Single-Family Home Rainwater-Harvesting System Demonstration Project For Stormwater-Runoff Control and Utility-Water Saving

By

John Hammerstrom
American Rainwater Catchment Systems Association

Tamim Younos
The Cabell Brand Center for Global Poverty and Resource Sustainability Studies

Founded in 1987

www.cabellbrandcenter.org

www.arcsa.org/

Acknowledgments

This special report is a collaborative effort between the American Rainwater Catchment Systems Association and the Cabell Brand Center for Global Poverty and Resource Sustainability Studies.

Credit and Citation:

Hammerstrom, J. and T. Younos. 2014. Single-family home rainwater-harvesting system demonstration project for stormwater-runoff control and utility-water saving. The Cabell Brand Center Special Report No. 100-2014, 34 pp.

Single-Family Home Rainwater-Harvesting System Demonstration Project For Stormwater-Runoff Control and Utility-Water Saving

John Hammerstrom and Tamim Younos

Abstract

This report summarizes results for a three-year study of a single-family home in Key Largo, Florida, supplied by dual water sources, i.e., rooftop rainwater and utility-supplied water for both potable and non-potable uses. The rainwater harvesting system incorporated a water treatment system for potable uses. The study measured captured rainwater and use, utility water consumed, and reduction in stormwater runoff. The excess rainwater was directed to a spreader swale for underground infiltration resulting in zero runoff. Over a three-year period, the system captured 108,500 gallons (72%) of all rainwater (150,500 gallons) that fell on the single-family roof. As a result, utility water consumption was reduced to 33.9 gallons per capita per day (gpcd), compared to the utility average of 107 gpcd. Total water consumption (utility water plus rainwater) was 83.6 gpcd, still below the utility average, but greater than that of water-conserving homes, due in part to increased rainwater consumption when the rainwater storage tank was full. The initial capital, maintenance and life-cycle costs were documented. Current and projected life-cycle-costs per gallon of treated rainwater are compared to utility. It is concluded that a well-designed and maintained rainwater harvesting system can 1) significantly reduce the amount of water required from a public utility; 2) deliver very high quality water that exceeds the U.S. Environmental Protection Agency (EPA) Drinking Water Standards at a competitive price; and 3) result in zero stormwater runoff. This rainwater harvesting demonstration project is expected to inspire investment in the modern revival of this ancient practice by governmental entities, philanthropists and homeowners.

Keywords
Rainwater use**,** potable water saving, stormwater management, energy saving, cost analysis

Contacts
Mr. John Hammerstrom (email: johnhammer@bellsouth.net)
Dr. Tamim Younos (email: tyounos@gmail.com)

Table of Contents

1. Introduction

Few, if any residential case studies are available that demonstrate the capability of rainwater-harvesting systems to manage water resources at a decentralized, residential scale, typical of many U.S. applications. There is a critical lack of data demonstrating the quantity and quality of water that can be collected from a residential rainwater-harvesting system as well as the resulting benefits of decreasing utility-water consumption and stormwater runoff. This report evaluates the effectiveness of rainwater harvesting for potable water use while reducing residential runoff and utility water demand. The report summarizes results from a three-year study (8/1/2011 to 8/1/2014) of a single-family home supplied by dual sources (rooftop rainwater and utility-supplied water). The intent of this report is to provide critical data for decision makers considering rainwater harvesting as a water supply and/or runoff reduction option.

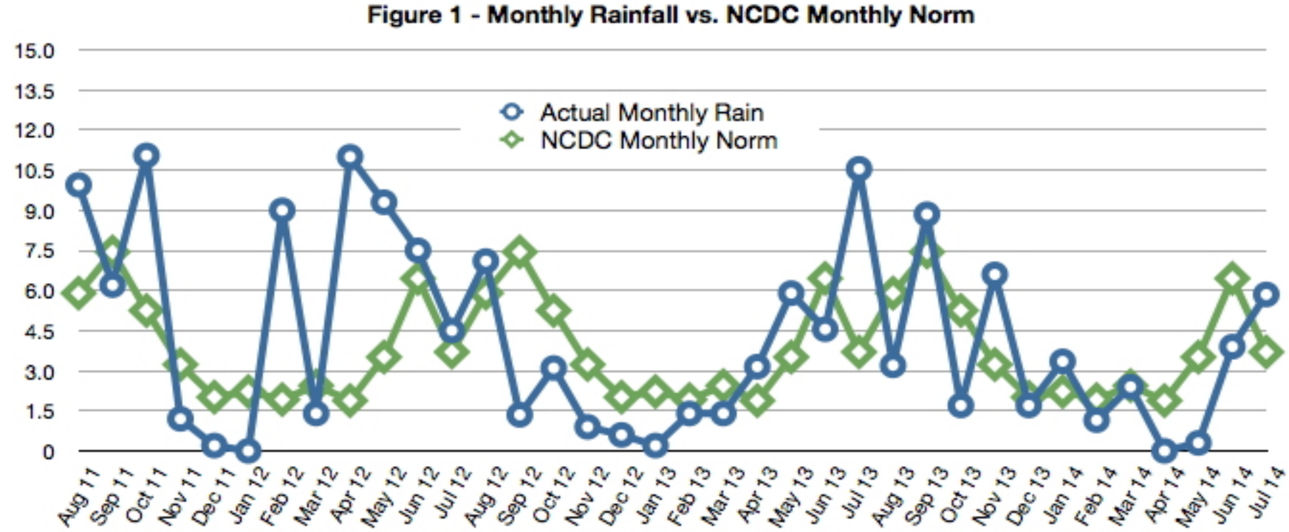
2. Methods

The rainwater harvesting project demonstration study was conducted for a period of three years (8/1/2011 to 8/1/2014). The study site is a single-family home in Key Largo, Florida, constructed in 2000 and occupied in 2002. The home is located in a native hammock with very porous terrain, consisting of ancient coral-reef Pleistocene limestone.

2.1 Rainfall Measurement and Pattern

Rainfall for the three-year study period (8/1/2011 to 8/1/2014) was measured regularly and after rain events, using a common garden rain gauge. According to the National Climatic Data Center (NCDC – www.ncdc.noaa.gov), the 30-Year (1981-2010) Monthly Normal precipitation for nearby Tavernier, Florida, was 45.95 inches. For the period of the study at the project demonstration site, the average annual rainfall was 50.2 inches per year. The rainfall (Figure 1) during this study did

Figure 1 - Monthly Rainfall vs. NCDC Monthly Norm



not follow the historical patterns in February through May 2012, when greater than average seasonal rain fell. The longest periods without rain were 58 days between December 2011 and

January 2012, 47 days between late March and mid May 2014 and 39 days in December through mid-January 2013.

2.2 Rainwater Capture System

Components of the rainwater capture system include a 1,956 square-foot white metal Galvalume™ roof with 6-inch copper gutters and splash guards (Figure 2); Schedule 40 PVC downspouts and conveyance; a pre-filtration and first-flush system (Figure 3); calming inlets (Figure 4); and a 7,500-usable-gallon, ground-level poured concrete tank which is integrated into the concrete home structure (Figures 5a and 5b). The total volume of the storage tank is 10,000 gallons, with usable volume diminished by unusable water below the foot valves and dead space above the overflow. The tank is separated into two halves by an internal concrete wall with overflow gaps at the top, such that when the first half is full, rain overflows to the second half. When the second half is full, the tank overflows passively to a spreader swale (Figure 6).

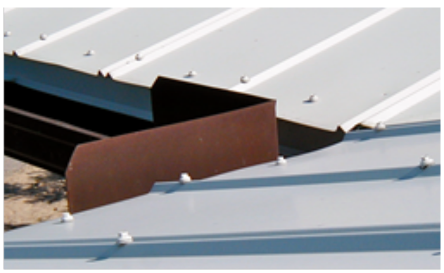


Figure 2

Figure 3

Figure 4

Fig 5a

Fig 5b

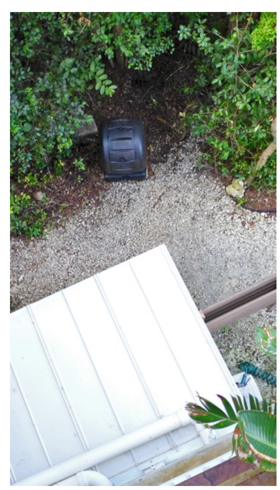


Fig 6

All components of the rainwater capture and rainwater-use system are made of potable-quality materials and comply with National Sanitation Foundation standards. All components of the system

are in compliance with ARCSA/ASPE/ANSI Standard 63-2013, with the possible exception that the home has copper gutters that were installed in 2001, well before a national standard was established. Standard 63 (4.9.2) states that copper roofing materials shall not be used for potable water systems. Since gutters are not strictly roofing material, the system may be in full compliance, but it nevertheless seems clear the intent of section 4.9.2 is to discourage the use of copper components.
Despite the presence of copper gutters and plumbing throughout the house, for this rainwater-harvesting system, over a twelve-year period (since 2001), none of the annual rainwater-quality tests performed by an EPA-certified lab detected copper concentration greater than 10% of the 1.3 ppm copper limit of the EPA Primary Drinking Water Standard. However, a more thorough investigation of the potential contamination of copper may be warranted, balancing their relative advantages such as life cycle and cost versus potential health risks.

2.3 Dual Water Supply System and Subsystems

The dual-use (rainwater and utility water) distribution system shown in Figure 7 incorporates three subsystems that can supply either utility water or treated rainwater (see Section 2.4) to (any or all of): 1) a dedicated single faucet in the kitchen for drinking and cooking; 2) all lavatories and showers; 3) toilets and hose bibs. Figure 7 shows the utility-water source at the top of the picture, with three on-off ball valves, and the treated rainwater source at the bottom, each with three valves paired to its utility-water counterpart.

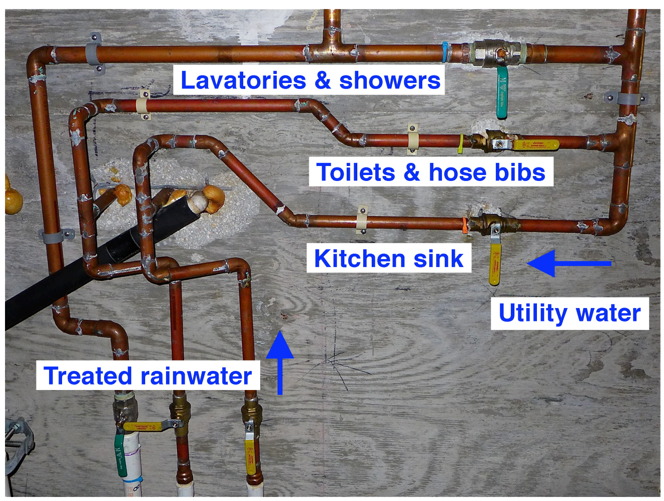


Figure 7. Utility water and rainwater dual-use system

The three subsystems can be manually switched as follows: a) when rain is plentiful during the rainy season, use rainwater for all inside and outside household potable and non-potable purposes; b) when rainwater tank levels decline, use utility water for hose bibs and toilet flushing, and use treated rainwater for drinking, showering and cooking; c) and when rainwater tank level is low during the dry season, direct treated rainwater for use in the kitchen sink (for drinking and cooking), and use utility water for all other purposes.

Beside the line dedicated to the kitchen sink, the only extra plumbing is the distribution manifold at the junction of the utility and the treated-rainwater systems. The treated rainwater and utility water are isolated from each other by a Reduced Pressure Zone (RPZ) valve for backflow prevention. Utility-supplied water is used increasingly as treated rainwater becomes less available.

2.4 Rainwater Treatment System

As described in Section 2.2 the rainwater harvesting systems is equipped with a pre-filtration and first-divert system, which consists of two Leaf Eater-Advanced™, self-cleaning rain heads and two SafeRain™ adjustable first-flush units (Fig 3). Rainwater then enters the first half tank through calming inlets (Fig. 4). When the first half tank is full, water decants to the second. A foot valve (Fig. 8) is located 6 inches above the bottom of each half where water can be drawn from either or

Figure 8

Figure 9

both foot valves by a ¾ hp Jet Pump shown in Figure 9. Water pressure is maintained by an 80-gallon pressure tank (Figure 10). For treatment, rainwater flows from left to right through the three canisters of a Pura Big Boy UVBB3, filtration, and 115-volt ultraviolet system (Figure 11). The first canister houses a dual-density polypropylene sediment filter, (nominal 25-micron pre-filtration and 1-micron post filtration), the second houses a 5-micron nominal carbon block and the final canister is the UV chamber for disinfection (Figure 11). After final treatment, the treated rainwater flows through the selection valves (Fig. 7) to the household fixtures.

Figure 10

Figure 11

Primary and secondary water-quality tests of 100% rainwater from the kitchen faucet were performed annually by National Testing Laboratories, Ltd., (ISO 17025:2005 accreditation), using

U.S. EPA and Standard Methods. The samples were shipped overnight with lab-provided ice packs in Styrofoam containers to the Michigan laboratory and processed less than 24 hours later per NTL testing protocol." Only cold water was sampled. Test results are described in Section 3 and Appendix A of this report. Appendix B shows the published annual test distributed by the local water utility, Florida Keys Aqueduct Authority.

2.5 System Operations and Management

Management of the tank's rainwater quantity is an exercise in finding a balance between retaining as much rainwater as possible to satisfy demands and the tank not go dry, and the competing purpose of reducing the tank water level to capture as much rainwater as possible and thereby minimize overflows.

Water level in the rainwater storage tank was recorded regularly, and storage tank overflow quantities were calculated from rainfall amounts that exceeded the tank's remaining capacity.
When full, the tank was partially emptied during the first 48 hours in a controlled manner for useful purposes such as long showers, car washing or plant watering (rather than indiscriminately wasted), in order to accommodate a 2-inch rain (which was approximately 2,000 gallons of storage). Shifting from conservation to profligacy and back depending on the availability of rainwater necessitated premeditated awareness of the resource availability.

Onsite uses of treated rainwater include uses typical of a residence, from landscape and toilet flushing to ice making. The home is equipped with dual-flush toilets, with the low-flush and high-flush used normally for liquids and solids respectively, but the high flush being used for both purposes during the rainy season to accelerate consumption. In South Florida, the rainy season is also the hot season. Between May or June and November (depending on when the rains begin), rainwater was used as the source for a "Cool-N-Save" air conditioning pre-cooling mist system (Figure 12) to reduce energy consumption and to reduce overflows.

Figure 12

As described above, utility-supplied water or treated rainwater system (for both potable and non-potable uses) can be selected manually for three subsystems through the use of six matched valves on the three subsystems. The choice of source enabled maximum rainwater storage and usage by adjusting household water consumption during the dry season (January to June) and rainy season (June to January). During the dry season, as the tank empties, the subsystems are gradually switched to utility-supplied water to conserve treated rainwater for drinking and cooking, until the rainy season arrived, when the valves were incrementally reversed.

2.6 Data Collection and Calculations

The following sets of data were collected over the project period of three years:

- **Rainfall** – measured after rain events by a simple, household direct-read rain gauge, in inches.
- **Rainwater harvested** – inches of rain converted to gallons based on 1,000 gallons/inch rainfall from the 1,956 square-foot, reflecting losses for roof efficiency, rainhead losses and first flush losses, or 82% efficiency. There was good correlation between one inch of measured rain and 1,000 gallons of new water measured in the cistern.
- **Utility water consumption** - determined from monthly household water bill and the water meter.
- **Water level in tank** - measured daily by a simple reverse-reading system that consists of a weighted float inside the tank connected by monofilament line through the tank wall to the indicator on the outside of the tank. The indicator shows a full tank when the level indicator was at the bottom of the outside of the tank, connected to the internal float at the top of the tank.
- **Overflow to onsite infiltration -** calculated from the total rainfall in gallons that exceeded the empty capacity of the tank before the rain event. For example, if there were 1,000 gallons of remaining capacity and the rainfall amount was 1,500 gallons (1.5 inches of rain), the overflow amount was 500 gallons.

3. Results and Discussion

Seventy-two percent (72%) of the total 150,500 gallons of rain that fell on the rooftop —or 108,850 gallons—was captured for household and landscape uses (Figure 13). The remaining 41,650 gallons (28%) was overflowed to an onsite spreader swale (Figure 6). Thus, the residential water system allowed for total onsite use of rooftop rainwater with near zero stormwater runoff.

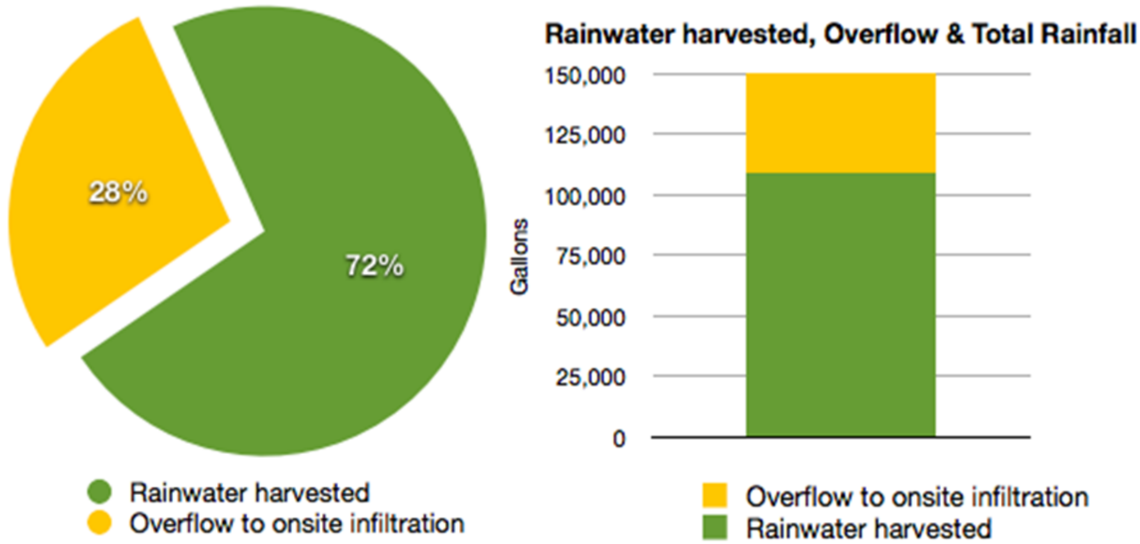


Figure 13 Harvested rainwater and use

3.1 Utility Water Saving

Figure 14 shows the impact of rainwater harvesting on utility water consumption. Of the total 183,077 gallons of water consumed during the three years, 108,850 gallons (59%) was provided by harvested rainwater. As a result of rainwater use, utility water consumption was 33.9 gallons per capita per day (gpcd) compared to the utility-wide average of 107 gallons per capita per day. Both treated rainwater and utility water were used during the study period and the combined total water usage was 83.6 gallons per day per capita, still below the average utility-wide consumption, but below that of water-conserving homes, due in part to the intentional accelerated consumption (creating tank capacity) to avoid potential runoff.

The greatest rainfall event (with the greatest overflow) during the 3-year period was 9.4 inches over a three-day period (July 15-18, 2013). During this event, 4400 gallons of rainwater were captured and 4,950 gallons overflowed to the spreader swale. Because this was the greatest overflow event, additional storage capacity of 4,950 gallons, for a total of 12,450 gallons (4950 + 7500) could have stored all of the rainwater during the three-year study. Overall, total rainfall captured during the three-year demonstration period (150,500 gallons) was nearly the same as the total water consumed for the period (183,077 gallons), which means with a 12,450-gallon tank and modestly increased efficiency and conservation, total rainfall could have met all demands with nearly zero overflows.

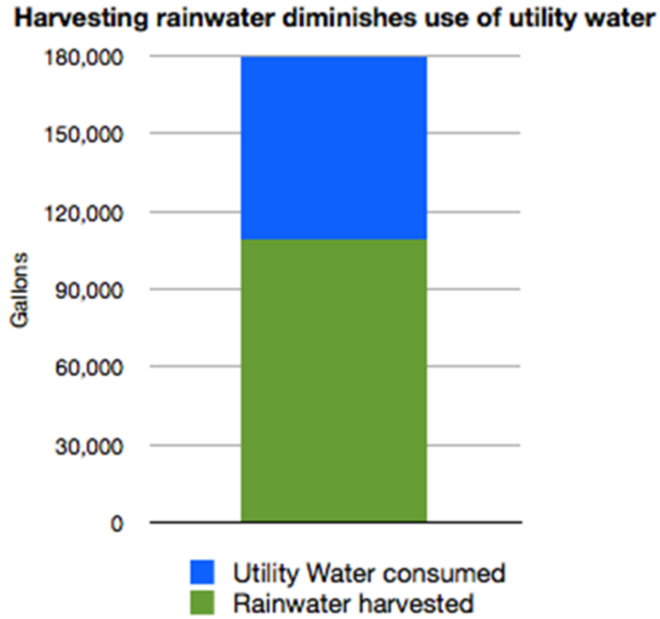


Figure 14. The impact of rainwater harvesting on utility water consumption

3.2 Captured Rainwater Quality

Table 1 shows treated rainwater quality compared to EPA standards for 2013. The quality of treated rainwater exceeded EPA Primary and Secondary Drinking Water Standards with one exception. The pH of the February 2014 water sample was 8.8, while the EPA upper limit is 8.5. While there is no definitive explanation, the pH has been greater than 7.0 for every annual test, quite likely because the presence of coral dust (calcium carbonate) and the pH raise is attributable to the concrete tank. It is worth noting that is difficult to measure pH of pure rainwater accurately. According to ASTM (American Society for Testing and Materials), "…high purity water is highly unbuffered and small amounts of contamination can change the pH significantly." It has been suggested that testing rain sample before striking the roof and also prior to entering the tank might result in a different pH value. However, there are obvious challenges with this approach and the associated costs of performing it are likely prohibitive.

See Table A1, A2 & A3 in the Appendix for complete three-year test results and Appendix B for same-year utility water annual test results. Appendix B shows the utility (Florida Keys Aqueduct Authority) annual system-wide water quality reports. Concurrent tests of utility water within the house were not done.

Table 1. Quality of treated rainwater compared to EPA Standards (2013 data)

Informational Water Quality Report

Watercheck w/PO

National Testing Laboratories, Ltd.
Quality Water Analysis

6571 Wilson Mills Rd
Cleveland, Ohio 44143
1-800-458-3330

Client:

Ordered By:
Hammerstrom, John [redacted]

Sample Number: 834258

Location:	Kitchen island sink faucet
Type of Water:	Other
Collection Date and Time:	2/18/2013 14:45
Received Date and Time:	2/19/2013 09:55
Date Completed:	3/1/2013

Treated rainwater

Definition and Legend

This informational water quality report compares the actual test result to national standards as defined in the EPA's Primary and Secondary Drinking Water Regulations.

Primary Standards: Are expressed as the maximum contaminant level (MCL) which is the highest level of contaminant that is allowed in drinking water. MCLs are enforceable standards.

Secondary standards: Are non-enforceable guidelines regulating contaminants that may cause cosmetic effects (such as skin or tooth discoloration) or aesthetic effects (such as taste, odor,or color) in drinking water. Individual states may choose to adopt them as enforceable standards.

Action levels: Are defined in treatment techniques which are required processes intended to reduce the level of a contaminant in drinking water.

mg/L (ppm): Unless otherwise indicated, results and standards are expressed as an amount in milligrams per liter or parts per million.

Minimum Detection Level (MDL): The lowest level that the laboratory can detect a contaminant.

ND: The contaminant was not detected above the minimum detection level.

NA: The contaminant was not analyzed.

✓ The contaminant was not detected in the sample above the minimum detection level.

● The contaminant was detected at or above the minimum detection level, but not above the referenced standard.

▲ The contaminant was detected above the standard, which is not an EPA enforceable MCL.

✚ The contaminant was detected above the EPA enforceable MCL.

✖ These results may be invalid.

Status	Contaminant	Results	Units	National Standards		Min. Detection Level
			Microbiologicals			
✓	Total Coliform by P/A	Total Coliform and E.coli were ABSENT in this sample.				
			Inorganic Analytes - Metals			
✓	Aluminum	ND	mg/L	0.2	EPA Secondary	0.1
✓	Arsenic	ND	mg/L	0.010	EPA Primary	0.005
✓	Barium	ND	mg/L	2	EPA Primary	0.30
✓	Cadmium	ND	mg/L	0.005	EPA Primary	0.002
●	Calcium	3.2	mg/L	--		2.0
✓	Chromium	ND	mg/L	0.1	EPA Primary	0.010
●	Copper	0.093	mg/L	1.3	EPA Action Level	0.004
✓	Iron	ND	mg/L	0.3	EPA Secondary	0.020
✓	Lead	ND	mg/L	0.015	EPA Action Level	0.002
●	Magnesium	0.45	mg/L	--		0.10
✓	Manganese	ND	mg/L	0.05	EPA Secondary	0.004
✓	Mercury	ND	mg/L	0.002	EPA Primary	0.001
✓	Nickel	ND	mg/L	--		0.020
✓	Potassium	ND	mg/L	--		1.0
✓	Selenium	ND	mg/L	0.05	EPA Primary	0.020
●	Silica	2.1	mg/L	--		0.1
✓	Silver	ND	mg/L	0.100	EPA Secondary	0.002
✓	Sodium	ND	mg/L	--		1
●	Zinc	0.018	mg/L	5	EPA Secondary	0.004
			Physical Factors			
✓	Alkalinity (Total as CaCO3)	ND	mg/L	--		20
✓	Hardness	ND	mg/L	100	NTL Internal	10
✓	pH	7.8	pH Units	6.5 to 8.5	EPA Secondary	
✓	Total Dissolved Solids	ND	mg/L	500	EPA Secondary	20
●	Turbidity	0.4	NTU	1.0	EPA Action Level	0.1

Page 2 of 6 3/1/2013 8:05:37 AM Product: Watercheck w/PO Sample: 834258

Note: See Table A1, A2 & A3 in the Appendix for complete three-year test results and Appendix B for same-year utility water annual test results.

3.3 Cost and Maintenance

The material cost for the rainwater harvesting system was $8,788, while the labor cost was estimated at 50% of the material cost, or $4394, for a grand total original cost of $13,186. Because this system was installed as part of a new-home construction, identifying and isolating the actual rainwater-system labor cost was not possible. Costs for individual components of the system are documented in Table 2 and the annual electricity cost to operate the rainwater system in Table 3.

Table 2. Total rainwater harvesting system material cost + labor cost (estimate)

	Downspouts, conveyance and calmed inlet	**4-inch downspout and conveyance PVC fittings**	**Rain Heads**	**First Divert**
Description	75 feet 4-inch Sched 40 PVC		Leaf Eater Advanced	100mm SafeRain Vertical Diverters
Cost each	$3 per foot		$33	$135
Number	75 feet		2	2
Total cost	$225	$200	$66	$270

	Concrete Tank - cost of concrete and rebar as part of home construction	**Potable tank coating 1.75 gal/100 sq ft**	**Foot Valves**	**1 ½ in PVC - 60 linear feet**	**Misc. check valves, shutoff valves and disconnects**
Description		Topcoat			
Cost each		$200	$90	$14 per 10ft	
Number		1	2	6	
Total cost	$4,981	$200	$180	$84	$150

Table 2 continued - Total rainwater harvesting system material cost + labor cost (estimate)

	¾ hp pump	Pressure Tank	Pressure Gages	Filtration and UV
Description		80 gallon		UVBB3
Cost each	$530	$560	$25	$730
Number	1	1	2	1
Total cost	$530	$560	$50	$730

	Distribution valves	One dedicated1/2" copper line to kitchen	Total Material Cost	Estimated Original Labor Cost - 50% of material cost	Grand Total Material + Labor Cost
Description	Apollo ball valves				
Cost each	$26	$58 per 10ft			
Number	6	7			
Total cost	$156	$406	**$8,788**	**$4,394**	**$13,186**

Table 3. Annual cost of electricity to operate RWH system

Rainwater Electricity Costs	UV 60W 24/7 kWh per year	Pump - .08 kWh per 80 gallons	Rainwater Electric cost/yr @ 10¢ per kWh
kWh	526	35	$56.06

Table 4. Cost per gallon comparison of utility water vs. treated rainwater

Utility water costs	5/8" Water Meter Cost				Total water bill cost	Number of years	Water Total Cost
Water bill history 2007-2014	$3750				$3,709	7	$7,459
2002-2014 Est	$3750				$6,358	12	$10,108
20 Years Est	$3750				$10,597	20	$14,347
Life Cycle Est	$3750				$15,896	30	$19,646
Rainwater costs	**Original Material Cost**	**Original Labor Cost – 50% of material cost Est.**	**Annual Costs - Filters & UV Bulb**	**Annual Electric Cost**	**Unscheduled Maint Cost Estimate**	**Number of years**	**Water Total Cost**
2002-2014	$8,788	$4,394	$250	$56.06	$225	12	$17,080
20 Years Est	$8,788	$4,394	$250	$56.06	$450	20	$19,753
Life Cycle Est	$8,788	$4,394	$250	$56.06	$675	30	$23,039

Table 4 continued - Cost per gallon comparison of utility water vs. treated rainwater

Utility water costs	Gallons per year consumed	Total gallons		Net Cost	Total cost per gallon	
Water bill history 2007-2014	36,614	256,300		$7,459	$0.0291	Actual costs 2007-14
2002-2014 Est	36,614	439,371		$10,108	$0.0230	Estimated 2002-07
20 Years Est	36,614	732,286		$14,347	$0.0196	Estimated
Life Cycle Est	36,614	1,098,429		$19,646	$0.0179	Estimated
Rainwater costs	**Gallons harvested per year - estimate**	**Total gallons**	**Value of utility water NOT consumed @ $5.75 per 1,000 gallon**	**Net Cost - Total cost of system minus $ value of water saved**	**Total cost per gallon**	
2002-2014	35,000	420,000	-$2,415	$14,665	$0.0349	Actual costs 12 years
20 Years Est	35,000	700,000	-$4,025	$15,728	$0.0225	Estimated
Life Cycle Est	35,000	1,050,000	-$6,038	$17,001	$0.0162	Estimated

Table 4 itemizes the factors used to calculate the cost per gallon of treated rainwater compared to utility water. For the seven years of available water utility records between 2007 and 2014, 256,300 gallons were consumed at a burdened (total water bill, including fixed monthly fees) cost of $3,709. The 5/8-inch water meter "system development charge" was $3,750. For twelve year, 20-year and 30-year cost-per gallon calculations, the $3,750 fixed cost of the water meter was added to the cost of water consumed and divided by the number of gallons. The total cost per gallon slowly decreased as the impact of the 5/8-inch water meter was "diluted" by additional water usage.

For the rainwater side of the comparison, the upfront cost, including the original material cost plus the estimated labor cost totaled $13,182. Annual costs for water treatment were $250 for four sediment filters (changed quarterly), two carbon blocks (changed semi-annually) and one annual UV bulb replacement. Historical and projected unscheduled maintenance costs were included. In 2012, a pressure-tank leak cost $100 to repair and in 2014, fixing a leaking check valve cost $125.

The electricity cost to operate the 60-watt ultraviolet sanitizer 24/7, plus the measured power from operating the ¾ hp pump at .08 kWh for every 80 gallons (to recharge the pressure tank) totaled $56.06 a year at 10¢ per kWh.

Since harvested rainwater displaced utility water that would have otherwise been purchased, the savings generated by the rainwater-harvesting system from NOT buying utility water equal to the quantity of rainwater harvested was subtracted from the cost per gallon calculations at the simple cost of utility water of $5.75 per 1,000 gallons. The monthly fixed charges of $13.57 were not subtracted, because the dual-source system would incur the fixed charges regardless of the quantity of utility water consumed. Based on historical trends, 35,000 gallons of harvested rainwater were used annually, while annual utility water consumed during the seven years of available historical billing was 36,614 gallons.

Considering all fixed and variable costs, the current cost (as of 2014) of treated rainwater is 3.49¢ per gallon, the 20-year estimate is 2.25¢ and the 30-year estimate is 1.62¢ per gallon, compared to the utility-water values of 2.30¢, 1.96¢ and 1.79¢ respectively. For these data, the cost per gallon of treated rainwater equaled utility water at the 25-year point, when the cost for both was 1.86¢ per gallon, after which rainwater was less expensive. Because the upfront costs for a rainwater system is likely to be greater than the upfront cost for utility water, but the "purchase" price of harvested rainwater is less than utility water, a durable rainwater system will deliver less expensive water after the upfront cost differential has been offset.

The $13,182 upfront cost of the rainwater system was amortized over 30 years as part of the home mortgage, which at 4% interest with a 20% down payment, equals a monthly payment of $50.

Beyond traditional Return on Investment calculations such as the 25-year break-even estimate, additional factors that could affect broader cost comparisons are: unpredicted maintenance costs, central sewer savings (not a factor for this study), net present value calculations, rebates, utility water rate increases, a rainwater-system lifespan of more (or less) than 30 years and the stormwater-runoff avoided costs.

For some, the water quality, reliability and security of an onsite rainwater-harvesting system may provide significant, albeit unquantifiable benefits. A Life-Cycle Assessment or Cradle-to-Grave Analysis should be performed to measure the relative carbon footprint of these two sources, but such analysis was beyond the scope of this project report

Maintenance of the system was relatively easy. The pre-filter rainheads and first flush devices were checked regularly, usually before and after rain events. After its original 2002 commissioning, the tanks were scrubbed annually with water and then wet vacuumed. After several years of finding only insignificant sediment on the bottom of the tanks, combined with the addition of calming inlets and the growth of a stable biofilm along the tank walls and floor that we found helped maintain a healthy system, annual cleaning was replaced by inspections. The low-maintenance metal roof and gutters were checked periodically.

3.4 Discussion

Dual-source systems can contribute to the resilience of the associated water utility by reducing demand during occasions of utility-water system failures. Conversely, should a failure occur in the rainwater system, utility water is available for all household uses.

Because there was no flow meter to measure the quantity of rainwater consumed, the quantity of rainwater harvested was used as a substitute for rainwater consumed. For the purposes of quantifying the total water consumed, actual utility water consumed was added to rainwater harvested. As a result, rainwater consumption was somewhat overstated by the quantity of rain remaining in the tank. At the end of the study period, 4,050 gallons remained in the cistern and thus rainwater consumption was overstated by that amount during the entire period. The effect on total water consumed over the three years was minimal. Removing the 4,050 "unconsumed" gallons of rainwater that remained in the cistern at the end of the study period would have decreased the total water consumed per capita per day from 83.6 to 81.7 gpcd.

Characteristics of the system and measurements resulted in overstating the per-capita consumption and the overflow. First, total household water usage per day in this study appears somewhat higher than the actual per-capita consumption because periodically high consumption rates of rainwater were utilized when the tank was full to intentionally create an "overflow-absorbing capacity." Secondly, overflow was overstated when the tank was completely full. Because there are no flow meters to measure actual consumption and the storage quantity (tank level) is the surrogate for consumption, there incorrectly appears to be no consumption (because there was no change in tank level from "full"), and therefore more overflow was reported than actually occurred.

Consequently, the data shows that higher than average rainfall increases the reported water consumption and overflow. As stated earlier, "rainwater harvested" was used as a substitute for actual water consumed. The rainwater harvested was higher than rainwater consumed because a full cistern was depleted rapidly to accommodate the next rain event. The extra space created by rapidly depleting a portion of a full tank contributed to greater rainwater harvesting quantities, which in turn appears as greater rainwater consumption. Thus, the total water consumed was greater than actual by the amount of water that was "wasted" to accommodate the next rain event, but may have been offset by the fact that no rainwater consumption was recorded when the cistern was full. Use of a flow meter to measure rainwater consumption would have eliminated these adjustments.

An anomalous event occurred in July 2014 while the residents were away. An automated landscape drip-watering valve failed in the open position, despite the manufacturer's claim that the valve would fail closed. As a result, the utility water consumed during the month was 27,200 gallons, compared to the previous six-year July average of 2,150 gallons. For the purposes of the study, the 27,200 was treated as an outlier and replaced by 2,150. Including the 27,200 would have increased the utility water gallon per capita per day (gpcd) consumption from 33.9 to 45.7, and increased the total water gpcd from 83.6 to 95.4.

The overflow was contained onsite by diverting it to a spreader swale. Since the original hydrology is maintained with no runoff from the impervious roof, the practice of emptying a portion of a full tank was discontinued after the study. Nevertheless, liberal uses of rainwater and air conditioning compressor cooling are still practiced during the rainy season.

4. Conclusions

This report summarizes a three-year study of a single-family home supplied by dual water sources, i.e., captured rooftop rainwater and utility-supplied water. The study measured rainwater captured, utility water consumed, and stormwater runoff. The rainwater harvesting system incorporated a treatment system for potable uses. The excess rainwater was directed to a spreader swale for underground infiltration. Major conclusions of this rainwater capture and use demonstration project are as follows:

1. The rainwater captured from this residential rainwater harvesting system reduced utility water consumption to 1/3 of the utility's average customer.
2. Rainwater captured in a well-designed and maintained system can be easily treated to deliver plentiful water that surpasses the EPA's Primary and Secondary Drinking Water standards.
3. Substantial amounts of rainfall were captured with a residential rainwater harvesting system over the study period. Coupled with common infiltration strategies and innovative uses of stored rainwater when the tank was full, rainwater harvesting precluded potential runoff from the impervious roof.
4. Selected, practical use of rainwater when the tank is full to accommodate the next rain event and avoid runoff is preferable to an automatic depletion system that arbitrarily and indiscriminately drains the cistern to a certain level.
5. For a durable rainwater-harvesting system, the cost of treated rainwater is competitive with utility water and will ultimately be less expensive per gallon.
6. Rainwater captured and used in conjunction with other management practices such as a spreader swale system allows for total onsite use of rooftop rainwater with near zero runoff.
7. Decentralized rainwater harvesting in dual-source systems contributes to the resiliency of the associated water utility operations.
8. Drought, stormwater runoff, water-quality concerns, aging infrastructure and sustainability issues are driving global water-use behavior changes. Further research is needed to identify the motivators that may allow rainwater harvesting to play a meaningful role in solving these growing problems.
9. Results of this study may inspire investment in the modern revival of this ancient practice by governmental entities, philanthropists and other funders.

Recommendations for Future Research

As noted, a Life-Cycle Assessment or Cradle-to-Grave Analysis should be performed to measure the relative carbon footprint of captured rainwater and utility water.

It is recognized that the level of user involvement required to manually manage the rainwater harvesting and use system can be beyond the interest of some homeowners. Homeowner education can be a key to successful and cost-effective rainwater harvesting system. There is a need to develop educational and outreach programs to increase homeowner knowledge about the benefits of rainwater harvesting systems and enhance their motivation to install rainwater harvesting systems.

Appendix A

Table A1 – Treated rainwater quality test results January 17, 2012

Informational Water Quality Report

Watercheck w/PO

National Testing Laboratories, Ltd.
Quality Water Analysis

6571 Wilson Mills Rd
Cleveland, Ohio 44143
1-800-458-3330

Client:

Ordered By:
Hammerstrom, John PO Box 860 Tavernier, FL 33070 ATTN: John Hammerstrom

Sample Number:	824833
Location:	Kitchen Spigot
Type of Water:	Other
Collection Date and Time:	1/4/2012 15:24
Received Date and Time:	1/5/2012 09:20
Date Completed:	1/17/2012

Treated Rainwater

Definition and Legend

This informational water quality report compares the actual test result to national standards as defined in the EPA's Primary and Secondary Drinking Water Regulations.

Primary Standards:	Are expressed as the maximum contaminant level (MCL) which is the highest level of contaminant that is allowed in drinking water. MCLs are enforceable standards.
Secondary standards:	Are non-enforceable guidelines regulating contaminants that may cause cosmetic effects (such as skin or tooth discoloration) or aesthetic effects (such as taste, odor,or color) in drinking water. Individual states may choose to adopt them as enforceable standards.
Action levels:	Are defined in treatment techniques which are required processes intended to reduce the level of a contaminant in drinking water.
mg/L (ppm):	Unless otherwise indicated, results and standards are expressed as an amount in milligrams per liter or parts per million.
Minimum Detection Level (MDL):	The lowest level that the laboratory can detect a contaminant.
ND:	The contaminant was not detected above the minimum detection level.
NA:	The contaminant was not analyzed.
✓	The contaminant was not detected in the sample above the minimum detection level.
●	The contaminant was detected at or above the minimum detection level, but not above the referenced standard.
▲	The contaminant was detected above the standard, which is not an EPA enforceable MCL.
✚	The contaminant was detected above the EPA enforceable MCL.
✖	These results may be invalid.

Status	Contaminant	Results	Units	National Standards		Min. Detection Level
			Microbiologicals			
✓	Total Coliform by P/A	Total Coliform and E.coli were ABSENT in this sample.				
			Inorganic Analytes - Metals			
✓	Aluminum	ND	mg/L	0.2	EPA Secondary	0.1
✓	Arsenic	ND	mg/L	0.010	EPA Primary	0.005
✓	Barium	ND	mg/L	2.00	EPA Primary	0.30
✓	Cadmium	ND	mg/L	0.005	EPA Primary	0.002
●	Calcium	6.2	mg/L	--		2.0
✓	Chromium	ND	mg/L	0.100	EPA Primary	0.010
●	Copper	0.065	mg/L	1.300	EPA Action Level	0.004
✓	Iron	ND	mg/L	0.300	EPA Secondary	0.020
✓	Lead	ND	mg/L	0.015	EPA Action Level	0.002
●	Magnesium	0.10	mg/L	--		0.10
✓	Manganese	ND	mg/L	0.050	EPA Secondary	0.004
✓	Mercury	ND	mg/L	0.002	EPA Primary	0.001
✓	Nickel	ND	mg/L	--		0.020
●	Potassium	2.8	mg/L	--		1.0
✓	Selenium	ND	mg/L	0.050	EPA Primary	0.020
●	Silica	2.130	mg/L	--		0.100
✓	Silver	ND	mg/L	--		0.002
●	Sodium	2	mg/L	--		1
●	Zinc	0.034	mg/L	5.000	EPA Secondary	0.004
			Physical Factors			
✓	Alkalinity (Total as CaCO3)	ND	mg/L	--		20
●	Hardness	16	mg/L	100	NTL Internal	10
✓	pH	7.5	pH Units	6.5 to 8.5	EPA Secondary	
✓	Total Dissolved Solids	ND	mg/L	500	EPA Secondary	20
✓	Turbidity	ND	NTU	1.0	EPA Action Level	0.1

Status	Contaminant	Results	Units	National Standards		Min. Detection Level
			Inorganic Analytes - Other			
✓	Chloride	ND	mg/L	250.0	EPA Secondary	5.0
✓	Fluoride	ND	mg/L	4.0	EPA Primary	0.5
✓	Nitrate as N	ND	mg/L	10.0	EPA Primary	0.5
✓	Nitrite as N	ND	mg/L	1.0	EPA Primary	0.5
✓	Ortho Phosphate	ND	mg/L	--		2.0
✓	Sulfate	ND	mg/L	250.0	EPA Secondary	5.0
			Organic Analytes - Trihalomethanes			
✓	Bromodichloromethane	ND	mg/L	--		0.002
✓	Bromoform	ND	mg/L	--		0.004
✓	Chloroform	ND	mg/L	--		0.002
✓	Dibromochloromethane	ND	mg/L	--		0.004
✓	Total THMs	ND	mg/L	0.080	EPA Primary	0.002
			Organic Analytes - Volatiles			
✓	1,1,1,2-Tetrachloroethane	ND	mg/L	--		0.002
✓	1,1,1-Trichloroethane	ND	mg/L	0.200	EPA Primary	0.001
✓	1,1,2,2-Tetrachloroethane	ND	mg/L	--		0.002
✓	1,1,2-Trichloroethane	ND	mg/L	0.005	EPA Primary	0.002
✓	1,1-Dichloroethane	ND	mg/L	--		0.002
✓	1,1-Dichloroethene	ND	mg/L	0.007	EPA Primary	0.001
✓	1,1-Dichloropropene	ND	mg/L	--		0.002
✓	1,2,3-Trichlorobenzene	ND	mg/L	--		0.002
✓	1,2,3-Trichloropropane	ND	mg/L	--		0.002
✓	1,2,4-Trichlorobenzene	ND	mg/L	0.070	EPA Primary	0.002
✓	1,2-Dichlorobenzene	ND	mg/L	0.600	EPA Primary	0.001
✓	1,2-Dichloroethane	ND	mg/L	0.005	EPA Primary	0.001
✓	1,2-Dichloropropane	ND	mg/L	0.005	EPA Primary	0.002
✓	1,3-Dichlorobenzene	ND	mg/L	--		0.001

Status	Contaminant	Results	Units	National Standards		Min. Detection Level
✓	1,3-Dichloropropane	ND	mg/L	--		0.002
✓	1,4-Dichlorobenzene	ND	mg/L	0.075	EPA Primary	0.001
✓	2,2-Dichloropropane	ND	mg/L	--		0.002
✓	2-Chlorotoluene	ND	mg/L	--		0.001
✓	4-Chlorotoluene	ND	mg/L	--		0.001
✓	Acetone	ND	mg/L	--		0.01
✓	Benzene	ND	mg/L	0.005	EPA Primary	0.001
✓	Bromobenzene	ND	mg/L	--		0.002
✓	Bromomethane	ND	mg/L	--		0.002
✓	Carbon Tetrachloride	ND	mg/L	0.005	EPA Primary	0.001
✓	Chlorobenzene	ND	mg/L	0.100	EPA Primary	0.001
✓	Chloroethane	ND	mg/L	--		0.002
✓	Chloromethane	ND	mg/L	--		0.002
✓	cis-1,2-Dichloroethene	ND	mg/L	0.070	EPA Primary	0.002
✓	cis-1,3-Dichloropropene	ND	mg/L	--		0.002
✓	DBCP	ND	mg/L	--		0.001
✓	Dibromomethane	ND	mg/L	--		0.002
✓	Dichlorodifluoromethane	ND	mg/L	--		0.002
✓	Dichloromethane	ND	mg/L	0.005	EPA Primary	0.002
✓	EDB	ND	mg/L	--		0.001
✓	Ethylbenzene	ND	mg/L	0.700	EPA Primary	0.001
✓	Methyl Tert Butyl Ether	ND	mg/L	--		0.004
✓	Methyl-Ethyl Ketone	ND	mg/L	--		0.01
✓	Styrene	ND	mg/L	0.100	EPA Primary	0.001
✓	Tetrachloroethene	ND	mg/L	0.005	EPA Primary	0.002
✓	Tetrahydrofuran	ND	mg/L	--		0.01
✓	Toluene	ND	mg/L	1.000	EPA Primary	0.001
✓	trans-1,2-Dichloroethene	ND	mg/L	0.100	EPA Primary	0.002

Status	Contaminant	Results	Units	National Standards		Min. Detection Level
✓	trans-1,3-Dichloropropene	ND	mg/L	--		0.002
✓	Trichloroethene	ND	mg/L	0.005	EPA Primary	0.001
✓	Trichlorofluoromethane	ND	mg/L	--		0.002
✓	Vinyl Chloride	ND	mg/L	0.002	EPA Primary	0.001
✓	Xylenes (Total)	ND	mg/L	10.000	EPA Primary	0.001
			Organic Analytes - Others			
✓	2,4-D	ND	mg/L	0.070	EPA Primary	0.010
✓	Alachlor	ND	mg/L	0.002	EPA Primary	0.001
✓	Aldrin	ND	mg/L	--		0.002
✓	Atrazine	ND	mg/L	0.003	EPA Primary	0.002
✓	Chlordane	ND	mg/L	0.002	EPA Primary	0.001
✓	Dichloran	ND	mg/L	--		0.002
✓	Dieldrin	ND	mg/L	--		0.001
✓	Endrin	ND	mg/L	0.0020	EPA Primary	0.0001
✓	Heptachlor	ND	mg/L	0.0004	EPA Primary	0.0004
✓	Heptachlor Epoxide	ND	mg/L	0.0002	EPA Primary	0.0001
✓	Hexachlorobenzene	ND	mg/L	0.0010	EPA Primary	0.0005
✓	Hexachlorocyclopentadiene	ND	mg/L	0.050	EPA Primary	0.001
✓	Lindane	ND	mg/L	0.0002	EPA Primary	0.0002
✓	Methoxychlor	ND	mg/L	0.040	EPA Primary	0.002
✓	PCB	ND	mg/L	0.0005	EPA Primary	0.0005
✓	Pentachloronitrobenzene	ND	mg/L	--		0.002
✓	Silvex 2,4,5-TP	ND	mg/L	0.050	EPA Primary	0.005
✓	Simazine	ND	mg/L	0.004	EPA Primary	0.002
✓	Toxaphene	ND	mg/L	0.003	EPA Primary	0.001
✓	Trifluralin	ND	mg/L	--		0.002

Status	Contaminant	Results	Units	National Standards	Min. Detection Level

We certify that the analyses performed for this report are accurate, and that the laboratory test were conducted by methods approved by the U.S. Environmental Protection Agency or variations of these EPA methods.

These test results are intended to be used for informational purposes only and may not be used for regulatory compliance.

National Testing Laboratories, Ltd.

NATIONAL TESTING LABORATORIES, LTD

Table A2 – Treated rainwater quality test results Mar 1, 2013 [Note: Cover page and Pages 4 through 6 of the results were omitted in the interest of space. No organic volatiles or “other” analytes were detected.]

Status	Contaminant	Results	Units	National Standards		Min. Detection Level
	Microbiologicals					
✓	Total Coliform by P/A	Total Coliform and E.coli were ABSENT in this sample.				
	Inorganic Analytes - Metals					
✓	Aluminum	ND	mg/L	0.2	EPA Secondary	0.1
✓	Arsenic	ND	mg/L	0.010	EPA Primary	0.005
✓	Barium	ND	mg/L	2	EPA Primary	0.30
✓	Cadmium	ND	mg/L	0.005	EPA Primary	0.002
●	Calcium	3.2	mg/L	--		2.0
✓	Chromium	ND	mg/L	0.1	EPA Primary	0.010
●	Copper	0.093	mg/L	1.3	EPA Action Level	0.004
✓	Iron	ND	mg/L	0.3	EPA Secondary	0.020
✓	Lead	ND	mg/L	0.015	EPA Action Level	0.002
●	Magnesium	0.45	mg/L	--		0.10
✓	Manganese	ND	mg/L	0.05	EPA Secondary	0.004
✓	Mercury	ND	mg/L	0.002	EPA Primary	0.001
✓	Nickel	ND	mg/L	--		0.020
✓	Potassium	ND	mg/L	--		1.0
✓	Selenium	ND	mg/L	0.05	EPA Primary	0.020
●	Silica	2.1	mg/L	--		0.1
✓	Silver	ND	mg/L	0.100	EPA Secondary	0.002
✓	Sodium	ND	mg/L	--		1
●	Zinc	0.018	mg/L	5	EPA Secondary	0.004
	Physical Factors					
✓	Alkalinity (Total as CaCO3)	ND	mg/L	--		20
✓	Hardness	ND	mg/L	100	NTL Internal	10
✓	pH	7.8	pH Units	6.5 to 8.5	EPA Secondary	
✓	Total Dissolved Solids	ND	mg/L	500	EPA Secondary	20
●	Turbidity	0.4	NTU	1.0	EPA Action Level	0.1

Page 2 of 6 3/1/2013 8:05:37 AM Product: Watercheck w/PO Sample: 834258

Status	Contaminant	Results	Units	National Standards		Min. Detection Level
Inorganic Analytes - Other						
✓	Chloride	ND	mg/L	250	EPA Secondary	5.0
✓	Fluoride	ND	mg/L	4.0	EPA Primary	0.5
✓	Nitrate as N	ND	mg/L	10	EPA Primary	0.5
✓	Nitrite as N	ND	mg/L	1	EPA Primary	0.5
✓	Ortho Phosphate	ND	mg/L	--		2.0
✓	Sulfate	ND	mg/L	250	EPA Secondary	5.0
Organic Analytes - Trihalomethanes						
✓	Bromodichloromethane	ND	mg/L	--		0.002
✓	Bromoform	ND	mg/L	--		0.004
✓	Chloroform	ND	mg/L	--		0.002
✓	Dibromochloromethane	ND	mg/L	--		0.004
✓	Total THMs	ND	mg/L	0.080	EPA Primary	0.002
Organic Analytes - Volatiles						
✓	1,1,1,2-Tetrachloroethane	ND	mg/L	--		0.002
✓	1,1,1-Trichloroethane	ND	mg/L	0.2	EPA Primary	0.001
✓	1,1,2,2-Tetrachloroethane	ND	mg/L	--		0.002
✓	1,1,2-Trichloroethane	ND	mg/L	0.005	EPA Primary	0.002
✓	1,1-Dichloroethane	ND	mg/L	--		0.002
✓	1,1-Dichloroethene	ND	mg/L	0.007	EPA Primary	0.001
✓	1,1-Dichloropropene	ND	mg/L	--		0.002
✓	1,2,3-Trichlorobenzene	ND	mg/L	--		0.002
✓	1,2,3-Trichloropropane	ND	mg/L	--		0.002
✓	1,2,4-Trichlorobenzene	ND	mg/L	0.07	EPA Primary	0.002
✓	1,2-Dichlorobenzene	ND	mg/L	0.6	EPA Primary	0.001
✓	1,2-Dichloroethane	ND	mg/L	0.005	EPA Primary	0.001
✓	1,2-Dichloropropane	ND	mg/L	0.005	EPA Primary	0.002
✓	1,3-Dichlorobenzene	ND	mg/L	--		0.001

Table A3 – Treated rainwater quality test results 2014 [Note: Cover page and Pages 4 through 6 of the results were omitted in the interest of space. No organic volatiles or "other" analytes were detected.]

Status	Contaminant	Results	Units	National Standards		Min. Detection Level
			Microbiologicals			
✓	Total Coliform by P/A	Total Coliform and E.coli were ABSENT in this sample.				
			Inorganic Analytes - Metals			
●	Aluminum	0.1	mg/L	0.2	EPA Secondary	0.1
✓	Arsenic	ND	mg/L	0.010	EPA Primary	0.005
✓	Barium	ND	mg/L	2	EPA Primary	0.30
✓	Cadmium	ND	mg/L	0.005	EPA Primary	0.002
●	Calcium	4.0	mg/L	--		2.0
✓	Chromium	ND	mg/L	0.1	EPA Primary	0.010
●	Copper	0.007	mg/L	1.3	EPA Action Level	0.004
✓	Iron	ND	mg/L	0.3	EPA Secondary	0.020
✓	Lead	ND	mg/L	0.015	EPA Action Level	0.002
●	Magnesium	0.12	mg/L	--		0.10
✓	Manganese	ND	mg/L	0.05	EPA Secondary	0.004
✓	Mercury	ND	mg/L	0.002	EPA Primary	0.001
✓	Nickel	ND	mg/L	--		0.020
●	Potassium	1.2	mg/L	--		1.0
✓	Selenium	ND	mg/L	0.05	EPA Primary	0.020
●	Silica	0.9	mg/L	--		0.1
✓	Silver	ND	mg/L	0.100	EPA Secondary	0.002
●	Sodium	2	mg/L	--		1
●	Zinc	0.005	mg/L	5	EPA Secondary	0.004
			Physical Factors			
✓	Alkalinity (Total as $CaCO_3$)	ND	mg/L	--		20
●	Hardness	10	mg/L	100	NTL Internal	10
▲	pH	8.8	pH Units	6.5 to 8.5	EPA Secondary	
✓	Total Dissolved Solids	ND	mg/L	500	EPA Secondary	20
✓	Turbidity	ND	NTU	1.0	EPA Action Level	0.1

Page 2 of 5 2/26/2014 1:18:48 PM Product: Watercheck Sample: 842670

Status	Contaminant	Results	Units	National Standards		Min. Detection Level
			Inorganic Analytes - Other			
✓	Chloride	ND	mg/L	250	EPA Secondary	5.0
✓	Fluoride	ND	mg/L	4.0	EPA Primary	0.5
✓	Nitrate as N	ND	mg/L	10	EPA Primary	0.5
✓	Nitrite as N	ND	mg/L	1	EPA Primary	0.5
✓	Ortho Phosphate	ND	mg/L	--		2.0
✓	Sulfate	ND	mg/L	250	EPA Secondary	5.0
			Organic Analytes - Trihalomethanes			
✓	Bromodichloromethane	ND	mg/L	--		0.002
✓	Bromoform	ND	mg/L	--		0.004
✓	Chloroform	ND	mg/L	--		0.002
✓	Dibromochloromethane	ND	mg/L	--		0.004
✓	Total THMs	ND	mg/L	0.080	EPA Primary	0.002
			Organic Analytes - Volatiles			
✓	1,1,1,2-Tetrachloroethane	ND	mg/L	--		0.002
✓	1,1,1-Trichloroethane	ND	mg/L	0.2	EPA Primary	0.001
✓	1,1,2,2-Tetrachloroethane	ND	mg/L	--		0.002
✓	1,1,2-Trichloroethane	ND	mg/L	0.005	EPA Primary	0.002
✓	1,1-Dichloroethane	ND	mg/L	--		0.002
✓	1,1-Dichloroethene	ND	mg/L	0.007	EPA Primary	0.001
✓	1,1-Dichloropropene	ND	mg/L	--		0.002
✓	1,2,3-Trichlorobenzene	ND	mg/L	--		0.002
✓	1,2,3-Trichloropropane	ND	mg/L	--		0.002
✓	1,2,4-Trichlorobenzene	ND	mg/L	0.07	EPA Primary	0.002
✓	1,2-Dichlorobenzene	ND	mg/L	0.6	EPA Primary	0.001
✓	1,2-Dichloroethane	ND	mg/L	0.005	EPA Primary	0.001
✓	1,2-Dichloropropane	ND	mg/L	0.005	EPA Primary	0.002
✓	1,3-Dichlorobenzene	ND	mg/L	--		0.001

Appendix B - Florida Keys Aqueduct Authority Annual Water Quality Reports 2011, 2012, 2013

Sampling Results

The following tables detail the concentrations of water quality parameters detected in the FKAA finished (treated) water, unless otherwise noted. The data presented in this table are from the most recent testing done in accordance with regulations. The U.S. EPA requires monitoring of more than 80 drinking water contaminants. Every primary regulated contaminant that was detected in the FKAA finished water, even in the minutest traces, is listed here. The tables contain the name of each substance, the highest level allowed by regulation (the MCL), the ideal goals for public health, the amount detected, the usual sources of contamination, definitions, and a key for units of measurement. This report is based on the results of our monitoring for the period of January 1 to December 31, 2011. A complete listing of all contaminants that are monitored is available upon request.

The state requires the FKAA to monitor for certain substances less often than once per year because the concentrations of these substances do not change frequently. In these cases, the most recent sample data are included, along with the year in which the sample was taken.

PRIMARY REGULATED CONTAMINANTS

Microbiological Contaminants

CONTAMINANT AND UNIT OF MEASUREMENT	MCL VIOLATION (YES/NO)	DATE OF SAMPLING (MO./YR.)	HIGHEST MONTHLY PERCENTAGE/NUMBER	MCLG	MCL	LIKELY SOURCE OF CONTAMINATION
Total Coliform Bacteria (% positive samples)	No	1/1/11–12/31/11	2.9	0	Presence of coliform bacteria in 5% of monthly samples	Naturally present in the environment

Inorganic Contaminants[1]

CONTAMINANT AND UNIT OF MEASUREMENT	MCL VIOLATION (YES/NO)	DATE OF SAMPLING (MO./YR.)	LEVEL DETECTED	RANGE OF RESULTS	MCLG	MCL	LIKELY SOURCE OF CONTAMINATION
Barium (ppm)	No	08/2011	0.012	NA	2	2	Discharge of drilling wastes; discharge from metal refineries; erosion of natural deposits
Fluoride (ppm)[2]	No	01/01/11–12/31/11	0.83	0.1–1.01	4	4.0	Erosion of natural deposits; discharge from fertilizer and aluminum factories; water additive that promotes strong teeth when at optimum levels between 0.7 and 1.3 ppm
Nitrate [as Nitrogen] (ppm)	No	08/2011	2.8	NA	10	10	Runoff from fertilizer use; leaching from septic tanks, sewage; erosion of natural deposits
Sodium (ppm)	No	08/2011	17.6	NA	NA	160	Saltwater intrusion; leaching from soil

Stage 1 Disinfectants and Disinfection By-products[3]

CONTAMINANT AND UNIT OF MEASUREMENT	MCL VIOLATION (YES/NO)	DATE OF SAMPLING (MO./YR.)	LEVEL DETECTED	RANGE OF RESULTS	MCLG OR [MRDLG]	MCL OR [MRDL]	LIKELY SOURCE OF CONTAMINATION
Chloramines (ppm)	No	01/01/11–12/31/11	3.87	1.0–4.6	[4]	[4.0]	Water additive used to control microbes
Haloacetic Acids (five) [HAA5] (ppb)	No	08/2011	6.9	NA	NA	60	By-product of drinking water disinfection
TTHM [Total trihalomethanes] (ppb)	No	08/2011	4.8	NA	NA	80	By-product of drinking water disinfection

Lead and Copper (Tap water samples were collected from sites throughout the community)

CONTAMINANT AND UNIT OF MEASUREMENT	AL EXCEEDANCE (YES/NO)	DATE OF SAMPLING (MO./YR.)	90TH PERCENTILE RESULT	NO. OF SAMPLING SITES EXCEEDING THE AL	MCLG	AL (ACTION LEVEL)	LIKELY SOURCE OF CONTAMINATION
Copper [tap water] (ppm)	No	09/2011	0.0351	0	1.3	1.3	Corrosion of household plumbing systems; erosion of natural deposits; leaching from wood preservatives
Lead [tap water] (ppb)	No	9/2011	2.69	0	0	15	Corrosion of household plumbing systems; erosion of natural deposits

[1] Results in the Level Detected column for radioactive contaminants, inorganic contaminants, and synthetic organic contaminants including pesticides and herbicides are the highest average at any of the sampling points or the highest detected level at any sampling point, depending on the sampling frequency.

[2] Level detected is the annual average.

[3] For chloramines, the level detected is the highest running annual average (RAA), computed quarterly, of monthly averages of all samples collected. For haloacetic acids or TTHM, the level detected is the highest RAA, computed quarterly, of quarterly averages of all samples collected if the system is monitoring quarterly or is the average of all samples taken during the year if the system monitors less frequently than quarterly. Range of Results is the range of individual sample results (lowest to highest) for all monitoring locations, including Initial Distribution System Evaluation (IDSE) results as well as Stage 1 compliance results.

Sampling Results

During the past year, we have taken hundreds of water samples in order to determine the presence of any radioactive, biological, inorganic, volatile organic, or synthetic organic contaminants. The table below shows only those contaminants that were detected in the water. The state allows us to monitor for certain substances less than once per year because the concentrations of these substances do not change frequently. In these cases, the most recent sample data are included, along with the year in which the sample was taken.

PRIMARY REGULATED CONTAMINANTS

Microbiological Contaminants

CONTAMINANT AND UNIT OF MEASUREMENT	MCL VIOLATION (YES/NO)	DATE OF SAMPLING (MO./YR.)	HIGHEST MONTHLY NUMBER	MCLG	MCL	LIKELY SOURCE OF CONTAMINATION
Total Coliform Bacteria (# positive samples)	No	1/1/2012–12/31/2012	1	0	Presence of coliform bacteria in 1 sample collected during a month	Naturally present in the environment

Inorganic Contaminants

CONTAMINANT AND UNIT OF MEASUREMENT	MCL VIOLATION (YES/NO)	DATE OF SAMPLING (MO./YR.)	LEVEL DETECTED	RANGE OF RESULTS	MCLG	MCL	LIKELY SOURCE OF CONTAMINATION
Barium (ppm)	No	02/2012	0.01	NA	2	2	Discharge of drilling wastes; discharge from metal refineries; erosion of natural deposits
Fluoride (ppm)	No	1/1/2012–12/31/2012	0.84	0.65–1.06	4	4.0	Erosion of natural deposits; discharge from fertilizer and aluminum factories; water additive that promotes strong teeth when at optimum levels between 0.7 and 1.3 ppm
Nitrate [as Nitrogen] (ppm)	No	2/2012	2.6	NA	10	10	Runoff from fertilizer use; leaching from septic tanks, sewage; erosion of natural deposits
Sodium (ppm)	No	2/2012	17	NA	NA	160	Saltwater intrusion; leaching from soil

Stage 1 Disinfectants and Disinfection By-Products

CONTAMINANT AND UNIT OF MEASUREMENT	MCL VIOLATION (YES/NO)	DATE OF SAMPLING (MO./YR.)	LEVEL DETECTED	RANGE OF RESULTS	MCLG OR [MRDLG]	MCL OR [MRDL]	LIKELY SOURCE OF CONTAMINATION
Chloramines (ppm)	No	1/1/2012–12/31/2012	3.68	NA	[4]	[4.0]	Water additive used to control microbes
Haloacetic Acids (five) [HAA5] (ppb)	No	8/2012	18.2	NA	NA	60	By-product of drinking water disinfection
TTHM [Total trihalomethanes] (ppb)	No	8/2012	27.6	NA	NA	80	By-product of drinking water disinfection

CONTAMINANT AND UNIT OF MEASUREMENT	MCL VIOLATION (YES/NO)	DATE OF SAMPLING (MO./YR.)	LEVEL DETECTED	RANGE OF RESULTS	MCLG	MCL	LIKELY SOURCE OF CONTAMINATION
Haloacetic Acids (five) [HAA5]–Stage 2 (ppb)	No	12/2012	NA	16.3–19.47	NA	60	By-product of drinking water disinfection
TTHM [Total trihalomethanes]–Stage 2 DDBP (ppb)	No	12/2012	NA	22.1–24.4	NA	80	By-product of drinking water disinfection

Lead and Copper (Tap water samples were collected from sites throughout the community)

CONTAMINANT AND UNIT OF MEASUREMENT	AL EXCEEDANCE (YES/NO)	DATE OF SAMPLING (MO./YR.)	90TH PERCENTILE RESULT	NO. OF SAMPLING SITES EXCEEDING THE AL	MCLG	AL (ACTION LEVEL)	LIKELY SOURCE OF CONTAMINATION
Copper [tap water] (ppm)	No	8/2012	0.036	0	1.3	1.3	Corrosion of household plumbing systems; erosion of natural deposits; leaching from wood preservatives
Lead [tap water] (ppb)	No	8/2012	5.9	0	0	15	Corrosion of household plumbing systems; erosion of natural deposits

Sampling Results

During the past year, we have taken thousands of water samples in order to determine the presence of any radioactive, biological, inorganic, volatile organic, or synthetic organic contaminants. The tables below show only those contaminants that were detected in the water. The state requires us to monitor for certain substances less often than once per year because the concentrations of these substances do not change frequently. In these cases, the most recent sample data are included, along with the year in which the sample was taken.

If you would like to see the list of all regulated contaminants, please go to our Drinking Water Standards Report on our Web site, www.FKAA.com, or contact Julie Cheon at (305) 295-2150 or jcheon@fkaa.com.

PRIMARY REGULATED CONTAMINANTS

Microbiological Contaminants

CONTAMINANT AND UNIT OF MEASUREMENT	MCL VIOLATION (YES/NO)	DATE OF SAMPLING (MO./YR.)	HIGHEST MONTHLY PERCENTAGE	MCLG	MCL	LIKELY SOURCE OF CONTAMINATION
Total Coliform Bacteria (% positive samples)	No	01/2013–12/2013	2.1	0	Presence of coliform bacteria in 5% of monthly samples	Naturally present in the environment

Inorganic Contaminants

CONTAMINANT AND UNIT OF MEASUREMENT	MCL VIOLATION (YES/NO)	DATE OF SAMPLING (MO./YR.)	LEVEL DETECTED	RANGE OF RESULTS	MCLG	MCL	LIKELY SOURCE OF CONTAMINATION
Barium (ppm)	No	04/2013	0.01	NA	2	2	Discharge of drilling wastes; discharge from metal refineries; erosion of natural deposits
Fluoride (ppm)	No	01/2013–12/2013	0.83	NA	4	4.0	Erosion of natural deposits; discharge from fertilizer and aluminum factories; water additive that promotes strong teeth when at optimum levels between 0.7 and 1.3 ppm
Nitrate [as Nitrogen] (ppm)	No	04/2013	3.1	NA	10	10	Runoff from fertilizer use; leaching from septic tanks, sewage; erosion of natural deposits
Nitrite [as Nitrogen] (ppm)	No	04/2013	0.08	NA	1	1	Runoff from fertilizer use; leaching from septic tanks, sewage; erosion of natural deposits
Sodium (ppm)	No	04/2013	19.2	NA	NA	160	Salt water intrusion; leaching from soil

Stage 2 Disinfectants and Disinfection By-Products

CONTAMINANT AND UNIT OF MEASUREMENT	MCL VIOLATION (YES/NO)	DATE OF SAMPLING (MO./YR.)	LEVEL DETECTED	RANGE OF RESULTS	MCLG	MCL	LIKELY SOURCE OF CONTAMINATION
Haloacetic Acids (five) [HAA5]–Stage 2 DDBP (ppb)	No	01/2013–12/2013	17.89	11.2–25	NA	60	By-product of drinking water disinfection
TTHM [Total trihalomethanes]–Stage 2 DDBP (ppb)	No	01/2013–12/2013	27.11	24.4–37.5	NA	80	By-product of drinking water disinfection

Lead and Copper (Tap water samples were collected from sites throughout the community)

CONTAMINANT AND UNIT OF MEASUREMENT	AL EXCEEDANCE (YES/NO)	DATE OF SAMPLING (MO./YR.)	90TH PERCENTILE RESULT	NO. OF SAMPLING SITES EXCEEDING THE AL	MCLG	AL (ACTION LEVEL)	LIKELY SOURCE OF CONTAMINATION
Copper [tap water] (ppm)	No	08/2013	0.0306	0	1.3	1.3	Corrosion of household plumbing systems; erosion of natural deposits; leaching from wood preservatives
Lead [tap water] (ppb)	No	08/2013	3.25	2	0	15	Corrosion of household plumbing systems; erosion of natural deposits

Definitions

AL (Action Level): The concentration of a contaminant which, if exceeded, triggers treatment or other requirements that a water system must follow.

IDSE (Initial Distribution System Evaluation): An important part of the Stage 2 Disinfection Byproducts Rule (DBPR). The IDSE is a one-time study conducted by water systems to identify distribution system locations with high concentrations of trihalomethanes (THMs) and haloacetic acids (HAAs). Water systems will use results from the IDSE, in conjunction with their Stage 1 DBPR compliance monitoring data, to select compliance monitoring locations for the Stage 2 DBPR.

LRAA (Locational Running Annual Average): The average of sample analytical results for samples taken at a particular monitoring location during the previous four calendar quarters.

MCL (Maximum Contaminant Level): The highest level of a contaminant that is allowed in drinking water. MCLs are set as close to the MCLGs as feasible using the best available treatment technology.

MCLG (Maximum Contaminant Level Goal): The level of a contaminant in drinking water below which there is no known or expected risk to health. MCLGs allow for a margin of safety.

MRDL (Maximum Residual Disinfectant Level): The highest level of a disinfectant allowed in drinking water. There is convincing evidence that addition of a disinfectant is necessary for control of microbial contaminants.

MRDLG (Maximum Residual Disinfectant Level Goal): The level of a drinking water disinfectant below which there is no known or expected risk to health. MRDLGs do not reflect the benefits of the use of disinfectants to control microbial contaminants.

NA: Not applicable

ppb (parts per billion): One part substance per billion parts water (or micrograms per liter).

ppm (parts per million): One part substance per million parts water (or milligrams per liter).