Journal of Sustainable Development; Vol. 7, No. 6; 2014
ISSN 1913-9063 E-ISSN 1913-9071
Published by Canadian Center of Science and Education

Evaluating American Rainwater Harvesting Policy: A Case Study of Three U.S. Cities

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Received: January 20, 2014 Accepted: February 11, 2014 Online Published: November 23, 2014
doi:10.5539/jsd.v7n6p133 URL: http://dx.doi.org/10.5539/jsd.v7n6p133

Abstract

In spite of increasing support for rainwater harvesting by public agencies, environmental organizations and well-defined industry guidelines, the researchers found a strikingly limited number of municipalities with formal rainwater harvesting policies and programs. With literature on rainwater harvesting limited to mostly instructional material, the researchers were compelled to examine the feasibility of rainwater harvesting guidelines and practices. International and domestic rainwater harvesting guidelines were considered. The researchers surveyed municipalities which have implemented rainwater harvesting policies and ordinances to determine the extent to which industry prescribed guidelines are feasible. The subject jurisdictions commonly regulated rainwater harvesting through ancillary city codes or programs though one enacted a stand-alone rainwater harvesting ordinance. The respondents evaluated system performance primarily through water conservation. The jurisdictions studied also concurred that identification of acceptable end-uses of rainwater and public education were the most feasible industry guidelines. System costs were identified as the main barrier to implementing rainwater harvesting. Economic subsidies and comprehensive planning policies were associated with program success.

Keywords: rainwater harvesting, rainfall, runoff, water conservation, ordinances, guidelines

1. Introduction

1.1 Water Supply and Rainwater Harvesting

Water usage in the United States has grown unabated at an alarming rate. According to the U.S. Environmental Protection Agency (U.S. EPA) public water use grew by 207% from 1950 – 2000 (Van Lare & Arigoni, 2006, 2). Hoekstra and Mekonnen (2012) further published world estimates of Water Footprints (WFs), water required to produce a nation's goods and services. Following China and India, the United States ranks third on the planet in per capita WFs at 1,053 Gm^3/yr (Cubic Gigameters/Year). Water consumption in these three countries comprises 38% of the global water footprint (Hoekstra & Mekonnen, 2012, 3323).This, among other factors, has led to a severe threat of water scarcity across the country (Kloss, 2008, 1). Indeed, it has been reported that if groundwater resources surrounding the Great Lakes are withdrawn at the current global groundwater extraction rate, the Great Lakes could be completely dry within 80 years (Barlow, 2011, 15). In 2003, a U.S. Government Accounting Office (U.S. GAO) reported that water managers in 36 states anticipated, "water shortages in localities, regions, or statewide within the next 10 years" (U.S. GAO, 2003, 5). In a subsequent report to Congress in May of 2014, the GAO noted that since its 2003 report, "key issues related to freshwater availability and use—such as concerns about population growth straining water supplies, lack of information on water availability and use, and trends in types of water use—remain largely unchanged." (U.S. GAO, 2014).

Water supply impacts have been attributed to water pollution/stormwater runoff, water use/extraction trends, population growth and climate change (U.S. GAO, 2003, 7; Food and Agriculture Organization of the United Nations, 2007, 4, 10 & 15). One study further indicated that if existing water demand patterns continue, then by 2030 global water demand should exceed availability by 40% (2030 Water Resources Group, 2009, 11).

Consequentially, water shortages could result in uncompromising economic, social and environmental impacts

(U.S. GAO, 2003, 8). These projected impacts call for proactive planning strategies which address water scarcity issues, including conserving and harvesting rainwater.

Rainwater harvesting is a simple way to capture and reuse rainwater. Its origins date back as early as 2000 B.C., when the ancient Romans developed catches that captured rainfall from impervious surfaces and retained it in a storage unit for later use (United Nations Environment Programme, 2002, 4; Kloss, 2008, 1). Contemporary rainwater harvesting follows the same principle of using impervious surfaces to capture rainfall for later use (see Figure 1). Rainwater harvesting systems can range from passive to larger-scale systems active systems. Passive systems collect rooftop rainwater runoff in small volume barrels (50 – 100 gallons) for non-potable use. Active systems collect rainwater from roofs and other surfaces such as sidewalks and parking lots and utilize pumps, water quality treatment and larger cisterns (1,000 – 100,000 gallons) (U.S. EPA, 2013a). Rainwater harvesting can also be implemented through communal level systems which collect rainwater from a cluster of residential development, store the rainwater and treat it at a centralized facility and re-distribute treated water back to residences (Cook, Sharma & Chong, 2013).

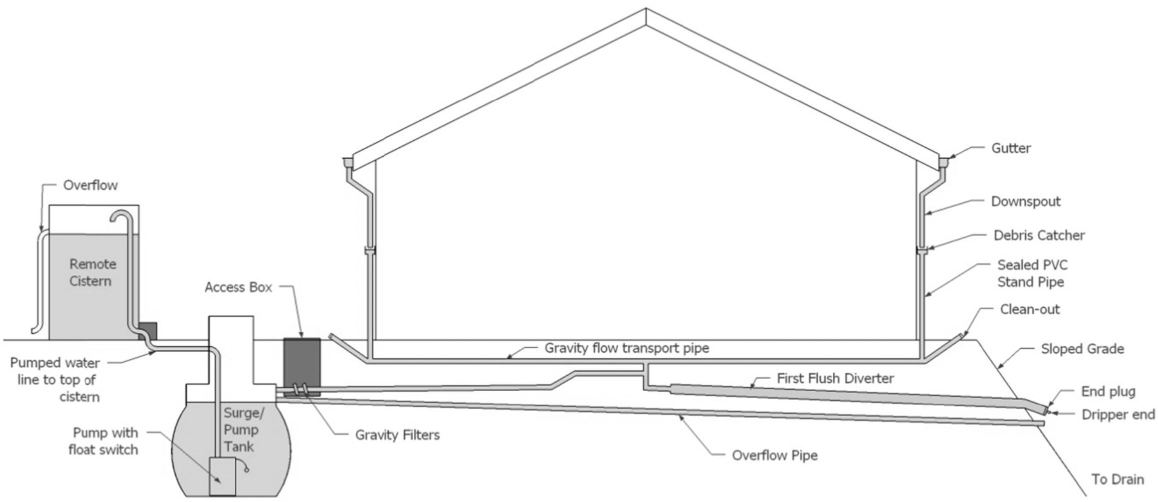

Figure 1. Rainwater harvesting diagram (diagram courtesy of Bob Burgess of the Rainwater Connection in *Greenplan*, Regional District of Nanaimo with permission)

Rainwater harvesting is regarded as a Best Management Practice (BMP), as it mitigates stormwater runoff and erosion; a method which conserves a community's water supply—thus lessening demands for potable water. It also acts as a low-impact, sustainable development method, as it reduces energy required for water transport (U.S. EPA, 1999, 5-1).

1.2 The Performance of Rainwater Harvesting Systems

Rainwater harvesting system performance can be evaluated in two ways: The economic costs and benefits of rainwater harvesting operation and physical issues relating to rainwater capture and maintenance. Table 1 on the following page summarizes primary costs and benefits noted in rainwater harvesting literature.

In spite of its longstanding history and promotion as an environmentally sound practice, rainwater harvesting is not without its shortcomings due to climatic, regulatory and physical factors. A principle weakness in rainwater harvesting is the possibility of a stipend water supply due to difficulties in projecting rainfall and unexpected inconsistencies in weather, such as exceptional drought, and weather-related inconsistencies (Thomas & Martinson, 2007, 30; Nolde-Khoury, 2010, 7). Sources also note problems associated with a lack of clear guidelines. Poor maintenance can result in the growth of algae and invasion by insects, lizards and rodents; it may also create a breeding ground for "disease vectors" (WaterAid, 2010, 2). Inadequately designed systems can have inefficiencies as well. There may also be expenses associated with increasing the sophistication of a rainwater harvesting system, impeding water system remuneration, and aesthetically obtrusive appearances of tanks which consume space (Nolde-Khoury, 2010, 8; Texas Water Development Board, 2010, 2).

1.3 International Rainwater Harvesting Policy

In evaluating American rainwater harvesting policy it is also necessary to consider prominent programs throughout the world. The most sophisticated examples of Rainwater Harvesting policy and programs are found in parts of the world where water supply is scarce or in decline: Germany, Australia and the United States Virgin Islands. These programs include systems of grants, subsidies and charges, communal rainwater harvesting and mandatory requirements.

Table 1. Costs and benefits of rainwater harvesting systems

Costs	Sources	Benefits	Sources
Capital Costs	U.S. EPA (2013a) Roebuck, Oltean-Dumbrava & Tait (2011) Leidl, Farahbakhsh & FitzGibbon (2010)	Water Conservation	U.S. EPA (2013a) Ward, Memon. & Butler (2012) Rahmen, Keane, & Imteaz (2012) Imteaz, Shanableh, Rahman & Ahsan (2011) Farahbakhsh, Despins & Leidl, (2009)
Energy Consumed	Cook, Sharma. & Chong (2013) Ward et al. (2012) Farreny, Gabarrel & Rieradevall (2011) Roebuck et al. (2011)	Reduction in Sewerage	Liedel et al. (2010)
Maintenance & Equipment Replacement	U.S. EPA (2013a) Ferenny et al. (2011)	Reduction in Water Treatment*	Cook et al., 2013
Metered Mains	Roebuck et al. (2011)	Economies of Scale*	Cook et al. (2013)
Overflow	Imteaz et al. (2010)	Reduced Footprint*	Cook et al. (2013)
Inspection Time	Gabe, Trowsdale & Mistry (2012)		
Decommissioning	Roebuck et al. (2011)		

*Applicable to communal systems.

1.3.1 Germany

Federal states (Laenders) and municipalities in Germany promote the collection of rainwater through investment grants, water extraction fees and a system of separate fees for water and effluent. Investment grants provide subsidies to private property owners or firms for rainwater collection and recycling. These subsidies are implemented as part of a program that encourages water saving devices and measures. Leanders also impose extraction fees on various entities which are included in water service delivery charges. Extraction fees follow the principle that higher water prices lead to conservation and recycling, providing a way of internalizing externalities of water extraction. Other Leanders charge separate water and effluent fees based upon the amount of household water draining into the central sewer system (Partzsch, 2009).

1.3.2 Australia

Australian cities have implemented communal rainwater harvesting systems which serve groupings of households. Communal systems collect, store, treat and re-distribute rainwater to households. Two examples include Brisbane and Salisbury. In Cap di Monte, which is located on the peri-urban fringe of Brisbane, the rainwater harvesting system collects rooftop rainwater through collector pipes and collection tanks. The water treatment plant uses filtration, UV treatment and chlorination for redistribution of potable water to each household and a community center (Cook, et al., 2013). The city of Salisbury also utilizes a centralized system, but instead of directly re-distributing treated water to households, it is used to re-charge groundwater (U.S. EPA, 2013a).

1.3.3 U.S. Virgin Islands

The U.S. Virgin Islands has demonstrated a tradition of mandatory rainwater harvesting to meet water shortages since the 1930s. The building code in the U.S. Virgin Islands was amended in 1996 for mandatory construction of rainwater cisterns for dwelling units not connected to a public water supply. (Solomon & Smith, 2007). Developers are required to install rainwater harvesting systems as a condition of building permit approval (U.S. EPA, 2013).

1.4 Rainwater Harvesting Policy in the United States

Rainwater harvesting, rainwater harvesting guidelines in the United States vary based upon national, state and regional scales. In the following sections we summarize primary guidelines at each level.

1.4.1 National Guidelines

The researchers identified two primary forms of criteria: Instructional material published by the U.S. EPA, and the American Rainwater Catchment System Association (ARCSA). The U.S. EPA's *Municipal Handbook: Rainwater Harvesting Policies, Managing Wet Weather with Green Infrastructures* (Kloss, 2008, 10) identified six factors, summarized below, for instituting municipal rainwater harvesting programs/policies.

(1) Establish specific codes or regulations for rainwater harvesting: As rainwater harvesting systems rarely require building and/or plumbing codes, rainwater harvesting frequently falls under other regulatory classifications, resulting in excessively rigorous governance. For that reason, rainwater harvesting systems ought to have their own codes and be instituted "as an acceptable stormwater management/water conservation practice" (Kloss, 2008, 10).

(2) Identify acceptable end-uses and treatment: Municipalities should identify acceptable uses for harvested rainwater and the required treatment for specified uses. According to Kloss (2008), "Rainwater is most commonly used for non-potable applications and segregated by indoor and outdoor uses. Non-potable uses typically require minimal treatment. Outdoor uses normally need only prescreening to limit fouling the collection system" (10). Harvested rainwater can also be used for potable applications, though it is subject to a special permitting process including filtration and disinfection to ensure rainwater quality is at a level suitable for drinking purposes.

(3) Detail required system components: Municipalities ought to clarify and define system designs in detail, delineating different design components/requirements.

(4) Permitting: Rain barrels should not require a permit due to their simplicity and lack of potential impacts. However, rainwater harvesting systems/cisterns/tanks for non-potable uses ought to employ a permit process as they can be obtrusive. Rainwater harvesting for potable uses or drinking water should be subject to more stringent standards and "should be inspected and approved by the public health department" (Kloss, 2008, 10).

(5) Maintenance: Maintenance is primarily the owner's responsibility.

(6) Rates of reuse: To ensure water retention efficiency, "the collected rainwater needs to be used in a timely manner to ensure maximum storage capacity for subsequent rain events" (Kloss, 2008, 10). As cisterns/systems are commonly used "with significant demands" (such as drought prone areas), the timely usage of the collected water is imperative (Kloss, 2008, 10).

While incentives are not listed as a part of the EPA's factors for establishing rainwater harvesting policies or programs, U.S. EPA's *Municipal Handbook, Rainwater Harvesting Policies, Managing Wet Weather with Green Infrastructure* further recommends that municipalities implement incentives for rainwater harvesting (Kloss, 2008, 9), and that education includes advising persons about needed actions to maximize the effectiveness of collected rainwater (Kloss, 2008, 10).

The American Rainwater Catchment System Association (ARCSA) also provides rainwater harvesting guidelines in the article, "Ten Strategies to Promote Rainwater Harvesting", written by the founder and former president of ARCSA (Krishna, 2010). These strategies are summarized as follows:

(1) Education: Includes conventional school-system instruction and curriculum, educational symposiums/workshops, outreach, and accessible informative literature for the public.

(2) Training: Training courses should be made available through ARCSA or through utilizing "networks" of engineering/agricultural/cooperative extension services that are accompanied with many "state land-grant universities" (Krishna, 2010, 1).

(3) State and/or regional chapters of ARCSA: State and/or regional ARSCA chapters can serve as liaisons with "local officials and their elected representatives," to provide a specialized "focus on RWH in their respective areas," customize publications, and facilitate local seminars regarding the significance of rainwater harvesting (Krishna, 2010, 1-2).

(4) Demonstration facilities: Demonstration facilities located in public areas provide residents with firsthand exposure to operating rainwater harvesting systems.

(5) Legislative support: Legislative support is a fundamental component for successfully promoting rainwater harvesting.

(6) State agency assistance: State agencies responsible for water and environmental issues can provide fundamental support.

(7) Local government support: Frequently, local governments have "departments that deal with water conservation and environmental issues" (Krishna, 2010, 2) and their support is crucial.

(8) Availability of credit: Inform local financial institutions/lenders about rainwater harvesting.

(9) Rainwater harvesting equipment sourcing: Rainwater harvesting amenities and "equipment" ought to be obtainable from an all-inclusive place—ideally, place(s) providing all services: equipment, design, and installation. "The goal should be to make it easy for the purchaser to obtain and install his or her RWH system" (Krishna, 2010, 3).

(10) Cost competiveness: Rainwater harvesting systems ought to be affordable. "[I]f the complete cost of the RWH system would be much higher than an alternative available to the owner, he or she may not choose the RWH system" (Krishna, 2010, 3).

In addition, the U.S. Green Building Council also awards Leadership in Energy and Environmental Design (LEED) certification review points to developments that include rainwater harvesting systems (U.S. Green Building Council, 2009). Rainwater harvesting is suitable for landscape irrigation and estimates suggest that the U.S. could save over one billion gallons of water per day if rainwater harvesting was used to meet 15% of residential irrigation/outdoor uses (Kloss, 2008, 1-2; Findlay, 2009, 80).

1.4.2 State and Regional Guidelines

Rainwater harvesting legislation and guidelines also vary between states and regions of the United States. Virginia, Georgia, North Carolina and Texas provide guidance manuals on rainwater harvesting (U.S. EPA, 2013a). A variety of doctrines also legislate water and watershed activity and use, but some doctrines can impede rainwater harvesting more than others. As presented by Findlay (2009), western states which experience more water scarcity implement doctrines of "Prior Appropriation." Prior appropriation is a "first in line" approach in which the first person or entity to put water to a beneficial use is granted a water right which supersedes all subsequent claims to water. Regions with a greater abundance of water, such as those in the eastern portion of the United States, follow the "Riparian Doctrine," which treats water as a common resource; landowners whose land abuts a body of water are granted the rights to the water for "reasonable" use. Both of these doctrines can impact rainwater harvesting.

The disparity between state water laws and a review of benefits and shortcomings call for more uniform criteria from federal and industry standards. Aside from ensuring consistency, these standards can also serve as benchmarks in evaluating rainwater harvesting policies and practices.

1.5 Limitations of American Rainwater Harvesting Literature

In a review of American rainwater harvesting literature, the researchers found that most rainwater harvesting is considered in a prescriptive fashion. While some shortcomings were noted primarily in terms of operational issues and inconsistencies in regulation, these issues were examined in a general fashion. Literature generally lacked critiques of rainwater harvesting policies or guidelines and potential implementation barriers. These gaps make it difficult to assess effectiveness of the guidelines offered by the industry and federal agencies. This compelled a closer examination of rainwater harvesting guidelines by considering the experience of those few jurisdictions which implement rainwater harvesting programs and regulations.

2. Materials and Methods

The dearth of formal programs in the face of well-established federal and industry guidelines raises the following questions: (1) How effective are prescribed rainwater harvesting programs? (2) Are there discrepancies between what environmental organizations and local governments consider feasible? (3) Are there any shortcomings or barriers (e.g., regulatory, political, economic) which impede rainwater harvesting programs? (4) Do municipalities consider rainwater harvesting benefits and costs when they develop regulations and incentives? (5) How do cities evaluate rainwater harvesting systems? (6) Do cities survey rainwater harvesting users for satisfaction?

Due to a limited number of rainwater harvesting regulatory programs in the United States, this research used a case-study approach by surveying jurisdictions with the most experience in this practice. The survey asked respondents to provide a description of their current practices and programs, identify potential implementation barriers, and rate the feasibility of federal and industry recommended guidelines.

2.1 Methodology

2.1.1 Subject Cities and Survey Participants

The best perspectives were obtained by surveying officials with experience in implementing programs and policies. Overall, the research sought to determine how perspectives of local bureaucrats and officials impinge on effectiveness of federal and industry guidelines (for example, whether they are feasible or not), and to explain why more residents do not engage in rainwater harvesting. In addition, the research examines how cities administer and evaluate rainwater harvesting policies and programs. This includes evaluation of costs, benefits, incentives and customer satisfaction.

In light of the limited number of jurisdictions with longstanding rainwater harvesting programs, Austin, Texas; Tucson, Arizona; and Portland, Oregon have all implemented rainwater harvesting regulations or programs in varying degrees (see Table 2 in results). The researchers found that the subject cities implemented their programs at different times, under a variety of situations, which provided an opportunity to analyze different approaches in a cross jurisdictional investigation.

According to the U.S. Census Bureau (2012a), Austin, Texas, had an estimated population of 790,390 persons in 2010 with a population density of 2,653. With a growth rate of 20% from 2000, it is the most rapidly growing of the three subject cities. Austin is also the geographically largest subject city at 297 square miles.

Austin is located in south-central Texas, in Travis County, at the juncture of the Texas Colorado River and Balcones escarpment. The Austin Metropolitan Watershed contains Barton and Onion Creeks. Austin has a sub-tropical climate with hot, humid summers and mild winters. According to the National Oceanic and Atmospheric Administration (NOAA) Austin has an average annual precipitation is 32.56”. (NOAA, 2014b).

As we introduce Austin’s water source we first distinguish the Texas Colorado River from the Colorado River which flows through Colorado, California and Arizona. The Texas Colorado River flows through central Texas, located in the Lower Colorado – Cummins Watershed - # 12090301 (U.S. EPA, 2013). Austin relies primarily on the Texas Colorado River, with supply provided by State Granted Water Rights and Lower Colorado River Authority contracts. Water from the Texas Colorado River is pumped by two treatment plants as it flows to Lake Austin (Austin Water Utility, 2013). Approximately 50,000 Austin residents also rely on groundwater obtained from the Barton Spring Segment of the Edwards Aquifer (Greater Edwards Aquifer Alliance, 2013). Recent drought conditions have taxed the aquifer. At the time of this report, the U.S. Drought Monitor has rated Travis County in a period of “Abnormally Dry” conditions (National Drought Mitigation Center, 2014).

Representatives from Austin Water Utility’s Water Conservation Division completed the distributed survey. The Division established a rainwater harvesting rebate program in 1998 and has a number of other water conservation programs.

Tucson, Arizona, had an estimated population of 520,097 in 2010 with a rate of growth of 6.9% from 2000. The city is 226.7 square miles in area and has a population density of 2,292 persons per square mile (U.S. Census, 2012b). Tucson has a desert climate with hot, arid summers and temperate winters. According to NOAA (2014c), Tucson has an average annual precipitation is 11.59". A major portion of Tucson's precipitation occurs during its monsoon season; the average total precipitation during this period is 6.08" (NOAA, 2014f). The City of Tucson is located in Pima County in the Santa Cruz River Watershed, within the Northern Sonora Desert. The National Drought Monitor has given Pima County an "Abnormally Dry" to "Moderate" drought rating (National Drought Mitigation Center, 2014b). In a similar manner, the Arizona Department of Water Resources (2014) estimated long term drought levels at "Moderate Drought" in the Tucson area.

Tucson relies on a variety of water resources: Groundwater supplies, which include replenished groundwater, imported and renewable groundwater, surface water and treated effluent. The city operates a dual source water system of potable and recycled water (City of Tucson, 2014). Tucson became the first municipality in the nation to enact a rainwater harvesting ordinance for commercial development (City of Tucson 2008, 1–3; Kloss, 2008, 3). Brad Lancaster, a prominent rainwater harvesting advocate and author of *Rainwater Harvesting for Drylands and Beyond*, (Lancaster, 2013) has been credited for much of the local movement. A representative from Tucson Water's Conservation Division completed the survey. The city has permitted the use of rainwater harvesting since 1991, as indicated in the survey, and the Division provides different conservation programs, including rebates for rainwater harvesting.

The City of Portland, Oregon, located in Multnomah County, covers 133.4 square miles. Its 2010 estimated population of 593 820 is considerable for its geographical size at 4,375.2 persons per square mile, and has the highest population density of the three cities. Of the three subject cities, Portland is the second fastest growing with an estimated rate of growth of 12.2% from the 2000 census period (U.S. Census Bureau, 2012c). Portland has a temperate, oceanic climate with warm, dry summers and humid, mild winters. Average annual precipitation is 36.03" (NOAA, 2014e).

Portland is located in the Willamette River Watershed, but it obtains its drinking water from the Bull Run Watershed from two reservoirs located 26 miles east of Downtown Portland (City of Portland Water Bureau, 2014). While Portland has not experienced drought conditions, it is not exempt from the effects of climate change. According to a study conducted for the Portland Water Bureau by Palmer and Hahn (2002) of the University of Washington, the Bull Run watershed is primarily fed by rainfall rather than snow pack. Climate change can affect precipitation, resulting in drier and warmer summers which pose severe repercussions on the summer water supply (Palmer & Hahn, 2002).

A representative from Portland's Bureau of Environmental Services' Clean River Rewards Program completed the survey. This program encourages rainwater harvesting for stormwater management and provides discounts to ratepayers who manage stormwater on their private property.

2.1.2 Survey Design

Primary data was obtained from survey responses administered to local officials in each subject city by e-mail. The survey evaluated the operating agencies' programs based upon the preceding literature and rainwater harvesting guidelines criteria taken from the U.S. EPA and ARCSA. The survey design consisted of open-ended questions, checklists, dichotomous questions requiring either a "yes" or "no" response, and questions featuring multiple-choice responses using a Likert scale rating.

Likert scale questions asked the respondents to rate the extent to which potential advantages of rainwater harvesting were realized in their respective cities; the extent potential impediments were encountered in the city's rainwater harvesting program, and the feasibility of a variety of program strategies. In the following section, the authors provide a brief summary of the findings.

The researchers next tested the feasibility of various rainwater harvesting programs by asking the respondents to rate the feasibility of a variety of program strategies on a Likert scale. The scale provided responses which included "Infeasible," "Relatively Infeasible," "Relatively Feasible," and "Feasible.". In a similar manner evaluations of system impediments were rated "Not an Impediment," "Somewhat of an Impediment," and "Impediment." A "No Opinion," response category was also provided for each scale.

3. Results and Discussion

3.1 Survey Results

3.1.1 Program Background

Rainwater harvesting programs have been in operation in each subject city for an average of 17 years. Administrative flexibility has been demonstrated by each city, although there was no consistency regarding how rainwater harvesting was administered among the three subject cities (see Table 2). This indicates that the implementation of rainwater harvesting programs requires administrative flexibility to accommodate municipal bureaucratic structures and traditional administrative practices specific to local governments.

3.1.2 Implementation and Regulatory Framework

The U.S. EPA suggests that jurisdictions should implement specific rainwater harvesting codes rather than consolidate them under other municipal regulations, such as plumbing codes and health codes, to avoid excessive regulation (Kloss, 2008, 10). The authors' survey asked their respondents to indicate the type of code under which rainwater harvesting is implemented to determine if they were "stand-alone" codes.

The second survey question identified whether the jurisdictions implement a permitting or review process for end-uses consistent with those recommended by the U.S. EPA. For example, non-potable uses normally require minimum treatment. In contrast, the collection and treatment of harvested rainwater used for potable applications requires a special permitting process and must be approved by the health department (Kloss, 2008, 10).

The researchers further investigated the extent to which jurisdictions regulate rainwater harvesting practices. This was done in three ways: First, by determining whether rainwater harvesting was permitted as a matter of course or by permit process. If a permitting process was indicated, the respondent was then asked to identify the type of permit. The researchers also inquired about the permitting process for indoor and outdoor potable and non-potable end-uses and rainwater barrels. Findings regarding the regulatory process are summarized in Table 2.

Consolidated codes were more prevalent than stand-alone ordinances. In contrast to Austin and Portland, Tucson has a specific rainwater harvesting code that applies to commercial development. The other cities regulate rainwater harvesting through plumbing, building or electrical codes. While a stand-alone code is preferable, it appears that consolidation may be more of an expedient way to include rainwater harvesting in existing ordinances such as a plumbing codes.

The subject cities offered financial incentives. All three subject cities offered incentives in the form of rebates and discounts.

The responding cities clearly delineate treatment of end-uses and regulations in the permitting and review process. All three subject cities followed the industry-prescribed guidelines which require that municipalities clearly delineate permissible end-uses, treatments, and regulations. The definition of end-uses (e.g., potable water) relates to public health, which can explain why each city gives this more consideration.

Potable versus non-potable end-uses determine the extent of a formal permitting process. The City of Portland has the best-defined permitting system of all the subject cities. This may be due to the fact that rainwater harvesting is directly tied to the city's stormwater management program as a Best Management Practice (BMP).

Table 2. Summary of subject rainwater harvesting programs and regulations

City:	Austin, Texas	Tucson, Arizona	Portland, Oregon
Agency	*Austin Water; Water Conservation Division*	*City of Tucson Water Conservation Division*	*City of Portland Bureau of Environmental Services*
Year Program Established	1998	1991	2001
Type of Program	Variety of water conservation programs which includes rainwater harvesting rebate program.	Variety of water conservation programs which includes rebates for rainwater harvesting and a municipal ordinance mandating rainwater harvesting for new commercial developments.	*Clean River Rewards Program:* A stormwater management program which encourages rainwater harvesting by providing discounts to ratepayers who manage stormwater on private property.
Administration	Austin Water Utility, Water Conservation Division.	Inter-departmental administration	Bureau of Development Services
Type of Code	Plumbing code	Municipal ordinance: required for new commercial development. Development standards.	Building, plumbing and electrical codes.
End Uses	Defines system types, treatments, and permissible uses.	Defines system types, treatments, and permissible uses.	Defines system types, treatments, and permissible uses.
Permitting Process	None required for non-pressurized systems; plumbing permit required for pressurized systems.	No permit required for outdoor residential non-potable systems and rain barrels.	All potable and non-potable uses require permits with exception to rain barrels.
Education/ Outreach/ Training	Full program	Program implementation with exception to utilization of ARCSA utilization and training.	No formal education, outreach, or training programs. Provides informational material.

Summary of survey responses.

While the other two cities implement rainwater harvesting, it is not necessarily a part of a formal program. Regulation is not required in Austin unless the system is pressurized, which relates to a plumbing code. Tucson requires a permit for indoor potable water, which directly bears on the suitability of water for consumption and public health. This is also consistent with end-use treatment previously surveyed. In sum, permitting is more focused on rainwater intended for potable as opposed to non-potable use.

Education, outreach, and training varied by city. Another question explored whether the jurisdiction followed educational requirements by the U.S. EPA and ARCSA. Among the three surveyed cities, only Austin meets and fully implements industry guidelines for training and outreach. This includes conventional school-system instruction, educational symposiums/lectures, demonstration facilities, accessible/informative literature, cooperative extension services, and ARCSA. Perhaps the reason Austin meets all of the education/outreach/training guidelines is that ARCSA was founded in Austin, and maintains its headquarters there. Among the remaining cities, Tucson has a well-developed educational program with exception to training, and Portland relies on dissemination of information on rainwater harvesting.

3.1.3 Evaluation of System Performance

The researchers next asked respondents how they evaluated the performance of local rainwater harvesting systems. These included six open-ended questions which considered: The number of systems established; how they evaluate performance; the monitoring of system costs; the sizing of barrels; whether costs and benefits formed the basis in calculating incentives, and the implementation of customer satisfaction surveys. Portland was not included in the analysis as the city does not implement a formal rainwater harvesting program per se. Rainwater harvesting is promoted through a Downspout Disconnection Program; rain barrels are allowed if they meet safety standards for overflow. Table 3 depicts how the remaining cities evaluate system performance.

Table 3. Evaluation of **r**ainwater harvesting **s**ystem performance

Criteria	**Austin**	**Tucson**
Annual data on number of systems.	Collects data on systems participating in incentive program.	Collects data on residential systems applying for a rebate and commercial systems which are required by ordinance.
Performance Evaluation Program.	Review of water conserved on systems greater than 500 gallons.	No current evaluation; rebates will be evaluated at the end of a three year period. Evaluation based on participation, spatial distribution and water conservation.
Rainwater Harvesting System Costs.	Installation cost data.	None at this time.
Barrel Size Requirements.	N/A.	Rebate program provides guidelines on barrel sizing and tracks capacity of cisterns installed.
Cost/Benefit Analysis as a basis of Incentives.	Future rebates will be structured on certain costs and benefits.	Rebates offered based upon barrel size. Full cost/benefit analysis will conducted at the end of the pilot program.
Customer Satisfaction Survey.	N/A.	N/A.

Summary of survey responses.

Each city based performance evaluation through their incentive and rebate programs. However, Tucson also collected data on systems which were required by ordinance. In addition, both cities used water conservation as a measure of system performance; Tucson also considered participation and spatial distribution. Of the surveyed cities, only Austin monitors installation costs. However, both Austin and Tucson noted proposals for future cost-benefit evaluation of the incentive and rebate programs. Neither Austin nor Tucson conduct customer satisfaction surveys.

3.1.4 Feasibility of Rainwater Harvesting Guidelines

Table 4 provides a summary of how respondents rated feasibility of rainwater harvesting guidelines. While it might be considered a “given” that cities with established rainwater harvesting programs would consider aspects of their programs feasible, the degree of feasibility over certain types of criteria varied by city response. This section considers criteria that are ranked as “Feasible” by a majority of responding cities (indicating greater ease of implementation) in comparison to those rated as “Relatively Feasible” with certain implementation. None of the criteria was rated “Infeasible.”

Education/outreach and identification of various end-uses are rated as "Feasible" by each responding city. As previously mentioned, the subject cities have developed education and outreach programs. Identification of end-uses includes permissible system types, required treatments, and delineation differences between each type.

Table 4. Evaluation of feasibility

Criteria	Austin	Tucson	Portland
Development of Ordinances	Relatively Feasible	Feasible	Feasible
Permitting	Relatively Feasible	Relatively Feasible	Feasible
System Design Guidelines	Relatively Feasible	Relatively Feasible	Feasible
Incentives/Subsidies	Feasible	Relatively Feasible	Relatively Feasible
Education	Feasible	Feasible	Feasible
Outreach	Feasible	Feasible	Feasible
Legislative Support	Relatively Feasible	Relatively Feasible	No Opinion
System Monitoring	Relatively Feasible	Relatively Feasible	No Opinion
Identification of End Uses	Feasible	Feasible	No Opinion

Summary of survey responses.

Strategies commonly rated by the subject cities as "Relatively Feasible" include permitting, system design guidelines, incentive/subsidies, legislative support, and system monitoring. Permitting and system design guidelines, incentives and guidelines may be less feasible in an environment of fiscal austerity. New permitting or administrative procedures may be hindered due to costs associated with administering and enforcing them. It is easier to incorporate rainwater harvesting under pre-existent codes (such as plumbing codes) or within a stormwater management program, such as the program implemented by Portland. Conversely, permitting, system design guidelines, and legislative support may also be politically unpopular, especially in pro-growth "frontier" states such as Texas and Arizona.

3.1.5 Rainwater Harvesting Advantages and Impediments

Based on the literature review, the researchers developed survey questions that measured the extent to which respondents considered various features of rainwater harvesting programs as advantageous, and the extent to which they felt any shortcomings posed as barriers. Responses were measured using Likert scale ratings. Benefits listed in the survey included Incentives/Subsidies, Stormwater Runoff/BMP, Green Building Amenity and Supplemental Water Supply. Responses are summarized in Table 5.

The respondents agreed that Education and Outreach were advantageous. With exception to Portland (which did not respond), respondents also agreed that incentives/subsidies are an "Advantageous" feature of program implementation and succession. All three cities deemed that identification of end-uses deserved an "Advantageous" rating, which corresponds to the previous finding that all cities practiced this method.

While benefits of Stormwater Runoff Management, Green Building Amenity, and Supplementary Source of Water were split between either "Advantageous" or "Somewhat Advantageous," it is noteworthy to mention that none of the criteria were identified as being "Not Advantageous."

The three subject cities also agreed that system cost was the only shortfall of rainwater harvesting implementation. Despite the fact that the responding cities have some form of rainwater harvesting, incentives or subsidies, system cost was the only rainwater harvesting constraint that had a unanimous response as an impediment of program implementation.

In contrast, the subject cities reported divergent responses for the other shortcomings. Portland identified system aesthetics as "Somewhat of an Impediment." According to the City of Austin, system aesthetics are not typically an impediment, considering most persons who install a system do so for their interests in rainwater harvesting and conservation. However, system aesthetics may become an impediment to individuals whose residences are further restricted by homeowner association regulations. Homeowner association regulations are private in nature and represent an extra layer of regulation beyond the purview of local government. If homeowner associations prohibit rainwater harvesting systems due to aesthetics, these rules pose an impediment to program implementation/succession.

Table 5. Evaluation of advantages and impediments of rainwater harvesting

Advantages			
	Austin	Tucson	Portland
Incentives/Subsidies	Advantageous	Advantageous	No Opinion
Stormwater Runoff Management/BMP	Somewhat Advantageous	Advantageous	No Opinion
Green Building Amenity	Somewhat Advantageous	Advantageous	No Opinion
Supplementary Source of Water	Somewhat Advantageous	Advantageous	Somewhat Advantageous
Education/Outreach	Advantageous	Advantageous	Advantageous
Impediments			
	Austin	Tucson	Portland
System Costs	Impediment: pressurized systems Somewhat of an Impediment: non-pressurized systems	Somewhat of an Impediment	Impediment
System Aesthetics	Situational	Not an Impediment	Somewhat of an Impediment
No Codified Building Codes or Guidelines	Not an Impediment	Not an Impediment	No Opinion
System Self-Maintenance (Owner Maintenance)	Impediment: pressurized systems Somewhat of an Impediment: non-pressurized systems	Not an Impediment	No Opinion
Other Implementation Obstacles	Uncertain of implementation obstacles	Not cost effective and legal constraints	Cost and rain barrel overflow

Summary of survey responses.

Austin also identified system self-maintenance as a potential "Impediment" for pressurized systems and "Somewhat of an Impediment" for non-pressurized systems. This may reflect that increased sophistication of pressurized systems calls for more maintenance.

System cost as barriers to rainwater harvesting programs. The researchers asked respondents to note any implementation barriers they encountered in implementing their programs. The survey used an open-ended question to provide the respondent with flexibility in mentioning barriers unique to locational or administrative circumstances. Each responding city identified cost as a barrier to program implementation and succession. This finding corresponds to the previous identification of cost as an impediment to rainwater harvesting programs (see Table 5).

3.1.6 Keys to Successful Rainwater Harvesting Programs and Implementation Strategies

The survey further identified strategies implemented by local government programs which made their rainwater harvesting programs successful. The survey used open-ended questions to explore program administration, history, and the use of incentives/subsidies. Respondents were also asked if rainwater harvesting was included in the planning process. Reponses are summarized in Table 6.

One major commonality between the three subject cities was the existence of rainwater harvesting policies in each general city plan. Comprehensive plans identify community issues and develop goals, policies and objectives around matters that communities deem important; this indicates that rainwater conservation is identified as a critical local priority. Incorporating rainwater harvesting into the planning process remains a crucial prerequisite to a successful program.

Table 6. Rainwater harvesting program and regulatory strategies

Strategy	Austin	Tucson	Portland
Subsidies/Incentives	Residential (single-family and multi-family), commercial, institutional, industrial.	Commercial, residential, demonstration sites.	Commercial and residential.
Rainwater Harvesting and the Planning Process	Rainwater harvesting policies in local, general plan.	Rainwater harvesting policies in local, general plan. City of Tucson Planning and Development Services involvement in regulation.	Rainwater harvesting policies in local, general plan.

Summary of survey responses.

3.2 Discussion

The dearth of long-established rainwater harvesting programs raises questions relating to program feasibility and effectiveness. The researchers considered rainwater harvesting programs in comparison to international and domestic programs and industry guidelines. International programs feature mandatory regulations supplemented with well-developed systems of grants and fees; implementation can extend to the communal level. In comparison, American rainwater harvesting is rudimentary, relying mostly on incentives to promote individual systems.

In assessing a program, a researcher faces a paradox: whether municipalities should be more proactive in following industry guidelines, or whether the guidelines themselves should be adjusted to accommodate unique local issues. A comparison of three well-established rainwater harvesting programs in different geographic settings addressed both sides of this paradox.

First, the benefits of rainwater harvesting are best realized in cities with a “stand-alone” ordinance. When rainwater harvesting was incorporated as a part of another local program, such as green building or stormwater management, cities listed these programs as “Somewhat Advantageous” in attaining rainwater harvesting objectives. This may indicate that the priority to implement rainwater harvesting may be weakened as it competes with other water quality mitigation methods. Furthermore, a specific rainwater harvesting ordinance should be consistent with land use and zoning regulations to ensure wider application, and ensure that homeowner associations do not prevent community members from engaging in rainwater harvesting. These issues warrant further study.

However, the researchers balance this finding with the fact that only one of the subject cities reported an ordinance exclusively devoted to rainwater harvesting. Cities with established programs differed in how rainwater harvesting programs were administered, either through specific ordinances or through existing local ordinances. This may indicate that a specific rainwater harvesting ordinance may be too costly or politically unpopular to develop. Cost was a prevalent issue noted by a majority of the jurisdictions. Also, differences in state legislation and local conditions may also have a bearing. For these reasons, the guidelines specified by the U.S. EPA and ARCSA, while preferable, may not be entirely practical for most cities. Incorporating rainwater harvesting into existing ordinances may be the most expedient strategy for municipal adoption. This warrants further research.

Effectiveness may also depend upon the traditional role of local governments in protecting public health and safety through ordinances related to public health and plumbing. This was evident in a majority of municipalities which delineate end-uses of harvested rainwater and provide more stringent review processes for rainwater intended for human consumption. The use of pressurized systems also made rainwater harvesting conducive to plumbing codes. The incorporation of rainwater harvesting as part of a stormwater management program further illustrates this point.

The efficacy of rainwater harvesting program guidelines also relates to how well guidelines fit local environmental, economic and political circumstances. Strategies rated by most cities as "Feasible" were identification of end-uses—which may already be required by health codes—and education and outreach, a traditional role of municipal government planning which can be varied to suit local budget and needs. Strategies considered "Relatively Feasible" include permitting, system design guidelines, incentive/subsidies, legislative support, and system monitoring, which depend upon adequate staff, political support and associated funding.

Systems costs are the greatest impediment to rainwater harvesting programs. This was noted in spite of the fact that all cities had incentives and subsidies. This not only indicates why incentive/subsidy programs exist, but it also raises the issue on how effective these tools have been. Austin and Tucson monitor system benefits through water conservation; only Austin tracks installation costs. For this reason, the researchers suggest that municipalities keep annual reports of their subsidy expenditures and construction of rainwater harvesting systems; in this manner, cities can benchmark the effectiveness of their rainwater harvesting programs through cost-benefit analysis. On an encouraging note, both Austin and Tucson are proposing cost-benefit analysis to assess their programs. Customer service surveys should also supplement this evaluation.

Another major commonality between each of the programs was the factors that made them successful, namely economic and planning mechanisms. Subsidies and incentives played an important role, and this was consistent with rainwater harvesting literature. However, this is at the discretion of available funding.

More importantly, each city incorporated rainwater harvesting policies into its comprehensive plan. This is significant, as policies reflect community-expressed priorities, and rainwater harvesting conservation is an identified local priority for these cities. While it may be more anticipated in Sunbelt municipalities where water supply issues are obvious, such as in Austin and Tucson, cities such as Portland with more water resource options may also be more compelled to promote this policy due to water quality (which also impacts water supply).

In addition to referencing suggestions and guidelines from agencies and organizations such as the U.S. EPA and ARCSA, local governments may be able to find guidance in the development of rainwater harvesting programs from Germany, Australia and U.S. territories which have successfully utilized rainwater harvesting. These include well-developed rainwater harvesting codes as well as interrelated incentive programs (Cook et al., 2013; Partzsch, 2009; Stark & Pushard, 2008, 22). The U.S. Virgin Islands have also mandated rainwater harvesting for residential and commercial use since the 1930s (Solomon 2007& Smith, 1; United Nations Environment Programme, 1998).

In developing rainwater harvesting regulations, the authors finally note an important caveat: A balance must be attained between providing well-specified regulation versus flexibility to ensure ease of implementation. For example, more regulation should be required for potable water due to public health concerns. Less regulation is needed for non-potable water. Fewer regulations for non-potable uses may be an impetus for people to install a rainwater harvesting system.

4. Conclusion

The survey of cities implementing rainwater harvesting programs provide mixed results regarding the effectiveness of formal guidelines. A majority of the responding jurisdictions relied on established ancillary city codes or programs rather than an ordinance specifically dedicated to rainwater harvesting; only one enacted a stand-alone rainwater harvesting ordinance. However, all jurisdictions concurred that the identification of acceptable end-uses of rainwater and public education were the most feasible industry guidelines. System costs were noted as the main barrier to implementing rainwater harvesting. Economic subsidies and comprehensive planning policies were associated with program success.

The small number of established rainwater harvesting programs calls for further research that considers not only policies and practices, but also education. Issues relating to water scarcity, while long recognized in the western half of the United States, are only beginning to be realized in eastern states. Public awareness of water scarcity provides the strongest impetus towards rainwater conservation.

Acknowledgements

The authors of this work wish to acknowledge the Department of Community and Regional Planning at Alabama A&M University for arranging the funding of this research.

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