expansion)

This is the second time I'm completing this survey, as I want to update my previous comments. Here, for this question, I have 2 850 gal tanks filled off of my roof.

1000 gallon tank collected from garage roof

300 gallons collected from house roof.

all harvested h20 is used for pool and irrigation.

We have two large tanks, and a series of dug trenches for gathering water near trees.

cisterns

basins in the yard, tank for rainwater from yard, laundry to landscape

Runoff from roof sent to multiple storage containers, totaling approximately 1900 Gallons. Also some channels dug to direct water to trees.

roof rain gutters attached to storage tank

Water collection from gutters into water tanks and also water diversion from other drains into French drains covering ground cover and trees

2 tanks with rain gutters feeding them, plus passive landscaping leading rain run off to trees and shrubs.

Bushman tanks feed ponds, ponds water plants

gutter flows into a 3000g tank. then it is pumped back into the irrigation system

We have two 860 gallon tanks. Also swales and berms in the landscaping to direct rainfall water to our plants.

Gutter and tank on the rear workroom. The gutter is about 20 feet long and feeds into a 865 gallon tank. We use the tank to water regularly.

One side of our house is guttered which drains into two 1,100 gal tanks. We also have nine other basins in our yard.

Just get water through gutters and have separated tanks in four corner of the house. Each tank about 210-360 gallons.

Rainwater is being harvested from 3,316 s.f. of roof area and collected in one 1320 gallon and two 865 gallon tanks. Approximately one half of east facing roof is diverted to a series of constructed drainage basins.

825 gal. cistern, landscape mounding/berms and tree wells.

Storage tank 250 gallons

- the front yard of my home has a system; the rainwater comes off the roof into basins and then seeps into the ground. The graywater from the washing machine drains into a pipe and flows into a basin which waters the citrus trees.

Passive and active in front yard. Cistern is 530 gallons

Active in backyard. Cistern is 1365 gallons

Multiple storage tanks with max capacity of about 1000 gals.

2 tanks

guttering to tanks located around house. washing machine piped to orange tree.

Tanks with gutter feeds

gutters to the water tanks

Basins and swales

Three 2500 gallon cisterns placed on different portions of our property to collect all of our 1600 square-foot horse barn roof drainage to supplement horse drinking water A cup of bleach after a big rain when the tanks filled up to prevent algaeand another to collect from the main house and garage probably 5000 square-foot for backyard grass and main drip system And a third to collect from the south portion of house and activity outside room and barbecue area probably another 2000 square-foot Bailey for the pool evaporation

The largest portion of our roof is a flat style roof, which is sloped to a collection system that goes into two cisterns. The ends of the building have sloped roofs. The water falling on to the ground below is directed away from the building and toward planted areas.

865 gal tank fed by guttering on our house. Hose at the bottom of the tank to water plants and a row of oleanders.

Tanks on the gutters of the house

Roof run-off to gutters. Basins and swales, curb cuts, to capture street run-off.

Passive on north slope side of central roof beam, two tanks on southside.

Large cistern collecting rainwater from roof.

Small rain barrel collecting water from 1 drain.

Pond and land shaping with berms in backyard.

Pond and land shaping with berms in front yard.

We have 2 cisterns ties to our roof (865 & 1100 gallons).

Roof collection into tanks. Greywater into garden area through a sump pump and hose for flexibility

1320 gal cistern collecting 1/2 of our roof runoff, plus several buckets for the other half.

A 1320 gallon Bushman tank tied to the roof downspouts with overflow to the landscape. Basins throughout the yard.

roof gutters that drain into storage tanks. Approx 1900 gal storage.

Passive: We have basins in the front and back yard

Active: We have 2 storage tanks

Graywater: Laundry and one shower, both go out to landscaped areas

Gutters around the house and a 1,000 gallon tank

We have rain gutters that drain to storage tanks. The tanks have garden hoses that we use to water garden plants and the overflow of the full tanks drains out to water trees.

2 1000 gal tanks and new rain gutter set up to supply the front and rear yard.

2 one thousand gallon tanks one at detached garage one at house

850 gal and 1100 gal cisterns collect rainwater off roof. Swales and berms for passive ground collection.

1. Storage tank collecting 1/3 roof area run off.

2. Swale/basin collecting water from porch roof gutter and brick patio runoff.

I have two cisterns hooked up to my irrigation system.

I had an 865 gallon tank installed behind my house. It collects rain from my 1600 square foot flat roof.

Roof runoff is diverted to tankage by a gutter system.

3 storage tanks connected to gutters

rain barrles and passive flow water basins around trees one 800+ gal and one 1300+ gallon collection/storage tank on either side of our house in the back yard. All water from the rear roof of the house and 60 ft patio roof runs thru gutters into these two tanks. I irrigate all the plants in my backyard from the water collected in these tanks. Depending on rainfall, I can water every-other-day for 1/2 hour for a few months. The gutters in the front of the house channel the water into the front yard to several shrubs and one mesquite tree.

I moved and no longer have a harvesting system.

four tanks: 1100 galls, 850 galls, + two smaller

Wet system

We have 2 different properties. Our original property has a rainwater harvesting tank; our newer property has 2 rainwater harvesting tanks and a gray water septic system integrated throughout our almost 3 year old home.

Two 650 gallon tanks.

Three 850 gallon tanks and 5+ retention basins scattered over the property.

1780 galvanized tank

A tank that collects water from the roof.

Washing machine drains into trees, 850, 400, 600 gallon cisterns in the back, 2 55 gallon in the front. Gutters in the fron and back of house and back of shed

Berms and basins.

3400 square feet of roof collection into 2800 gallon above ground tank (dark brown/red)

Gutters with two tanks; 1100 gallon and 2800 gallon.

3 linked 800+gallon tanks. Pump and back flow preventer

Berms to harvest water on site slope and prevent flooding and erosion

I have water cisterns that are attached to hoses and used to water plants.

Two storage tanks for roof rainwater collection and a gray water system. Also earthworks

Cisterns attached to gutters

several storage systems, to harvest from all scuffers from the roof, except for one 860 gal, 340 gal, 3x 75 gal, 2x 85 gal passive system for the patio roof into the garden with earthworks and landscape

rain gutters that drain into water tanks, one on each side of the house

Fairly new active system includes 850 gallon tank collecting water from roof. Tank is currently full with not all that much rain since completing tank install. I am in process of running distribution lines so can use on more of landscaping.

Passive system involving landscaping and use of street water is an ongoing project as I move soil to direct and hold rain water where needed.

We collect water from our roof (roughly 60% of total roof area) into 2 tanks

2-875 gallon cisterns harvesting off of a 600 square foot art studio roof.

Laundry to Landscape.

Various swales around my yard mostly fed from the downspouts on the house.

1320 gallon tank capturing rainwater from the roof.

Added new gutter across entire length of house which empties into a 1011 gallon tank. Since I have only desert landscaping I use the water to only fill my swimming pool.

865 gal. bushman linked to gutter. dug out earth to collect rain water naturally in many areas in my yard.

2 500 gallon barrels and 1 1350 gallon barrel

Tank and Passive

We capture water from 100% of our home's roof. Water is stored in a above ground cistern and connected to our irrigation system.

roof collection in addition to berms

I have a pitched roof house and have installed gutters on back half. My tank is 1310gals

Two cisterns

There is an 865 gallon tank (in the back yard) and guttering down the long roof line that empties into this tank.

Water collected from roof via gutters and stored in 860 gal. above ground tank pipe from one gutter goes underground then back to top of tank

One downspout directed to a series of earthen catchments. This is the passive system.

One 300 gallon tank which is clear poly that I painted to stop algae growth. It is set on pillars one foot up to give it gravity flow. I made a very flat and wide strainer with stainless steel which has proved to be very effective at self maintaining as clumps of leaves which come down the spout wash off the top

Two more tanks total 2000 gal tied in tandem with an equalizing pipe. The water from these tanks feed to a well pump set at 25 psi which pressurizes a pipe system on the property which enable the drip system as well as the swamp cooler float to work.

Gutters with cistern

2 825 gallon cisterns with gutters, collecting water from the roof.

2 cisterns collected from roof gutters

Gutters drain into channels, which distribute water to bermed areas around trees.

Basins and berms to capture rainfall. Gutters on the roof to a cistern that feeds a manual drip system for supplemental irrigation of desert plants. All less than 2 years old.

Two large barrels on each side of the home connected to our rain gutters. Same set up with small tank on chicken coop. Laundry water runs to back side of property.

Two 1000 gallon tanks receiving about 3/8's of the total roof runoff. Tanks will be hooked up to the irrigation system.

3 cisterns

Two 865 gal tanks from main roof gutter to vegetable gardens

One 100 gallon urn from small roof area gutter for watering with hose in front of house--fig tree and potted plants

Washing machine to vegetable garden

Small storage tank collects from 2 scuppers off from my flat roof over garage and bedroom.

Three tanks with a capacity of 1800 gallons that are connected with underground 11/4" pvc piping and used for irrigation.

Passive- I have made dirt berms. eyebrows to stop water runoff to water trees

Active- I have installed 2- 865 gallon tanks which collect water runoff from the roof of my house

Basins and rock work, greywater to a basin, three 865 gallon tanks, one 2825 gallon tank collecting run off from roof.

One 1,320-gal. and one 65-gal. tank, each collecting from downspouts/gutters. Pails kept in bathrooms.

5 cisterns ranging in size from about 400 gallons of 1300 gallons.

We collect rainwater from three roof areas and pipe the water underground to three pop-up valves. We worked with Watershed Management to place basins and berms in the yard, hoping for a riparian environment when plants get established.

Water runs from roof to basin in front and back yards. As well I have basins along the Greenlee Road side of my home which takes in street water from rain which works great. I wish the City would be more proactive in getting neighborhoods to have basins along their property boundaries where they could accumulate the street runoff, especially as this portion of your property is City owned.

Roof collection into 3000 gallon tank. Gravity feed to hose.

We have a large sloped property and had a ton of eathworks done to slow and keep the water on our property.

Two tanks off of a roof

Swales and berms in one part of the yard for collecting runoff and overflow from cistern. 3 1150 gallon cisterns around the house

Tank to collect rainwater from gutters as well as earthworks

rock work to make basins for catching rain

One side of roof, gutter into large double sided 1060 Gall tank.

Passive water collection/routing techniques were first applied to our 1-acre home site to help mitigate drainage and erosion issues from water coming off of the roof of our 2500 sq. ft. home. Gutters had never been installed on this 25-yr old home so the second phase was to install them on all roof edges and scuppers along with 4" drain pipe to distribute the water to selected areas for better plant sustainment and percolation. The third step was installation of a 2,800 gal plastic tank for water harvesting and controlled distribution around the property. Finally, a second tank with 1300 gal capacity will be installed this month.

(2) plastic storage tanks, and (4) 55-gal plastic storage containers. Water collection is from rain water runoff from the roof, plus gray water collected from a pan in the kitchen sink.

Gutters collect roof rain water into cistern, distributed throughout yard with a hose.

Approximately 2300 gal. Underground from roof. 12 volt solar system returns water to surface for distribution.

Active system in front yard and back yard with a large gallon cistern located in both areas.

Burms for water collection and storage tank

We have a 1200 gallon steel culvert cistern, passive earthworks/landscape features, curb-cuts to harvest water off the street, and a laundry to landscape graywater system. We also have a couple of small 55 gallon rain barrels.

1100 gal tank connected to roof gutter

2 1,100 gallon tanks to collect rain water from the roof of our house. We also use buckets to capture rinse water from doing dishes and buckets to catch water from our shower whenever we take one.

1000 gallon plastic tank connected to half of our roof's gutters via a wet-plumbing system. We additionally collect water from out shed's roof with two 55gal drums.

Our system consists of 3 rain catchment tanks (500 gallon, 420 gallon and 205 gallon - also have 2 rain barrels (60 gals.) to catch overflow) filled by roof runoff, plus have made small berms to capture and direct rain flow to plants. We use this water for vegetable garden, rock garden and flowers.

Roof Rain water harvesting with overflow to basins.

Installed gutters and rain diverters to roof of house which directs all water to five olive trees for irragation.

Gutters direct feed two tanks of 1100 Gallons each, Bushman, plastic. Additionally a diverter feeds a fluid transport surplus 300 gallon tank. Trees have embankments built to retain run-off as passive collection.

We have a series of passive systems of berms and basins to hold and direct water to gardens. We have 2 cisterns to collect rooftop water to redistribute on plants and one cistern to collect water from the evap cooler we use for plants, pool filling (ugh) and outdoor washing.

We have ~ 1900 gallons of storage. The water is collected exclusively from roof run off via gutters. We have two connected 420s; one 660; one 265; one 80 and one 50.

I have a graywater system from my washer and I have two 865 gallon cisterns

Three (865) tanks. Black PVC pipe, Two different kinds of headers. Currently working with a welder and making our own.

I have 4 tanks that collect water from my roof, and two storage tanks (one with sprinkler system attached) which I fill from the active tanks.

860gal tank

I have a cistern InThe front and a barrel in the back of the house.

1,300 gallons. Two Bushman tanks: 205 gal, 660 gal. 15 30-gal. Rubbermaid Brute garbage cans.

Capture water from gutter system and roof

3 black plastic 50 gal containers from Home Depot; over flows drain into trees

I have 2-1,120 gal. cisterns and a complete roof gutter system.

gutters with two large cisterns; earthwork to cache water and divert to large trees

No water leaves site except through sewer, all rain stays on site. One 1,950 gallon culvert cistern. Extensive berm-n-basin system reinforced with riprap.

Home is fully guttered with 6 downspouts draining into underground piping which empties into basins dug 24" deep and filled with composted material which creates numerous garden areas.

Cistern in front and barrel in back

Rainwater 1 -2500 Gallon and 1000 Gallon Tank

Small 60 Gallon gray water (washing machine)

Passive system to collect roof water and redistribute around the landscape to retention basins around fruit trees (one mission pomegranate and one old tangerine) and native trees/shrubs. Grey water system to distribute shower/laundry/sink water to the two fruit trees (direction valve to adjust the flow to each tree).

We have gutters and 4 rain barrels that total 315 gallons. Hoses are connected to the overflows to direct overflow directly to plants.

Collection from rooftop into two cisterns. Used to irrigate plants and to top off pool.

Drains from metal roof collect rainwater in two tanks equaling more than 3000 gal total capacity used to water garden and landscape around the house.

total gray water system installed when house was built

check dams in various locations on property

Multiple tanks, one 1350 gal on East side, one 450 gal on SW end and 4 85 gal decorative tanks on porch and back yard for potted plant watering.

Multiple swells and trenches retain water from soil run off and roof water to water trees and veggie garden. 1000 gal. tank collects water from 1/3 of roof. Used for trees and green house plants.

Gutter installed to approximately 90% of drip line, 2 1,100 gallon storage tanks, various berms around property

3 cisterns 1. 880 gallons 2. 220 gallons 3. 85 gollons

Capture Roof Rain Water, (1) 2600 gallon container & (1) 130 gallon container

863 gallon tank with connection from the house to the tank by way of 4" pvc

Rain gutters directing water to a collection tank.

Passive landscaping geography and plant placement to collect water/shade as appropriate to plant needs. Actively, two tanks with roof water collection, 1600 gal each. A pump and city water add as needed to maintain tank volume for irrigation purposes only.

We have 3 865 gallon tanks to collect rainwater from two houses on the same property.

1400 Gal plastic cistern

installed seamless gutters from Star Aluminum. To reduce leaks. Great investment.

Two tanks supply water to basins of trees or into watering cans. One of the tanks also supplies water to potted plants and is on an automatic timer.

metal cistern at one property, precast cement cistern at another property

865 gallon cistern collecting water from 1,000 square foot catchment with overflow to planted area (plus three stock tanks, about 300 gallons total, collecting other roof runoff at three sites, not part of rebate program)

2 1320 gal cisterns off the roof. One to the plants on the south and east sides of the house and the other to the trees on the west/northwest side of the house

I have 3 tanks for a total of 2610 gallons. I capture runoff from a wash on my property.

Cisterns/storage tanks

earthworks in the front to capture roof water for trees and a cistern (2800 gal) in back to capture rainwater for gardens

Guttered roof with 3, 865 gallon cisterns.

An 850 gallon tank on east side of house off of carport fed from rainwater running off front of house.

Berms built to direct ground water, wells dug to irrigate new trees, cistern to water during dry season

gutter and 850 gal tank

I have 3 cisterns with 1 handling the over flow from my largest.

2 cisterns that collect from my roof

Rain channeled into french drain system, then to trees in yard then out of yard to trees in common area

We have two above ground tanks -- one is 865 gallons and the other is 1320 gallons. They are fed by gutters capturing the rainwater for 1/2 of our roof. We have also dug drainage retention ponds in three places in our yard.

Two 865 gallon tanks

I have two cisterns, both can store 865 gallons of water at my home. I have one french drain that drains into a small area where the drains into a small hole near some trees. At my rental property on Mountain Avenue I have 3 865 gallon cisterns and one 500 gallon cistern where the water flows into it

2x 3000 gallon steel culverts

1x rooftop/gutter collection system

Patio home with 1400 gallon water (per inch of rain) capacity off of flat roof Installed:(2) 205 gallon bushman tanks attached to (2) 50 gallon barrels under wrap around patio- downspout fed; (2) attached 50 gallon barrels and (1) 90 gallon barrel off 2 garage scuppers with rain chains. (1) 65 gallon barrel off small front patio with gutter/downspout feed. Total harvest capacity 765 gallons of rain water, All overflow systems divert water away from building structure to desert landscape.

3 cisterns to collect roof water from gutters, 1 tank to collect laundry water, out door shower area that runs freely, and many berm and basin tree wells, etc

Earth berms at front of property to slow runoff from yard slope. Several tanks to collect rain water, largest being around 835 gallons.

roof with gutters and two large cisterns

We have two silo/type tanks and numerous 55 gal drums, all holding rain water from the roofs of our house and garage.

two 865 gallon tanks, one on north, one on south side of house. Ridgeline runs east/west. Three 55 gallon drums attached in series on shed on north side of house.

6000 gallons of rain cysterns connected to house's gutter system, berms and catch basins to slow runoff into wash.

140 gallon barrel. Passive swales with roof gutters and downspouts.

rain water harvesting through the gutters into a 1300gal Bushman tank on one side and 2X275gal cube water tote/tanks on another side.

Wet system; 1 -1110 gallon tank and 1 - 865 gallon tank

Rain gutters collect water which is piped to collection basins complete with pop-ups. We have overflow basins as well.

One 3000-gallon roof collection cistern; two, connected 350-gallon roof collection cisterns

Extensive earthworks passive collection

Two 550 gallon tanks that fill from the roof

We have a rain barrel connected to the downspout collecting rainwater from our roof.

Rain gutters on 90% of the house and patios, feeding into two large tanks (900 and 1200) on opposite sides of the house.

Guttered water goes into 850 gallon cistern for outdoor plants.

865 gallon tank off back porch roof

Gutters, downspouts, and 2 tanks.

I have two storage tanks that collect water from the roof of my house

Tow tanks, one 1250 gl. second 850 gl.

And earth work land/scape.

To the best of my abilities all rainwater and grey water resources are utilized on my property by means of active and passive systems.

Aluminum gutters on edge of roof direct runoff to cistern and to landscaping.

3000 gallon collection tank with roof run-off.

Variety of landscape watering sites on property

Grading to catch water, rainbarrels

three tanks for roof harvesting

Earthworks, 2 steel culvert cisterns (5,000 gals combined), pump/filtration/purification system

three large tanks plus collection areas in some areas of property

2 of 3 tanks overflow into earthwork basins. 2 of 3 tanks have first flush filters. Had to install gutters to collect water for tanks. Have 4 passive basins - 1 in back yard, 3 in front.

We have two active systems:

The first has (2) 865 g tanks tied together for 1730 g total supplied from 1960 sqft roof area. This system is connected to drip irrigation with a low flow, positive displacement pump that is activated by an irrigation timer.

The second is (1) 400 g tank supplied from 450 sqft roof area that captures water for delayed distribution. This tank overflows into a passive retention basin.

Direct drain pipe from washer to rubber/plastic container outside, drains to gravity. Intending to add a sump pump to better drain water to areas of the yard.

Three basins surrounded by berms and interconnected for overflow.

Basins for tree wells, 1100 gal tan fed from roof.

I have two 650 gal cisterns for my roof. They capture about 50% of the runoff. The other 50% goes via rain gutter into passive storage recharge areas in my desert landscape. The cistern water is used to water desert landscape and two citrus trees via manual hoses and gravity fed seep hoses. I also have timers I can use on the cisterns for when I am away.

Water from all surfaces from roof to patios is collected and redistributed throughout the property. Dry river bed, basins, and berms.

865 gal tank for roof water.

basins and swales. Gutters connect to basins.

Rainwater collected off of around 1550 square feet of a flat roof into a 865 gallon Bushman tank. Then I installed a 1 HP Bushman pump to irrigate my entire property with a gate valve to shut off the front yard irrigation if I want to. Works really well and I love it..

Gutters with 2 downspouts to passive and gutters to 800+ gallon cistern.

1350 gal tank running to pump to dispense to plants and trees

Large FatBoy tank that collects rainwater from gutters from the roof runoff.

Gutters to cisterns, earthworks. Grey water includes kitchen sink, bathroom tub/shower, washing machine. These systems are at 2 different houses.

I have 3 tanks total volume of 2300 gallons. The largest is aprx. 1200 gallons to collect water for above ground garden. The smallest is to water 2 fruit trees. The 3rd is medium size to water the rose bushes on 3 sides of the back yard.

Passive system involved moving dirt to direct rainfall where most needed by plants.

Active system involves collecting rain from 2/3rds of my roof and collecting it in a 865 gallon tank.

Multiple swales, a dry well, installed multiple rain gutters that channel water to desired locations within the yard, mulch.

Single 1320 gallon Bushman tank collects entire house; goes by timer to single orange tree. Huge extra benefit is water collection eliminates occasional rainwater ponding against adobe (1936) masonry. Shower graywater goes to buried gravel sump for large mesquite (shower can be switched to sewer w/ 2" Jandy valve; I never use this though). The neighbor to west has garage that drains onto my lot, so I use that thru gutter system to frontyard landsaping.

rain gutters that go into a tank.

Landscape with use of rain gutter and one storage tank

I have a 1600 gallon tank

2 Bushman storage tanks, storing 1320 and 1110 gallons collecting by gutter with 3 down spouts.

3 large premanufactured cisterns

1320 Gallon tank feed by roof water runoff via gutters and down spouts.

3 tanks capture rain off my roof. over flow goes to roses and garden

graywater from sink/shower of one bathroom and washing machine to 100 gal collection tank; electric pump turned on and off manually feed hoses that deliver water to depressions holding plants. Wet rainwater system to 2500 gal tanks deliver water by gravity.

Two large tanks that collect water from the roof

We have two 860gal cisterns that collect rainwater from the roof, which then one of them is used to water a small vegetable garden along with the roof runoff from the separate garage roof. The other cistern is used to water 3 trees and four bushes. The trees also get street rainwater runoff using basins to collect the water. The water from front part of the roof is channeled to a citrus tree and an ironwood tree. These two trees also receive bath/shower water from the kids' bathroom. The gray water from the laundry waters three trees in the backyard- a quince, fig and an oak.

All of the plants mentioned above are new additions to our yard since we moved here in 2013. The citrus tree was transplanted from the backyard, since it had to be removed for construction.

cistern 2800 gallon

1360 gallon tank collecting half of my roof.

Two 865 gallon tanks supplied by scuppers and gutters

One tank of 1350 gal. capacity and another of 850 gal. which drain a 2400 square foot roof.

2- 420gal. tanks on East side of house

Rainwater enters a 55 gallon drum that we use as the "rinse". It rises to a "T" once the barrel is full, and then enters the cisterns. The 55 gallon barrels have fernco fittings, easy to remove for yearly cleaning. The cisterns have an overflow to low ground at the back of the property for recharge.

large cistern (1700 gal) w gutters collecting all rainwater from house, 2 -50 gal barrels collecting rainwater from large storage shed through gutters/downspouts,

gray water collection from washing machine, hose leads to 50 gal barrel that drains through another hose into plants

4 tanks collecting rain water used on plants; washing machine water piped to plants

Rooftop harvest into 10000 gallon above ground cistern

Washing machine hose to irrigation

1 1400 gal reservoir

3 65 gal reservoirs

Above collected via rain gutters.

1 rain gutter empties into front yard with passive collection into berm.

Driveway runoff directed into front yard.

Backyard overflow slowed by berms.

Berms etc to try and harvest rain from the street, 3 cisterns & gutters to harvest the roof water, moveable pool hose for watering with washing machine water

roof gutter

Gutters extending 90' on one side of our house that drains into an 865 cistern to harvest the rain.

1110 gallon Bushman tank. Two 750 gallon galvanized tanks set in concrete. Two 865 gallon Bushman tanks.

Active system is four (4) separate tanks at four (4) separate downspouts. Total capacity is 3,200 gallons.

Earthwork berms, ground depressions and channels from roof rain water to collection areas.

I have two tanks, one of each side of the house that collects rain water from my roof. One is 898 gallons and the other is 1200.

Roof gutter to pipe to 3 tanks all connected to drip irrigation lines in garden. Shower bucket for hand watering roses

Tanks with gutters

865 gallon tank - water runs off the roof into the gutters and into the tank.

water system consists on 3 tank, a 1560 Gallon on the east side of home to collect rain water from Gutters on east side of home. Connected to gutters via underground piping network. 2 other tanks are connected to the west side gutters.

Gutters feeding water tanks. Using hose to distribute water from tanks

Swales and berms are used to keep water from flowing down the street and to water trees. Vegetation has been planted to prevent erosion.

washing machine pumps greywater to underground chamber

lots of basins, a new 2825 gallon tank and gutters with 2500 sq feet of catchment

2,800 gallon tank collecting from roof

1700 gallon capacity in cisterns in 3 locations around the house. This water is used for a vegetable garden, 3 native trees, an orange tree, and other landscaping. Overflows and washing machine water goes directly to trees. Clean kitchen graywater (eg from washing veggies) is collected in a plastic tub which we use to water landscaping and house plants. We have created shallow basins into which rain water flows to water bushes and trees.

We have two Bushman 1320 gallon tanks and a 70's territorial home with a leaning flat roof. We capture 100% of roof runoff. Previously, 100% the roof runoff was directed to a wash behind the home through two 4" plastic hoses.

We have three water harvesting tanks that capture runoff from the roof. We use pumps to water a vegetable garden and fruit trees. We also have berms and channels for passive water harvesting for our desert landscape.

water off the roof

I have multiple tanks with transfer capabilities to pump between tanks. I have installed several distribution lines leading to areas requiring irrigation.

The tank is filled from water on the roof running into gutters and down spouts into tank

All passive currently...berms, reservoirs, French drains, rock work and gutters

I have 1- 850 gal drum and 2 sets of 3- 55 gal drums

Two 850 gallon tanks. One at southeast corner; one on northwest corner plus two 60-gallon tanks on north side of patio that collects roof water from north gutter. Wish I had another 850 gallon tank on that side, also.

Berm around trees and planting. 3 places in the yard.

Two interconnected 865 gallon rain barrels.

865 gallon water harvesting tank

550 gal tank. never worked

~900 gallon storage tank fed by rainwater using gutters

gutters and storage tanks

greywater routed to yard with bio-safe soap

manual collection of sink water with bio-safe soap upkeep of berms two or three times per season

keeping gutters clear of debris about three/four times per year; cleaning out "first catch" pipes once per year; reparing/replacing pipes as needed; covering spigots/replacing as needed

We collect all rainwater in gutters which empty into our storage tank.

Rooftop rainwater to storage barrels.

Our roof surface is about 3000 sq ft. Based on the course recommendations we purchased 2 1320 gal and 1 865 gal Bushman tanks. In the spring we will connect the captured water to our 4 zone irrigation system. We also installed seamless rain gutters to capture most of the scuppers.

Our active system failed last fall and we have not yet replaced it. Relying now on sculpted/sloped landscape to direct water into yard.

Permaculture basins, berms and such. Gutter and 1300 gallon water-storage tank. Outdoor washing machine with graywater system.

gutters that fill two large cisterns and take a little bitty front roof piece to a rain chain into a basin. Basins throughout the yard front and back. A 55 gallon barrel in front yard that facilitates hand watering (this one I treat for mosquitos)

Most rainwater from the roof goes into cisterns or on landscaping

Swales and mounds fed by rain gutters

900 gallon tank filled by roof runoff

terraced landscape with collection basins for trees, channeling of wash runoff and coffer dams for passive, gutters all around the roof to feed into 2000 gal total capacity tanks placed on concrete block bases to raise off the ground enough to allow gravity driven drainage. An additional 800+ gal of storage is set up around the property (almost an acre) near the trees to allow movement of primary reception water to these locations and removed harvested water from the primary system and thus allow additional capture during rainy season.

Rain gutters. Back half of house lead to storage cistern. Front half of house lead to passive collection zones.

We have three tanks that collect water from the gutters on our roof. The overflow from the tank is channeled to plants. We also water our plants and garden with hoses from the tanks.

I have 2 1500 gallon tanks at either end of the house. Collection is split from the back of the house where the flat roof drains. The entire roof surface drains to the tanks, I also have swells and basins to keep the flow of the yard minimized. I use zero pressure valve timers and hoses to water the plants from the tanks. Typically, an inch of rain will fill both tanks.

It is an 800 gallon tank made from plastic.

Gutters to tank

Two tanka that get weer from the roof

Rain water collection only

Berms around trees. Rain gutters discharging to three storage tanks totaling 2200 gallons.

800 gallon cistern and passive systems in both front and back yards.

i have a storage tank for my front yard, in my back yard graywater from my washing machine goes to two basins and runoff from my roof goes into another basin through rain gutters.

tank collects water from the roof.

Two 875 gallon cisterns collecting water from a 600 sq ft art studio (metal roof) in my back yard.

Washing machine gray water with hose attached so I can water at my discretion. Every load goes to plants except when we use bleach. I use Oasis detergent which is not harmful to the plants or soil.

Three separate collection basins, rock lined.

Gutters attached to in-ground sprinkler heads and one roof water catching 1,100 gallon cistern.

Awesome and the best thing i have done in 2016.

3 garage can size barrels running together for 150 gallons off my gazebo.

3 tanks connected to garden hose

459 gal cistern made from culvert

swales & desert plants to keep water on property

washing machine water into a swale

Rain water only

1320 gal receives water from â…" of our roof! A hose is attached near bottom of cistern which allows me to fill 15-20 gal containers and water 80% of my potted plants and new trees which I have planted! I also have accumulated rainwater off the front patio in a myriad of tubs to conserve some of the rain & protect the foundation of our home!

2 large tanks that collect roof water and a distribution system under ground.

Passively, a swale that irrigates trees.

We have two large above ground storage tanks totaling 2400 gallons. One on each side of the house

Water from outdoor "room" harvested in 865 gal tank.

860 gal tank rain water storage

3 tanks: 2@850 gallons; one@550 gallons collecting water from the roof via rain gutters from the front of the house.

Water falling off the roof goes to a inground system that directs water to a sump pump which then pumps the water to the tank. One section of the roof has a gutter that collects the water and takes it directly to the water tank

Two 2850 gallon cisterns

Overflow basin formed in the area where the swimming pool was removed. It was created to look like a natural basin.

Rainwater off the roof storage tank and then multiple large passive basins at several places throughout the property.

Three tanks, two 550 Gal. and a 1100 Gal.

I Have a System with a 2875 gallon tank. Three downspouts are involved. My tank is located in the front yard. One downspout is a wet system to the tank. Another downspout comes directly from the gutter into the tank. The third downspout flows to a low section in the front yard to soak into the ground.

875 gallon cistern and low water drop system on xerascape.

2-2800 Bushman tanks which collect rainwater from the roof.

2 800 gallon and 1 400 gallon water storage from roof.

1340 gallon tank off guttered roof

Rock stream in front, small tank in back

From the roof we have gutters and leaders. There are double leaders to catch debris from the roof and when that pipe is full the clean water goes into the pipe that carries the water to our cisterns.

Both washing machines have Lto L.

2000 sf home has one rainwater tank in place with 4 more to come.

864 gallon rainbarrel. Scupper with drainage/rock to fruit trees.

We have two large tanks connected to our rain gutters and multiple small tanks throughout our property we use for animal water and plants.

I have ten 55 gallon blue barrels collecting rainwater from roof runoff and one 1100 cistern for roof runoff.

I collect water from the shower in buckets

Tree wells and rock build up to create small terraces to hold grey water comes from the washing machine to fill wells of 5 trees. Trees include: canyon hackberry, three pomegranate trees and one fig tree. The trees have done exceptional well in the three years since I planted them and put in the grey water system.

Landscaping around trees to catch rain water and stop run off.

Gutters on main house and 865 tank, and gutter on shed with smaller tank

2- 1200 gallon cisterns

One tank in the front yard, 860 gal

We collect rain water from my house roof. The water is channeled down from the gutter collection, through a 4" heavy gauge pcv style tubing it travel about 30 feet underground, to the rear corner of my back yard. Then it goes up to the top of a 2850 gallon above ground storage tank where it is stored for my use to irregate my plants and tree's that make up my landscape.

at this time although my recovery system was installed late this year and we missed most of this last years rain. My system gathered a full tank on two ocassions this season. And i have not needed to use any city water to irregate.

In fact my 2850 gallon tank is full to the top right now.

and i have been able to water my landscape as needed rather than starving the plants on our previous watering schedule of water conservation.

thank you for the financial help as this has turned out to be a very smart move on both our parts. This system also solved a flooding problem that occured in my back yard when to monsune rains came in the summer mounths.

1100 GALLON TANK,98% OF ALL WATER ON THE ROOF GOES INTO GUTTERS AND INTO TANK.WATER AT THIS TIME IS USED FOR DEEP WATERING OF TREES AND SMALL LAWN,

Roof collection system to a 450 gallon storage tank.

Rip rapped retention basins

Rip rapped drainage to the retention basins

2/3rds of house roof drains into gutters for passive distribution on property. 1/3 of roof drains into 865 gal tank for collection.

Swails, basins and a 1200 gallon collection tank. We also added gutters.

3 150 gallon tanks that fill with the gutter downspouts.

We have 2-865 gallon tanks hooked together harvesting from the roof. We also have 2-55 gallon tanks to store from grey water from the washing machine.

One 750 gallon cistern in the front yard. This was a self-constructed cistern consisting of a 4' diameter culvert set in a concrete foundation. One 2850 gallon cistern in the back yard. This is a Bushman Tank. One 55 gallon cistern off of a small shed.

1320 gallon system collecting from approximately 1000 square feet with overflow into earthworks. Laundry to Landscape system that delivers graywater to citrus and native plants.

Passive: several earthworks in back and front gardens; two 850 gallon tanks; roof water goes to either tanks or earthworks; L2L goes to fruit trees in basins.

Passive watering for approx 20 drought tolerant trees. 2200 gal of active collection from ~3000sq.ft. roof area.

3 cisterns collect from rain gutter system

1. Two 660 gallon tanks joined collecting from a roof area about 15 ft. by 43 ft.

2. One 205 gal. tank collecting from a covered patio.

I also put plastic bushel baskets out to collect from roof areas w/o rain gutters.

Front yard is half passive and half active. Front yard has 500 gallon cistern. Would have liked a larger cistern, but was limited by small area.

Two tanks, a ~1300 gallon wet system and a 700 gallon dry system, collect water from gutters on the back of the house for use in the garden. Gutters on the front feed basins and beds for landscaping. I also use the condensate from the air conditioning system when it produces water.

active system is 2000 gallons collected from roof

It'a a 72 ft x 6 in. long rain gutter that empties into 2875 gallon poly tank, which overflows into a 1350 gal poly tank. Gravity flow from tanks to 3 automatic valves and onto plants.

We have one 1500 gallon tank collecting water off the roof of our main house. We'd hope to have a 2nd tank collecting water off the guest house roof soon. We also have small retention basins on the property and hope to put in more of these as well.

2 tanks -1300 and 300 gallons plastic tanks

Rain water stays in yard, does not run down the road or into drain. It soaks into my yard.

Berms, swales + extended downspouts from roof to yard areas. Also bank stabilization in front yard.

Gutters and 865 gallon collection tank

We have one 820 gal barrel, one 250 gal barrel an two 50 gal barrels.

We also have a sump pump in two of the barrels that collect rain water more quickly so we can transfer rain water into the larger barrel. We manually water our citrus trees, small garden and other vegetation from the rain water barrels. Our landscaping is also designed to capture rain water and direct it to the Citrus trees.

gutters to tanks

2 cisterns, one is 400 gal, one is 1500 gal. I landscaped with native plants using basins and earthworks

Laundry to Landscape waters four new trees and some established flowering plants; it includes earthworks. Cistern collection waters native plants plumbed from flat roof to cistern, and cistern to spigot. Watering is done by hand. There are also eight basins that collect water passively, one which has a pop up for slant roof collection.

large plastic cisterns fed by two roof down spouts

Some rainwater from the roof is directed into three rainwater tanks with first-flush geatures, which we use to manually water plants; the rest goes into mulched basins via downspouts that are directed via underground pipes to pop-ups in selected basins. Washing-machine water is piped to selected mulched basins in part of the yard.

1,500 gallons steel tank installed by Southern Arizona Rain Gutters, Inc. (SARG)

We are grateful to the City of Tucson to help us make that purchase possible with their generous rebate system!

We have two major basins in our small yard to collect rainwater. We have two 550-gallon cisterns also with spouts from the roof. I use that water to irrigate my plants.

Passive and active rainwater systems

Gutter and downspout for 90 feet of back roof (total length) downspout into 1150 gallon tank

2 large tanks that capture all flat roof rain water to water new fruit trees and garden. Laundry water runs into basin and waters surrounding edible trees.

Two streetside basins were constructed by Watershed Management Group to harvest rainwater coming down the street. One palo brea tree was planted in each basin to eventually provide streetside shade. Grasses and pollinator shrubs were planted in the basins to absorb and retain rainwater. In the front yard, two existing rain gutters that drain the front of the house were directed into basins, which were connected to one to two additional overflow basins so that all rainwater that falls on the property is used on the property. Native shrubs that attract pollinators (butterflies, bees, insects) were planted in and around the basins. The washing machine was outfitted to direct greywater to a row of privet trees along the east side of the house.

We have one 2800 gallon tank with a pump attached to it. We also have a 55 gallon barrel.

We have 2- 1,100 tanks that collect rain water off of 1/2 area of the roof - the larger slope area of the roof. Tanks are at SW and SE edges of roof. We also collect and reuse swamp cooler bleed off water during the summer months.During the summer months, laundry uses biodegradable detergent and water is diverted to outside grass area using a self-made downspout and hose system in a repurposed 5-gallon bucket.

Two 1100 gallon cisterns connected to a Rachio controller.

We have a 3000 gallon cistern collecting from the entire roof with earthwork berms and basins collecting runoff from the sloped property. Cistern supplies water to a future garden and to established palm trees and oleanders through buried pvc piping.

Gutter runs on one side of the home, two steel drums at one end. Water flows into one drum (collecting drum), second drum is attached to the collecting drum.

Currently draining about 2,000 sq. ft. of roof area into 2025 gal. storage tank. I plumbed it into an on-demand pump and into drip irrigation system, with isolation valves so when tank is empty system can use city water.

collecting 100% of rooftop rainfall using gutters and two plastic tanks, 1350 gallons each. 1600 ft2 of rooftop gives us about 3" of rainfall storage capacity in these tanks.

Gutters and pipes to two large above ground cisterns (around 1320 each).   Also have created passive system with earth works to direct runoff after full to trees.

rooftop to gutters to tank. tank to trees and garden.

Active rainwater harvesting off of roof into two separate cisterns. Passive system to collect rainwater from city easement to drain neighborhood water. Greywater harvesting from both shower and laundry.

1. An 850 gallon tank that collects water off half of our roof. 2. A basin that collects water of a quarter of our roof. 3. A berm that collects water from a quarter of our roof.

We utilize both passive and active systems in both front and rear yards. The passive system utilizes gutters and rainchains from our free standing ramada and our carport as well as earthworks to direct rainwater to trees planted in swales. The active system catches runoff from a 1700 square foot roof and directs it into two tanks (1320 gal & 420 gal) at two seperate locations in the rear enclosed yard. The 1320 gal tank is fed from the bottom and the 420 gal is fed from the top. The disbursement is via gravity utilizing garden hoses.

We also have a grey water system that runs from our laundry to the landscape that waters a seperate section of a side yard that contains a tree and some arid land plants.

A pair of 1000-gallon tanks catching water from gutters running along our two primary rooflines.

Gutters with two tanks

Half of the roof pitch is going into a gutter that is being diverted into a tank. The tank is then used to water everything in the yard. The front yard has berms to hold water for the trees. They are then covered by rock so the HOA doesn't know ;)

rain gutters installed on east and west sides of house, each goes to a separate water tank

Passive- created dips throughout yard where a large amount of run off occurred. 3 cisterns collecting water used for gardens.

880 gallon water cistern with wet and dry feeds, passive water basins as well.

I have 3 - 50 gal black plastic containers from Home Depot located at three corners of the house. Hose from each container go out to trees to take care of the overflow when tanks are full

collection of rain water from roof to 1300 gal tank

New House construction in 2014, with move-in during October 2015. The roof was designed to drain 85% to a single point on the rear, southeast corner; with two additional scuppers on the northwest corners and currently draining to the desert. The system incorporates a 2600 gallon tank, with 4" PVC pipe used to make all the input features, including roof pickup, first flush, tank and overflow. The outflow consist of an all brass, 1" connection. The head pressure has proven insufficient to realistically drive the drip feed irrigation system surrounding the house. Work is in progress to integrate a 12VDC pump with 45W solar panel array to boost the pressure but tying this into the drip system controller has proven challenging. The tank filled within the first three rainfalls during late June 2016 - early July and remained essentially full since then. The outflow is designed to fully fill the tank and has required the man-access cover to be sealed with a hand made gasket to prevent seepage from causing minor problems as the water flows down the outside and away. Still working on these problems.

Close System with 1000 and 2500 gallon tanks collecting rain via gutters

4 rain gutter collection tanks totaling just under 2000 gallons. Runoff from rooftops is collected then used for watering of trees and plants.

We have 2 1,000 poly tanks installed. One fills into the other, then we turn off the valve so that the other fills up. It takes less than one hour of rain from 1/4 of our roof to fill them.

- One 600 gallon tank and one 440 gallon tank. They recover the rainwater from half of the roof.

We start with the principle of keeping the rainwater that falls on our property to stay on our property. To that we have added four cisterns, with a total capacity of 3,400 gallons. The idea is to try to water our landscape only with rainwater and greywater. We have basins that hold the overflow. We harvest water that flows down the street using two curb holes and two permitted basins in the easement next to the street. We harvest the water from our laundry and our bath tub.

We have basins in both our front yard and easement as well as several in our back yard. Most of these have been in place for 4-5 years and the vegetation is well established. We have water harvesting tanks on each side of our east/west sloping roof. One tanks is 850 gallons and the other is two attached tanks which combine to collect 1100 gallons. Both tanks are used to water gardens as and landscape plants (neither is on a controller). Gray water from the laundry is routed to a front yard tree

1300 gallon active gravity ved system gutter collection. landscape - basins for collecting during rain. Greywater - plumbed from washer to permanent garden area. mulch covering garden where lines empty with ability to switch to standard drain when using not compatible cleaning products

I have two 4800 gallon cisterns that are fed by gutters from our roof. City water is supplied to the cisterns when the rain water is depleted. The water is pumped through a drip system to our landscape. There is an automatic timer and solenoid system to turn the water on/off.

Water runs from the roof into a 600 gallon tank.

Passive is a rain chain that funnels roof water to a pot which channels it to a holding basin.

Storage cistern collect rainwater from the roof and holds it or diverts it through terraced area to reduce erosion

Two 1320 gallon tanks. Draining three separate roof areas of our house

Direct gutter flow in front yard to front landscape. I have a 660 gallon collection tank in the back yard

2-865 cisterns capturing roof water with overflow into passive system + passive system capturing rainfall falling outside of roof

Two 1,110 gallon tanks linked together. Water from downspout is connected to tanks by underground pipes. The over flow valve is connected to pop-up near fruit trees. The L2L pipes are also under ground going to emitters at six fruit trees.

Passive collection off of portion of front roof into a bricked-in raised bed with salvia. Active system with 2 865 gal. tanks in back yard. Tanks are fed by 6 in gutter along entire length of roof's east side. 1 inch of rain will fill both tanks.

I have two 220 gal. Bushmaster barrels - one in front yard and one in back yard. They are both services by gutters. Overflow drain for one goes into a natural drain. The other goes across a sidewalk and into native plant vegetation.

One large 850 gallon tank that harvests from garage roof

We had gutters and downspouts installed that capture approx 2/3 of the runoff from our flat roof home. We capture about 50% of that runoff in a cistern system consisting of two 560 gal vertical cisterns situated in our backyard. I employ a 1/2 hp portable utility sprinkler pump to distribute the rain water to a small lawn, flowers, shrubs, and a 10,000 gal pool.

Two swales to capture roof runoff.

1,500gal. poly tank, entire 1.25 acre property parceled with catchment berms.

Passive system includes tree berms and channels to control serious erosion problems and to water existing desert trees, and small rain garden w/native flowering vegetation.

Graywater system is laundry to landscape using 2-way valve (brass 1"), 1" poly tube to 1/2" poly tube for emitters into inverted plastic flowerpots w/rock covers to treewell trench filled with bark mulch. Currently water 2 desert willow trees and 1 mesquite.

Two 865 gallon tanks used as water for plants

Put in a French drain type system that channels the water that comes out of my roof downspouts into areas planted with native plants. There's a drain pipe that channels the water.

1100 gal tank fed by gutters on east and south side of house

1150 Gal cistern with 3 down spouts that recover water from 65% of the roof line.

Swales and rock along with natural vegetation for passive water collection.

Rain chains to direct water from other down spouts.

Three tanks sited around the house to capture water for landscape and gardens. Just added a fourth tank off a new addition to the side of the garage.

I have a large roof. It covers my home, guesthouse and carport. With help from the rebate, I replaced my gutters and installed three 865 gallon Bushman plastic containers on the west side of my house. (The rebate only covered part of this. I made a significant personal investment.) About a year later, I an installed an additional 420 gallon tank on the eastside, which I use entirely for my vegetable garden.

2600g tank from 2/3 of house gutters. Rest goes to tree basins.

2 x 865 gal cisterns in series. Collecting from 3000+ sq ft roof

3200g cistern on 600sqft garage roof

greywater drain/planters on every sink that abuts an outside wall

passive (no cistern) gutters to landscape from 1600sqft dwelling

We have 3 825 gallon above ground cisterns and multiple basins in the ROW and rear yard

4 cisterns. 865 gal, 865 gal, 300 gal, 250 gal.

1100 gal storage tank supplied by house roof gutter and pipe system.

Approx. 1000 sq. ft roof to gutter to 1340 gal tank via wet pipe.

Passive earthworks throughout yard, one large cisterns and two smaller rain barrels to collect roof run-off, one shower drain run to a pop-up bubbler between trees, one shower drain to outlet in a planted basin, swamp cooler drain line runs to citrus trees, outside washing machine has 4 potential drainpipes that each go to different plants/trees, kitchen sink drain goes to infiltration chamber underneath garden area. Still saving up for one additional large cistern that will collect off the largest portion of the roof!

One 865 gallon at a 1200 square ft house. Much of the yard is sealed to retain water in rear yard.

The water from the washer goes into an area in the yard where there are basins lined with rock. The waters soaks into the ground and waters three citrus trees. The front yard is passive water harvesting and is landscaped with low water plants.

We have one 865 gallon cistern that receives water from one side of our roof. Rainwater from the other side is passively sent to landscape

4 cathments on the side of the house to capture water that comes off of the roof and the driveway

2 corrugated cisterns fed from gutters through the lids. 1 1600 gallon and 1 450 gallon.

Gutter to cistern- 1/2 roof goes to cistern, other half is passive to plants in yard.

Passive: System of berms, basins & drainage channels in front & (especially) rear of home.

Active: Gutters drain water from "flat" roof into pipes that carry it to 3 cisterns located on east, south and north of house (rear).

We have a 2700 gallon above ground tank fed by rain gutters along both the front (south) and back (north) of the house. We also have a small 200 gallon tank fed by the gutter on the east side of the house.

See above; one approx 2800 gal water tank and hand-built berms.

Water draining from roof and deck on backyard side of the house is diverted by gutters to a 4' x 10' tall cistern. Water draining from roof on garage side of house is caught by gutters and diverted underground to trees and shrubs near driveway. Additional water is diverted by gutters to trees and shrubs outside rear yard.

I have 4 tanks in my backyard, swales in my front yard, and grey water delivery from my washer in a courtyard.

Two cisterns that drain into a contoured rain garden; olla ball system, with pots irrigated by a barrel (which is manually filled by a hose); laundry-to-landscape system.

Rainwater harvesting tank collecting water from roof. I also have many passive systems, but these were not part of the rebate program.

I have earthworks in the front yard and driveway to keep water from leaving my property. I have a laundry to landscape via multiple hoses. And I have 3 tanks roughly 2500 gallons of rain water storage. Only once in the last two years have all tanks filled.

4 rain barrels tied to gutters from roof.

We have roughly 2000 sq ft house and 450 sq ft ramada. one quarter of house is routed via rainchain and sleeve pipe to a large courtyard basin. The rest is collected in 4 plastic cisterns (3 x 1320 and 1 x 850).

A 300 sq foot carport is directed to a basin. 2 sheds about 90 sq ft each are directed to basins/fruit trees. Our yard has several shallow basins and gentle swales for water retention. Except for about 15 feet of sloped driveway, we rarely lose runoff, unless the cisterns are overflowing and heavy downpour.

Laundry runs passively to some large shade vines. Master shower runs to a basin for jacaranda. Both have 3-way valve for shutoff (eg when using bleach, cleansers). We regularly collect clean kitchen sink water by hand in 3 gal sink basins for irrigation. Finally, we use a fountain pump to send about 80% of guest BR bath water through a window to a barrel for irrigation.

3 cisterns. 1100 gal, 984 gaL. 65 gal

2 1500 gal storage tanks collect rain water from dwelling roofs, multiple basins catch runoff, Approx 3000 gal capacity.

Large plastic tanks

Standing seam metal roof (approx 2000 sq.ft.) with gutters around full perimeter of roof draining at two low points to screened rain heads. Each of the two rain heads connects to a 4"dia downspout pipe with a 4"dia x 6' tall first flush pipe with cleanout at bottom. Each of the two 4"dia downspout pipes continue down and underground to rise up in base of the rain tanks. Two rain tanks are site built of 6' diameter corrugated metal culverts set in a concrete base and coated inside with 'Blue Max' rubber with a metal lid with access door, 7' tall, ~1450 gallons each, ~2900 gallons total. Each tank has 4" dia overflow standpipe down through the base to underground and to a remote planting basin with a bubbler cover. A 2" flush bottom drain is connected to a 2" valve which then tees into the 4" overflow pipe underground. An additional 2" pipe connects the two tanks underground with a 2" valve so the tanks can be connect (to maintain same water level) or isolated (so one tank can be drained separately if needed).

We have a swale around an area of native vegetation in our front yard which is fed by water coming in from the street as well as overflow from one of our cisterns. We also have 3 1150gal cisterns, two in the backyard and one in the front yard fed by the roof gutters/downspouts.

The big house has 2 connected aboveground plastic tanks, 530 gal + 265 gal, which receive all runoff from the main roof. The guest house has an 865 gal tank. All the tanks are Bushman brand, bought from Loomis Tanks in Marana.

An 1800 gallon culvert-style cistern with two wet feeds, and basins around fruit trees

Two tanks, one 850 gallons, one 500 gallons, connected to roof gutters. And a couple other smaller tanks similarly connected. What is 50 gallons and the other is 75 gallons.

About 1/3 of my roof area (1100 Sq Ft) flows into a 2400 gal above-ground tank through 2 separate pipes. One pipe is a "wet" system that comes from the gutter at the front of the house, and one is a "dry" pipe that flows from the gutter at the back of the house. The tank is then attached to an irrigation system (using 1/2" main line) that irrigates the landscape on the front-side of the property. The passive system is the remainder of the roof surface area and consists of 4 different downspouts. 3 flow passively into contoured areas, and one empties into a bermed basin surrounding a mesquite tree.

We have three bushman tanks that are all connected to water our garden

Rainwater coming off the roof is directed into downspouts and then that water is directed to trees and other vegetation via earthwork channels. General Yard landscape so that water is directed to trees and other vegetation.

2, 800 gallon tanks conected to house gutters

850 gallon tank with water collecting from roof to rain gutter to pipe into tank.

3000 gallons total capacity. One 500 gallon tank in front yard, two 500 gallon tanks in back yard and one 1500 gallon tank in back yard. System used to water citrus, other landscaping and garden. I no longer require city water for my plants.

850 gal tank supplied by adjacent roofs via gutter and downspout.

Water collected from about 30% of roof area. Input pipe goes underground to the cistern site. Overflow waters trees. Includes first flush system and a means of draining above ground input pipes during hard freezes. Output pipe is insulated. Three 3/4" taps and one 1-1/2 tap

We have about a 750 gallon above ground steel tank that collects water from about half our flat roof adobe home which was included in the rebate program.

We had an additional tank of about 100 gallons that collects water from our corrugated metal roof on our ramada which was installed later and not included in the rebate program.

400 gallon plastic water tank for rainwater collection on one downspout, earthworks/landscaping for 3 downspouts. Washing machine grey water system to fruit trees

roof to tanks

gutter to 1100 gal tank

Backyard: rain basins, 3 tanks connected totaling 2500 gallons; laundry and sink greywater

Frontyard: rainbasins, 1 tank, 865 gallons

1000 gallon rain collection tank that gets filled via rain gutters along the roofline.

Gutters on home connected to two 2800 gal above ground tanks. Numerous small and large ponding areas to collect runoff. Greywater directed to several citrus trees.

Two cisterns, one in the front yard, one in the back yard. Total gallons is 1700. Rain gutters installed at the same time as the cisterns to be one system.

Q3 Text: Please elaborate on problems with your system

see above notes, need more storage

having to completely drain large tanks so they don't freeze! That's annoying, though it has only been an issue once during this mild winter.

Both cisterns systems have a first flush. When water sits in the first flush, it starts to smell, so I empty the first flush out from time to time.

gutters overflowed due to hail that collected in the filter bakcing up the down spout. Hail in August!!! All problems were fixed.

The most difficult failure has been the longevity of a continuing mosquito problem which finally subsided with the coming of cool weather in the late fall.

Anti-siphon needed be be installed. Otherwise in a very strong surge, the cistern would be drained out the overflow. Problem completely fixed with one small alteration.

Everying I need watered is at waist level or in pots about 18 high. When the level drops in the tanks, the flow is too slow or even non-existant. I will have to buy pumps.

I had mosquitoes breeding in the metal cistern. I didn't find the larvae until the water level got low, and it surprised me because I couldn't find ANYWHERE they could have come in. Brad Lancaster said the eggs could get in from the roof, but it's a very flat roof and the ONLY place up there that might attract a female is the swamp cooler. There are a few times in fall or spring where the cooler is filled but not running every day. I'd like to know if anyone else has that problem. Should I put a mosquito dunk in there once a month?

mosquitos in tanks

cleaned silt and works perfectly

None of the above problems have or will occur if U pay attention and do simple maintenance!

Installers put screening on the inside of the overflow hole and the tank was overflowing from a crack in the top, until I reached inside and figured out the problem.

The biggest issue is the greywater sump. It is needed because of the level of the output drain but the small amount of water that remains in sump often causes bad smell during pumping. The rainwater collection clogged up at the gutters and down pipes until we installed a first flow diversion which works well but requires maintenance

After getting the tanks/gutters installed by one company, we learned that there should have been a first flush filter to prevent debris from clogging where the water enters the tank. We could have this done, but don't have the money right now.

filter screens into tanks clog up, sometimes faster than I can maintain them. Also, gutters need to be cleaned out regularly so they don't clog with debris and overflow

resolved the odor problem by putting screens over gutters so mesquite pods cant get in.

we use a "sock type" filter on the inlet pipe instead of the basket/screen to collect debris.

Broken parts were a tap which was kicked by a young boy and broke off

Original downspout configuration inadequate for volume of water accumulated by gutters.

I had cisterns with a none sealed top and initially had difficult with mosquitos and algae. Once covered, these difficulties were resolved.

one tank leaked at the faucet area. otherwise no problems yet...

All working better than expected -- so far.

had to re-plumb system initially as one tank settled more than the other, so overflow needed to be changed to the higher tank

Some seals were leaking a little bit and needed a little bit more sealant.

Small leak where there are threads for hose connector

The strainers on the discharge from the gutters are not adequate size and need to be cleaned frequently of clumped piles of leaves. I have subsequently made on new strainer of my own design which is more effective but need to make several more. The strainers on the market are not adequate

None really

Gutters were undersized

we learned to clean the gutters more often!

Tank functions fine, but too close to house, issue with painting outside wall

Overflow pipe was not properly sealed at union with tank causing water to flow down the side of the tank when it was full

Detergent scum appears to attach to plastic pipes due to electrostatic forces. Manual cleaning required about once per year.

Algae which seems common. Filter basket got a small hole in it. I fixed basket with mesh metal that I glue gunned on it

Doing all we can and followed instructions but still see some mosquitoes coming out of the tank or the overflow, during the high water months. Also the collection point at the gutters, point in which all the water collects, often overflows and cascades violently outside, causing ground erosion and water proximity to the house, which is exactly what we didn't want in the first place.

During very heavy monsoon storms, the amount of roof water exceeds the ability of the gutters to hod and diect the water into the cisterns. The overflow pipes on the citerns also can be overwhelmed during a heavy rain which then leads to errosion around the cister.

Nothing serious

leaves in gutters

Have to stay on tree maintenace to keep from cloging gutters

I am having problems regulating the flow from the tanks. I am going to look into a ew pump system. I am not here in the summer and would like a more reliable system to control flow to the plants when I am gone.

odor in laundry tank only

Smaller tank is clear (old vegetable oil tank) and allows a lot of algae buildup. Most tanks are treated with "mosquito dunks" in warm months to prevent mosquitoes.

We were losing water for the collection cistern in the back yard. We had a contractor come and put a metal piece on the roof which now guides the water to the gutters

SARG installed the tanks, the one on the south side is installed in such a way that it is impossible to adequately clean out the debris filter on top of the tank that the gutter flows into, resulting in 50-75% water loss for that tank...rain overflows around screen and run down side of tank, puddles at base of tank. Have called SARG a few times, they came out, but each fix only made it worse.

Cystern has leak that shows u when full, around bulkhead.

Javelina (I think) pushed against the outlet plumbing and broke the pipe.

Ground settleling

I think one of the tanks has eroded or sunken as pipe no longer connects to tank

I have not checked on silt or mosquito, becaue is well shut, but I have not checked it

The fine inlet screens on Bushman tanks are susceptible to clogging due to fine silt partials coming off the roof

Too much water delivered to gutters at the same time, I.e., very heavy rainfall.

I have to be monitor the system and done about water to stand in the

I have recently adjusted burms and reinforced with rock to decrease chance of overflow.

Cheap plastic debris screens improperly installed pvc was buried close to surface

system new and just now reached 2/3rds fill level

Debris has collected in the gutters and resulted in overflow. Requires more regular cleaning of gutters than I had anticipated.

very fine outlet screen on Bushman tank plugs with floating debris, resulting in tank overflow at gutter inlet

Need to clean gutters. I put screens on the gutters to keep debri out of the pipes

overflow occurrs during heavy rains.

leaves small branches etc clogging gutter downspouts

We have resolved the algae issue by painting the slightly translucent cistern with elastomeric. Gutter overflow has occurred when rains have been heavy. When that happened, the water flowed to landscaping.

Poor choices of water spigots. They constrict the flow and it take too long to water plants.

never worked from the installer issues

regular cleaning of filters required

Less than convenient filter screen maintenance setup.

We made a poor choice with our tanks and paid a good deal of money to have handsome wooden sheathed tanks installed. They failed miserably after about 3 years.

(installation errors)

semi annual cleaning of gutters and screens into tanks is required to keep from clogging

I failed to clean out gutters

excess rainwater

Leaf litter/dust clogs filter & must be cleaned frequently; otherwise water collection inhibited

It's too new to have had any issues yet

Cover over unused overflow opening has slow leak I when water level is high.

didnt realize how often I needed to clean out the gutters. Extremely large down pour in passive system overflowed into street

minor leak from bulkhead

They have been minimal: some replumbing overflows because tanks settled; installed gutter filters to prevent plugging of line to pop-up; cleaning of debris filters; direction of greywater to mulched areas

these are only minor problems

Smelly tank when it dried up last summer. But then with the first big rain everything seemed alright.

none new system 11/2016

We have to inspect regularly and correct these issues

Sometimes the flow of summer rain is so great that the intake opening cant handle the amount of water that is falling.

installers did not think through debris filtration and as a result lots of water that should have gone into tank did not. I must replumb and reconfigure inlet to alleviate futher issues. Manufacturer does not make accessing leaf screen easy, i.e. screws to hold lid in place in lieu of latching system. I will remedy that also. Install was done just to get job done and go. If you wish further elaboration contact me.

All were minor adjustments to the system following the initial install in June. The smaller tank was filling too fast and the overflow was flooding an open patio area and being lost to the alleyway. We installed a baffle in the gutter which directed more runoff to the large tank and adjusted the earthworks to slow down the overflow back toward a tree and away from the patio.

gutter caused water to pool on the roof at then ends near the downspouts causing rot and then leakage, cost 2,000 to replace roof section and address the issue

New tank had a leak. Over time, I believe it self- sealed with fine debris from the roof.

See Q2. The overflow erosion is minor but ongoing during most rains since even light showers collect a significant quantity of water.

The filters on the tanks often clog and overflow. It is often difficult to tell though because it is not large debris but a clear film that covers the openings in the screen.

After 18 months I noticed that water was gushing out of the intake of one take and the gushing water was flowing back to the foundation of the house. After more than one visit to fix the problem, the company finally identified that the tanks were installed wrong and that they both needed to be emptied , in order to correct the installation. Once that was done, I noticed that swarms of mosquitos were coming out of the tank. The company refused to come over to correct the problem and told me that I would have to unscrew the screens and add mosquito dunks, which I did. Needless to say I will never recmmen this business to anyone.

Clogged wire screen at overflow portal. PVC overflow pipe has come loose with heavy flow with water then running down side of barrel.

Birds nesting in gutters block water flow

Mesquites leaves and beans have clogged the gutter and filter screen. These are minor issues that we have to check on a few times a year

lacks screen to fill pipe

Downspout connection

None yet, but only had since April 2016.

Gutters overflowed because of two 90-degree elbow-turns at outset of downspout; changed these to two 45-degree to eliminate overflow problem. Also, the tank has overflowed from the fasteners at the inflow/outflow joint; tightening of the nuts required after about the third year.

Tank issues were from initial installation 8 years ago; tanks have since been repaired.

earthwork overflow only during heaviest downpours. Cistern odor due to leaf litter in gutter. Tank overflow pipe issue quickly fixed by installer, as was an instance of pipe detached from rainhead.

Need to clean debris filter before every rain event or the gutters will overflow

tank was not properly sealed so had to be scraped down and sealed about a year after it was installed

1 debris filter doesn't work, the one that over the Scupper. Water sheets off of it. We had 3 different companies tried to address the issue. It is not resolved and we have to use inconvenient fix for it.

unintended vegeation growing in channels.

Q4: Explanation of expected problems

See above

The spigot part on the cistern broke, I think I have found a way to prevent this.

The debris filter clogs up from time to time so I just clear it out (mainly dead leaves)

Future maintenance would include flushing silt/debris from container bottom.

mosquitos, but we just put dunkers in to help with that

Somewhat. The solution was to run an interconnected overflow system of pipes underground and emptying into a small arroyo on my property

Algae expected.

misquite leaves and beans clog gutters so we have to be sure and check and clean routinly

Initially we had to adjust depth and drainage channels between basins, but after the initial adjustments there have been no further issues.

Some pipe joint caulking was necessary to correct early, but minor leaks

gutters need cleaning, tank needs washing,

Just need to maintain curb cut water runs into basins. They naturally accumulate debris. The same with gutters. Need cleaning a few times a year.

Clogging

just what is stated above

fine tuning expected

Low output, thought the volume of water would create some pressure.

There is always plant debris that gets into gutters and screens

Clean the debris screen. Drain the fill pipes.

Clean every few months

see above, faucet leak

cleaning first flush filter after every 1/2" rain or more is important in fall when leaves are collecting on roof. Not and unexpected surprise or problem for me.

New systems have start up issues sometimes

keep fgutters and cistern screens clean

Clean guttering and filter on tank.

k keeping gutters and screens clean

There are always minor bugs in systems when they are installed.

As noted above otherwise working as expected.

I was aware that as part of maintenance, it is important to clear debris and flush cistern occasionally.

Clear surplus tank grew algae; tree debris clogged downspout

a little bit of trial and error. Also diligent about cleaning filters

as noted above

Part of experimentation in construction

screens were used to cover all openings to keep mosquitos out

Algae in small tank, debris reduce flow from roof to large tank

Some debris is common, just needs cleaning now and then. Overflow sometimes due to heavy rain.Algae due to lots of sun and some organics getting into the small tanks.

Clearing trences to maintain depth. Not much of a problem.

a few repairs of small leaks and a pump clog due to glue from pipe repairs clogging the system.

Gutters overflow because one tank cannot handle amount of water from surface area being captured.

I thought the battery powered valve for out floe would be better than it was.

Fell behind in cleaning gutters causing overflow.

gutter issues due to lack of owner cleaning : - (

Need to clean filters more often.

I don't have enough capacity for heavy, extended rains

all of my cisterns at times are not large enough. water flows from the cistern over flow pipes

Water seems to leak from 1x steel culvert. Not yet repaired.

cleaning of bushman overflow filters with toothbrush and vinegar every couple of rainstorms- disassemble and clean out bushman intake filters after each rain.

I knew that gutters need to be cleaned out. And tha basins eventually silt up and need to be shoveled out.

Mostly related to mosquitoes.

see above, am in process of once again trying to contact SARG for a fix

I have Steel tanks going into concrete slabs. Two of my tanks leak. I have not been able to sea them totally. I think Bluemax is a faulty sealant.

Leaves and debris have required cleaning out of the gutters and filter

firts rain debri and dried leaves from roof

Known maintenance requirements, just nailing down the frequency

Gutters need to be cleaned out periodically.

debris from adjacent trees periodically clogs filters

Occasionally clear out debris and growth and/or dig out basins.

some minor erosion/settling occured under one of the cisterns. I worried that it might happen. We have been able to relevel the tank without diassembling the installation. Also, I did not install debris filters in the piping from the rain gutters--a rookie mistake. I have not experienced serious problems but may have to retrofit with filters at some point.

Fall detritis is a natural occurrence that needs to be address. Not a big deal.

Only un-planned issue involved distrubution of water from holding tank

low pressure gravity irrigation system must pass thru irrigation timer valve: inlet screen to timer plugs easily. Need more elevation head for the tank outlet (need to raise tank)

Graywater pump lasts about 1 yr with heavy filtration from sources, much less with poor filtration

except the car driving on the side walk and on the edge of the basin

the tank overflow was not enabled to drain away from the house.

debris filter clogged, gutter overflow, ponding-too much clay in soil

Cleaning filter screens

filters built into cisterns need to be cleaned more often than expected

Clean out screens.

One tank is quite near a large eucalyptus tree which sheds leaves constantly into the gutter thus clogging the debris filter if the gutter is not kept clean of leaves.

Adding additional berms where needed

clean debris out of gutters and basins

Small number of PVC pipe joint failures

Gutters and tank filter require periodic removal of grit and tree debris

Mosquitos - Used the mosquito larva product to kill larva. Problem abated

filters need cleaning

Contractor who built custom tanks misstated their sturdiness. Should have gone with the standard metal or plastic tanks on the market.

Leaves in gutters

I have intentionally planted desert trees and removed all the majority of cactus and thus have on going clenaup of leaves and debris even without the harvesting system

Inlet filter clogged from shingle gravel.

Debris at tank entry point

The need to clean out the gutters

Cistern filter needs to be checked and cleaned regularly

Clean filter screens regularly and gutters.

Needed to remove drain screen. This screen was finer than the fill screen, therefor small particles/acacia leaves got into tank

Large basin so expected more than 24 hours to seep into ground when filled

One must keep the screen on one intake of the tank clean.

Need frequent gutter cleaning

the strainer at the collection point of the gutter has to be cleaned, depending on the amount of rain.

Had to rip rap desert sloped areas to prevent silt build up from erosion into retention basins

We failed to clean the debris filter

I took some risks in my design and am pretty lazy about maintenance.

Some bank destabilization in front yard.

filter & gutter cleaning; mulch replenishment (planned)

Sort of explained but not in detail

See above

intake screens need to be clear of debirs

Connectors to the tank required adjustment and minor leak repairs at debris filters.

Kind of, didn't think about silt problem, but a natural thing to happen

I have a first-flush system that accumulates debris and needs to be manually cleaned twice annually

Debris plugging gutters and screen into the tank

Ours is a relatively new system. Installed June 2016, and we expected minor adjustments to the system once the rains began.

Clogging of screens and the first flush systems was more or less expected

tree leaves accumulate in gutter, installed leaf guards but they can be thick enough to cause water to be blocked

The seepage is due to the sloppy way in which the manufacturer installed the attachment screws to man-cover threaded ring to the tank. In their mitigation, the tank is not intended to be over filled in the manner I'm driving it.

I did not do the maintenance recommended when first needed.

It is relatively maintenance free except for gutter and screen cleaning.

not changing the filter in a timley maner causes the solinoids to fail and they have to be replaced

I expected fines to accumulate on the surface of the swale, inhibiting infiltration.

Earthworks needed strengthening and better overflow design which fixed problem

I have to clean away leaves & plant material from the drains from time to time

Cheap undersized gutters, New roof coating contaminated tank

Mesquites leaves and beans have clogged the gutter and filter screen. These are minor issues that we have to check on a few times a year

rain gutter clogs

Occasional cleaning of screened gutter downspout is necessary.

did not get around to preventing them

Gutters fill with leaves once a year or so, it just takes a a few minutes to clean them out. Algae in the tank was also expected and not nearly enough to cause any problems.

The basin pond was somewhat expected because of the clay ground. It was just a matter of learning more.

nothing out of the ordinary, everything was within normal limits

Pine tree needles need to be cleared regularly.

With heavy downpours the gutters cant handle the water volume and overflow.

I should have known to clean the filter at the top of the tank on occassion. My fault.

Expected manufactured items to last longer - possible too much stress on tin from 4 inch pvc piping

Tanks only hold 240 gals total and two tanks are light colored.

As described in Q3, we had an inflow pipe detach from rainhead, and an overflow pipe initially set to high, which made water overflow from top hatch. Quickly fixed by Ethos

Leaf catchers need regular cleaning, basin sediment trap needs regular cleaning

I forgot to check screen and clean

general periodic maintenance: cleaning gutters, cleanout of tank every 3-5years, cleaning leaf filters, emptying 1st flush, replacing mulch in basin

Constant improvement on ponding areas.

Q4: Explanation of Unexpected problems

my system is still new (as of last summer); so stay tuned for more.

Gutters leak because they are vinyl, aluminum is worth the extra cost.

DId not know of potential persistent mosquito problem.

Regular mfg. overflow port was inadequate causing water to flow down the side of tank exterior.

I had to buy extra parts due to mosquitos getting into only one of my tanks. The other tanks had screens.I also have a lot of dirt in the bottoms from the roof runoff due to a school yard next door not watering their grass and the dirt blowing across to my yard and roof. One tank has algae.

Not expected, because there are no openings that I could find, anywhere.

I followed all purchasing procedures, the project was designed by the installer,I took the class. The general manager, Randall, tried to blame all the issues with the installation and design on me. He was rude and we got into a shouting match. His customer service is in the basement. I will not do business with this company again and will not recommend them. I wish I had more time to spend on my complaints, but I have a memorial I am preparing. I am now a widow and on a fixed income with one income source, myself. This harvesting project turned out to be much more expensive than was anticipated, with several unexpected consequences, including mosquitos. I forgot to mention that they installed the tanks wrong originally and it took three visits by them before they realized their mistake. They have no supervision or follow up of their field personell to make sure the job is done right. Their MO is to blame the customer, never take responsibility.

I thought I would be able to clean the screens myself.

the leaf catcher clogged and gutters clogged with leaves as well

If it would have been installed correctly, there would have been no issues

Filter design failed. Got a replacement with new design.

Same as noted above.

Surprised no maintenance instructions were provided.

Debris had to be removed from collection traps.

Thought seals would be better on tanks. Thought sand in basins was enough to allow complete filtration.

ne sealed top and initially had difficult with mosquitos and algae. Once covered, these difficulties were resolved.

Expected the overflow to happen only at overflow outlet

what is a first flush filter? I don't know

Smaller, white tank which is not covered well.

I did not expect the mosquito issue.

Minor repair issues

I clean out gutters on roof and filters at top of tanks prior to rain events

When the system was installed the amount of rain was calculated but didn't take into account monsoon storms that might overwhelm the system.

When first installed, water seeped through concrete floor of tanks - I put in water proof coating and this has solved the issue.

mosquito problems were the worst issue

Covers on overflow ports on tank leak

the metal one leaked because the blue sealant hadn't fully sealed the seams in the cistern. on the cement cistern moisture was coming through the walls

Repair of broken outlet pipe (see above)

Did not anticipate insufficient rainfall.

L to L system not used for 2 weeks during summer, & "critters" moved into some hoses - blocked them from delivering water to landscape.

We thought the filtering system would work and keep debris out of the tank.

Debris has collected in the gutters and resulted in overflow. Requires more regular cleaning of gutters than I had anticipated. Also, I did not anticipate that I would have to actively fight with my regular landscaper to keep the swales. The landscapers all want to level the areas out. In addition, my regular maintenance landscaper has to be constantly instructed to put the yard debris in the swale areas instead of throwing it in the trash.

I have not done any maintence to my tank

the basins have solved water pooling issues in the carport and backyard

But may need to clean out in future

overflowed, and install never worked, complete waste of time and money

Did not expect overflow leaking, requested maintenance instructions and told there is none by installer, SARG.

tanks should be on concrete pads so no shifting occurs

A leak occurred from a bad bulkhead, but this was fixed. On the self-built tank, during heavy rainfall, the inlet pipe cannot handle all of the flow. When the tank is full, some of the water overflows from the top of the tank instead of the overflow line.

seals at top of tanks leak when the tanks are full

Gutters need to be cleaned more than once a year

need to periodically clear tree debris from hoppers capturing water from roof

how hard it was to unplug the downspout-to-popup line because of the design

Drain line leaked. Roof debris very frequent

Sense the setup its just worked.

Algae and mosquitos

The problems were related entirely to incorrect installation

Did not think birds would block water flow

first flow water flow pipes and valves are constantly mucked.

Regular maintenance seems to keep things going well.

I never realized how fast gutters clog with leaves. Has been difficult to source leaf diverter

Downspout is homemade, allows light access at tank strainer

The leaking tank was unexpected, but was fixed very quickly by the installers

I used a 2" overflow line and it is not big enough for the small tank. In heavy monsoons it started overflowing the lid and backing up the gutter. I ended up cutting the overflow shorter which helped.

I didn't expect the greywater backup.

Olla ball system took some experimenting; several plants died from lack of water. System seems to be working now that the proper plants have been found.

Didn't install a First Flush device on advice of Southern AZ Rain Gutters, but wish I had now.

I didn't expect gutters to overflow. A lot more water coming off roof to go down downspouts properly

Algae should have been intuitive i guess

Q5: Other preventative maintenance

Mosquito dunks every 30 days

broken pipe

re-routing overflow and natural runoff to balance

glue stopped holding one of the overflow pipes to tank

Clean debris screen.

Clean debris filters to cisterns

Clean filter at gutters' pour-point into pipe that leads to cistern

provided second overflow outlet.

Installed screens to problem tank.

Tanks were emptied completely to install tanks properly. Rock and fabric placed below inflow to prevent waterfall (gushing!) from digging out the soil. We've now added, at my expense, a 25 foot extention on the outflow to direct the water off the property into the alley so that the saguaro doesn't get overwatered. We will have to see if additional ground modification needs to be done to prevent water from flowing back toward the foundation of the house, as it has done with several rain events.

add mosquito repellents

Clean the debris from the screens at the top of the tanks.

caulking of inflow duct joints

clean first filters on cistern

added more gutter screen to prevent debris from entering pipes

A cup of bleach after a big rain when the tanks filled up to prevent algae

I will paint the tanks. Have not yet.

Remove roof debris from filter via clean out cut out in rainhead box

Clean intake filters on tanks.

wire filters clogged and caused overflow at input to tank

Dug basins lower

Put more dirt and stones on berms.

repaired faucet, see above

system is only 5 months old

Install mesh screen on gutter top

Replace screens

Clean screen on tank and empry out my silt trap

Clean screen filter for large storage tank

Cleaning sediment from basins and reinforcing the walls of berms. Plantings to help reinforce the berms and slow water force.

clean cistern filters

installed screens over gutters to minimize debris, added mosquito donuts to tank

Clean filters in large tanks

Replace laundry to landscape pipe due to UV light damage. The flex pipes don't last long if exposed.

Clean inlet and overflow screens

clean out tank inflow screen

disassembling and cleaning bushman intake and overflow filters

clean stainless screens routinely in 3 cistern tanks at gutter collection, clean nasty black water sludge that builds up in wash machine collection tank

I clean the gutters nearly monthly

Reinforcing outlet plumbing to prevent future breakage.

Cleared inlet and outlet filters on tanks

Planted a vine to cover the water tank

wrap pipes to protect from freezing

I have redirected and extended overflow drainage to increase the length of exit flow channels into drainage basins

clean out underground pipe at it's end and drains in block wall, and river bottom. Maintain wood chips in basins.

Installed in-line leaf and debris trap in downspout.

Make sure yard debris does not overwhelm the swales. Also, had to refine the dry well in order to insure water flowed into it properly.

clean all tank screens, often!

Brush catchers(cages) in scuppers

mosquito larvicide added to tank

Barrier around 1400 gal tank to prevent undermining.

clean the large screened pan filters in cisterns

Screens on gutters.

Occasionally remove soil out of collection areas and place on berms to maintain height.

Maintain berms

Clean screened top entry to tank

clean out screens at gutter outflow

mosquito control floats tablets in all partially open systems in which mosquito larvea have been found

Clean debris filters

Seal the overflow plates on the top sides of the cistern so they don't leak.

Eliminate pockets of leaf debris on roof

Cup of bleach couple times a year in each tank

Cistern checked. Added rock to basin.

JUST CLEAN FILTER AT THE TOP OF TANK AFTER EACH Rain

Clean inlet screen

insulated outflow plumbing

regularly clear first-flush lines after rains

SARG provides annual preventive maintenance as part of warranty

Clean out street debris in streetside water basins.

adjust gutter system and overflow outlets

Water got a little smelly and brown, but okay after tank cleanout

Cleaning of tank debris screen.

prevent mosquitoes from breeding in cisterns using dunks

Installing wire fencing and planting climbers around the tank to extend the life of the tanks.

I will look into cleaning the tank once it's empty again.

Eventually the attaching screws for the man-access threaded ring will be sealed with silicon seal.

Clean screens on tanks.

clean debris screen at inlet after every rain

Remove filters once a year to clean off mud that collects. Also I have wrapped the tank with sun shade material to help preserve the plastic.

installed covers over cisterns

clean out the screen at top of tank

Hoe surface of swale to increase water infiltration.

vermin screen on gray water outlet

No mosquitos present but placed biological controls for prevention

clean out basins

clean tank inlet filter

Clean roof

three sinks and one bathtub all drain to our trees, and at the first shared 90-degree elow/turn (unglued/never glued) I have had to snake on occasion (too many coffee grounds!) --- changing this turn from one 90 elbow to two 45s will elimnate problem.

Clean second flush filter

installed overflow pipes

We probably should have painted tanks. Instead we have wrapped them with 6 foot reed privacy fencing providing partial shade. We don't have first flush

Clean out vegetation in channels

Dirt settling on bottom of tank. With annual cleaning of tank and periodical maintenance and frequently checking inlet into tank, I avoid other issues

Created gutters on tank

Q6: Other repairs

glue stopped holding one of the overflow pipes to tank

anti-siphon mechanism added

Gutter installation has been bad to direct flow to tanks.

On my plastic system, the vertical pipe settled and became disconnected from the elbow coming out of the tank. Thankfully, WMG had put a screen right there by the elbow, and no mosquitoes got in.

By the way, the company made me do the mosquito treatment. Awful company

One tank settled against the house and had to drained and moved.

flush out pipe clogged with debris.

Replace scupper rainbow head

plan to add mulch an ongoing redesign of passive contouring

adding "sock type" filter on end of inlet pipe. It seems to filter the debris better than the basket with screen.

Rocks to berms

Put more dirt snd stones on berms.

Increased downspout capacity to keep up with gutter accumulation. Also required additional overflow capacity to keep pace with inflow.

Mandated back flow inspections

repaired faucet see above

Adding distribution lines for added areas of yard.

Change out screens at scuppers

I have taken photos of yard during heavy rains for future measures

Basket repair

Installing an overflow pipe underground for cistern overflow.

Re-built conduit system and headers

extended overflow pipes as needed

repainted metal cistern with another coat of bluemax, recoated cement cistern with Thoroseal

we have not had to make any repairs to our water harvesting system, we routinely need to clear sediment in the passive overflow basins mainly silt

Addition of metal guide on roof to redirect water

see above

Tried to eliminate leak by tightening bulkhead.

redesign of the passive system is part of the process.

Continued efforts tore-seal inside of tanks whendry.

I did have a 3" rain event that required some basin repairs, but I am sticking with initial design due do to infrequency of such events

Raised the berm that keeps the water from flowing into the street

Just relocated tank overflow pipe with pop up valve.

graywater pump replacement

Inserted filters to catch debri and spliced the pipe and inserted s drain plug to drain pipes if needed.

repair of passive system burms after heavy rains.

Added overflow pipe drainage line to overflow tank

maintain berms

Painting elastomeric on exposed pvc pipe.

repair of installation mistakes related to the plumbing of the system into the tanks

additional screens over gutters and channels on roof

Added sight glass.

added chlorine

installed short shallow invert and lined it with small rocksfor over flow to exit to street drain

Replace bulkhead

Valve seat needed tightening, sun deterioration of plastic parts

Minor adjustments to the passive system and installation of larger mesh screen on the rainhead of the larger tank to prevent overflow at the rainhead intake.

roof repair

:^) Fortunately, the tank and piping are robust enough that the Javelina have not proven to be a problem to the extent they are with the plants and drip irrigation hoses, even though they regularly troop around the former.

dig out basins periodically.

replaced the solinoid

tightened valve at top of cistern

sealing tanks where pipes are connected

adding missing parts to correct bad installation

install siphon on outflow to harvest water down to 1/2" above tank bottom

Added filters on pipes going into the tanks.

redesign of laundry catchement; clean gutters constantly.

repair broken pipe

we added one new catchment

Enlargement of passive system & addition of third cistern

always adding mulch - to be expected

I consider mulching basins to be maintenance, not repair. After hurricane Norbert 2014 we added berms to prevent water flow to patio.

lid reapaired from rust

adjusting valves to avoid leaks

Tried various debris screens and modifications of the end of the gutter. Nothing has worked on this particular skupper.

Screen at input area of cistern clogged with construction debris. Removed the screen since it was redundant anyway.

Q8: Why is maintenance your greatest concern?

Gutters

Needs to be done almost every time it rains

leaves from overhanging tree

This needs to be done most often

Have trees that result in clogged filter if I don't clean gutters.

I just forget and then the water doesn't flow into the tank. But filling the tank has not been a problem.

Will continue with this. Need to flush cisterns to remove dirt/debris..Not sure how to best flush the tanks.

due to mesquite leaves and pods

Because it has to be done often, and it's not visible from eye level. I hate when the gutters over flow and I have to put out buckets while it's raining!

requires ladders

Its the only one.

Dirty gutters prohibit good drainage

Gutter buildup prevents causes overflow and prevents entry into the tank.

1

My neighbor has an African Sumac that tends to grow over my roof

to make sure water flows properly

Affects overall collection of water.

Debris in the gutters ultimately ends up in the filters and impacts collection efficiency.

Cannot keep gutters sealed

Clean gutters keep filters clean

Clean gutters mean clean screens

Should be completed periodically

leaves are always coming

Water will flow off roof and not in cistern

Harder to do

Just so I don't get a lot of leaves on screen

if not cleaned, water flow to tank stops

Screens clog and water bypasses

requires roof access thus it introduces a bit more risk

Prevent gutter overflow

Because water overflow from gutters at collection point is causing ground erosion and unwanted water proximity to the house

leaves, other debris may otherwise fill and clog filters

Have to get on roof

keeping the gutters clean keeps the cistern cleaner

Leave litters can easily clog the gutter and leads to overflow

Both are equally concerning due to use of ladder

Harder for me to get to as i age.

Mesquite trees

requires ladder

Most difficult to monitor

I don't want the asphalt shingle gravel in my raintank.

dirt/dust tends to build up on the roof

causes overflow if not done frequently

acumulation of dried leaves and roof debri

pine needles impede proper flow

Desire to keep as much leaf litter out of the cisterns as possible

Prevents rainwater from being delivered to tanks

leaves

The less debris in the gutters the less debris I have to clean out of the trap.

Thought they would cleam themselves

Water will pool on the roof if the gutters do not perform properly. This promotes the likelihood of water damage to the roof and increases the possibility of mosquito breeding pools.

there was no filter plaed into the gutters before the water runs down into the tank

rainwater collection hindered unless debris moved often

Need to keep system clean to allow collection.

don't get water into tank if gutters are clogged

lost water

prevent overflow

Not really a concern just something that has to be checked regularly

If gutter is not kept clean then ther debris filter clogs and we fail to capture that rainwater.

System requires gutters to be open to drain water

I fthe gutters aren't clear, the water overflows onto the ground and floods my back porch.

we have large mesquite that overhangs house and drops leaves n pods

leaf litter accumulation affects the water collection

Proximity of trees adjacent to gutters

Keeping gutter clean requires cleaning roof channels that drain into gutter. Safety in walking aroundthe roof is becoming a concern

if gutters are clogged, screws up everything downstream

this is not a big concern, but since it is my only concern, it is the greatest

this is above ground and requires using a step ladder (safety hazards)

to avoid overflow

And filter screens

Need to make sure gutters drain properly, but this is the same as I would do without tanks

The design of the piece that supposedly prevents debri isn't totally functional.

Stops system

If I rid the gutters of debris then less leaves will potentially make it into cistern!

If gutters block downspout, no water collected contacting someone to clean

difficult to do

prevent overflow!

routine matter

Have to get up on the roof to do this, but I have been doing this for years.

Prohibits water from getting in tanks

most ditectly affects amount of rain collected

If I don't clean the gutters, they clog, and my rainwater dumps into the yard instead of the tank.

Keep water flowing

system plugs an causes water overflow

Excessive debris in tank may result in necessitating more frequent cleaning

Lots of falling leaves from trees

prevents contamination of the cisterns

to keep positive water flow

Access issues

Stops collection

I would no longer recommend installing a system without leaf diverter and first flush

We have a tree near roof and gutters

If the gutters are blocked, then the rainwater is lost and wasted.

lose water if the debris filter clogs

i have installed mosquito screen at the gutter to prevent mosquitoes, so i regularly must clean the gutter/screen due to excessive roof-borne debris & silt

Our gutters seemed to get a lot of trash in them when the wind blows. If we do not clean them then the down pipe always gets clogged

only because it involves ladder, no real concerns and gutters need cleaning anyways

check strainer on roof before each rain

Just want it to be effective

gutters are undersized DIY style, mesquite pods build up

concern that the screens on cistern don't get plugged.

First Flush

I don't like to have stinky water in the first flush

water won't go into tank if the filter fills with leaves

Last filter before water enters the tank is very important.

Because they fill up quickly after every rain.

i want to capture lots of clean water

Has the biggest impact on performance efficiency

difficult access

After every rain

My problem is NOT tree debris. I have large Leaf Cutter Ant nests nearby, and when the ants swarm, they wind up dying and littering my roof. If I don't clean the dead ants off the roof, they wash into the gutters, and their wings form into a "paper" that block my filtering screens.

Gutters overflow if not clean

have to disconnect gutter pipe to remove cover to clean filter

Ease the flow of water into the tank

This is the only regular maintenance, the others are not re-occuring.

Rainwater would not enter cistern unless filter is clean

these get clogged fairly easily, and water then overflows before going into the tank. As long as we chek once in a while and clean when necessary, it is not a problem.

None are a great concern. It's a pretty simple system.

cumbersome access

I don't want to hinder the flow of water to my storage tank.

clean gutters and filters, because otherwise no water will flow into the tanks

messiest, biggest hassle

so wont overflow

if it's full/blocked water runs down side of house

to avoid plug

ensure no growth in top of tank, and reduce fine sediment that can get into tank

Dirt and particles from roof.

Minor maintenance issue

After the initial adjustments to the systems and addition to of screens to increase longevity, we have settled into routine maintaince of the system. Cleaning out the first flush is imperative at this point to reduce the possibility of odor associated with standing water in the pipes.

Difficult for rentering

helps in mosquito prevention

not a concern/done to prevent odor buildup

most frequently neglected

when leave catchers clog, water does not enter the system

Prevent cloged screen & water loss

Clean Tanks

Very messy process to clean out last debris at bottom of tanks.

Confined space entry. Large tanks require climbing in

This is a time consuming process that involves more than one person-which can be inconvenient.

205 gallon tanks cumbersome for me to manage

No concern. May need very occasional cleaning of silty material.

water gets smelly and brown

Labor intensive

Most difficult because of size of tanks

This requires the most work

Paint Tanks

Ultraviolet sunlight is harmful to plastic

At least two coats because of our heat.

Re-inforce Basins

Soil is compacted

This is actually connected to the desire of bermuda grass to grow in the basin, which we have to keep up on pulling out.

Tank situated on a slight grade and erosion control prevents the tank from becoming unlevel.

this is in a sloped area of my landscape. I am very concerned about erosion and disruption of landscaping in a significant rain event. I also receive water from a neighboring landscape.

plants are affected by the erosion

We need to do this more often than expected

May need to add more rip rap to prevent erosion from desert into retention basins

Don't want to compromise the tank or plumbing

Lint Cleanout

with two dogs that shed, hair buklds up in to system requiring regular flushing.

Just expect to have to do it.

Prevent back flow into home

We get unnecessary overflow

Soap Buildup

This is actually the sump maintenance

The fact that there is occassionally soap buildup makes me think we should have more mulch or other material to mitigate the soap

Replace Broken Pipe

its annoying to have to keep replacing the over flow pipe. that plastic isn't up to withstanding the arizona weather.

Replace Valves

Valves should last longer than 2 yrs

Add Mulch

keep unwanted weeds under control and keep soil moist for native plants planted in the basins

basins fill with water and mulch goes everywhere, tired of buying more mulch and refilling

Keep moisture in the soil during extreme heat

Mosquito Treatment

keep them away

Mosquitoes often prevent use of outdoor patio.

don't like mosquitos in yard

mosquitos are bothersome for outdoor activity

because tucson doesnt need mosquitos.

Apply BT monthly

Friends complain if mosquitos

I can't figure out how mosquitos can be sealed out

Do not want mosquitos

can not enjoy backyard

to maintain pleasant outdoor environment

we have mosquiotes in the area and the decorative tanks can allow some access if excess rain overflows them.

Fear or west mile virus

most frequent maintenance issue

do not want to create a mosquito habitat

Only have this problem with the small tank systems I put in. Can get really bad if I don't keep a head of the game.

Can't have mosquitos.

on going during monsoon season

Do not want to have Mosquitos around.

Wet feed system is hard to keep an eye on

Ensure that people and pets are secure from harm

Repair from Tank Overflow

The overflows were eroding my driveway

Because the overflow, so far, has flowed back toward the house. Recall that the system was designed by the company. I am worried that continued saturation of the foundation will cause settling.

water leaked into house

Problem easily solved

In heavy rains we still loose a lot of water from the system not able to handle the volume and leads to a errosion.

if the overflow is not controlled it leaves a large puddle near the foundation of the house

still can't get south tank to work properly, due to installation problem that SARG cannot or will not fix. Wasted water defeats the purpose of having the tanks in the first place.

seal was and still is loose

it could potentially flow into house.

Tank overflowed after side top round plates were sealed. Not sure where the tank is leaking. This occurred with last rainfall once. We will continue to monitor for accurate assessment before requesting another fix.

Unintended erosion of soil into earthworks.

If the tanks continue to settle....

Re-design after rain

it's time consuming to redesign.

Greatest amount of water to make my property more lush for free

Our property is at a low point in the neighborhood. Therefore, we have to be careful to keep nuisance water from other properties from coming on to our property and overflowing our retention basins.

We have to reassess rainfall & impact constantly

insure water is getting to trees/plants

Each downpour is different. It takes probably a couple of years to calibrate ponds and catchments until perfection. It's fun work, though, and one gets to know the immense potential of rain toward ultimate water autarky.

it fixed the problem completely

manual labor hardest for me to do

It a lot of work. Have to fill some areas and dig out others.

Other from Q5

Still worjing on this - extending area served by overflow/runoff. Tank fills quickly.

If debris screen gets clogged, the cistern does not fill.

1) The screen holds some debris in a way that prevents ever getting it really clean. 2) The mesh will certainly allow grit to get through. Q: should there be two stages of filter, the first coarser than what's there, and the second finer?

necessary to prevent external flooding

Wouldn't characterize it as "concern," just a preventative measure. I remove the debris because that contributes to biomass feed build up at the bottom of the tank eventually

just normal maintenance

none is of great concern at this point

mineral from roof shingles clogs screens

if i do not clean the screens on top of the bushman tanks we loose some of our collection capacity it blocks the amount of water that can enter the tanks in large rain events and we loose some collection to leakage. Therefore i make a habit to clean my screens twice a year and it takes about 5 minutes a tank to unscrew the top cap and remove screen and spray off in garden then reattach and replace the gutter down spout. we do not have first flush systems and I perfer this it is much simplier

My phone did not populate Q7...2,3,1,4

temps get into the low 20's here

required frequently and unpredictably; when I might not be home

Keep large debris out of systen

1

replacing screws afterProcedure takes some doing so it's easy to put it off, removing the lid can be problematic

Not much of a concern.

ground squirrels compromise berms and they must be fixed

prevent overflow

keeps algae at minimum

Needs to be cleaned a couple of times of season. Once had water too restricted and it couldn't handle the flow in.

As stated earlier, poorly thought out plumbing to tank and resulting loss of water into tank

public health

This a problem because the screens don't look dirty, it's not till you have a rain event that you notice the water spilling over the edge because of the film on the screen.

won't run into tank

That's all I've needed to do so far.

did not want basin to have too much silt. It was alot of work to shovel all the site out of the basins.

water in tank compromised by mosqito, algae

the first two listed I would do anyway without having had a tank/cistern installed; the third one, too, actually; so this last one I chose because of that but also because it is a bit of a pain.

yard still fills with water

I chose this because it relates to the eventual predicted failure of plastic tanks. The remainder of actions are either routine or rare.

Other from Q6

necessary, but problem-free since

I have to check to make sure downspouts are directed to tanks every time it is going to rain. And sure enough, the spouts have shifted and I lose water if I can't catch it soon enough.

eager to do it but no time. love the work just no time

to better filter debris from the water

It's expensive and an overkill

Not anymore. Now ready for anytning

it was a lot of work, and the metal cistern had developed a pinhole leak which I was able to plug with the new coat of bluemax

Not able to resolve.

One tank leaks so bad that it really effects efficiency of system. Fortunately, the large tank is not the biggest problem.

cost

Because the tanks were not installed properly in the first place, every rain event, especially the major ones, directed a substantial amount of water toward our house foundation., which could cause settling issues. Some of the rain back flow from the tank was extraordinarily heavy.

was a lot of work

We have to climb up a ladder 2 clear this screen because the debris doesn't slide off of it as we have had to prop it up to get the water to go through it instead of sheeting off.

Caused serious overflow at gutter. No longer a problem.

Q15: Explanation of maintenance requirements affecting water quality

I'd like to be able to filter the water for drinking, but it's hard to keep up with the elastomeric coating each year, so I get runoff from bare tarpaper in spots.

The maintenance/modifications have improved the system

if I do not keep the gutters clean I lose the water

The screens and gutters must be kept clean or the rain doesn't flow into the tank very well or not at all.

we are not harvesting our full potential

Neglected maintenance of curb cut reduced amount of water that could enter.

Algae and silt

not so great with all that mosquito dunker poison in the water

If the water is sitting too long, it gets an odor.

water pours out of the top instead of being collected in the cistern

only when screens are plugged

it flows freely and brings all the water to the cisterns

odor in water--see answer below

The water goes into the overflow and out of the tank instead of into the tank

When gutters do not work properly water pools where it should not.

not rebuilding the basin's wall has affected the amount absorbed into the soil never worked even with repeated fixing

As stated above, tanks completely failed (fell apart) and need to be replaced.

foul water since first cleaning was delayed due to not knowing about it

More algae than expected

I could have collected more.

As memtioned, can get a little brown and smelly

Refer to earlier answers re: tank inlet plumbing and debris issues.

Siltier than we had hoped.

not changing the filter in a timley maner caued the soliniod to go bad

Water became infested with mosquitos. That problem appears to be fixed.

Strong sulphur smell impies impurities to me, so I wash my vegetables after I use harvested water to water them.

first-flush capacity does not allow for extra debris volume during heavy rains.

Some odor issues

some dirt and such in tank

Q16: Explanation of not installing same system

Would install a system to filter soil/debris from roof drainage into cisterns.

Actually, not sure, because it will all depend on whether the repairs I have made will fix the overflow problem coming back toward the house foundation

I would like the tanks to be a higher quality with a system the homeowner can use to remove and clean and replace the screens.

I would work on a passive system more than an active storage system. If I did a storage tank again, I would put more money into it and go with a larger tank with pump

Probably install larger tanks since in a good rainfall mine fill up quickly.

Accessing and moving the collected water to where it would be useful is too difficult

I would locate my tanks so the downspout is long enough to move it without have to remove it

Would use bigger tank...if I had space.

I would install screens over gutters and seal the cistern top better

But I'd add another cistern in back

I would put in a pump with it.

it is not enough water for the price put to it.

Not pump

I would strongly recommend against pumping graywater.

Unclear how much water I am receiving and limited gravity feed options from my tank

I would like to have installed a different pipe system to collect debris in vertical pipe with a lateral pipe above going to tanks.

I would not use the 2 systems I put in containing 3 each 55 gal. barrels connected to store 165 gal. They do not store enough water.

never

The contractor should not be building these things. They are beautiful but useless.

I would have designed the front of the house to have larger gutters and more tank capacity as that portion of the system overflows with less than 0,25 inches of rain fall. As a result, I have constantly added additional remote storage to the front of the property to move water from the front tanks to them to keep the front tanks empty.

There are more efficient systems for my house

I would put in a larger tank.

I would install more storage capacity

I wish I had a bigger tank

Would eliminate first flush water and just use a better screening system at intake.

not enough water pressure

Would use better filter system and larger tank.

I'd rather have a corrugated metal tank on a flat cement pad instead of a plastic tank that was just dropped into place and is tilted.

My landscape still relies heavily on city water. I would have preferred to have all pots watered by rainwater, but I find the olla ball system too finicky.

If I were starting now, I would put more emphasis on passive design. Distributing water from cisterns is labor intensive. We use a flow through pump unless the water level and pressure is high

Would buy a tank without a peak; would have a coating or light blocking exterior

Q17: Other shared information

No.

No, I knew a lot about it previously. The Extension class was good too.

buy tanks that can hold water during freezes without breaking

Nothing I can think of. We did lots of research before and attended the Pima Water Smart class on water harvesting in order for us to qualify for the rebate. We learned lots in the class. We love the system!

A conversation about the width of the gutters to be installed might have been helpful. Perhaps because we have curved tile roofing, the standard width of the gutter makes for a narrow reach into the gutters when I want to clean out leaves. I couldn't quite get everything out. But then, who has ever gotten everything out of their gutters?

Methods of dealing with the mosquitoes would have been REALLY helpful.

I would not have lined my leach ares with a type of cloth filter material over the bed of rocks

discussion of inflow port and consequences of overflow possibilities

I should have thought about it being A LOT of water and not connected to the irrigation system. We had to put the tank where it is, so we couldn't have easily connected it or placed it by the irrigation control...but still.

No. Installers were great, recommended ideally one size larger cistern. Perhaps the larger would have been better, but very difficult to conceal in a neighborhood where concealment is required. Very happy with my choice.

None.

The best way to use the system in a raised garden bed and other raised areas n the yard.

Someone needed to explain more about flow of water levels. If the hose is laying on the ground, then it comes out alright, but I have to lift the hose up to water pots, (sometimes over 5 feet) and it will not work without a pump. Also, the gutters were not installed correctly and I am still having a problem about that, although I think if they had been installed properly, it would be a great system.

No

Need advice as to how best to redirect natural water drainage into a basin for growing landscape plants.

No, I think I was pretty well informed. Except for the FIRST systems I put in, back when plans for using 55 gallon drums were circulating. What a lot of work THAT was, raising and plumbing those drums, then having to take them down a couple years later when they began to rust through! Yikes!

I had to remind the installer to put in a first flush standpipe

NO

I should have done more research and planning regarding the initial placement of the tanks and the need to compact the soil below each tank. I should have focused more on the placement/impact of the overflow pipes on the tanks initially. I have been learning as I go re interconnections among the tanks, installation of the pump and drip irrigation control valves, backflow preventers, etc. All is fascinating and the results are gratifying.

Better classroom instructions and caveats from the company that large rain events will cause severe backwash which is not preventable without additional funds, sometimes extensive.

I would have liked to have known more about what the flow of water would be like from the tanks. We are just using gravity, and the flow from the tanks is not the best.

i wish someone could have relayed how satistying capturing rainwater is

No Went to seminar and had all the information I needed/.

I would have liked a second larger tank which it seems I could have kept filled

no

More info about how to pump water out with portable pump

No

We did a lot of research finding a large, affordable tank. Tucson water was not helpful in directing us to many sources of tank supply. I have heard my friends complain that the tank company in town makes it too expensive to cover costs. We found a company out of California for our tank. they delivered for free. We also got a tank on craigslist that fit into corner of our patio, I hear, this size is not considered big enough any more. Since rules have changed since we installed you have made it harder to do be qualified for harvesting rebates. Or so I am told by my friends after they see my system.

no

No

Gutters should be fully screened along their whole length to keep debris down. This was not something I found in my study prior to installation.

It was more expensive to do the earthworks than anticipated but our yard is very big and there were a lot of problems previously

No

We would have like that the larger tank be placed more level. We will need to add sand and level out when it is next empty.

Possibly ways to pump it so it would spray over the vegetable garden, as well as automating the watering. When away, I rely on a timer on my host bib.

We installed the graywater systems ourselves (didn't use the rebate). It would have been better to have more help planning like we did with the passive system done with Watershed Management Group. We also had the tanks/gutters installed before having a design plan. After those were in place, I started working with WMG. If I could do it over, I would have worked with WMG first before putting any system in place. I did some research, and took the rebate classes, but is not my area of expertise. Paying for a design plan was definitely worth it.

better design expertise for the overflow of one of the tanks

Basin is too deep but we didnt have much info or experience with local soil and weather when we created it.

I do think it would be good to reimburse homeowners who install smaller tanks at the same rate as a large tank. It would have been more efficient for me to install three 560 gallon tanks, but the cost was too great and the reimbursement was much less.

Come up with a manual describing likely problems and techniques for maintaining and sustaining systems.

No

We had a great deal of information available to training sessions that we voluntarily attended. By working with Watershed Management we gained an incredible amount of knowledge that has helped us tremendously.Some of the questions above do no apply.

Yes, that the system needs to be elevated or have a pump to be usable.

Not sure

My gutter/downspout installation uses conventional residential materials. I would be interested in seeing how larger scale (commercial?) materials might be better suited to the capacities needed to keep pace with the rainwater accumulated during a heavy downpour.

No, we gave it great thought before proceeding.

City never told me back flow preventer was required until a year after they approved the system and awarded the rebate

No

Training on maintenance.

For me, some things need to be learned and figured out "hands on". I educated myself through your workshops and materials as well as I could and am now learning by watching and maintaining and adding to my system. Only thing I don't remembering learning before hand was way to distribute and best take advantage of water collected.

no

All info provided was helpful and more than sufficient.

no. the class was great. spent a little too much time on corrugated tanks.

I would like to have known that I could not hook a watering system on a timer to the tanks, and I would have to water everything with hoses.

only pay for tank - not installation

No, I felt I had all the information I needed.

Inability to connect to irrigation system.

No.

The program seems OK, but the installer I used was terrible--Southwest Gutter. I still think it is improperly installed --there is this big opening around the drain pipe where mosquitos live

Very little info was available on how to pressurize the water to make it useable. I researched and figured it out myself

As a homeowner doing the installation of basins and berms I would have liked to be able to borrow equipment for measuring grades.

Danger of packrats burrowing behind.

I have gotten such a great deal of pleasure from the passive water harvesting. As I told visitors to the tour last fall - the basins appear to have increased the foliage in my yard immensely, and the shade produced from the trees is wonderful. The west side of my property is very livable.

No

I would have liked more accurate descriptions of the size of the tanks. It was a surprise when the tanks were too tall to allow water to flow into them from the gutters, thus necessitating some work by us to dig down the earth where the tanks would sit.

I want to set up an automatic watering system from the harvesting tanks that is completely off the grid, i.e. 12 v, solar powered with battery storage. Having more info to allow such a system to be built by the homeowner would be very useful.

Better written clarification of all rebate parameters, including combination of tank sizes to accommodate the most rebate dollars.

I felt very informed.

The engineering information provide was very helpful in establishing the system but because I choose to use a 12 volt system I had to develop it by trial and error and there were several errors. As time and money permit I intend to add additional capacity as I'm only using about Â½ the potential and run out of water in early summer.

The water pressure issue was hard to overcome when I first started using the system.

The class was very helpful and informative so my answer is no.

The gutters overflow possibility and the mosquitoes infiltration, how to prevent these problems?!

It took personal experience to learn how much water I use, and therefore what size catchment tanks I needed. If I had it to do over, I would have bought a 1000 gallon tank instead of the 420 gallon tank.

No. We were well educated before installation

None

No, I think given our budget and our house and property circumstances we had enough information.

Can't think of anything.

I wish I would have worked closer with my welder from the beginning. Between the two of us, we've got it dialed in. I made some mistakes on my own before I started working with her.

No.

works well

There needs to be clear explanation of how different roofing materials effect water quality, so as to manage expectations and plan for uses. The fact is that asphalt shingle roofs leave petrochemical residues in the water, and this water isn't recommended for use on edible plants. That said, certain practices can help improve soil biology to mitigate risks associated with the waterâ€“â€“ this needs to be further studied, discussed and explained.

No The class was very useful

Not really. I'd like to have a pump on the cisterns to push the water when the tank is low, and to the farthest parts of the yard.

I need to design and build an additional system to collect rainwater from the roof. calculate that another 3000 gal tank could be filled several times per year if effectively collected.

Putting up gutters yourself is a lot of work - I would recommend that a professional company do seamless gutters.

I was well informed before starting projects.

I would have liked to know that when installing gutter the drip edge on the house will be bent and sometime cut or drilled. I'm not real happy with the way the drip edge was modified in some areas in order to get proper drainage on the gutter.

Mosquito larvae hatching in cistern stored water

none

"1. I would have preferred to put in a completely passive system - but the grading and boundaries of my yard was not appropriate for that type of rainwater harvesting.

2. Long before the official program, I began ""routing water"" away from the house foundation and to planting areas via underground PVC. I learned to direct/locate PVC runs away from the house foundation as quickly as possible - that is - not to run the PVC along the house foundation. I mistakenly did this - and ""broke"" the termite barrier for my house. An important ""Lesson Learned""."

Great program. I feel great about "doing" something to preserve the earth's water.

More discussion on outlet control

Not necessarily other information, but my design failed to address water from the front of the house being piped to the back of the house. During heavy rains, the system overflows and with the additional front yard water, a drain pipe was required through the block wall in the back yard to ease flooding conditions during monsoon rains. A simple oversight but easily corrected.

I think everything was explained clearly at the seminar I was required to take in order to receive the rebate.

No, I had a good understanding of what to expect.

Best local dealers

The overflow pipe should have a screen to cover the end...otherwise rodents crawl up inside it.

"My HOA is a pain in my ass. My neighbors think its great I'm doing this but the board is full of a bunch of control freaks. I can only keep the cisterns if no one sees them but yet they will not fix the earth moving away from my wall in front of my property every time it rains. I would like to see if someone from your organization would go out to these groups and teach them about water harvesting. I live on a hill side at Sunrise and Craycroft. The road leading up the hill from my home becomes a very fast moving river when it rains. I can't even imagine what the people at the bottom of this road experience when it rains.

"

The culvert doesn't produce enough water to justify the cost.

Make the system as perfect as possible. A well designed system can be used for years with some, but not a huge amount of maintenance.

A better method for using water with an on demand pumping system for landscape.

No.

A better recommendation for sealant than blue max. More info on leak prevention.

"Information on electric pumps to use the water more efficiently on exterior plants.

I currently use a bucket to manually water plants.

Perhaps information on integration into an existing drip irrigation system."

Using my captured rainwater is considerable less convenient and more time consuming compared to using my automatic drip system. But I still do it.

No works fine

No

If I do it again I'll be sure to install for more water capacity

Nope

a better selection and understanding of the pipes, fittings, and components necessary to connect everything together.

No.

I did not fully understand the importance of a debris filter. Perhaps kit that was sold with the cistern and designed to fit the pipe diameter would have made this easier. At the time I didn't carry through with figuring it out on my own.

I hope to install a cistern in the future.

How dependable pump was

A different first filter system.

More information regarding use of water collected would have been helpful, but I am learning as I go which maybe is best way to determine needs.

I would have liked to know that I would have a continual battle with my regular landscape maintenance and handyman about how the yards should be maintained. Perhaps tips on how to deal with these folks would have been handy.

I would like tank sitting on higher ground so there would be move gaveity for drainage

More water hook ups

no

na

Needs to have a better filtering system.

I think we needed one more tank.

yes- would have liked alternate method of gutters leading to cistern. These are underground. i would have liked those I see in town that go from roof to top of cistern.

No

None

No.

I would have placed tanks in higher position related to garden to allow better gravity flow to irrigation lines.

I would have liked to put in water storage cisterns but at the time did not have the funds. The work I did was limited to what I could do myself more could have been done if I knew where to go to get help.

When we bought/installed our first cisterns (tied together), it was before there were half-day workshops, so we really were flying somewhat blind. We have learned a lot since then, from experience, Watershed Management Group (excellent!), and attending a workshop.

It was difficult finding an economical system to install. It would be helpful to have a list of DIY suppliers in Tucson. Unfortunately, I believe the terms of the rebates have changed and require a contactor to perform the work (or the subsidy applies to using a contractor). This is counterproductive for customers who seek a DIY solution.

Large roof areas and slight differences in elevation create issues of intermediate transport of water into the main storage system.

I think it's hard to anticipate the full extent of what water harvesting will entail, how a system will work, and what maintenance will be required. Nevertheless I am happy with my system and feel the benefits out weigh the effort and costs incurred.

Should have installed another drum on northwest corner. May do that sometime. Had Land Tamers trim back trees that hung over gutter. This has to be done yearly. That has solved the gutter problem. I'm using seamless gutters.

so much - I wouldn't recommend any system and I caution people

I would have like to have know what support the installers were offering to give for the first year when I had the most questions/needed the most support. I have had my system for many years and have added to it. I would like to add more storage tanks, the the rebates are wonderful.

I wish we would have taken the class prior to installation.

None

You are welcome to come and visit us

None

No

the use of the roof area to calculate water volume is only part of the calculation to design a truly adequate system..especially for pitched roofs. The run off rate from a steeply pitched roof makes to velocity of the water in one of our typical localized down pours exceed the reach of the lip of even the larger gutters and makes the water overshoot the gutters and "escape" the capture..... during a typical monsoon this is really problematic as I would estimate that as much as double the volume of water captured escapes by over shooting the gutters..I have installed some sheet metal vertical fences on the gutter lips in the worst areas to try to mitigate the escape but it is not completely efficient and often overflows even the larger diameter down spouts or over shoots the entry into the capture barrels.

Tucson Water and Southern Arizona Rain Gutters didn't communicate clearly about the rebate, so when I applied for the rebate I did not get as much as I expected. But SARG gave me a refund on my gutters and tanks so make up for the mistake. Overall the rebate is great, but the program is a little too complicated for most people and they aren't going to invest the time and mental energy to figure it out. Watershed Management Group has some great ideas on how to simplify the rebate program and I hope Tucson Water will work closely with them to make improvements.

I have a desert landscape and appreciate not using drinking water on the plants.

The design of the first flush screen needs to be improved.

None

No

I wish I had more information on who to use to install the unit. I already hired a company before I went to the class. I would have changed a few things.ElziE

I am interested in a curb cut, yard basin for tree planting. I want to harvest rain water from the street runoff.

"Found that even well established landscape companies were clueless as to installing any water harvesting projects. Need to know competent and reliable sources for installation.

"

"Maintenance instructions/information. How to attach a cistern to a drip irrigation system or new drip irrigation system if possible, for the summer months. Is there a special valve or tubing that could be installed to the spigot?

Additional Plan to attach another smaller tank if overflow happened due to excess water. Better to have the water in a tank than overflowing where water is not needed or pooling. Consultation with an arborist or plant nursery about tree planting now that we have an supplemental water supply. Would be nice to have a local referrals for these types of projects/ future needs. "

I would like to now install off gutters from my home. Love the water harvesting

the water is surprisingly clear

The water harvesting class was sufficient. The formula to determine roof area to storage capacity was perfect.

If I was to install the system from scratch - it would be part of the entire lawn irrigation system (i.e. the irrigation for the lawn would pull the water directly from the tank/s) As of now - I manually unload the water from the tank to utilize watering plants,etc

Some more examples of systems with the pros and cons of each type of system and ways to overcome the cons.

The class gave me all the information I needed.

I am considering a clean water storage system of some sort because the water in the big tank cannot be used for drinking - without boiling and straining.

No. The WMG was very thorough in the info that they dispensed.

no

Prior to adding an addition to myy house and beginning to design a garden, Ii would have made sure that a water harvesting expert be an active part of the design process with architect and landscapers.

Harvesting class pretty well covered the subjects I needed information about.

I found out how much using a ball valve shutoff really increases the flow on the spigot.

An understanding of good practice on distance to place the tank from the house. Have seen anything from 1 foot to 10 feet minimum.

would prefer better traps/filters coming off the rain gutters

We installed rain water storage tanks at our last house in rural AZ so had experience.

Portable water pump. How to pump water out of cistern. Water spout as base takes for EVER to water plants

Info about how to combat algae

I wish the company that installed the system took a little more time to consider some simple improvements that would have improved it, like T-ing the dry system in to the wet system and connecting the tanks. But, these things take time, and can still be done.

None

I would have done more of the same earth works. I would have installed tanks.

If the water is going to be used to fill pool too is there a certain maintenance that should be done to prevent algae growth in the pool?

better timer to run to drip hose

Our cistern was installed by the gutter company. However, they did not install it properly. We had to empty the tank, prepare the bed, reinstall the underground pipe to one of the cisterns, and reinforce the base with rock. We used our landscape guy to do it and have had no problems since then. More information about the installation up front would have been helpful.

That there might be any maintenance to the system (as opposed to the features, such as adding mulch or watering plants).

a detailed schematic drawing of all the elements from the roof to the cistern

Ideas for clean-out designs of the downspout-to-basin delivery system. Our plug occurred where the downspout goes into the pipe, and we had difficulty getting clean-out hoses and snakes to the area.

I did my share of research before placing an order with SARG. I knew the folks at Watershed Management who are doing an excellent job to improve prudent water management in Tucson. I attended their classes and volunteered many hours to get to work and look at other systems, and to increase my experience. I also got to know other sustainable energy orgs in town. I highly recommend to network with this organizations.

WMG did a systematic job!

no

Watershed Management Group was very good at informing and educating me about the system and it's functioning. The plumbing company told me about the greywater system when they installed the valves.

Although I am capable with plumbing and electrical and most other facets of construction would have liked more info on rainwater systems. Experience is a good teacher, but those with minimal skills must rely on installers - not always a good thing.

I could have used more input on how to beneficially use the water.

No

No. I studied many possible solutions before installing the system.

No. The company that did the install (Ecosense) along with the class that we took with Dr Murieta did an excellent job of preparing us.

Not that anyone else could have provided. I should have done a better study of where the studs in our walls were.

No. Did the a lot of reading and planning prior to install. I also called around and asked questions. I learned a lot of the great rain water harvesting community here in Tucson. I think thats why it has been such a great success. The plants love it and it has more than paid for itself.

gutter/roof warning....can't skip cleaning gutters and gutter guards may work as roofs to the gutter and BE a problem and not be a cure

n/a

how to use collect water in landscaping

See Q16

No...I did a lot of research

No none. We went to the rainwater harvesting class provided by Tucson Water. We bought our tanks and gutters from the Southern AZ Rain Gutter outfit on Stone. They spent less than 1/2 a day to install the two 1,000 above-ground poly units as well as the seamless gutter system. We could not have done such a professional install ourselves. The tanks were virtually free since the rebate covered the cost of the tanks.

I did not realize that the tanks should have been installed on a higher platform to maximize the gravity flow.

The people who installed the tank didn't really care if the system worked. I had to monitor them and correct some things.

No

No

Should have taken the required class before installation/learned a great deal at the class

Plumbing for L2L does not need to be done by a licensed plumber if it is done properly and to code as ours was. The rules changed between the time we had the plumbing installed, submitted paperwork, and inspection. We were not able to get our rebate for the cost of labor. This was unfair and unethical since the change in policy was made without anyone knowing about it. We should have been grandfathered in.

Is site location for the water harvesting tanks ultimately my responsibility, or is the design the responsibility of the company? They've told me all the problems were due to my error.

No. The required class taught me what to expect.

Plumbing choices and details would have been helpful.

ideas on how to pump out water & overflow ideas due to heavy rain

Info on gutter cleaning techniques for 2 story homes

Better elevation illustrations to see roof heights and tank heights for planning purposes.

No, I did quite a bit of research.

"I suggest making sources of leaf diverters & first-flush more documented & available, and making them ~strongly~ suggested in the pre-rebate seminar/training. I think first-flush was covered, but leaf diverters were glossed over, and obviously are my primary issue.

I haven't taken the greywater class; I've already had that system a long time pre-rebate. I've since got a book showing how my clog(s) were due to poor design. Now I'm still doing my greywater the 'wrong' way (underground), but the pipe is so big it hasn't clogged in several years."

na

In retrospect, I think I would have liked to the tank to be more elevated than it is to provide a bit more head pressure. I would have appreciated information about what is necessary to elevate a tank that size about a foot or so. Also, some additional information about how to get the water from the tank to the desired areasâ€"even if slightly higher than the tank dischargeâ€"would be nice. Pump options, perhaps? Currently the water from the tank is being moved by hand in 5 gal. buckets which is not terribly efficient.

more about water pressure

more info on filters, screens, water quality maintenance

I was fairly knowledgeable when installing the various systems, and did most of the work myself.

More on first flush filter and downspout.

Yes and no. So much of it is learning by trial and error. I guess maybe I would have liked to see more examples of systems, but I know that each one is pretty unique.

No. That the contractors were good at what they did but not great businessmen

Basics such as positioning for best elevation, depth below surface, etc., would have been helpful.

We had an abundance of information about water harvesting and have used it to assist others with irrigation systems, basins and swells, and systems to avoid runoff. Tucson Water has done an exemplary job of educating its water users about harvesting rain water and reducing water usage.

I wish I had doubled my systems capacity as recommended by the installer, but I rejected his proposal.

no

We thought we had a good idea of the height of our cisterns but they proved to be much taller than anticipated when they arrived. Thus we had to dig down a few inches in each location so they would actually be lower than the downspout. I also would have liked to know more clearly where the overflow would be compared to the intake, as in some cases we would have requested that the overflow be installed on a different side.

I would like to have installed more storage capacity.

When permits are required. Options for base of tank. Options for scuppers. How to abate algae.

I find the lack of information regarding materials types to be frustrating. The different types of piping (Sched 40, ABS, etc) means you can't just mix&match parts. Same thing with gutters - they have rounded rectangular downspouts, but pipes are a different shape - why not just have the gutter whole be "round"? And, some PVC has different thickness than others, so even using adapters gets tricky...

I FEEL I PD. TOO MUCH FOR AN INFERIOR GUTTER INSTILATION. I BOUGHT 2 GUTTERS FOR FRONT OF MY CARPORT FOR $20. AND INSTALLED MYSEF TYING INTO SYSTEM. I FEEL IT WOULD HAVE BEEN WAY CHEEPER, IF I HAD JUST BOUGHT MY TANKS AND AND DONE PROJECT MYSELF.

Making people more aware of the outlet pressure that will be expexted. Need to build a storage tank at higher level to get some PSI from tank. It works just fine for me as my garden is next to it and doesn't require much psi.

The class was great, I learned enough to get me going. Sources for tanks and other equipment would have been helpful

Workshop was great. Our system was the first major one for our installer so some improvements mentioned in #16 about might have been good to have.

Location options, knowledge that you can only water below the tank level

no

We feel that the calculation for how much rain water comes off the portion of the roof with gutters was possibly not correct. We feel that less water is actually collected than originally calculated. We need to get another tank to collect the amount we truly wish

I would recommend taking the harvesting class first before ordering the installation. That way the consumer has information about design and technicalities.

Appendix D: IRB Approval Letter

Research
Office for Research & Discovery

Human Subjects
Protection Program

1618 E. Helen St.
P.O.Box 245137
Tucson, AZ 85724-5137
Tel: (520) 626-6721
http://rgw.arizona.edu/compliance/home

Date: November 30, 2016
Principal Investigator: Ethan Thomas Vimont
Protocol Number: 1611980118
Protocol Title: Tucson Water Harvesting Maintenance
Level of Review: Exempt
Determination: Approved
Documents Reviewed Concurrently:

Data Collection Tools: *etv_maintenance survey draft 11.3.2016.docx*
HSPP Forms/Correspondence: *appendix_f_0_edits.docx*
HSPP Forms/Correspondence: *Appendix f signature.pdf*
HSPP Forms/Correspondence: *f107_v2016-07_0_edits EDIT_11.25.DOC*
HSPP Forms/Correspondence: *f200_v2016-07_edits EDIT_11.25.doc*
HSPP Forms/Correspondence: *f200 signature.pdf*
Informed Consent/PHI Forms: *cover letter_invite EDIT_11.25.docx*
Informed Consent/PHI Forms: *cover letter_invite EDIT_11.25.pdf*
Other: *Rupprecht_CV_11.08.16.pdf*
Other Approvals and Authorizations: *Rupprecht Investigator Agmt.pdf*
Recruitment Material: *cover letter_invite EDIT_11.25.docx*

This submission meets the criteria for exemption under 45 CFR 46.101(b). This project has been reviewed and approved by an IRB Chair or designee.

- The University of Arizona maintains a Federalwide Assurance with the Office for Human Research Protections (FWA #00004218).
- All research procedures should be conducted according to the approved protocol and the policies and guidance of the IRB.
- Exempt projects do not have a continuing review requirement.
- Amendments to exempt projects that change the nature of the project should be submitted to the Human Subjects Protection Program (HSPP) for a new determination. See the Guidance on Exempt Research information on changes that affect the determination of exemption. Please contact the HSPP to consult on whether the proposed changes need further review.
- You should report any unanticipated problems involving risks to the participants or others to the IRB.
- All documents referenced in this submission have been reviewed and approved. Documents are filed with the HSPP Office. If subjects will be consented, the approved consent(s) are attached to the approval notification from the HSPP Office.