PLG 596B: ARIZONA WATER POLICY

Policies for Implementing Water Harvesting in Arid Regions

A continuum of options

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Introduction

Future growth often challenges communities to provide services and resources at a level of quality and price that residents expect. In the Southwest U.S., this challenge often manifests in the form of increasing pressure on potable water resources. In addition, cities in this arid and semi-arid region face the prospect of increasing temperatures due to climate change impacts. Water harvesting, an ancient practice that has been used in many parts of the world to augment water supplies, can represent one way to help ameliorate both of these problems by providing an alternative source of water for outdoor irrigation and supporting an enhanced urban tree canopy without affecting potable water supplies. In the United States, water harvesting has gained in popularity in recent years for a variety of reasons, including its branding as "sustainable" stormwater management and its ability to address water quality issues traditional stormwater infrastructure cannot. At the same time, the Southwest has less modern experience with water harvesting than many other parts of the country, meaning that adopting water harvesting practices can face uncertainty or even stiff resistance. In addition, much of the research surrounding water harvesting has been conducted in more humid regions of the country, providing less guidance to jurisdictions in Southwestern states. Despite this difficulty, several communities in Arizona have had success in implementing water harvesting on a municipal level.

This paper explores the policy options available to urban areas in the Southwest interested in implementing water harvesting. The Environmental Protection Agency (EPA) and other organizations have authored several guidance documents outlining these various policy options. However, many of these documents focus on the experiences of more humid areas of the country. To understand how these policy options differ in the Southwest in general, and in Arizona in particular, this paper first reviews these policy reports, then traces the experiences of three case study communities in implementing various types of water harvesting policies. Using these experiences as a guide, policy recommendations are developed for other municipalities in the Southwest that wish to incorporate water harvesting into city life and practices. The policy options available can be characterized as a continuum of options, ranging from easy-to-implement actions to more expensive and politically difficult - yet potentially more rewarding - ordinance development.

Background and Context

Water harvesting at its most basic involves the collection of rainwater that drains from an impervious surface and the use of that collected water for various purposes, from drinking to toilet flushing to landscape irrigation. However, modern discussions of water harvesting require the explanation of a few distinctions in technique and terminology. First, water harvesting can involve either active or passive systems. Active water harvesting tends to be more familiar to most people. This technique directs rainwater from an impermeable surface such as a rooftop to a storage container, usually through the use of gutters and downspouts. These storage containers can range in size from 55-gallon drums to cisterns made of various materials that can hold thousands upon thousands of gallons of water.[1] Passive water harvesting, on the other hand, uses soil and vegetation to act as the "storage container" for the water. This type of water harvesting also directs rainfall from an impermeable surface, quite often using the same gutters and downspouts as in active water harvesting, but sends the water directly to depressed soil basins and/or landscaped areas. As can be expected, based on the extra materials needed for active water harvesting, this technique tends to be more expensive than passive water harvesting.[2]

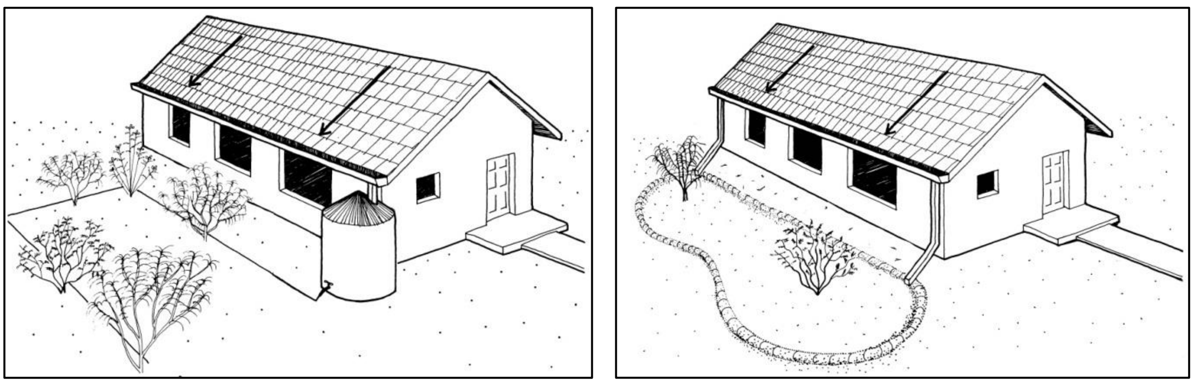

Figure 1: Active (left) and passive (right) water harvesting[3]

In addition to the differences between active and passive water harvesting, two points of terminology should be made clear. Several water management and organizations, and many municipalities, have recently shown increased interest in stormwater management techniques known as green infrastructure and low-impact development (LID). The U.S. EPA defines green infrastructure as "an adaptable term used to describe an array of products, technologies, and practices that use natural systems—or engineered systems that mimic natural processes—to enhance overall environmental quality and provide utility services. Unlike single-purpose "gray" stormwater infrastructure, which uses pipes to dispose of rainwater, green infrastructure uses vegetation and soil to manage rainwater where

[1] Rain Tank Depot, "Plastic Rainwater Tanks," <http://www.raintankdepot.com/c-3060/plastic-vertical-rain-water-tanks> (25 April 2013).
[2] Doug Pushard, "Active Versus Passive in Rainwater Catchment," Green Fire Times, 1 September 2010, <http://greenfiretimes.com/2010/09/active-versus-passive-in-rainwater-catchment> (25 April 2013).
[3] Patricia Waterfall, Harvesting Rainwater for Landscape Use, 2nd ed. (University of Arizona: College of Agriculture and Life Sciences, 2006), 5.

it falls."[4] A non-profit organization, the Low Impact Development Center, which dedicates itself to promoting LID, defines this term as "a comprehensive land planning and engineering design approach with a goal of maintaining and enhancing the pre-development hydrologic regime of urban and developing watersheds."[5]

As demonstrated by these two definitions, green infrastructure and low-impact development have much in common with one another. Indeed, the terms are often used almost interchangeably. They both aim to address the impacts of development on the natural hydrology of a site. Conversion of natural or agricultural lands to urban uses often involves a significant increase in impervious surfaces, from roads to rooftops. These impervious surfaces, unlike natural soils and vegetated cover, generate large quantities of stormwater runoff during rain events.[6] As techniques that emphasize mimicking natural, or pre-development, hydrology, green infrastructure and low impact development both emphasize keeping the "extra" water caused by development as close to its source of generation as possible. Therefore, the use of green infrastructure and low impact development often results in techniques and installations that look a lot like water harvesting, and especially passive water harvesting. This paper treats these three terms—water harvesting, green infrastructure, and low impact development—as more or less interchangeable with one other. This reflects the experience of many municipalities, who are looking to all of these techniques to solve the same types of problems.

Despite the growing popularity of these approaches, their implementation has been unevenly focused across the United States, with much more activity in the Northeastern, Northwestern, and Midwestern regions.[7] The Southwest, in contrast, has had much less recent experience with water harvesting and green infrastructure, partly for reasons of motivation discussed below. Coincident with this trend, much more research regarding these approaches exists for those more humid regions of the country. This research includes detailed instructions on how to install various specific techniques, case studies, and performance evaluations. Conditions in the Southwest are different enough from these humid regions to make translating this research from one area to another difficult and to some extent, even inadvisable. Tucson, AZ, for example, receives less than 12 inches of rainfall per year. Portland, OR and Philadelphia, PA—two cities receiving a lot of attention as green infrastructure models—receive

[4] Environmental Protection Agency, "Green Infrastructure," 23 April 2013, <http://water.epa.gov/infrastructure/greeninfrastructure/index.cfm> (20 April 2013).
[5] Low Impact Development Center, "Welcome," 2011, <http://www.lowimpactdevelopment.org> (20 April 2013).
[6] Chester L. Arnold Jr. and C. James Gibbons, "Impervious Surface Coverage: The Emergence of a Key Environmental Indicator," Journal of the American Planning Association 62, no. 2 (1996): 244-245.
[7] Environmental Protection Agency, "Green Infrastructure Case Studies," 23 April 2013, <http://water.epa.gov/infrastructure/greeninfrastructure/index.cfm> (20 April 2013).

43.1 and 42.1 inches, respectively.[8] As a more visual example, plant palettes differ greatly in the Southwest. This means that many of the photographs illustrating green infrastructure look quite foreign to potential Arizona implementers (Figure 2). Rainfall regimes vary quite significantly in the Southwest, including both overall annual amount of precipitation, as well as the unique monsoonal pattern found in some parts of this region. The Southwest also experiences much higher evapotranspiration rates than more humid parts of the country do. All of these differences mean that the way water harvesting and various green infrastructure techniques are implemented could vary quite significantly in the Southwest from what the research from other parts of the country shows.

Figure 2: Rain garden in Seattle (left) and Tucson (right)[9, 10]

The differences listed above are just a few of many. In March of 2012, the annual AridLID conference was held in Tucson, Arizona. At that conference, the University of Arizona's Water Resources Research Center hosted a workshop to identify the unique low impact development-related research needs in the Southwest that cannot be answered by work done in other parts of the country. Scientists, researchers, and practitioners came together to develop a prioritized list of the most compelling research questions that must be answered before municipalities in the Southwest can fully embrace green infrastructure techniques. The chart below outlines some of the unique conditions participants identified in addition to those listed above.

[8] US Climate Data, "Climate: United States," <http://www.usclimatedata.com> (25 April 2013).

[9] Matt Hickman, "Needed: a deluge of rain gardens in the Puget Sound by 2016," Mother Nature Network, 22 June 2011, <http://www.mnn.com/your-home/organic-farming-gardening/blogs/needed-a-deluge-of-rain-gardens-in-the-puget-sound-by-2016> (18 April 2013).

[10] Technicians for Sustainability, "Rain Gardens," 2011, <http://tfssolar.com/residential/rain-water/how-it-works-2/rain-gardens> (18 April 2013).

Unique SW Conditions Identified during the 2012 AridLID Conference
Supplemental irrigation needed to establish plants
High growth rate and retrofit needs
Prior appropriation laws
Surface water and groundwater connection not well known, and laws are separate
Auto-centric layout of towns and cities
Soils- lack of organic material, erodibility
Soil texture different from temperate regions
Daily temperature extremes
Higher concentrations of trash/pollutants due to infrequency of rainfall events

Table 1: Unique conditions affecting implementation of water harvesting in the Southwest[11]

Not only do more humid regions of the country differ from the Southwest in terms of the types of climatic and landscape conditions listed above, but the motivations that lead them to implement water harvesting also differ quite significantly. A major source of ongoing water pollution problems in many municipalities, and a major driver behind the EPA's push to encourage green infrastructure, are combined sewer overflow events. Over seven hundred cities in the U.S. have combined sewer systems. These types of systems collect sewage, industrial wastewater, and stormwater runoff in the same pipes which lead to wastewater treatment plants. The plants treat the combined wastewater before discharging it to a receiving water body. In large or intense storm events, however, the quantity of runoff generated can overwhelm the capacity of the wastewater treatment plant, sending the runoff, along with untreated sewage and industrial chemicals, straight into the receiving water body without any treatment.[12] These occurrences, known as CSOs, can wreak major environmental damage. For example, the seven largest dischargers in the Great Lakes region dumped an estimated 18.7 billion gallons of combined sewage and stormwater runoff into the lakes, just in 2011.[13]

Preventing this type of pollution by controlling stormwater runoff is a key role that the EPA and others see green infrastructure playing. As the map below illustrates, however, no municipalities in

[11] Jenna Cleveland, "Co-creating an arid-adapted, integrative green infrastructure research agenda: A workshop of the 2012 AridLID Conference," January 2013 (unpublished report), 18-22.
[12] Environmental Protection Agency, "Combined Sewer Overflows," 16 February 2012, <http://cfpub.epa.gov/npdes/home.cfm?program_id=5> (20 April 2013).
[13] Alliance for the Great Lakes, "Special Report: Sustained federal infrastructure investment needed to curb Great Lakes sewage overflows," 19 June 2012 < http://www.greatlakes.org/csoreport>.

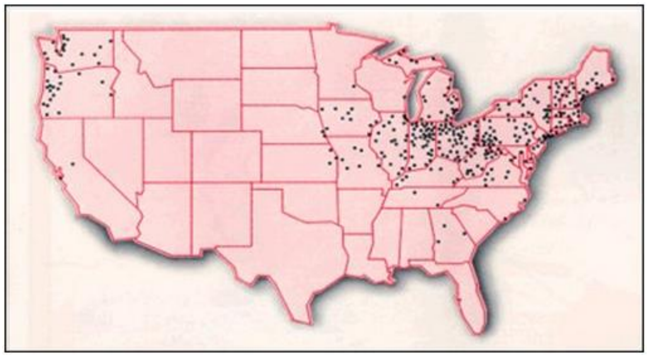

Figure 4: Locations in the US with combined sewers[14]

the Southwest have combined sewers, completely removing this major driver for other parts of the country from the region. Also connected to this major motivator is the general idea, prevalent in temperate regions in the country, that green infrastructure helps to manage "wet weather." Much of the research on water harvesting focuses on this aspect of the approach, as way to help municipalities deal with their excesses of rainfall and runoff. Certainly Southwestern municipalities have had to deal with flood conditions in the past, and can expect to continue to face these problems in the future, but in this region a more common motivating force behind water harvesting is a lack of water, rather than an excess of it.[15] Again, this can mean that implementing water harvesting takes a much different form in states like Arizona, with much less reference to the experiences outlined in so many of the case studies.

Discussion of these difficulties and lack of prior experience gives rise to the question, "Why should municipalities in the Southwest even attempt to pursue water harvesting?" Despite the difficulties discussed above, many answers to this question exist, beginning with climate change. Climate change models show strong agreement that temperatures in the Southwest will rise in the future. Though less certain, models also show that the region will receive less rainfall than in the past.[16] These two changes add up to water supply uncertainty. This uncertainty was a highlight of the recent *Colorado River Basin Water Supply and Demand Study* authored by the U.S. Bureau of Reclamation, which estimated that demand by the seven basin states would exceed the supply of the river by 3.2 million acre-feet by 2060.[17] For the municipalities that receive water from the Central Arizona Project

[14] Environmental Protection Agency, "Combined Sewer Overflows Demographics," 15 October 2008, <http://cfpub.epa.gov/npdes/cso/demo.cfm?program_id=5> (20 April 2013).
[15] Pima County Regional Flood Control District, "A Brief Overview of Historical Flooding," <http://rfcd.pima.gov/outreach/flooding> (20 April 2013).
[16] Jonathan Overpeck et al, "Southwest Climate Assessment: Summary for Decision Makers," (Tucson, AZ: Southwest Climate Alliance, June 2012), 5-6.
[17] U.S. Bureau of Reclamation, Colorado River Basin Water Supply and Demand Study, December 2012, ES-7.

(CAP) canal, this projection is especially worrying since CAP has the most junior priority of all the allocations along the river.

Even for municipalities (and industries and farmers) with higher-priority water rights, such a significant imbalance between supply and demand should signal the importance of action to either correct this imbalance or find additional supplies. Of course, the difficulty with the latter option is that additional supplies are scarce and getting more expensive, due to infrastructure costs and the energy supplies required to treat and deliver water from sources like desalinated seawater or brackish groundwater.[18] Harvested water, on the other hand, is by its nature a completely local supply. If used outdoors to irrigate landscapes, it generally requires no treatment and very little in the way of a delivery system.[19] Though rainfall does not have the predictability or reliability of a source like the Colorado River, it nevertheless represents a way for a community to maximize the diversity of its water supply portfolio. Moreover, as the Colorado River Supply and Demand Study shows, the Colorado River may not always have the predictability and reliability it had in the past. Indeed, rainwater harvesting was one of the alternative options analyzed by the Supply and Demand Study, which found it to be a feasible, though costly, technique to augment supplies. Given relatively conservative assumptions, the report estimated that rainwater harvesting within the basin could yield 75,000 acre-feet of water per year.[20]

Besides the temperature and precipitation alterations predicted by global climate change models, population growth rates represent a further contributing factor to a potential imbalance in the Colorado River system. Before the economy experienced recession in 2007 and 2008, several states in the Southwest were among the fastest-growing in the nation, including Arizona. Though experts have recently revised population projections downward to reflect the realities of the nation's slowed economic growth, the Southwest region can still expect to rebound in the future and experience significant rates of population increase.[21] High rates of population growth will further tax already stretched supplies, including water from the Colorado River. This prediction makes it all the more urgent for water managers and jurisdictions to diversify supplies and pursue all the water conservation measures available to them.

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[18] Susanna Eden, Tim W. Glass, Valerie Herman, "Desalination in Arizona: A growing component of the state's future water supply portfolio," Arroyo (2011): 10-11.
[19] Christopher Kloss, "Managing Wet Weather with Green Infrastructure Municipal Handbook: Rainwater Harvesting Policies," (U.S. Environmental Protection Agency, December 2008), 9-10.
[20] U.S. Bureau of Reclamation, F7-5 – F7-7.
[21] CAGRD & Underground Storage Committee, "CAGRD Mid-Plan Review: Enrollment, Demand and Obligation," 23 November 2011, 4, 23.

A third argument for the importance of pursuing water harvesting policies in the Southwest connects the two reasons given above. Urban heat island effects are a real and growing concern across the country, but the Southwest, as "ground zero" for climate change-induced temperature increases, could be especially vulnerable. The urban heat island is a concept that reflects the fact that developed areas, due to their high levels of impervious surfaces, absorb heat in the daytime and release that heat much more slowly and less completely at night than natural or vegetated areas. This heat retention makes urban areas much less comfortable places to live. Furthermore, research has shown that in Phoenix, Arizona, low-income areas are disproportionately affected by the urban heat island, making this phenomenon an issue of environmental justice.[22] Research has also shown that increasing vegetation in urban areas is one of the most cost-effective ways of mitigating the urban heat island.[23] With water supplies constrained as discussed above, water harvesting represents a way to increase vegetation and canopy cover in urban areas without straining potable water supplies.

Finally, some researchers and analysts have declared that the "hard path" approach to water management has ended.[24] The hard path refers to water management strategies that rely on expensive—and extensive—infrastructure, and has been criticized for an over-emphasis on demand and cost-benefit analyses that ignores social equity and environmental sustainability.[25] This infrastructure includes large dams, canals, and other capital-intensive ways to collect and deliver water supplies. In contrast to this lies the "soft path" approach to water management. The soft path involves focusing on demand management rather than supply augmentation to meet water resources needs. As Oliver Brandes and David Brooks write in *The Soft Path for Water in a Nutshell*, "the soft path works within ecological limits and promotes local public participation to ensure sustainability of our water resources."[26] This type of water management offers more flexibility than traditional single-purpose built infrastructure, a flexibility that could prove crucial as water managers deal with the uncertainties of climate change. Soft path approaches also emphasize matching water quality to use, helping to reduce the costs of meeting all users' needs. Harvesting rainwater clearly falls into the soft path side of water

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[22] Sharon L. Harlan, "The Urban Heat Island in Phoenix: Impacts on Neighborhoods," 25 April 2012 (PowerPoint Presentation), 2-4.
[23] William D. Solecki et al, "Mitigation of the heat island effect in urban New Jersey." Environmental Hazards: 6 (2005) 39.
[24] Peter H. Gleick, "Global Freshwater Resources: Soft-Path Solutions for the 21st Century," Science 302 (2003): 1524.
[25] David B. Brooks, and Oliver M. Brandes, "Why a Water Soft Path, Why Now and What Then?" International Journal of Water Resources Development, 27 (2011): 315-316.
[26] Oliver M. Brandes and David R. Brooks, "The Soft Path for Water in a Nutshell," (Ottawa, ON: Friends of the Earth Canada, August 2007), 1.

management. Rainwater can replace water treated to potable standards used for irrigation. Moreover, its collection involves very little built infrastructure for conveyance.

Literature Review

Organization	Report
Environmental Protection Agency	Managing Wet Weather with Green Infrastructure Municipal Handbook: Funding Options
	Managing Wet Weather with Green Infrastructure Municipal Handbook: Retrofit Policies
	Managing Wet Weather with Green Infrastructure Municipal Handbook: Green Streets
	Managing Wet Weather with Green Infrastructure Municipal Handbook: Rainwater Harvesting Policies
	Managing Wet Weather with Green Infrastructure Municipal Handbook: Incentive Mechanisms
American Rivers	Local Water Policy Innovation
Water Environment Research Foundation	Models for Governance, Management, Maintenance and Financing
	Regulatory and Incentive Systems
	Successful Public Education Systems
	Stormwater BMP Retrofit Policies
Natural Resources Defense Council	Rooftops to Rivers
	Rooftops to Rivers II
	Capturing Rainwater from Rooftops
Sonoran Institute	Sustainable Water Management

Table 2: Literature reviewed

For all of the reasons discussed—climate change and water supply uncertainty, population growth, urban heat island mitigation, and transition to a soft path approach to water management—Southwestern communities should pursue the implementation of water harvesting. However, as mentioned above, these municipalities have less recent experience with water harvesting, and fewer resources and examples on which to draw in developing implementation policies. This section of the paper reviews available literature on policy options for implementing water harvesting to glean commonly-advised strategies for municipalities wishing to pursue water harvesting. Several national and regional organizations, as well as the Environmental Protection Agency, have authored reports laying out policy recommendations. The chart above shows the reports included in the literature review. Though authored by different agencies, the reports reviewed offered similar policy options for implementing water harvesting, including the development of demonstration sites, removal of code barriers, creation of stormwater utilities, provision of incentives, and establishment of regulations. The chart below gives a brief summary of these options and indicates the reports in which each is mentioned.

Policy Option	**Supporting Literature**
Demonstration sites, pilot projects: Small-scale implementation of water harvesting techniques to prove effectiveness and gain community support	• Managing Wet Weather with Green Infrastructure Municipal Handbook: Green Streets • Local Water Policy Innovation • Models for Governance, Management, Maintenance and Financing • Successful Public Education Systems • Rooftops to Rivers II • Capturing Rainwater from Rooftops
Removal of code barriers: Examination of municipal codes to identify and eliminate unintentional hindrances to water harvesting	• Managing Wet Weather with Green Infrastructure Municipal Handbook: Rainwater Harvesting Policies • Local Water Policy Innovation • Rooftops to Rivers • Rooftops to Rivers II • Capturing Rainwater from Rooftops
Creation of stormwater fees/utility: New source of revenue generation, based on amount of impervious surface, to fund and encourage decentralized stormwater management	• Managing Wet Weather with Green Infrastructure Municipal Handbook: Funding Options • Managing Wet Weather with Green Infrastructure Municipal Handbook: Incentive Mechanisms • Models for Governance, Management, Maintenance and Financing • Stormwater BMP Retrofit Policies • Rooftops to Rivers
Provision of incentives: Financial and non-financial rewards for implementing water harvesting	• Managing Wet Weather with Green Infrastructure Municipal Handbook: Rainwater Harvesting Policies • Managing Wet Weather with Green Infrastructure Municipal Handbook: Incentive Mechanisms • Regulatory and Incentive Systems • Stormwater BMP Retrofit Policies • Rooftops to Rivers • Rooftops to Rivers II • Capturing Rainwater from Rooftops

Development of regulation: Requirements to implement water harvesting techniques	• Managing Wet Weather with Green Infrastructure Municipal Handbook: Rainwater Harvesting Policies • Local Water Policy Innovation • Regulatory and Incentive Systems • Rooftops to Rivers II • Capturing Rainwater from Rooftops • Sustainable Water Management

Table 3: Policy options in the literature

First, several of the reports emphasize the utility of demonstration sites in creating acceptance of water harvesting practices. Demonstration sites can be characterized as an educational tool, with pilot projects also performing a similar function. Though many areas of the country have experience with small-scale water harvesting, such as small rain barrels,[27] some of the newer, passive, more large-scale applications of water harvesting have less direct familiarity. Demonstration sites, therefore, offer a way to establish that familiarity before wide application of a particular technique. The Water Environment Research Foundation's (WERF) report on Successful Public Education Systems calls out several key components of an effective demonstration project. These components include installing the demonstration project in a highly-trafficked, pedestrian area; inclusion of signage at the site; dissemination of information through print media; and the establishment of a citizen advisory committee.[28] This report points out that the most successful and well-installed green infrastructure projects can blend seamlessly with their surroundings. Therefore, demonstration sites play the key role of "letting citizens know that the natural area provides more than just aesthetic and recreational benefits," further claiming that "when consumers know what to ask for and developers know what to provide, multi-benefit stormwater features can become 'business as usual.'"[29]

Similar to the educational role played by demonstration sites, pilot projects can also help instill familiarity and comfort with new approaches to water management. In its municipal handbook on green streets, for example, the EPA contends that pilot projects "are necessary to demonstrate that green streets can work in the local environment, can be relied upon, and fit with existing infrastructure. Pilot projects will help to dispel myths and resolve concerns."[30] Especially in states like Arizona, where these practices remain relatively untried, pilot projects can help ensure that techniques are viable and effective. This is important in convincing potential practitioners themselves that water harvesting is

[27] Texas Water Development Board, "Texas Guide to Rainwater Harvesting," 2nd ed., (TWDB, 1997), ii.
[28] Water Environment Research Foundation, "Successful Public Education Systems," (WERF, June 2007), 1.
[29] Ibid, 1.
[30] Robb Lukes and Christopher Kloss, "Managing Wet Weather with Green Infrastructure Municipal Handbook: Green Streets," (U.S. Environmental Protection Agency, December 2008): 16.

worth pursuing, before they then work to convince the public through demonstration sites. Public parcels offer convenient locations at which to implement demonstration sites and pilot projects. The municipality is likely already a willing participant and these lots generally have a high profile in the community's eye. In fact, the Natural Resources Defense Council's *Capturing Rainwater from Rooftops* includes "require use of rainwater harvesting and reuse on all public properties" as one of its major policy recommendations.[31]

Another widespread recommendation across the literature reviewed addressed removing barriers to water harvesting found in municipal codes and ordinances. The EPA's report on implementing rainwater harvesting, *Managing Wet Weather with Green Infrastructure Municipal Handbook: Rainwater Harvesting*, points out that plumbing codes often act as stumbling blocks when they are overly cautious in treating rainwater as a potential health hazard. For example, neither the Uniform Plumbing Code nor the International Plumbing Code includes provisions or guidelines for dealing with rainwater, though they do address the use of reclaimed water and graywater. This has led many jurisdictions to treat rainwater with the same stringency as that required for either graywater or reclaimed water.[32] However, the EPA has determined that small-scale, residential use of harvested water for outdoor irrigation generally requires no treatment, and that even larger-scale irrigation uses or non-potable indoor uses such as toilet flushing pose little human health risk with proper treatment.[33] Plumbing codes can also form barriers when they "make no provisions for rainwater reuse or require downspouts to be connected to the stormwater collection system, thereby eliminating the possibility of intervening to intercept roof runoff…"[34] Further impediments to the implementation of water harvesting and green infrastructure can come from municipal codes that mandate certain zoning densities, minimum parking requirements and road widths, continuous curbs, and certain landscaping design obligations.[35]

Therefore, these reports conclude that an important early step for a municipality wishing to implement water harvesting to take is to review and remove any such code barriers.[36] In its report on water harvesting as a water resource management strategy, the National Resources Defense Council

[31] Noah Garrison, Christopher Kloss, Robb Lukes, "Capturing Rainwater from Rooftops: An Efficient Water Resource Management Strategy that Increases Supply and Reduces Pollution," (National Resources Defense Council, November 2011), 19.
[32] Christopher Kloss, "Rainwater Harvesting Policies," 3.
[33] Noah Garrison, Christopher Kloss, Robb Lukes, "Capturing Rainwater from Rooftops," 19.
[34] Christopher Kloss, "Rainwater Harvesting Policies," 7.
[35] Brent Denzin, "Local Water Policy Innovation: A Road Map for Community Based Stormwater Solutions," (American Rivers and Midwest Environmental Advocates, September 2008), 4.
[36] Christopher Kloss, "Rainwater Harvesting Policies," 7.

advises municipalities to revise local plumbing and public health codes to "include rainwater harvesting as an accepted practice, establish acceptable end uses of rainwater, and set appropriate treatment, design, construction, and maintenance standards."[37] The EPA recommends that plumbing codes for harvested water loosely follow those for reclaimed water or graywater, but reflect "lower levels of initial contamination and targeted end uses."[38] Communities can also undergo a process known as "green" or "sustainable" code review, in which planners, citizens, consultants, and others comb through existing ordinances to identify outdated language that could be blocking implementation of water harvesting either by direct wording against necessary practices, through ambiguity, or through omission. These types of reviews can also identify areas in the code that do a good job of promoting or encouraging water harvesting.[39]

A third issue that much of the literature touches on is the need for dedicated funding to deal with stormwater management issues. This can be true for traditional stormwater infrastructure, but especially true for green infrastructure, not because it necessarily costs more to implement, but because a municipality's existing funding structure may not include a space for green infrastructure techniques. Municipalities have found several ways to overcome this type of difficulty, including in-lieu fees, impact fees, and real estate taxes.[40] Another option, and one that several policy reports identified, is the creation of a stormwater utility that can leverage stormwater fees. Stormwater fees can help growing communities pay for new infrastructure, or can assist older communities in retrofitting or repairing existing (and aging) infrastructure. In addition, stormwater fees have been characterized as a more equitable way to deal with a community's stormwater issues than other methods because stormwater fees are generally charged based on a property's contribution to runoff generation—the parcel's amount of impervious surface. Though existing municipal departments can bill and collect a newly-instated stormwater fee, many communities choose instead to create a separate entity, a stormwater utility, to handle those actions.[41]

Besides providing a dedicated stream of revenue to fund new stormwater infrastructure, stormwater fees can also incentivize the use of water harvesting techniques by rewarding green

[37] Noah Garrison, Christopher Kloss, Robb Lukes, "Capturing Rainwater from Rooftops," 19.
[38] Christopher Kloss, "Rainwater Harvesting Policies," 7.
[39] Tetra Tech, "City of Phoenix Code Review to Promote Green Infrastructure – Case Study," (City of Phoenix, 30 January 2013), 1-5.
[40] Environmental Protection Agency, "Managing Wet Weather with Green Infrastructure Municipal Handbook: Funding Options," (EPA, September 2008), 1.
[41] Environmental Protection Agency, "Funding Options," 2.

infrastructure practices with fee reductions or credits.[42,43] Table 3 below outlines different types of fee reductions the EPA suggests that a municipality can use to target the stormwater management goals they hope to accomplish through the program. In their report *Models for Governance, Management, Maintenance and Financing*, WERF states that municipalities should offer rate payers ways "in which they can reduce their fee by reducing the amount of stormwater generated (source controls) or reducing the amount of stormwater and pollutants entering the storm drain system (treatment controls)."[44]

Goal of Discount	Mechanism for Fee Reduction	Process for Implementation
Reduce Imperviousness	• Percent fee reduction • Per-square-foot credit	• Percent reduction in imperviousness • Square feet of pervious surfaces
On-site Management	• Percent fee reduction • Quantity/Quality credits (performance-based)	• List of practices with various credits • Total area (square feet) managed
Volume Reduction	• Percent fee reduction • Performance-based quantity reduction	• Percent reduction in imperviousness • Performance-based • Total area (square feet) managed • Practices based on pre-assigned performance values
Use of Specific Practices	• Percent fee reduction • One time credit	List of practices with various credits

Table 4: Framework for Stormwater Fee Discount Program[45]

Stormwater fee discounts represent one type of incentive, but the reports from the literature review point to several other methods that municipalities can use to encourage water harvesting. As the EPA points out in its report, *Managing Wet Weather with Green Infrastructure Municipal Handbook: Incentive Mechanisms*, these types of strategies "allow municipalities to act beyond the confines of their regulatory authorities to improve wet weather management on properties that may not fall under updated stormwater requirements or other state and municipal policies, codes and ordinances."[46] Just as with stormwater fees, depending on a community's needs, these incentives can target new construction by wrapping into the development process or they can focus on retrofitting existing development, or even address both new construction and retrofits. Many types of incentive

[42] Environmental Protection Agency, "Funding Options," 4.
[43] Christopher Kloss and Crystal Calarusse, "Rooftops to Rivers: Green Strategies for Controlling Stormwater and Combined Sewer Overflows," (National Resources Defense Council, June 2006), 14-15.
[44] Water Environment Research Foundation, "Models for Governance, Management, Maintenance and Financing," (WERF, June 2007), 2.
[45] Environmental Protection Agency, "Funding Options," 4.
[46] Environmental Protection Agency, "Managing Wet Weather with Green Infrastructure Municipal Handbook: Incentive Mechanisms," (EPA June 2009), 1.

mechanisms exist, including development incentives, grants, rebates, and awards and recognition programs.[47] Some examples of development incentives that a municipality can implement include fast-tracked development reviews or offering density bonuses for parcels that include water harvesting.[48,49] Grants and rebates supply up-front funding or reimbursements to property owners that install water harvesting practices. Awards and recognition programs recognize model projects and promote those projects to the public and can even offer monetary prizes in a contest-type setting.[50]

As seen from the examples of incentive mechanisms described above, this type of strategy can either involve an exchange of money from a municipality to a property owner, or can be non-monetary in nature, such as the development incentives. What type of incentive a municipality chooses will depend on the overall goals of the program as well as available funding. Incentive mechanisms have several advantages in addition to this flexibility in program implementation and freedom from funding necessity. A municipality can also apply incentive programs very strategically, based on geographic areas most in need of focused stormwater management. Conversely, incentives can also have a very broad geographic focus. In addition, because these types of programs are entirely voluntary, they are generally among the politically easiest water harvesting implementation policies to put in place.[51]

A fifth way for municipalities to pursue water harvesting is through the development of regulations that require such practices. These types of regulations can come in the form of development codes or ordinances. The code or ordinance language can reflect the goals that the community wishes to achieve with the regulations. Thus, one municipality's ordinance might emphasize the use of native plants within stormwater management features, while another might aim for the inclusion of recreational features within those types of features. In many instances, these codes and ordinances are modifications of a community's requirements for stormwater control through the National Pollutant Discharge Elimination System (NPDES). The EPA developed this system to help mitigate non-point source pollution stemming from urban runoff. Stormwater rules vary by community, but generally include sizing criteria for retention and detention basins and other types of stormwater infrastructure. Communities can proactively add green infrastructure features to these requirements.[52] Overlay zones, which add additional restrictions on top of the existing zoning, can also be used to

[47] Environmental Protection Agency, "Incentive Mechanisms," 1.
[48] Noah Garrison and Karen Hobbs, "Rooftops to Rivers II: Green strategies for controlling stormwater and combined sewer overflows," (NRDC 2011), 36.
[49] Water Environment Research Foundation, "Regulatory and Incentive Systems," (WERF, June 2007), 2.
[50] Environmental Protection Agency, "Incentive Mechanisms," 1.
[51] Environmental Protection Agency, "Incentive Mechanisms," 1-2.
[52] Water Environment Research Foundation, "Regulatory and Incentive Systems," 1.

require specific techniques in areas that cause problems for the community. Suggested key components of a water harvesting ordinance include the intent, scope, authority, administration, and definitions to be used, as well as clear requirements. Also important are outlining exemptions, variance standards, easements for inspections and maintenance, enforcement of the regulation, as well as the appeal process.[53]

The literature reviewed also offered extensive recommendations on how a municipality can develop and implement these types of regulations. One key recommendation urges municipalities to work with stakeholders to develop regulations. These stakeholders might include planners, citizen groups, and decision-making bodies such as city councils.[54] For concerned citizens that wish to guide their communities toward the adoption of water harvesting regulations, several suggestions also exist. First, activists should raise public awareness about the stormwater or water resources issues they wish to resolve through regulation, with the hope that this awareness will translate into community support for the regulation. A zoning code and comprehensive plan should be enacted in communities that do not currently have them. Then citizens can approach the local decision-making body to propose the ordinance and request action. If a municipality's council and/or planning commission proves uninterested in pursuing regulation, citizens often have recourse to referenda to force the issue through a public vote.[55] Much of the literature encourages the use of both regulations and incentives to achieve the best results. WERF states that "while regulatory requirements for certain types of stormwater management might be a straightforward way to achieve a community's goals, incentives can be used to garner support and good will from the development community because they offer tangible benefits that positively impact bottom lines."[56]

Methodology

As mentioned above, the majority of the literature available—including the reports discussed in the previous section—reflects the experiences of more humid areas of the country, with little reference to the arid and semi-arid Southwest. To understand how policy implementation to encourage or require water harvesting might, or might not, be different in this region, three case studies from Arizona were selected for comparison. The three communities chosen were the City of Tucson, the Town of Oro Valley, and the City of Sierra Vista. Selection of these three municipalities was first predicated on their adoption of water harvesting policies, and second on the very different types of policies each

[53] Denzin, 19-20, 22-27.
[54] Water Environment Research Foundation, "Regulatory and Incentive Systems," 1.
[55] Denzin, 5-7.
[56] Water Environment Research Foundation, "Regulatory and Incentive Systems," 1.

community chose. This latter point helps to provide a spectrum of comparison for the ways in which these various types of implementation came about. Tucson passed the country's first-ever commercial water harvesting ordinance, Oro Valley created a stormwater utility, and a Sierra Vista non-profit established a rebate program. Interviews with local experts either involved or familiar with the policies created in these communities were conducted to provide further detail to the language of the policies themselves.

Municipality	Interviewee
City of Tucson	Rodney Glassman, former city council member
	Ann Audrey, environmental consultant and former city staff member
	Joseph Linville, Lead Planner, Landscape Section, Planning and Development Services
	Eric Barrett, landscape architect
Town of Oro Valley	Paul Jungen, Stormwater Engineer, Development & Infrastructure Services Department
City of Sierra Vista	Cado Daily, Water Resources Coordinator, Water Wise Program, UA Cochise County Cooperative Extension
	Linda Stitzer

Table 5: Interviews conducted

Case Study: City of Tucson Commercial Water Harvesting Ordinance

The road to Tucson's commercial water harvesting ordinance was a long one, and began with several rather vaguely-worded sections of the city's land use code requiring developers to make "maximum use" of site-generated stormwater. In creating the "maximum use" requirement, the City intended to accomplish the code's stated goal of developing landscaping requirements that conserve energy, water, and other natural resources, as well as reducing soil erosion and contributing to groundwater recharge.[57] In the "Use of Water" section of the land use code, the City requires that developers make maximum use of the runoff for "supplemental onsite irrigation purposes" and that "the landscape plan shall indicate use of all runoff, from individual catch basins around single trees to basins accepting flow from an entire vehicular use area or roof area."[58] The section goes on to state that "storm water and runoff harvesting to supplement drip irrigation are required elements of the irrigation system for both new plantings and preserved vegetation."[59] Prior to the inclusion of this language in the

[57] Ann Audrey, ed., City of Tucson Water Harvesting Guidance Manual (City of Tucson, October 2005), 26.
[58] City of Tucson, "Land Use Code," (COT, 1 July 1995), LUC Section 3.7.4 Use of Water, Section 3.7.4.3.B Storm Water Runoff.
[59] City of Tucson, LUC Section 3.7.4 Use of Water, Section 3.7.4.5.B Irrigation.

code, there had been considerable grassroots interest and effort within the community around water harvesting, but the land use code was the start of regulation.[60]

In 2005, to address both the somewhat vague language in the code and the fact that developers really did not know enough about water harvesting to comply with the code, the city created a water harvesting guidance manual and adopted it through ordinance #10210. The manual, entitled *City of Tucson Water Harvesting Guidance Manual*, was intended primarily for commercial developers, but was written in a way so as to be applicable to residential use as well. Components in the manual include water harvesting principles and the basics of integrated site design, an approach to development that "matches the needs of a site…with the products of a site…to create an efficient design that saves resources…while improving the function and sustainability of the site."[61] Further sections in the manual detail several water harvesting techniques, from microbasins and swales to mulch, then gives design examples for several types of sites, including subdivisions, commercial parcels, and public rights-of-way. An extensive appendix section covers details such as code requirements, engineering considerations, calculations, xeriscape landscaping, precautions for avoiding breeding mosquitos, and water harvesting sites and resources specific to Tucson.

As informative and detailed as the water harvesting guidance manual was, Rodney Glassman, a former aide to Congressman Raul Grijalva and the main force behind the development of the City's commercial water harvesting ordinance, felt that the existing requirements and guidelines did not go far enough. He stated that in practice, "any developer that tried to implement based on the handbook would have to get a variance." Further, he wanted to "make conservation the rule, rather than the exception" in Tucson, and successfully campaigned for the Ward 2 seat on the city council on a platform of harvesting rainwater, graywater, and solar energy. Beyond a general belief in the importance of instilling a conservation ethic in the city, Mr. Glassman was also motivated by concerns over water supply, stating "everyone talks about finding the next bucket of water, why not maximize the bucket we've already got?"[62] Once the city council voted to develop the ordinance, Mr. Glassman encouraged the formation of a stakeholder group to craft the language of the ordinance. He had previously worked at KB Homes and held a real estate license, so was able to bring both developers and realtors to the table. Moreover, he holds a degree in Arid Lands Resource Sciences from the UA, so was also able to include environmental advocates in the process.[63]

[60] Ann Audrey, personal communication to author, 4 April 2013.
[61] Audrey, "Manual," 3
[62] Rodney Glassman, personal communication to author, 2 April 2013.
[63] Glassman, 2 April 2013.

The stakeholder group was overseen by a professional facilitator hired by the city. Once the process was started, no elected officials were involved, a factor that Mr. Glassman felt helped to expedite the process. Though the environmental advocates (and Mr. Glassman) originally wanted to require that commercial developments harvest 100% of the runoff generated by their sites, developers pushed back, saying that they had no way to use the amount of water a 100% capture rate would generate. In addition, compliance at that level would require the use of tanks, an expensive prospect. Based on this feedback, the focus shifted to a demand-based consideration, and staff member Ann Audrey developed calculations showing that 50% of landscape plant demand could be met through passive techniques only. This solution met with the acceptance of the developers and eventually the environmental advocates as well. Once the language of the ordinance had been decided, an advisory panel was created to author the accompanying development standard. This was a very intensive process primarily involving city staff and developers. However, the time and effort invested by the parties paid off, to the extent that then-mayor Bob Walkup declared the public hearing for the acceptance of the ordinance the smoothest he had ever experience.[64]

In all, the process took less than a year. The ordinance took effect June 1, 2010. Developers are given 3 years for plant establishment before having to prove that they are meeting the 50% requirement, so results have not yet been recorded. Moreover, the requirement is waived during periods of drought, leaving some uncertainty as to when results will finally be available. Despite the current lack of hard data to prove that the ordinance has achieved savings in potable water used for outdoor irrigation, success has been measured in other ways. Joseph Linville, a city planner who reviews landscape plans sees the primary benefit of the ordinance in terms of project design, pointing out that "engineers and architects and landscape architects now often evaluate the need and the potential for directing rainwater to landscape spaces early on in project development. This type of collaboration and focus on using water constructively is a re-education for some and a reinforcement of the region's conservation ethic for others."[65] On the other hand, implementers of the ordinance, including Eric Barrett, a landscape architect, have criticized some of the inflexibilities in the policy as hindering its effectiveness.[66]

[64] Ann Audrey, personal comm., 4 April 2013.
[65] Joseph Linville, email to the author, 12 April 2013.
[66] Eric Barrett, email to the author, 18 April 2013.

Case Study: Town of Oro Valley Stormwater Utility

The Town of Oro Valley's motivation in creating a stormwater utility was quite different from Tucson's in creating the water harvesting ordinance. According to Paul Jungen, a stormwater engineer with the town, the primary impetus was to meet legal requirements for both stormwater quality and quantity. The National Pollutant Discharge Elimination System mandates that all towns with fewer than 100,000 citizens located in an urban area have a stormwater plan that addresses issues of stormwater quality. FEMA flood control rules and regulations address issues of stormwater quantity. The town found itself without a dedicated funding stream to meet these legal requirements, so opted to set up a stormwater utility as a way to generate that funding stream. The utility took part in several council meetings and work study sessions to address questions and concerns from council members and the public about the stormwater fee, as well as addressing "numerous customer queries" in the first year of the fee's implementation. In addition, the town has a five-member, all-volunteer, Stormwater Utility Commission that "provides a forum to hear and recommend issues surrounding bonds, expenses, and service fees." This commission also monitors performance measures and citizens regularly attend the commission's monthly meetings to voice concerns and hear updates related to stormwater runoff. Mr. Jungen credits this commission with the community's strong positive support for the utility and fee.[67]

Oro Valley's stormwater utility charges properties a fee based on the amount of runoff generated by the property, a figure based on the amount of impervious surface found on the site. In developing its fee structure, the town determined that the average impervious area for Oro Valley residences is around 5,000 square feet. This number became the standard Equivalent Residential Unit (ERU) by which each parcel would be measured and charged for its contribution to stormwater runoff within the town. Residential parcels are charged a flat fee of one ERU per month, in part to make the fee easier to develop and apply, while non-profit and commercial parcels are charged based on the number of ERUs to which their impervious area is equivalent. In addition to generating the fees necessary to meet stormwater quantity and quality obligations, the stormwater fee also encourages green infrastructure practices by offering commercial and non-profit sites a 25% maximum credit for meeting certain requirements aimed at reducing the amount of water and pollutants leaving a site.[68]

A parcel owner can receive the 25% credit by participating in an annual or ongoing stormwater education program. Owners can also receive the credit by installing first flush technology on their

[67] Paul Jungen, email to author, 3 April 2013.

[68] Town of Oro Valley Stormwater Utility Commission, "Stormwater Utility Service Fee Proposal," (TOV, 3 January 2008), 18-21.

sites.[69] “First flush” refers to the first portion of a rainfall event, usually measured in fractions of an inch, that is believed to contain a higher proportion of contaminants than the subsequent volumes of runoff. This reflects the fact that the initial precipitation volume picks up and carries any dust, chemicals, droppings, etc. that may have deposited on impervious surfaces since the last rain event.[70] To date, only two parcel owners have applied for and received this credit. The stormwater utility is fairly young (authorized in 2007), but measures success through a variety of performance measures and indicators such as storm cleanup costs, number of community outreach events, reduced drainage problems, and inspections of the town’s stormwater infrastructure.[71]

Case Study: Sierra Vista Subwatershed Water Harvesting Rebate

Sierra Vista’s motivation in developing its water harvesting rebate was yet again different from the experiences of Tucson and Oro Valley discussed above. The goal of the rebate program is to help mitigate overdraft of the Sierra Vista Subwatershed aquifer by replacing groundwater used for outdoor irrigation with rainwater. Reducing overdraft of the aquifer is critical because an endangered plant, the Huachuca Water Umbel, is found on the San Pedro River, which is fed by the regional aquifer. Ft. Huachuca, a 73,334 acre army base located in Cochise County, is a major economic driver of the region. About half of Sierra Vista’s population consists of army personnel assigned to the Fort, along with their dependents. The acceleration in groundwater pumping that has accompanied the population rise in Sierra Vista, in part due to expansion of activity on the Fort, has affected the base flows of the San Pedro, threatening the river’s riparian habitat and consequent biological diversity.[72] If the US Department of Defense determines that the Fort’s activities are detrimental to the survival of the umbel it could reduce the Fort’s mission, with far- reaching negative impacts to Sierra Vista’s economy.[73]

The city’s experience with rainwater harvesting is fairly new. It recently allowed rain tank volumes to be factored into reducing the required size of the detention basins on commercial properties. In addition, the city has also unofficially committed to putting rainwater harvesting systems on all new city buildings. Sierra Vista applied for a grant from the Walton Family Foundation to enact a water harvesting rebate program, but the foundation granted the funds to the non-profit Cochise Water Project instead. In March 2013 the city partnered with the Cochise Water Project to administer a rebate

[69] Town of Oro Valley Stormwater Utility Commission, 18-21.
[70] Michael K. Stenstrom and Masoud Kayhanian, “First Flush Phenomenon Characterization,” (California Department of Transportation, August 2005), xii.
[71] Jungen, email, 3 April 2013.
[72] Dawn McKnight and Colin Deihl, “A Submission Pursuant to Article 14 of the North American Agreement on Environmental Cooperation,” (Earthlaw, 14 November 1996), 2-3.
[73] Cado Daily, email to author, 5 April 2013.

program in the city. As could perhaps be guessed by the relative newness of water harvesting in the subwatershed, the Cochise Water Project has experienced several stumbling blocks in setting up and administering its program. Water Project staff have faced a steep learning curve as to how to set up rebate programs and how to properly put together a rainwater collection system. The program is not currently requiring any data collection from rebate recipients, making it difficult to track the effectiveness of the program in reducing groundwater use. Community involvement has been minimal, though Cado Daily, a Cooperative Extension specialist for Cochise County, recently completed a master's thesis that indicated there is overall acceptance of water harvesting within the Sierra Vista Subwatershed.[74]

Policy Recommendations

Several lessons about implementing water harvesting come out of these case studies. When looking at Tucson's experience, a continuum of policy options emerges. The city had significant community experience with water harvesting, boosted by strong advocates like water harvesting guru and Tucson resident Brad Lancaster. In addition, the city's water utility, Tucson Water, offered a small rebate program that helped residents become familiar with the "look" of water harvesting. A rather vague requirement in the land use code nevertheless put water harvesting on the radar of the development community. The water harvesting manual served to educate developers and the public about proper water harvesting techniques and encourage compliance with the "maximum use" policy. Finally, a quantitative ordinance made water harvesting mandatory for all new commercial developments. A policy continuum like this, moving from less to more stringent, could be especially helpful when a municipality, such as Tucson, wants to adopt water harvesting because it is "the right thing to do," rather than in response to a crisis situation. On the other hand, as the examples of Oro Valley and the Sierra Vista subwatershed showed, a different approach might be more appropriate if clear problems are being addressed. In these types of cases, a more direct route to implementation can be taken.

Whether a community chooses to follow a more gradual path to implementing water harvesting or to take the more direct route, several components would seem to help make any policy more effective, based on the experiences of the three case study communities as well as the policy literature. First, a community must clearly identify the problem it hopes water harvesting will solve. This is especially important for municipalities in arid regions that will probably face different challenges from

[74] Daily, email, 5 April 2013.

those discussed in much of the national literature on water harvesting. The issue at hand will determine what type of policy is chosen to solve it, as the experiences of Oro Valley and Sierra Vista show. For this reason a community's chosen policy will be most effective if it is deliberately crafted with the goal of solving a clearly defined problem.

Showing that the water harvesting policy chosen is truly solving the problem is also very important. This requires the collection of data on the techniques used and the sites implementing those techniques. A community should therefore write requirements for data collection and the administration of that data into the policy language. Again, this type of provision is especially important for Southwestern municipalities because less research exists on the effectiveness of water harvesting in this region. The type of data collected will vary depending on the policy chosen, but could include aspects such as potable water offset, increases in urban vegetation density, quantity and quality of stormwater runoff before and after policy implementation, cost comparison of "gray" and green infrastructure implemented, and many others. Though neither the literature reviewed nor the communities studied make much mention of data collection, the inclusion of such a requirement in a policy would help ensure the effectiveness of the policy chosen and also act as a source of information for other arid-located communities pursuing their own implementation policies.

In all of the case studies, interviewees emphasized the importance of involving the public in the policy development process and educating citizens about the benefits of water harvesting. Demonstration projects are a great way to do this, and may be the best first step a municipality could take. In the case of policies like Tucson's commercial water harvesting ordinance and Oro Valley's stormwater fee, the inclusion of the sectors to be regulated—in these cases commercial developers and owners and non-profits—can also help to generate acceptance and buy-in from those sectors. An ongoing forum to address concerns also proved invaluable in Oro Valley's experience. In whatever form it takes, a municipality's policy development process should provide ample opportunities for community inclusion and feedback. Including a citizen or volunteer forum into the language of the policy is also highly recommended.

Finally, ensuring the policy cannot be easily ignored by writing in enforcement actions and other consequences is very important to seeing desired outcomes. Though little of the literature reviewed touched on enforcement actions, a policy without "teeth" can be assumed to be less effective than one with real consequences for noncompliance. The City of Tucson tied its commercial water harvesting ordinance to its previously-existing drought code. In effect, this means that if a property fails to meet the requirements of the ordinance after three warnings, the city has the ability to turn off the parcel's water supply (Audrey, personal comm.).[75] It still remains to be seen if the city will exercise its right to act on this provision, but the inclusion of the option in the policy at least leaves the door open for enforcement.

Conclusion

Despite the fact that so little research exists to address water harvesting in the arid areas of the United States, municipalities in the Southwest have made strides to implement these techniques. Moreover, despite differences in rainfall regimes, plant palettes, and motivation, the policies that cities in Arizona have used to implement water harvesting have been largely the same as those suggested by national-scale reports that focus on more humid regions in the nation. So while participants of the AridLID Conference workshop cited lack of arid-focused data as a major barrier to the implementation of green infrastructure, cities are nevertheless choosing a soft path approach to address some of their water management concerns. The ability of the Southwestern municipalities examined in the case study section to implement water harvesting depended on a very clear and immediate concern (Oro Valley, Sierra Vista) or on having a strong champion with the right skills and background to push action (Tucson). As knowledge about and familiarity with water harvesting in arid regions grows, however, municipalities following these early implementers will have the ability to incorporate their successes and lessons learned, and therefore have an easier road to implementing their own water harvesting policies.

[75] Audrey, personal comm., 4 April 2013.

Bibliography

Alliance for the Great Lakes. "Special Report: Sustained federal infrastructure investment needed to curb Great Lakes sewage overflows." 19 June 2012. < http://www.greatlakes.org/csoreport> (20 April 2013).

Arnold Jr., Chester L. and C. James Gibbons. "Impervious Surface Coverage: The Emergence of a Key Environmental Indicator." Journal of the American Planning Association 62, no. 2 (1996): 243-258.

Audrey, Ann, ed. City of Tucson Water Harvesting Guidance Manual. City of Tucson, October 2005.

Audrey, Ann. Personal communication to author. 4 April 2013.

Barefoot, Jennifer A. and Victoria Collier, eds. "Sustainable Water Management: Guidelines for Meeting the Needs of People and Nature in the Arid West." Sonoran Institute.

Barrett, Eric. Email to the author. 18 April 2013.

Brandes, Oliver M. and David R. Brook. "The Soft Path for Water in a Nutshell. Ottawa, ON: Friends of the Earth Canada, August 2007.

Brooks, David B. and Oliver M. Brandes. "Why a Water Soft Path, Why Now and What Then?" International Journal of Water Resources Development, 27 (2011): 315-344.

CAGRD & Underground Storage Committee. "CAGRD Mid-Plan Review: Enrollment, Demand and Obligation." CAGRD, 23 November 2011.

City of Tucson. "Land Use Code." COT, 1 July 1995.

Cleveland, Jenna. "Co-creating an arid-adapted, integrative green infrastructure research agenda: A workshop of the 2012 AridLID Conference." January 2013 (unpublished report).

Daily, Cado . Email to author. 5 April 2013.

Denzin, Brent. "Local Water Policy Innovation: A Road Map for Community Based Stormwater Solutions." American Rivers and Midwest Environmental Advocates, September 2008.

Eden, Susanna, Tim W. Glass and Valerie Herman. "Desalination in Arizona: A growing component of the state's future water supply portfolio." Arroyo (2011).

Environmental Protection Agency. "Combined Sewer Overflows." 16 February 2012. <http://cfpub.epa.gov/npdes/home.cfm?program_id=5> (20 April 2013).

Environmental Protection Agency. "Combined Sewer Overflows Demographics." 15 October 2008. <http://cfpub.epa.gov/npdes/cso/demo.cfm?program_id=5> (20 April 2013).

Environmental Protection Agency. "Green Infrastructure." 23 April 2013. <http://water.epa.gov/infrastructure/greeninfrastructure/index.cfm> (23 April 2013).

Environmental Protection Agency. “Green Infrastructure Case Studies.” 23 April 2013. <http://water.epa.gov/infrastructure/greeninfrastructure/index.cfm> (20 April 2013).

Environmental Protection Agency. “Managing Wet Weather with Green Infrastructure Municipal Handbook: Funding Options.” EPA, September 2008.

Environmental Protection Agency. “Managing Wet Weather with Green Infrastructure Municipal Handbook: Incentive Mechanisms.” EPA June 2009.

Garrison, Noah, Christopher Kloss and Robb Lukes. “Capturing Rainwater from Rooftops: An Efficient Water Resource Management Strategy that Increases Supply and Reduces Pollution.” National Resources Defense Council, November 2011.

Garrison, Noah and Karen Hobbs. “Rooftops to Rivers II: Green strategies for controlling stormwater and combined sewer overflows.” NRDC 2011.

Glassman, Rodney. Personal communication to author. 2 April 2013.

Gleick, Peter H. “Global Freshwater Resources: Soft-Path Solutions for the 21st Century.” Science 302 (2003): 1524-1527.

Harlan, Sharon L. “The Urban Heat Island in Phoenix: Impacts on Neighborhoods.” 25 April 2012 (PowerPoint Presentation).

Hickman, Matt. “Needed: a deluge of rain gardens in the Puget Sound by 2016.” Mother Nature Network, 22 June 2011. <http://www.mnn.com/your-home/organic-farming-gardening/blogs/needed-a-deluge-of-rain-gardens-in-the-puget-sound-by-2016> (18 April 2013).

Jungen, Paul . Email to author. 3 April 2013.

Kloss, Christopher. “Managing Wet Weather with Green Infrastructure Municipal Handbook: Rainwater Harvesting Policies.” EPA, December 2008.

Kloss. Christopher and Crystal Calarusse. “Rooftops to Rivers: Green Strategies for Controlling Stormwater and Combined Sewer Overflows.” National Resources Defense Council, June 2006.

Linville, Joseph. Email to the author. 12 April 2013.

Low Impact Development Center. “Welcome.” 2011. <http://www.lowimpactdevelopment.org> (20 April 2013).

Lukes, Robb and Christopher Kloss. “Managing Wet Weather with Green Infrastructure Municipal Handbook: Green Streets.” U.S. Environmental Protection Agency, December 2008.

McKnight, Dawn and Colin Deihl. “A Submission Pursuant to Article 14 of the North American Agreement on Environmental Cooperation.” Earthlaw, 14 November 1996.

Overpeck, Jonathan et al. "Southwest Climate Assessment: Summary for Decision Makers." Tucson, AZ: Southwest Climate Alliance, June 2012.

Pima County Regional Flood Control District. "A Brief Overview of Historical Flooding." <http://rfcd.pima.gov/outreach/flooding> (20 April 2013).

Pushard, Doug. "Active Versus Passive in Rainwater Catchment." Green Fire Times, 1 September 2010. <http://greenfiretimes.com/2010/09/active-versus-passive-in-rainwater-catchment> (25 April 2013).

Rain Tank Depot. "Plastic Rainwater Tanks." <http://www.raintankdepot.com/c-3060/plastic-vertical-rain-water-tanks> (25 April 2013).

Solecki, William D. et al. "Mitigation of the heat island effect in urban New Jersey." Environmental Hazards: 6 (2005): 39-49.

Stenstrom, Michael K. and Masoud Kayhanian. "First Flush Phenomenon Characterization." California Department of Transportation, August 2005.

Technicians for Sustainability. "Rain Gardens." 2011. <http://tfssolar.com/residential/rain-water/how-it-works-2/rain-gardens> (18 April 2013).

Tetra Tech. "City of Phoenix Code Review to Promote Green Infrastructure – Case Study." City of Phoenix, 30 January 2013.

Texas Water Development Board. "Texas Guide to Rainwater Harvesting," 2nd ed. TWDB, 1997.

Town of Oro Valley Stormwater Utility Commission. "Stormwater Utility Service Fee Proposal." TOV, 3 January 2008.

U.S. Bureau of Reclamation. Colorado River Basin Water Supply and Demand Study. USBR, December 2012.

US Climate Data. "Climate: United States." <http://www.usclimatedata.com> (25 April 2013).

Water Environment Research Foundation. "Models for Governance, Management, Maintenance and Financing." WERF, June 2007.

Water Environment Research Foundation. "Regulatory and Incentive Systems." WERF, June 2007.

Water Environment Research Foundation. "Stormwater BMP Retrofit Policies." WERF, 2009. <http://www.werf.org/liveablecommunities/toolbox/retrofit_pol.htm> (18 April 2013).

Water Environment Research Foundation. "Successful Public Education Systems." WERF, June 2007.

Waterfall, Patricia. Harvesting Rainwater for Landscape Use, 2nd ed. University of Arizona: College of Agriculture and Life Sciences, 2006.