Scaling Green Stormwater Infrastructure Through Multiple Benefits in Austin, Texas:

Distributed Rainwater Capture on Residential Properties in the Waller Creek Watershed

Sarah Diringer, Morgan Shimabuku, Heather Cooley, Madeline Gorchels, Jennifer Walker, and Sharlene Leurig

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Texas Water Trade is a nonprofit organization harnessing the power of markets and technological innovation to build a future of clean, flowing water for all Texans. We were founded in 2019 with catalytic support from the Harte Charitable Foundation. Our vision is durable, long-lasting water supplies in Texas that ensure future economic growth, ecological resilience and abundant drinking water for present and future generations, no matter their income or zip code.

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Sharlene Leurig is Chief Executive Officer of Texas Water Trade, a nonprofit harnessing the power of markets and technological innovation to build a future of clean, flowing water for all Texans. Sharlene is a sustainable water finance expert with extensive experience in Texas on long-range water planning, infrastructure finance and water transactions. Formerly, she directed the Texas Environmental Flows Initiative, a collaboration of The Meadows Center for Water and the Environment, the Harte Research Institute, The Nature Conservancy and several other groups, to purchase water for the bays and estuaries of the Texas Gulf Coast. She also chaired the Austin Water Forward Task Force, which developed a groundbreaking 100-year water plan approved unanimously by the Austin City Council in 2018. She holds a Bachelor of Arts in Physics and English from Washington University in St. Louis and a Master in City Planning from the Massachusetts Institute of Technology, where she was a fellow in the MIT-USGS Science Impact Collaborative, focusing on the role of science in multi-stakeholder resource planning and dispute resolution. Sharlene lives in Austin, Texas.

ACKNOWLEDGEMENTS

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We held two convenings with additional City of Austin staff and local environmental non-governmental organizations including representatives from City of Austin's Office of Sustainability; The Meadows Center for Water and the Environment; Urban Patchwork; Keep Austin Beautiful; Tree Folks; Doucet Engineers; Shoal Creek Conservancy; Partners for Education, Agriculture, and Sustainability (PEAS); Public Interest Network; Waterloo Greenway; and The Nature Conservancy.

The views expressed in this report are solely those of the authors and may not reflect the opinions of those who provided input and feedback.

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SUMMARY

The City of Austin, Texas is facing an increasingly uncertain water future—from decreasing water supplies and more intense droughts to periodic flooding and water quality impairments. Austin is addressing these challenges head on, from investments in water efficiency and water reuse to rainwater harvesting and stormwater management.

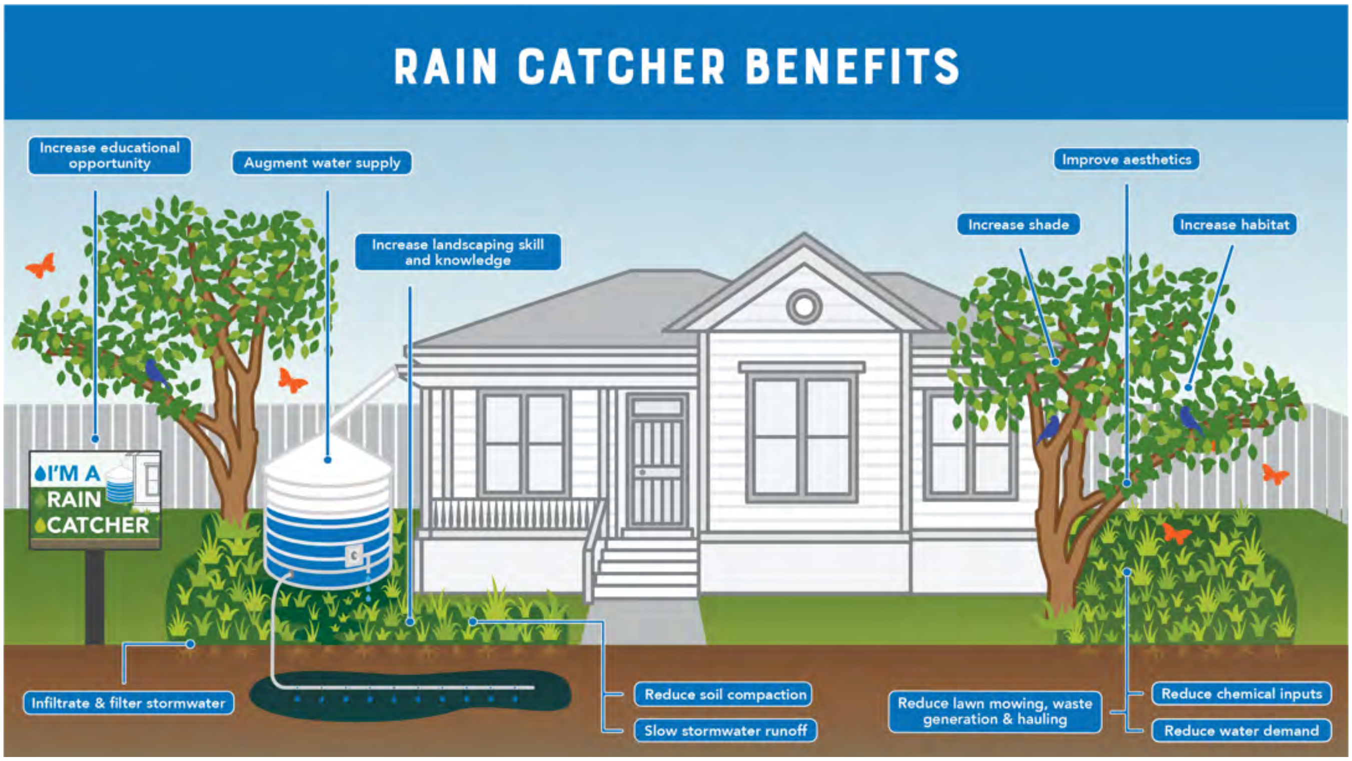
The Rain Catcher Pilot Program

Austin's Watershed Protection Department and Austin Water are working together to pilot green stormwater infrastructure through the Rain Catcher Pilot Program in the headwaters on of the Waller Creek Watershed. The program provides rebates to residents in the upper watershed for installing rain cisterns and rain gardens on their properties, with additional rebates for incorporating trees into the design. Austin Water and the Watershed Protection Department have partnered with Urban Patchwork, a local non-profit, to help residents streamline the design, installation, and payment process for program participants.

Installation of the Rain Catcher Pilot Program on a residential property in the Upper Waller Creek, including a 1000-gallon rain cistern, rain garden, and shade tree.

The Rain Catcher Pilot Program channels rainwater from roofs into cisterns that slowly release the water into rain gardens. This helps to slow runoff from the property by infiltrating water into the soil. By utilizing rainwater for irrigation, residents can improve water supply reliability. In addition, if residents include trees, the program can help increase shading, habitat, and property values. By incorporating native landscaping, residents can reduce their water demand and chemical inputs while reducing the need to mow the lawn. Finally, the program can help to educate neighbors on the importance of rainwater capture and sustainability.

Figure S1. Benefits of Rainwater Capture on Residential Properties



Source: Watershed Protection Department and the Pacific Institute

Who Benefits from the Rain Catcher Pilot Program?

Water and the Environment

If implemented on 75% of properties, the program can reduce **peak flows** in urban creeks by approximately 23% and reduce erosive events by 42%. While energy savings were minimal for pumping and treating water, the program can reduce total **water demand** for irrigation by between 1,2500 and 2,500 gallon per year.

Community

The program can reduce **urban heat island** effect and local **air temperatures** by 0.5°C, leading to reduced **greenhouse gas emissions** from air conditioning by 170 tons of CO2 in the Upper Waller Watershed, and increase **carbon sequestration** in healthy soils and in trees. In addition, the program can provide a resilient and distributed source of water during emergencies.

Residents

Residents will each save $7 per year on their air condition **energy** bills, while reducing **water** bills for irrigating landscapes. While this may not be much for each house, this amounts to nearly $10,000 in local savings in the Upper Waller Watershed. In addition, residents may be able to reduce nuisance flooding in their yards and necessary lawn mowing.

Austin's Urban Forest

Each tree in Austin provides approximately $120 in community and environmental benefits per year, through energy savings, stormwater runoff reduction, air quality improvements, carbon sequestration, and aesthetics. The program can support Austin's tree canopies by planting native trees and providing a more reliable source of water during drought.

How Can You Get Involved?

Residents

While the program is not available yet outside of the Upper Waller Watershed, Austin residents in the Upper Waller Watershed can install rain gardens on their own property. More information can be found here on the City of Austin website.

Non-Profit Organizations

Non-profit organizations can promote rain gardens and rainwater harvesting systems as part of their green stormwater infrastructure work throughout Austin. For more information on collaboration and partnerships, reach out to Urban Patchwork.

Austin City Departments

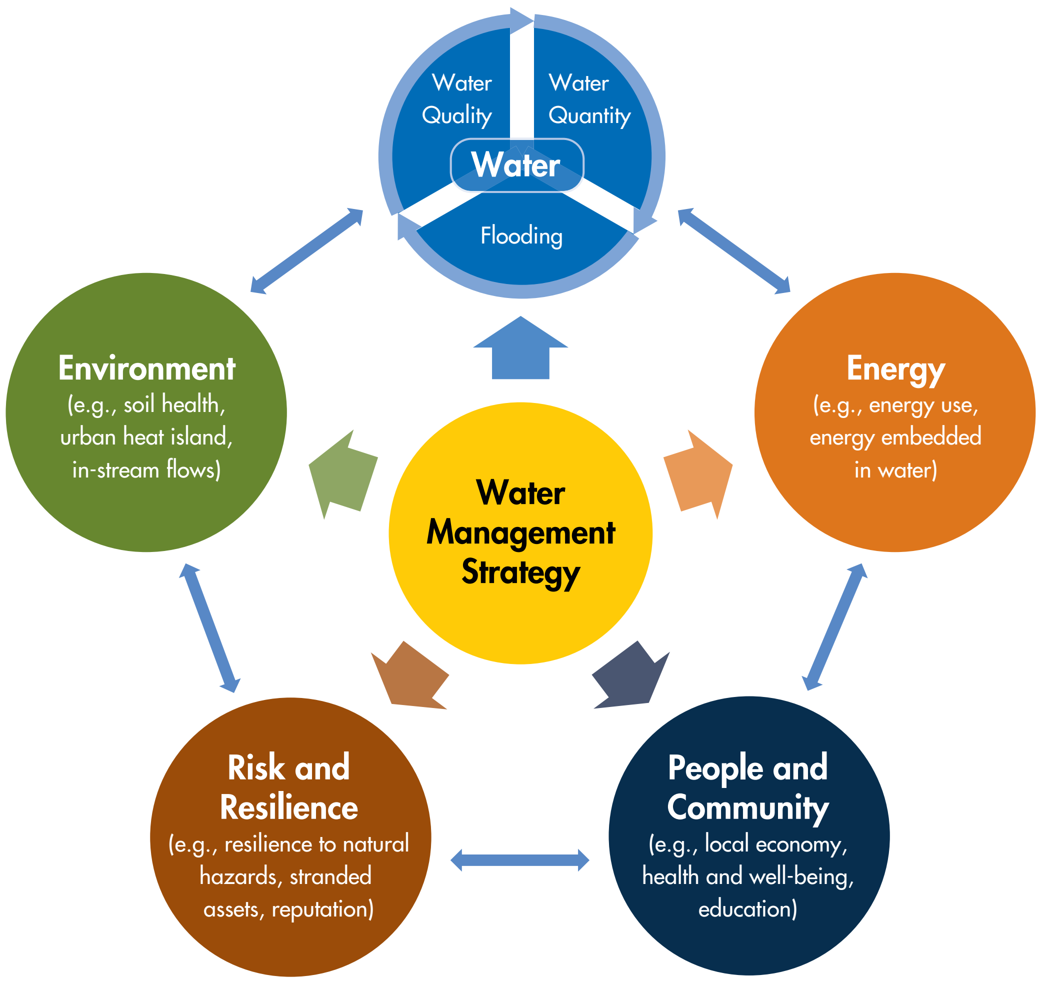
The program has a unique "stackable rebate" that combines incentive programs from several city departments into a single rebate for residents. For city departments interested in learning more about this rebate program, contact the Watershed Protection Department.

For more information, visit the Rain Catcher Pilot Program website.

A Multi-Benefit Approach to Water Management

This resource was developed by the Pacific Institute in collaboration with Austin Water Protection Department, the National Wildlife Federation, and Texas Water Trade as part of the Pacific Institute's Multi-Benefit Initiative. Public agencies, water utilities, and communities throughout the United States acknowledge the importance of multi-benefit water projects, yet there is no standardized approach for systematically identifying and evaluating these benefits or additional trade-offs. Researchers at the Pacific Institute and the University of California, Santa Barbara have developed a framework to help water managers identify, evaluate, and communicate the multiple benefits of water management. More information is available at the Pacific Institute website.

Figure S2. Benefit Themes for Identifying Relevant Benefits and Trade-Offs of Water Management Strategies



Source: [Diringer, et al. 2019]

INTRODUCTION

The City of Austin, Texas is facing an increasingly uncertain water future—from declining water supplies and more intense droughts to periodic flooding and water quality impairments. Several citywide planning efforts seek to address these challenges, including the Water Forward Plan, a 100-year plan to ensure adequate water supplies for a growing city; a Climate Adaptation Plan produced by the Office of Sustainability; and a Watershed Protection Master Plan to address flooding, erosion, and water quality impairments in the city.

At the same time, there are projects that could be implemented in Austin to meet multiple objectives identified in these plans. For example, green stormwater infrastructure (GSI), such as rain gardens, bioswales, and cisterns, are often implemented to slow and infiltrate stormwater, thereby improving streamflow in urban creeks and reducing runoff. In addition, they provide an alternative water supply for irrigation and improve climate resilience to drought or water supply challenges. In addition to helping support these citywide planning goals, research has shown that GSI projects provide additional economic, social, and environmental benefits, including improved soil health and biodiversity, reduced local air temperatures, community engagement, and others.

Source: Carlos Alfonso, Unsplash

Over the past year, researchers at the Pacific Institute collaborated with the National Wildlife Federation and Texas Water Trade, as well as city staff in Austin, to understand the multiple benefits provided by GSI in Austin. Using the Pacific Institute's Multi-Benefit Framework, we identified the potential benefits of rainwater capture in Austin, quantified several project benefits, and examined how these benefits could be used to develop partnerships with additional city departments and encourage residents to install rainwater capture systems.

In this report, we describe our work to engage with stakeholders and identify, evaluate, and communicate co-benefits of rainwater capture in Austin, using the Rain Catcher Pilot Program (RCPP) as an example. The purpose of this report is to provide city staff in Austin and throughout the United States with a template for understanding the benefits provided by water-related projects and how to mitigate potential trade-offs. In addition, we hope the report helps Austin's water managers determine the scalability of a local rainwater capture program and supports community groups and non-governmental organizations (NGOs) in advocating for sustainable water management projects.

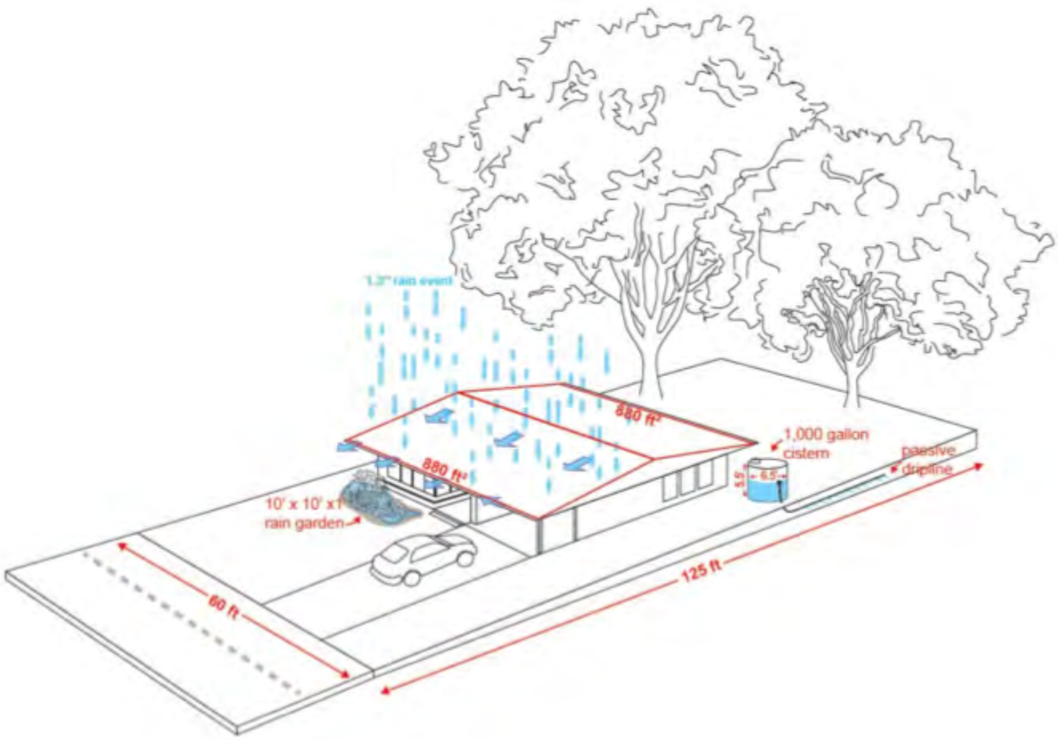
Rain Catcher Pilot Program

Austin's Watershed Protection Department (WPD) and Austin Water are implementing GSI through the RCPP, which installs GSI on public and private property, including schools, public land, commercial properties, and residential properties. We focused this test case on describing the multiple benefits and trade-offs of the residential portion of the program, which includes large cisterns with a rain garden and trees (Figure 1).[1] The RCPP is a collaborative outreach and rebate program designed to remove barriers for the adoption of rainwater harvesting systems and rain gardens. It combines three separate rebate programs: (1) rainwater cisterns and rain gardens from Austin Water, (2) rain gardens from WPD, and (3) trees through the Urban Forestry program. The city has partnered with local environmental NGOs to streamline the funding process, coordinate the design and installation, and support outreach for the program.

The RCPP is being piloted in the Upper Waller Watershed (referred to as WLR-3), a predominately residential area north of downtown Austin (Figure 2). The watershed is approximately 1 square mile and contains 46% impervious surface. The residential program was first offered as a pilot to 25 residents in WLR-3 in 2018-2019 and will expand by approximately 450 homes per year in 2020-2022. In 2023, the program will be available to all residential homes in the Upper Waller Watershed. While rain capture is not likely to mitigate a 100-year flood event, the goal of the pilot program is to determine if these interventions can effectively improve watershed health, reduce localized flooding, and provide additional benefits to residents and communities.

1 The size of the cisterns depends on roof size and owners' preferences, and are likely to range from 500-1000 gallons.

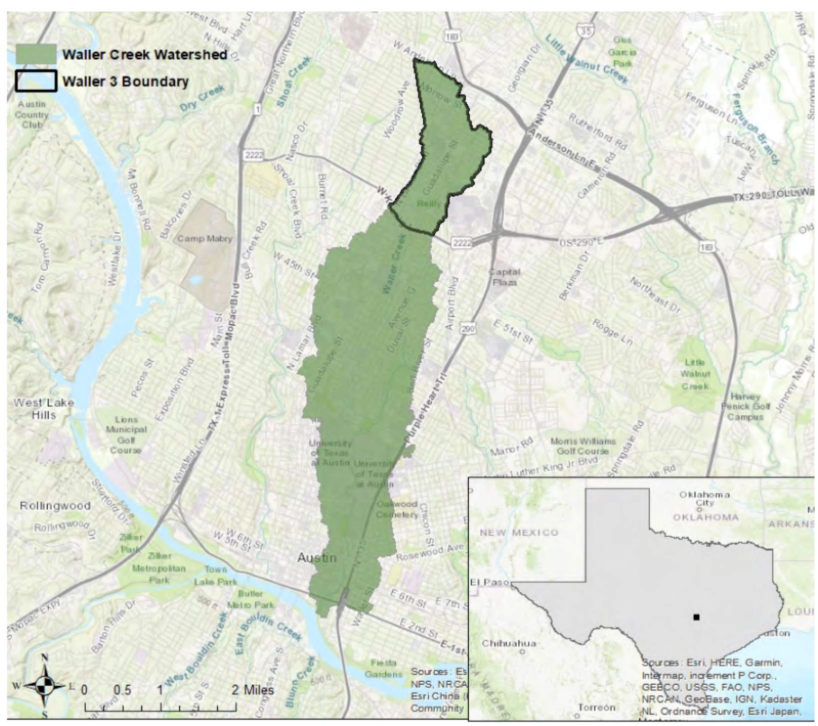
Figure 1. **Schematic of the Rain Catcher Pilot Program Implemented on a Residential Property, Including Rain Garden and Cistern with Passive Dripline**



Source: Austin Watershed Protection Department

Figure 2. **Map of Upper Waller Creek Watershed, North of Downtown Austin**

Source: [Brown, Culbert, Gorchels, and Odion (2020)]

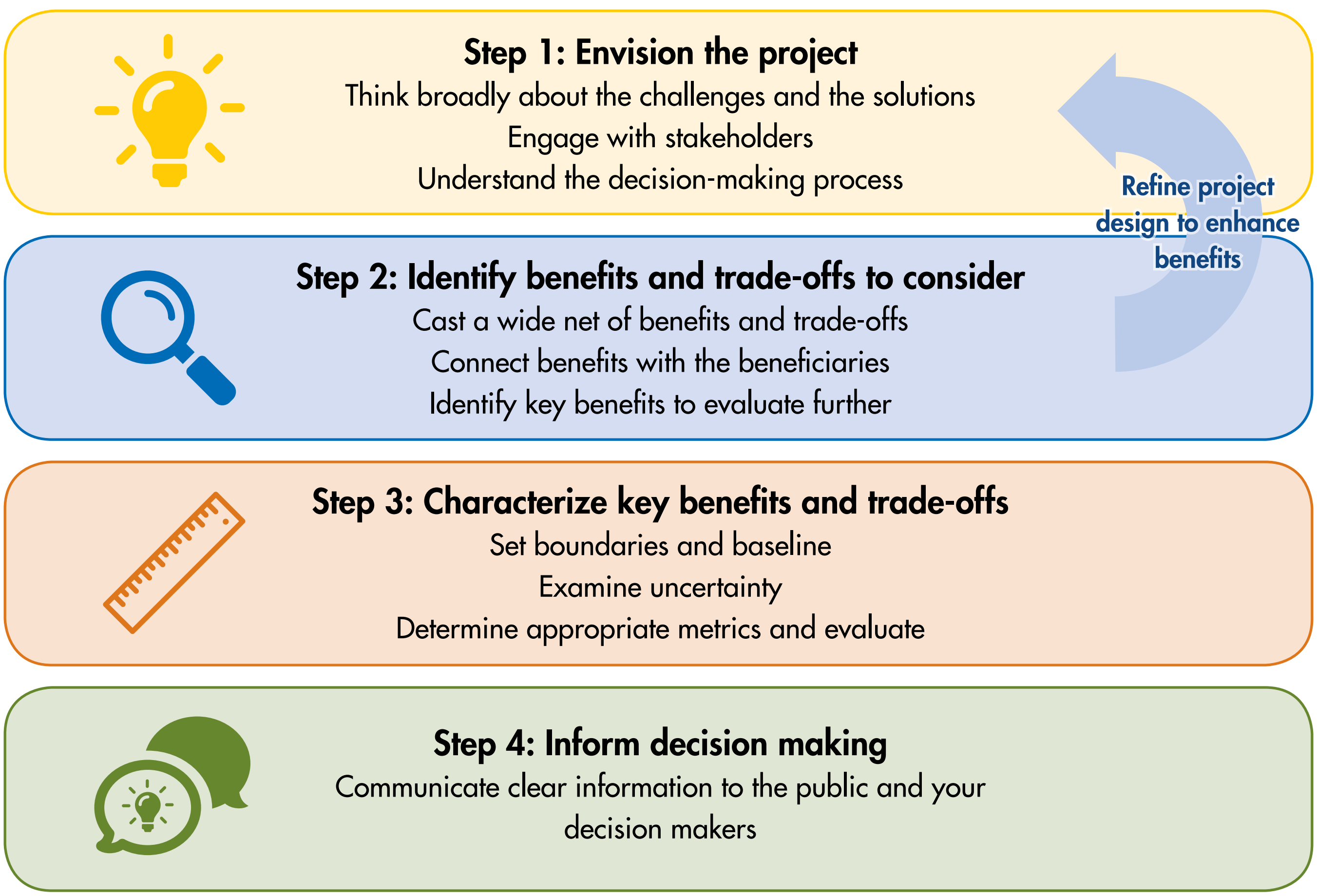


A Multi-Benefit Approach to Water Management

To better incorporate multiple benefits into the RCPP, we applied a Multi-Benefit Framework developed by the Pacific Institute and researchers at University of California, Santa Barbara. The Multi-Benefit Framework provides a stakeholder-driven process for incorporating co-benefits and trade-offs into water management decisions (Diringer et al. 2020). The framework includes a four-step approach, including (1) defining the project vision and options, (2) identifying benefits and tradeoffs, (3) characterizing key benefits and trade-offs, and (4) informing decision making. The steps are meant to be flexible and adaptable for a range of water management options. Incorporating the entire process or key components can help to achieve more transparent, systematic, and informed decisions.

The *first step* in the Multi-Benefit Framework is to identify the goals of the project and potential project alternatives. Water managers begin to determine relevant stakeholders, including property owners, community members, local and regional government agencies or departments, and businesses. As a result of this step, water managers can clearly define the project goals, plan for the decision-making process and stakeholder engagement, and develop a list of potential management strategies to pursue.

Figure 3. Multi-Benefit Framework Steps Toward Informed Water Management Decisions



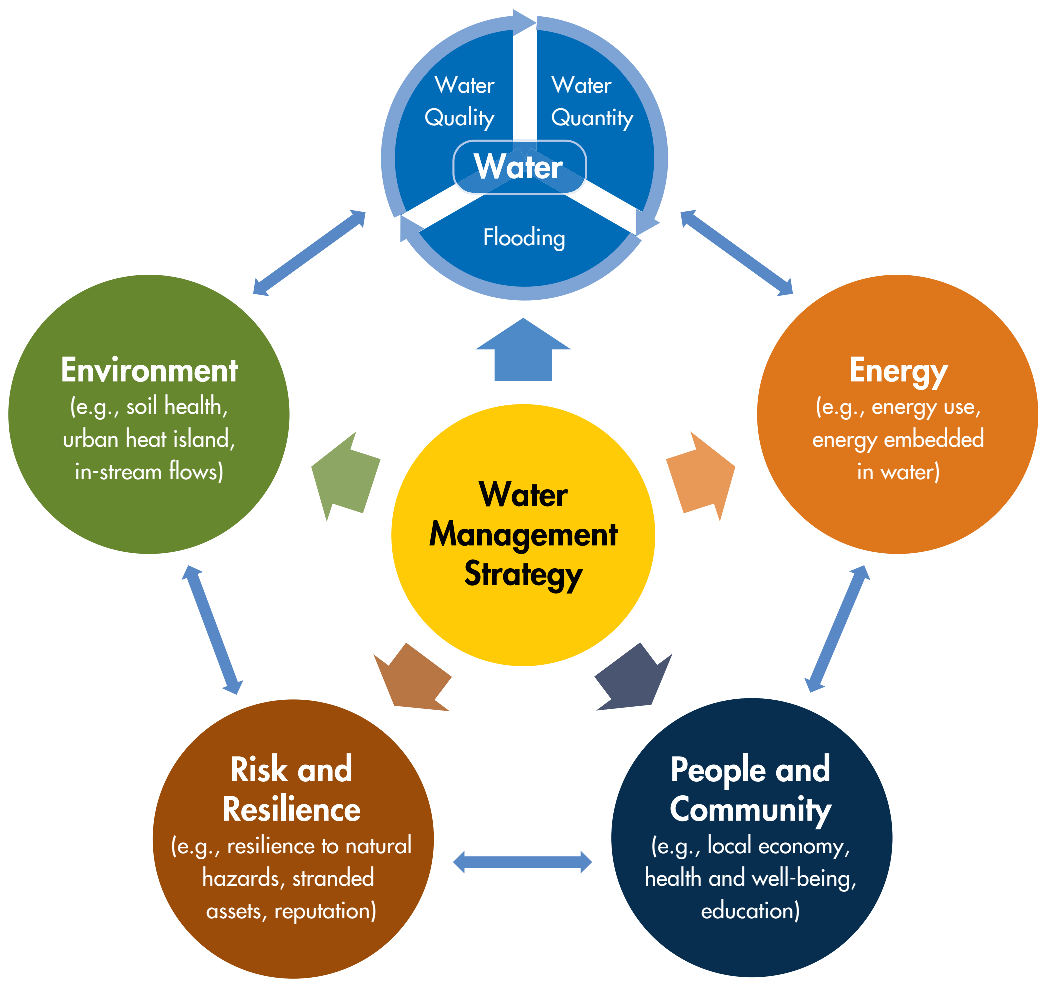
Source: Diringer, et al. 2020

The *second step* is to determine the potential benefits and trade-offs of the project options. To facilitate this process, we defined five benefit themes: (1) Water; (2) Energy; (3) Environment; (4) People and Community; and (5) Risk and Resilience (Figure 3). These themes provide a starting point for identifying and organizing benefits and costs more methodically and transparently. Stakeholders play a particularly important role in this step because they can help determine the benefits of greatest interest to them, as well as potentially concerning trade-offs.

The *third step* of the framework is to characterize the benefits and costs of the project. While there are many potential benefits, finding good-quality data to assess each benefit can be a challenge. However, there are methods and tools available for conducting quantitative and qualitative analyses of specific benefits and costs (e.g., an ecosystems services analysis) and for integrating these results into a comprehensive assessment (e.g., a benefit-cost analysis).

Finally, the *fourth step* of the framework is to inform decision making through translating and communicating results of the analyses to decision makers and stakeholders. As a result of this step, stakeholders should have a better understanding of benefits and trade-offs of each project option,

Figure 4. Benefit Themes for Identifying Relevant Benefits and Trade-Offs of Water Management Strategies



Source: Diringer, et al. 2019

and decision makers should be equipped to make an informed and transparent decision.

In this test case, we worked through each of the steps provided within the framework to provide a systematic approach for assessing benefits and trade-offs within the RCPP. As a result of this process, water managers can more easily identify opportunities to share costs among project beneficiaries; discover design improvements that can leverage additional benefits; identify the need for any mitigation strategies; engage with stakeholders to increase the transparency of decision-making processes; and increase overall support for the project.

Installation of the Rain Catcher Pilot Program on a residential property in the Upper Waller Creek, including a 1000-gallon rain cistern, rain garden, and shade tree.

STEP 1: DEFINING THE PROJECT VISION AND GOALS

The RCPP was initially designed as a collaborative, multi-benefit project. WPD was interested in reducing in-stream erosion and improving baseflow duration, while Austin Water was interested in augmenting local water supplies. Given these interests, WPD began modeling the impacts of the proposed pilot to determine if increased uptake of rain gardens and cisterns could reduce erosion in local waterways and restore creek flow while improving water supply reliability.

While the pilot was initially designed around these goals, new design options emerged as additional departments and partners were engaged. For example, while WPD may not have been able to justify installing additional trees on properties, the Urban Forestry program could clearly articulate how tree installation would help meet their departmental goals. In the current pilot, residents can select from rain gardens and rainwater cisterns. By engaging with Urban Forestry, the implementation of rain gardens may include climate-appropriate landscapes and/or trees. We also identified additional city departments that can be engaged in the design and implementation phases of the pilot.

While city departments are contributing to aspects of the RCPP, the program allows residents to decide on the GSI designs for their properties. For this reason, there are four primary decision makers that need to be engaged in the RCPP from design to implementation and scaling: city staff, the city council, Austin residents and homeowner’s associations, and non-profit organizations and philanthropies who work to implement and fund green infrastructure. We found that each of these decision makers needs different information in order to make an informed decision. In addition, the information may need to be presented differently to each group. Through interviews and stakeholder meetings, we identified the preferred decision-making process and form of communication for each.

- City departments in Austin often respond to detailed consideration of the project. Some departments, including WPD, are especially data driven and need to see quantitative information for a pilot project or to scale the program.
- Austin City Council members are likely to respond to seeing how the benefits of the program align with the missions of city departments (e.g., water, energy, WPD, public health) and comprehensive plans, such as Imagine Austin and Strategic Direction 2023.
- Austin residents and homeowner associations respond to professional, glossy guides with references, including an easy-to-understand "how to" manual for implementing the projects.
- Environmental non-profits requested access to easy-to-digest information that connects the program to their environmental or community goals, and information that could be incorporated into funding proposals and conveyed to funders. This might include single sentences describing the benefits of the program, and how their contribution can help to advance this work.

Understanding the decision makers and the decision-making process for each stakeholder at the beginning of the process guided our analysis and communication for the benefits and trade-offs of project options.

Source: US EPA

Installation of a raingarden in a metropolitan area.

STEP 2: IDENTIFYING THE BENEFITS AND BENEFICIARIES

In addition to meeting the primary goals identified by WPD, Austin Water, and Urban Forestry, distributed rainwater capture systems provide additional co-benefits, such as reducing the urban heat island effect, improving climate resilience, and reducing energy use and greenhouse gas emissions. Identifying co-benefits of the RCPP can help to engage additional partners and generate support for the project. Moreover, it may help to recruit homeowners for the program and scale uptake on residential properties. This process is explored in more detail in the following sections.

Defining Potential Benefits

We examined the benefits provided by the RCPP by considering the outputs and outcomes from each project. Water management strategies can alter natural or social "processes" that can then lead to a broad range of benefits. For example, rain gardens can increase stormwater infiltration, which can reduce peak flows in nearby creeks and standing water on the property. Or, reducing chemical inputs to the landscape could improve water quality, reduce energy consumption for manufacturing, and improve soil health. Here, we outline how the activities and processes can lead to potential benefits or trade-offs.

Activity: The management strategy implemented (e.g., rain garden and/or cistern, with or without trees).

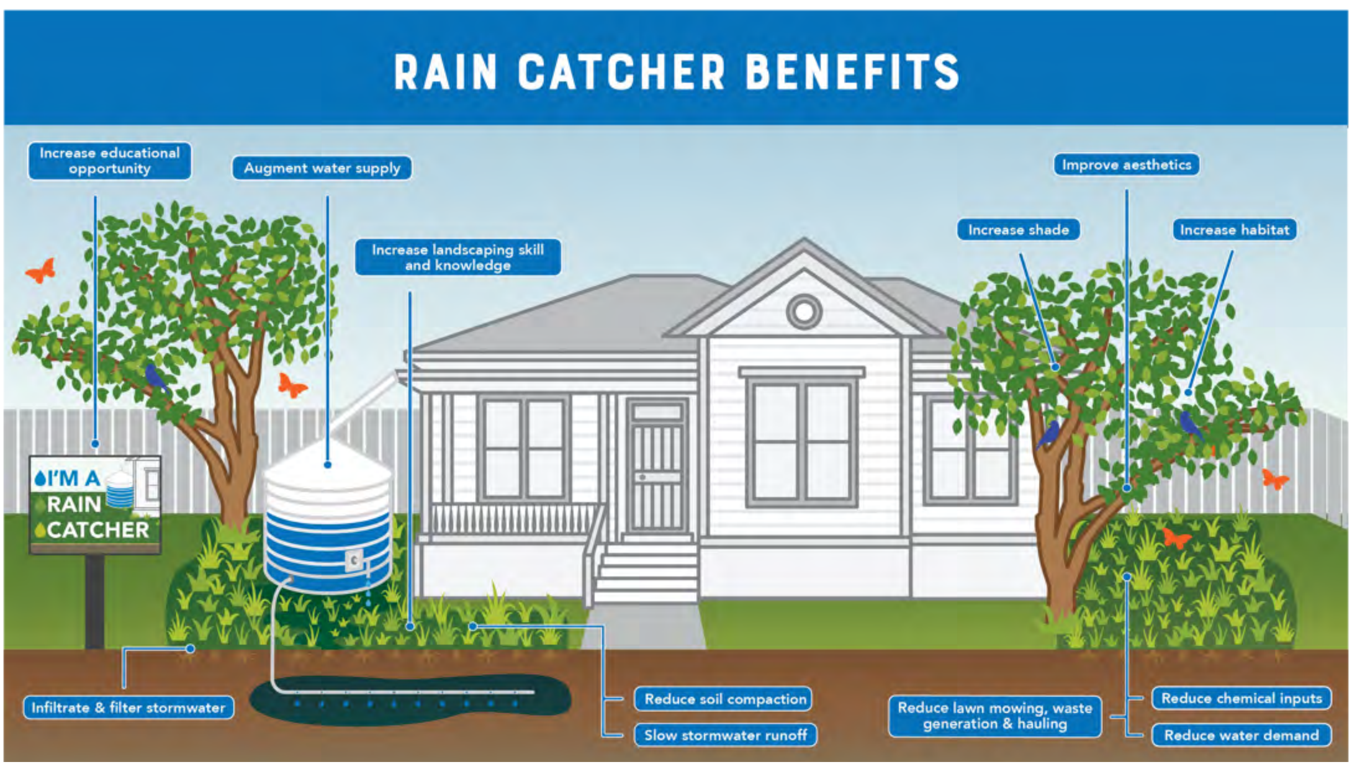
Outputs: The change in physical or operational processes that result from the selected activity, assuming effective implementation of the activity.

Outcomes: The benefits and trade-offs that result from an activity.

Benefits of Greatest Interest: The outcomes from an implemented project that are of greatest interest to the stakeholders.

To identify the potential benefits of cisterns and rain gardens on residential properties in Austin, we first identified the processes affected (i.e., what does the strategy do?) and then examined the benefits and trade-offs that may result from these changes (Table 1; Figure 5; Appendix A). There are a variety of implementation options for these systems, and therefore we examined the outputs and outcomes provided by each of the

Figure 5. **Basic Sketch of the Rain Catcher Pilot Program Implemented on a Residential Property, Including the Processes and Outputs**



Source: Watershed Protection Department and the Pacific Institute

Table 1. Rain Capture Processes and Potential Benefits for Several Rainwater Capture Implementation Strategies

Processes	Outputs	Outcomes (i.e., Benefits and Trade-offs)	Activity Options			
			RGC	RGCW	RGCW + CAP	RGCW + Trees
Infiltrate and filter stormwater	Reduce contaminant runoff	Improve water quality, meet regulatory targets, improve environmental quality	X	X	X	X
	Reduce localized flooding	Reduce water damage, reduce mosquito breeding*, improve relationships with owners/ residents, improve neighborhood reputation, improve home values, avoid infrastructure costs	X	X	X	X
	Recharge groundwater	Support in-stream flows/extend baseflow	X	X	X	X
	Increase soil moisture	Improve plant health, reduce water demand, reduce urban heat island effect	X	X	X	X
Store and use rainwater	Increase site-level resilience	Reduce risk of water supply shortfalls, personal resilience, allow for irrigation reliability		X	X	X
	Augment local water supply	Reduce water withdrawals, improve water supply reliability, increase stream flows, reduce energy usage, avoid cost of new supply, reduce risk of water supply shortfalls	X	X	X	X
Slow stormwater runoff	Reduce erosion in-stream	Improve water quality, improve stream bank resilience	X	X	X	X
	Extend baseflow in-stream	Increase biodiversity, improve water quality	X	X	X	X
	Reduce localized erosion	Improve soil and tree health	X	X	X	X
Enhance green space	Increase total green space	Reduce impact of impervious area and impervious area fee	X	X	X	X
	Increase native habitat	Increase biodiversity			X	X
	Improve usability by people	Health and well-being, recreation, increase engagement with environment, support for local economy, house values	X	X	X	X
	Improve aesthetics	Health and well-being, house values			X	X
	Decrease total water demand	Meet water conservation goals, improve water supply reliability, reduce energy consumption for water extraction/treatment/transport	X	X	X	X
	Increase biomass	Reduce greenhouse gas emissions, increase soil carbon			X	
	Reduce chemical inputs (pesticide and fertilizer)	Improve water quality, reduce energy consumption for manufacturing, improve soil health			X	
	Increase shade	Reduce urban heat island effect, increase soil moisture			X	X
	Reduce soil compaction	Improve soil carbon and soil moisture	X	X	X	X

Continued on Next Page

Table 1 (Continued). Rain Capture Processes and Potential Benefits for Several Rainwater Capture Implementation Strategies

Processes	Outputs	Outcomes (i.e., Benefits and Trade-offs)	Activity Options			
			RGC	RGCW	RGCW + CAP	RGCW + Trees
Change how people interact with, use, and maintain system	Build neighborhood relationships	Improve community resilience	X	X	X	X
	Reduce lawn mowing	Reduce gas/energy input, improve air quality, reduce greenhouse gas emissions, improve health			X	
	Reduce landscape maintenance	Cost savings, more time for recreation			X	X
	Support green jobs	Improve local economy	X	X	X	X
	Decrease hardware purchasing/ maintenance	Cost savings, more time for recreation			X	X
	Increase public education through signage/ programing	Improved public education, increase environmental stewardship	X	X	X	X

Notes: Strategies include rain garden and cistern with passive irrigation (RGC), rain garden and cistern with water used directly by resident for irrigation (RGCW), and implementation of rainwater capture with climate-appropriate plants (RGCW + CAP) or Trees (RGCW + Trees). (*) indicates a benefit only if implemented with intentional design.

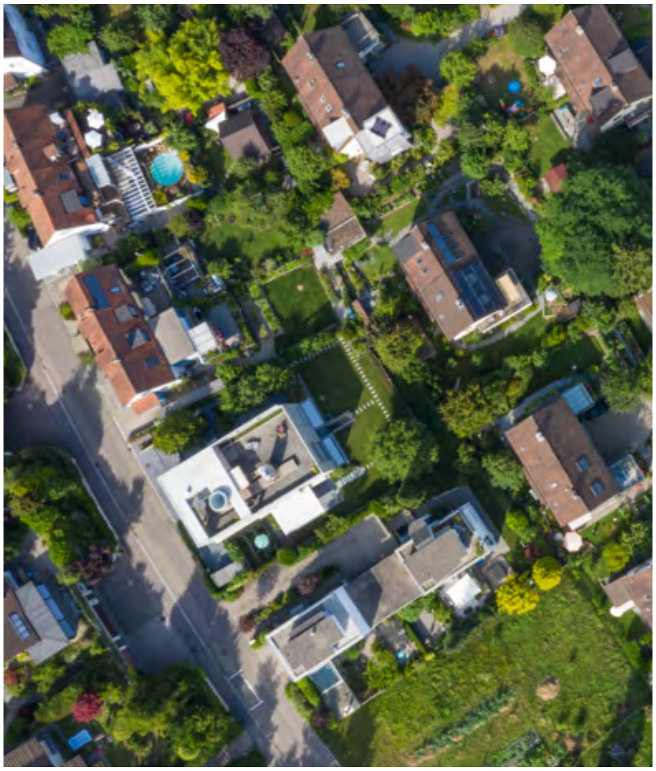
options. They are organized in a table to allow for better comparison among project options and to help stakeholders identify the benefits that are of particular interest to them.

It is important to note that these projects likely need to reach greater penetration before measurable benefits are achieved. For example, a single tree on a property may cool a house by providing shade but is not likely to substantially help cool air temperatures throughout the community. WPD staff are modeling implementation approaches to determine the scale at which the program needs to be implemented (e.g., 25%, 50%, or 75% uptake by residences) to achieve departmental goals. This process can be applied to other benefits to understand the importance of scaling.

Connecting Benefits and Beneficiaries

In addition to identifying the benefits, we sought to connect the benefits with potential beneficiaries. Many of the co-benefits will accrue to different stakeholders. For example, energy savings from reducing potable water demand will not directly affect a resident's energy bill but would reduce the water utility's energy bill. Conversely, shading a home can provide a direct benefit to a resident by reducing energy for air conditioning on hot days.

Designing the program with stakeholders in mind is especially important for the RCPP because the systems are installed on residential properties and require buy-in from community members and city staff. In addition, NGOs play an important role in the RCPP because they engage directly with



Source: Florian Schmid, Unsplash

much of the community and are the organizations physically installing these systems. The key stakeholders for the RCPP in Austin include (but are not limited to):

- Austin City Departments: WPD, Austin Water, Office of Sustainability, Austin Energy, Public Health, Urban Forestry, Parks and Recreation Department, Economic Development Department, Public Works Neighborhood Partnering Program, and Innovations Office
- Austin City Council Members
- Residents: Homeowners, Renters, and Neighborhood Associations
- NGOs: Tree Folks, Urban Patchwork, Children in Nature Collaborative of Austin, The Nature Conservancy, Austin Parks Foundation, Austin Youth River Watch, and Partners for Education, Agriculture, and Sustainability.

During this step, we interviewed project partners at the City of Austin and NGO stakeholders to understand the benefits of greatest interest to each of them. In addition, ongoing survey efforts allowed us to understand the benefits to and preferences of local residents and homeowners. These benefits of greatest interest were then used to update potential project designs to achieve those benefits, and communications materials to highlight the benefits of greatest interest to each stakeholder group. While we did not engage with all relevant stakeholders, additional interviews could help to leverage additional benefits for stakeholders, potentially leading to partnerships and opportunities to scale the project. Below, we describe our findings for each of the primary stakeholder groups.

ENGAGING WITH THE PUBLIC SECTOR

WPD developed the RCPP to determine if GSI could effectively reduce the need for expensive, centralized stormwater infrastructure and provide additional benefits, while increasing public awareness of watershed challenges and solutions. They combined efforts with Austin Water's existing GSI rebate program, which is primarily focused on reducing local water demand and increasing water supply reliability.

In addition to WPD, Austin Water, and Urban Forestry, there are other city departments interested in scaling GSI and the RCPP that could be program partners. The Office of Sustainability, for example, connects different city departments and entities that have a role in sustainability. In 2018, the Office of Sustainability published a Climate Resilience Action Plan for city assets and operations, which relied on building relationships and engaging with Austin Water, WPD, and other city departments. Office of Sustainability staff expressed that they were particularly interested in the potential ecological impacts of climate change and how native trees and habitat can help to build

Source: City of Austin, Watershed Protection Department

Newly installed rain cistern in the Waller Creek Watershed, Austin, Texas

resilience. Similarly, there is a strong interest in understanding how programs can support equity in Austin and provide green space and resources to under-resourced communities.

Austin Energy may also be a potential future RCPP implementation partner based on potential energy savings from water treatment and distribution facilities and air conditioning usage. WPD and Austin Water can continue to advance the RCPP and similar projects by understanding and communicating the benefits of the programs and connecting them to other departments and interdepartmental efforts.

ENGAGING WITH RESIDENTS

WPD and their partners have surveyed residents to understand their barriers and motivations. A recent study surveyed residents on their interest in GSI and obstacles to adoption (Johnson 2017). While residents were generally willing to install GSI, the primary obstacles were cost, maintenance, and the need for help with installation. The study also found that residents would be more in favor of adopting GSI if the direct benefits of those strategies is presented clearly (i.e., reducing yard maintenance time or cost).

Conducting surveys and engaging in more in-depth conversations with residents would allow WPD and others to identify and communicate the direct benefits of programs to residents. As a part of this project, The Nature Conservancy is conducting surveys and in-depth interviews with residents that will provide additional information on which benefits can be used to help support the decision-making process. Initial findings indicate that residents are particularly interested in addressing on-site drainage concerns, reducing water use for irrigation or gardening, and creating a more "natural" yard that requires less maintenance. As the program evolves, understanding and communicating these benefits will become increasingly important.

ENGAGING WITH NGOS

The NGO community in Austin is diverse. We focused on engaging with NGOs familiar with GSI because they will be instrumental in working with residents and installing these systems. In a group discussion with local environmental NGOs in Austin, attendees identified the need to quantify benefits and trade-offs, as well as effectively communicate those benefits to residents, city council members, and funders.

The NGOs we spoke with were interested in all benefit themes and took a "systems view" of GSI, given the way it impacts everything around it. Benefits of GSI that generally came to the forefront of these conversations included:

- **Water**: Water quality, water supply, and flood control
- **Environment**: Ecological function, plant health, tree canopy, and greenhouse gas emissions reductions
- **Energy**: Reduced energy use for air conditioning
- **Community**: Resilience, user experience, stewardship, aesthetics, workforce development, and reduction of urban heat island effect
- **Risk and Resilience**: Community resilience and ecosystem resilience

In addition, the NGOs we spoke with acknowledged the potential trade-offs of green infrastructure. For example, NGOs responsible for maintaining GSI systems expressed concern about training crews and volunteers to adequately maintain new types of infrastructure. Some NGOs were concerned that GSI could exacerbate gentrification and that parks might increase crime and safety challenges, including the need for increased feces abatement and trash control. While many felt these trade-offs did not outweigh the benefits, acknowledging them can help to identify potential mitigation strategies that may be required prior to scaling.

The Role of Equity in Identifying Benefits and Trade-offs

Many of the stakeholders engaged felt that equity was an important lens to apply during project and program development. More specifically, two considerations were identified:

1) Where should project locations be targeted and installed to maximize benefits for communities with the greatest need?

There are potentially local benefits of the RCPP, including reductions in on-site nuisance flooding, increases in tree canopy, and reductions in urban heat island effect. Identifying the areas of greatest need in a community can help to determine where to target these programs in the future.

2) What might prevent interested, low-income residents from engaging in the project?

Some of the residents who want to participate in the RCPP may not be able to because of existing challenges on the property, income limitations, life stress, etc. For example, if the roof is failing or no rain gutters are installed, a homeowner or renter may be less likely to install a cistern and rain garden.

These two questions were continuously asked during project design and implementation phases in order to improve the equitable distribution of benefits. While the RCPP is currently being piloted, these questions will play an important role in determining how to scale the program in an equitable way throughout the city. In the future the program will likely include a pathway for community members enrolled in the Community Assistance Program with the City of Austin utilities to obtain additional assistance.

Key Benefits for Stakeholders and Decision Makers

The RCPP provides many potential benefits of interest to stakeholders. By examining the priorities of city departments and interviewing project partners and stakeholders, we identified the benefits of greatest interest to each (Table 2).[2] These benefits can be prioritized for characterization during Step 3 (Characterizing Key Outputs) and

2 The residents in the RCPP consist of a diverse range of community members that have many interests. Therefore, we listed them only for the benefits that may accrue on-site to them. We acknowledge that many will likely have interests beyond just the direct or on-site benefits.

Table 2. Key GSI Benefits of Interest for Stakeholders in Austin

Theme	Benefit	Stakeholder Interested
Water	Minimize erosive events	WPD
	Reduce nuisance flooding on-site	WPD, residents
	Reduce water pollution	WPD
	Reduce water demand	Austin Water, residents
	Augment water supply	Austin Water, residents
Energy	Energy for water treatment and delivery	Austin Energy, Austin Water
	Energy related to heating/cooling buildings	Austin Energy, residents
Land and Environment	Improve habitat and biodiversity	Environmental NGOs, Development Services Department (Forestry), WPD, Office of Sustainability, Parks and Recreation Department
	Improve air quality	Office of Sustainability, Austin Health Department, Austin Energy, Environmental NGOs
	Improve in-stream flows, extend hydrograph	WPD, Environmental NGOs
	Greenhouse gas emissions reduction and sequestration	Office of Sustainability, WPD, Environmental NGOs
Community Benefits	Reduce urban heat island effect	Parks and Recreation Department, Development Services Department (Forestry), Public Works Department, Office of Sustainability, WPD, Environmental NGOs, residents
	Human health and safety	Austin Health Department, Development Services Department, Public Works Department
	Local jobs	Economic Development Department, Urban Patchwork, residents
	Educational opportunities	Austin Water, WPD, Office of Sustainability, Parks and Recreation Department, Residents, Environmental NGOs
	Improve/reduce on-site maintenance	Residents
	Increase property values	Economic Development Department, residents
Risk and Resilience	Improve reputation for city	City of Austin, residents
	Reduce/defer infrastructure investments	WPD, Austin Water, Austin Energy
	Regulatory compliance	WPD, WPD Policy and Planning Division, Public Works Department, Austin Water
	Climate resilience	Office of Sustainability, WPD, Development Services Department (Forestry)

for communicating with stakeholders during Step 4 (Supporting Decision Making).

Revisiting the Project Options: Examining Opportunities and Trade-offs

Once these benefits were highlighted, we revisited the implementation strategies for two reasons. First, we wanted to know if there were opportunities for implementing the RCPP that could achieve additional benefits. For example, the stakeholder group discussed incorporating incentives or resources for including climate-appropriate plants in the rain gardens to achieve additional water savings.

We also used this opportunity to examine the likely trade-offs among project options. Most notably, the cisterns can be implemented with a slow-release drain that will continuously release water to a rain garden over time. This is likely to achieve the greatest benefits for WPD. However, if the water is slowly released, this may not offset water demand for landscapes as dramatically. Residents are given the option to opt-in for slow-release systems, but it is not required. There may be opportunities to increase the size of the cisterns so that they achieve both goals. WPD is currently examining the optimal size for the cisterns, including opportunities for offsetting water demand. In addition, WPD is considering "smart cisterns" that will empty prior to storm events, to ensure that capacity is available when it is needed to benefit erosive events.

Stormwater infrastructure in the Waller Creek Watershed, combining concrete and natural vegetation, referred to as "gray-green infrastructure."

STEP 3: CHARACTERIZING KEY OUTPUTS

During this step, we worked to characterize the key benefits and trade-offs identified by stakeholders. Given the range of potential benefits of the RCPP, we quantified and described benefits that (1) were not already being evaluated by project partners or stakeholders, (2) have well-described numeric methods, and (3) are of greatest interest to our project partners. This work can be expanded over time as more benefits are quantified and/or determined. These included:

- Reducing urban heat island effect and improving human health
- Energy for water treatment and delivery
- Energy for cooling buildings
- Reducing greenhouse gas emissions
- Carbon sequestration

Water

The RCPP was designed to work in conjunction with traditional stormwater controls to reduce erosive events (i.e., events that can mobilize stream gravel 16 mm or smaller) and improve hydrology in Austin's urban streams. By incorporating smaller infiltration-focused stormwater controls on private parcels, the RCPP has the potential to increase infiltration and improve water quality, as well as reduce peak flows in nearby creeks.

WPD modeled the benefits of rain gardens and cisterns. Using the Soil and Water Assessment Tool with the Green Stormwater add-on, Glick et al. (2016) found improvements in the modeled stream flashiness (i.e., baseflow, peak flow, and rate of change) for all densities of stormwater controls. With adoption of cisterns and rain gardens on 25%, 75%, and 100% of houses in the Upper Waller Watershed, peak flow was reduced


Source: Markus Spiske, Unsplash

by 9.8%, 23%, and 33% respectively. Erosive events were reduced by 14%, 42%, and 63% with adoption levels of 25%, 75%, and 100%, respectively. Other hydrologic metrics did not respond as clearly to different cistern and rain garden adoption levels.

In 2019, WPD expanded this study to compare the benefits of rainwater capture and rain gardens with more traditional stormwater control measures (e.g., sedimentation and filtration stormwater controls) (Porras et al. 2019). When comparing these options, the modeling results were inconclusive on the potential benefits of rain cisterns and rain gardens compared to more traditional controls. However, there are additional co-benefits provided by distributed infiltration methods (compared to more traditional controls). Additional modeling efforts are underway to re-examine the metrics and methods used for comparing distributed and centralized stormwater control methods, as well as to examine additional implementation scenarios.

In addition to restoring urban hydrology, WPD and Austin Water examined the potential for the RCPP to offset potable demand by providing an additional water source to residents for outdoor landscape irrigation. With 1,000-gallon cisterns installed, the program would save approximately 2,500 gallons of water per home annually for residents that use the water directly for irrigating landscapes. For houses that direct the water to a rain garden, rather than use it for irrigating larger landscapes, WPD estimates that the program could reduce water use by 1,250 gallons per year (Austin WPD 2018).

Environment

Many of the RCPP's environmental benefits (improving habitat, biodiversity, and air quality, carbon sequestration, and greenhouse gas emissions reductions) stem from planting trees. The City of Austin has prioritized tree planting and care as part of their long-term vision. In addition, City of Austin staff have dedicated substantial energy to describing the social, environmental, and economic value of urban forests (City of Austin and Urban Forestry Board 2014).

CARBON SEQUESTRATION AND GREENHOUSE GAS EMISSIONS

The RCPP has the potential to sequester carbon through planting additional trees and improving soil moisture and health. Modeling efforts on soil moisture and associated soil carbon are underway at WPD and will improve understanding of these benefits. The benefits of carbon sequestration in trees depends on the type of tree and age. In 2014, Austin's urban canopy included 33.8 million trees and sequestered 92,000 tons of carbon, valued at \$11.6 million per year (Nowak et al. 2016). The value per tree depends on the type of tree and age. In Austin, the value of each tree was estimated to be up to \$150 per tree per year.

In addition to sequestering carbon, trees help to reduce building energy use and associated carbon emissions (Nowak et al. 2016). The greenhouse gas emissions reductions from building energy, as well as savings in energy demand for pumping and treating water, is explored more in the energy theme.

Energy

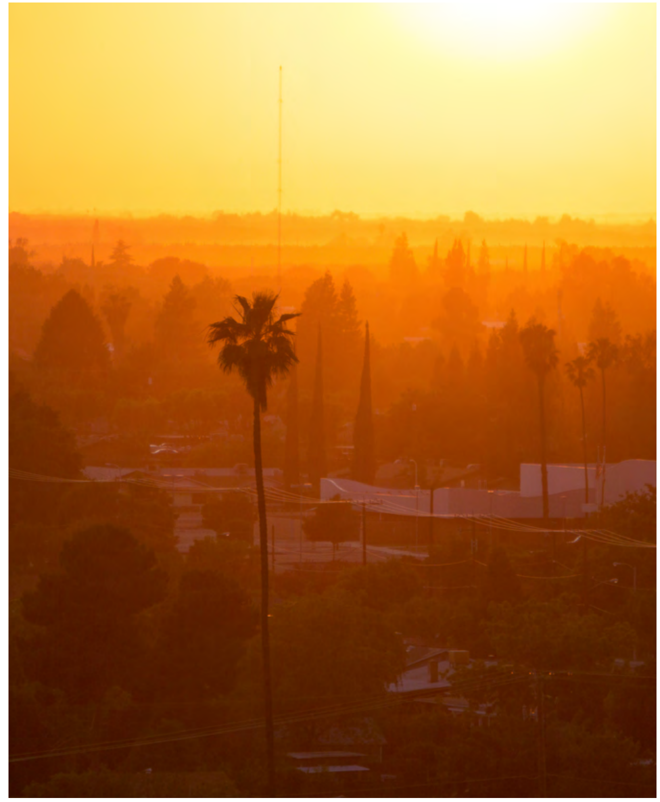
The RCPP can reduce energy consumption in Austin by reducing energy used to treat and distribute potable water, and to cool buildings.

ENERGY FOR WATER TREATMENT AND DISTRIBUTION

The RCPP could offset potable water demand by allowing residents to use water captured in cisterns for landscape irrigation. Reducing potable demand will also decrease energy costs and carbon emissions for water treatment and distribution. Using the Water Energy Simulator (WESim), we quantified the energy savings from reducing water demand for irrigation. The RCPP has the potential to reduce Austin Water's energy usage by 2.2 – 2.8 kWh per 1,000 gallons of water saved, and Austin Energy's carbon emissions by 0.002 tons CO2eq per 1,000 gallons (detailed analysis in Appendix B). For reference, a household refrigerator uses between 400 and 2,600 kWh per year (Energy Star n.d.), so these energy savings are not likely to sway stakeholders. However, depending on the volume of potable water offset by the cisterns, the RCPP has the potential to reduce energy use and carbon emissions throughout the city.

URBAN HEAT ISLAND EFFECT AND ENERGY FOR HOUSEHOLD COOLING

Air temperatures in cities are substantially higher than in adjacent rural areas. In the United States, the average difference can be as much as 16°F



Source: J. Carl Ganter, Circle of Blue

for severely affected cities (Imhoff et al. 2010). This phenomenon, known as urban heat island effect, results from differences in surface heat reflection and absorption. High levels of dark, impervious surfaces, lack of vegetation, and urban geometries increase heat absorption and decrease evapotranspiration. This leads to increases in temperature and thermal discomfort. Increased thermal discomfort can cause psychological stress, decrease productivity, and lead to death in vulnerable populations (Kjellstrom, Holmer, and Lemke 2009; Kovats and Hajat 2008; Poumadere et al. 2006).

In Austin, satellite imagery shows increased land surface temperatures in the urban core of Austin, especially when compared to surrounding areas (Figure 6) (Karimipour 2017; Richardson 2015). While Austin does not exhibit the most extreme urban heat island effect, it could be worsening through climate change and increasing urbanization. Rapid development over the last 30 years has increased Austin's daily average temperature by 5°F (Karimipour 2017).

The RCPP project may reduce temperatures both on individual properties and on a neighborhood scale by increasing irrigation, soil moisture, and tree cover. Individual homes incorporating trees to increase shading could see multiple-degree reductions and accordingly lower energy bills (Akbari, Pomerantz, and Taha 2001). We used the Surface Urban Energy and Water Scheme (SUEWS) to evaluate the project's impact on air temperature, considering high, middle, and low implementation (25%, 50%, 75%) (Sun et al. 2019). These temperature reductions were converted to energy reductions using the difference in days that require centralized cooling using the method of Deschênes and Greenstone (2011). Residential energy reductions for 2017 scenarios were calculated using the City of Austin's energy rates and average annual household energy consumption.

Modeling in SUEWS indicates that RCPP projects could reduce average temperatures in the Upper Waller Watershed pilot area by up to 0.5°F when fully implemented. Wide adoption of RCPP and other green infrastructure could help reduce or mitigate urban heat island effect throughout the city, leading to improved air and water quality, decreased energy loads, increased productivity, and improved vulnerable population resilience.

We found that the RCPP has the potential to reduce average air temperatures by approximately 0.6°F in 2050 and reduce peak temperatures by 1.3°F on high temperature days. As a result, the RCPP is expected to reduce energy consumption by between 46 and 84 kWh/year for each household, equivalent to a \$5-\$9 savings for customers on their annual energy bills (Table 3). When aggregated across 1,200 homes, total annual energy savings ranges between 55,000 kWh (low implementation scenario) and 100,000 kWh (high implementation scenario), equivalent to between \$5,800 and \$11,000 of annual savings. When converted into reductions of greenhouse gas emissions, the RCPP is expected to save between 110 (low implementation scenario) and 200 tons (high implementation scenario) of CO2 equivalent annually.

Figure 6. **Relative Land Surface Temperatures Delineated by Relative Intensity in Austin Delineated by Census Tracts, with Darker Red Representing Warmer Land Surface Temperatures**

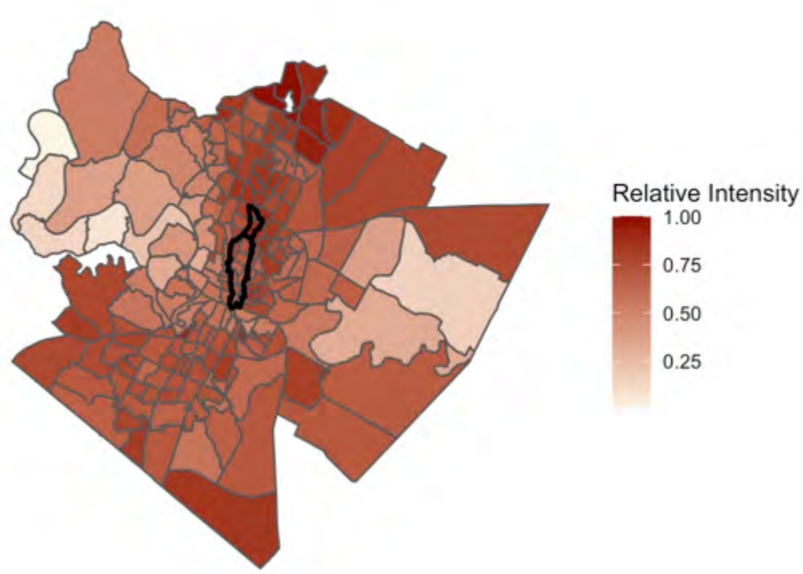


Table 3. Annual Savings by Household and Aggregated Across the Upper Waller Watershed for Low, Medium, and High Levels of Project Implementation

Processes	Annual Household Savings			Annual Aggregate Savings		
	Energy Savings (kWh)	Monetary savings (USD)	Emissions reductions (t CO2 eq)	Energy Savings (kWh)	Monetary savings (USD)	Emissions reductions
Low	46	5	0.09	55,000	5,800	110
Medium	71	7	0.14	86,000	9,000	170
High	84	9	0.17	100,000	11,000	200

Source: Brown, Culbert, Gorchels, and Odion (2020)

For more information on this analysis on urban heat island and energy savings potential, visit: Brown, Culbert, Gorchels, and Odion (2020).

People and Community

Installing rain gardens and cisterns on residential properties can benefit the resident directly, as well as the surrounding community. In addition to the benefits to urban heat island effect, here, we focus on the potential impacts of the RCPP on property value and jobs, and educational opportunities.

PROPERTY VALUE AND JOBS

Benefits of the RCPP to the local economy are often quantified through their impacts on property values and local jobs. The City of Austin and WPD are making a concerted effort to ensure that the RCPP can provide or improve local jobs through training programs and connecting local professionals with residents and projects. The City of Austin provides the Grow Green Landscape Professional series, which trains local professionals in sustainable landscape services, including designing and maintaining rain gardens. The names and businesses of professionals who complete the training are included in a searchable database, and residents are provided a fact sheet with interview questions to ensure they are hiring the right professional for the job.

Source: Max Goncharov, Unsplash

The potential impacts of the RCPP on property values can be estimated based on values in the literature. Braden and Johnston (2004) estimated on-site stormwater retention increased property values 0-5% through improvements to nearby water quality and reduced erosion and sedimentation. The benefits to property values are likely to accrue only once enough on-site systems are installed to provide these environmental benefits. Additional research can examine the changes in property values driven by these programs.

The potential impact on property values spurred additional conversations on equity and gentrification, focused on how to implement the RCPP in an equitable way. The emerging debate around gentrification and GSI does not contend that bioretention swales, trees, parks, and other green infrastructure features are damaging to marginalized and low-income populations. Rather, it argues that certain types of physical changes to a particular space can affect the perceived and real value of that space, leading to economic and cultural shifts that could conflict with the economic abilities or cultural norms of existing residents (Haase et al. 2017; Safransky 2014; Wolch, Byrne, and Newell 2014). Rather than condemning green infrastructure, advocates argue that work is needed to figure out how existing residents can benefit from GSI (Weber and Benham 2019). City staff involved in the RCPP continue to discuss these challenges and engage with residents to determine how to deploy these programs without displacing communities.

EDUCATIONAL OPPORTUNITY

While the focus of this study is on the RCPP for residential properties, additional rain capture systems have been installed on local schools to provide educational opportunities for young students. From 2012 to 2019, WPD partnered with the University of Texas (UT) Cockrell School of Engineering to bring UT students and Austin Independent School District (AISD) students together to design GSI systems for AISD campuses. WPD provides grant funding for school-led GSI via the Austin Office of Sustainability Bright Green Future Grants program. Additionally, WPD provides lesson plans that support state learning objectives, funds Partners in Education, Agriculture, and Sustainability to lead green stormwater infrastructure lessons at several schools, and recently created videos to show educators how to make and use "Soak-in, Run-off" models, which show how variations in land cover impact surface flow, infiltration rates, and filtration.

Additional educational materials, including lesson plans for grades 4-6 and 6-12, can be found on the City of Austin website.

Risk and Resilience

As part of this work, we examined how the RCPP can contribute to climate resilience, as well as more local neighborhood and personal resilience. While there are additional sources of risk, we focused on these to help build partnerships with other agencies that are addressing these sources of risk and pathways to resilience.

CLIMATE RESILIENCE

The Austin Climate Resilience Action Plan describes several hazards, vulnerabilities, and action areas for improving resilience. Specifically, four hazards were described for short-term and long-term planning, including extreme heat, drought, flooding, and wildfire. In Austin, climate projections predict an increase in average annual temperatures and a greater number of extreme heat days. In addition, changing precipitation patterns are likely to lead to more variability, longer droughts, and heavy rainfall events.

While the RCPP is not likely to reduce the risk of high-intensity flooding events, there are opportunities to connect the program to citywide resilience planning efforts, especially for helping to mitigate extreme heat and drought events. Continuing research at WPD will incorporate climate impacts into modeling the effectiveness of RCPP over time.

Personal and Neighborhood Resilience

Stakeholders we spoke to in Austin were particularly interested in how the RCPP could help contribute to personal and neighborhood resilience. For example, in extreme events, the RCPP has the potential to provide an additional source of water that does not rely on centralized water or energy systems. In addition to providing water during emergencies, the RCPP can provide an additional source of water during drought restrictions, because it allows residents to continue watering their landscapes and trees using captured rainwater.

There is also potential for the RCPP to build neighborhood cohesion and resilience if it is implemented with these values in mind. WPD staff discussed the importance of engaging with neighborhood and homeowner associations in order to build trust and to develop successful implementation strategies. Supporting these relationships through the RCPP and other programs can help to strengthen this sense of neighborhood cohesion.

Source: Mitchell Kmetz, Unsplash

MONITORING ADDITIONAL BENEFITS

There are many benefits that are challenging to model but could be monitored over time, such as habitat improvement and increased biodiversity, or impacts to on-site nuisance flooding. Given that the RCPP is a pilot program, there is even more desire and ability to monitor these potential benefits and determine if the projects are likely to achieve these outcomes.

Residents identified that they are interested in GSI that can reduce on-site nuisance flooding and maintenance. This is particularly challenging to model because it depends on local installation and how residents will interact with their systems. However, surveys with residents prior to and following installation can provide supporting information on whether these benefits can be achieved. In addition, because these benefits are of importance to many residents, the system can be designed to address both of these challenges.

Source: Ryan Riggins, Unsplash

Similarly, Austin Water is interested in understanding the reduction in potable water demand provided by cisterns and rain gardens. While water savings can be estimated for installed cisterns, there is considerable uncertainty in how residents will use the available water and if this actually leads to a reduction in demand. Monitoring water demand, especially for outdoor irrigation (if possible), can provide more information on the direct benefit of the program.

Local NGOs identified an interest in understanding how the RCPP and GSI more broadly can affect local habitat and biodiversity. There are modeling approaches for determining the potential impacts of projects to habitat (e.g., InVEST); however, these models are often designed for large-scale projects. Monitoring programs can be put in place to examine the relationship between GSI programs in Austin and habitat and biodiversity.

There are certainly additional potential benefits that are of interest to local stakeholders. Evaluating stakeholders' interests prior to installation can help design projects to meet those interests and determine monitoring and evaluation programs that can be put in place as the project is installed.

STEP 4: SUPPORTING DECISION MAKING

Decision making relies on tailored communication of the benefits and trade-offs provided by the project. A key piece of this step is developing outreach materials to convey the information to each set of decision makers and stakeholders.

City of Austin

For WPD, the team must demonstrate to departmental decision makers that the RCPP can provide a measurable benefit to stormwater management and/or an educational benefit that supports WPD's mission. Additional city departments in Austin respond to detailed reports on the benefits and potential impacts of projects, as well as how the projects intersect with other citywide programs.

In this report, we identify Austin Office of Sustainability and Austin Energy as potential stakeholders to engage with on the RCPP. Here, we demonstrate the potential benefits of the RCPP to these departments, along with benefits to additional city departments and benefits to residents the environment. To effectively scale this work, WPD will likely need to communicate this information to specific departments, as well as city council members, to achieve buy-in from potential partners. As these partners are engaged, additional benefits can be identified and quantified, leading to additional partners, incentives for residents, and scaling of GSI citywide.

Residents, Homeowners, and Neighborhood Associations

Homeowners and renters in the Upper Waller Watershed can apply for the RCPP, but often need additional information to participate in the program. Initial survey results from The Nature Conservancy indicate that residents need to understand the on-site benefits, such as addressing on-site drainage, reducing water use for irrigation or gardening, and creating a more "natural" yard that requires less maintenance.

Developing personal relationships within communities can be a key component of the outreach strategy. Through this strategy, WPD is focusing on providing community members with relatively short, professional information on how RCPP can help solve local problems (For example: WPD's "Create a Rain Garden in Six Steps" fact sheet). WPD has also prepared and posted videos explaining rain garden components, as well as presentations on project design and plant selection. The current resources are available on the City of Austin website, allowing users to easily find the fact sheets and presentations, as well as local grant programs and rebates for rainwater capture.

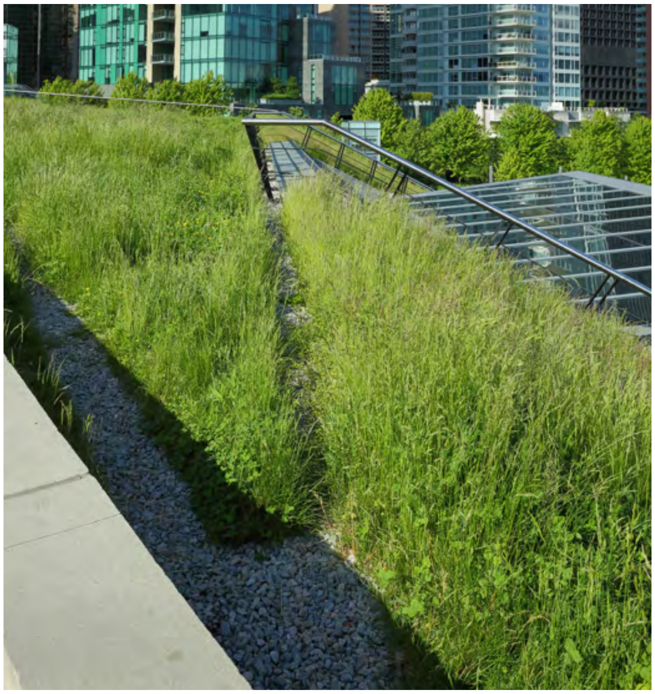
The Nature Conservancy and UT are currently conducting research to understand the benefits of rainwater capture that are of the greatest interest to residents, as well as additional barriers to implementation.

The information provided here can help support these efforts by providing a system for organizing the benefits provided by the RCPP, as well as quantification of several benefits to help develop materials for engaging with residents.

NGO Partners

Many of the environmental NGOs in Austin are dedicated to scaling GSI and other nature-based solutions. For these groups, it is often important to ensure that proper data and information is available and to empower them to engage on these strategies. Environmental NGOs that we spoke with expressed interest in resources for quantifying and evaluating the impacts of these strategies on water quality, urban heat island effect, and community livability, among other things. The Pacific Institute has compiled resources in an online library for examining the benefits and trade-offs of nature-based solutions (along with other water management strategies) that can assist with finding documented benefits of these projects to the community, environment, and economy (Pacific Institute 2020). For example:

- US EPA's 2014 report, "The Economic Benefits of Green Infrastructure" on Lancaster, PA, which provides data requirements and methodologies for evaluation of water-related benefits (avoided capital costs of storage needs, avoided operational costs from wastewater treatment), energy-related benefits (reduced energy use for indoor temperature control), air-quality benefits (smog reduction, including ozone, NO_2, SO_2 and PM_{10}), and climate change-related benefits (CO2 reduction from carbon sequestration, reductions in water and wastewater pumping and treatment, and building energy use).



Source: Maxvis, iStock

- TreePeople's 2007 report, "Rainwater as a Resource: A report on three sites demonstrating sustainable stormwater management," which outlines the costs and benefits provided by trees (tree canopy, carbon storage, carbon sequestration, energy savings), stormwater management (runoff reduction, avoided storage), and air pollution benefits (ozone, NO_2, SO_2 and PM_{10}, and CO removal), as well as additional non-quantified benefits.

Each resource is tagged with specific water management strategies that are discussed and the benefits or trade-off that is outlined. The resource library provides users with a list of resources to search for data and information.

Despite the documented benefits of GSI, there remain challenges in communicating these projects, including what to call them (e.g., are they "urban seeps," "bioswales," or "rain gardens"?). Conversations with NGOs focused on how to effectively communicate the benefits of GSI to the community through quantitative values, storytelling, and connecting GSI with what people are experiencing. For example, during algal blooms, NGOs discuss the water quality benefits of GSI and during drought, they can pivot to discussing the water supply or conservation opportunities.

An Equity Lens

Equity will continue to be an essential component of designing and implementing RCPP, through both determining project locations that benefit communities with the greatest need and reducing barriers that may prevent low-income residents from engaging. There are practices that can be put in place to ensure rainwater capture programs are available for a greater number of residents. Awareness remains an important component of successful program implementation, including awareness of financial resources and incentives for installing GSI. In addition, the city is exploring how to build robust programs that can connect people with the resources they need, for GSI or otherwise.

The first iteration of the RCPP is being implemented in the Upper Waller Watershed. If the pilot is successful, there are opportunities to examine how and where this program should be implemented next, including a discussion of equity. Implementing a multi-benefit approach can help to identify areas that will maximize benefits and allow for robust planning to reduce potential trade-offs.

KEY LEARNINGS AND NEXT STEPS

This report outlines a process for examining and evaluating the multiple benefits provided by rainwater capture, as well as opportunities to communicate these benefits to residents, environmental NGOs, and city staff. By utilizing the Multi-Benefit Framework, collaborators can identify additional beneficiaries of the project and engage with potential partners to scale RCPP within the City of Austin.

Outcomes of Examining Multiple Benefits

Water projects are co-funded by several city departments: Connecting the benefits of the rainwater capture with relevant departments and organizations can support co-funding agreements among the different beneficiaries. The rebate for RCPP is currently designed to capitalize on rebates from Austin Water, WPD, and the Urban Forestry program. By contributing to a single "stackable rebate," residents can more seamlessly install GSI, funded by different entities.

City staff have a stronger relationship with stakeholders: Environmental NGOs play an important role in implementing the RCPP. By discussing the broad benefits and trade-offs of the RCPP, both city departments and NGOs have a deeper understanding of the key benefits of interest for each entity and ways to improve project design that will maximize those benefits. Pacific Institute staff facilitated discussions between WPD and environmental NGOs, and WPD staff noted the importance of an external entity to help guide a more transparent discussion on the benefits of GSI and barriers to implementation.

Source: Tomek Baginski, Unsplash

City staff and residents can weigh trade-offs: Developing multi-benefit programs will require trade-offs or compromises among the stakeholders. To maximize water supply benefits to Austin Water, rain cisterns should be installed to offset water demand for irrigation and rainwater stored in the cisterns until it is used for that purpose. WPD is interested in installing cisterns and rain gardens to improve stream health, and thus slow release cisterns that drain continuously will provide the greatest direct benefit. By examining these trade-offs during the design and pilot phases, these departments can discuss potential compromises or design options that will provide benefits to both, including increasing cistern size or requesting residents drain the cistern slowly before rain events.

Monitoring plan can prioritize key benefits of interest: There are additional benefits that are difficult to model but can be quantified or verified through on-the-ground monitoring. For

Source: Jeremy Banks, Unsplash

example, residents may be particularly interested in whether the RCPP can mitigate on-site nuisance flooding. By identifying this potential benefit during the pilot phase, city staff can evaluate it during implementation.

Scaling the RCPP and GSI in Austin

Tailored outreach and communications for stakeholders: Through this process, we identified key stakeholders engaged in the RCPP, as well as the benefits of interest to these groups. An important next step is to tailor communications to different stakeholders, as outlined in Step 4. Austin Water and WPD have developed some materials to engage with NGOs and residents. As additional information and resources are available, these materials can incorporate the key benefits of interest for different stakeholders and effective messaging strategies.

Incorporating businesses and multi-family homes into the RCPP: Business parcels and multi-family housing complexes have large potential for scaling rainwater capture. City staff can increase engagement with the business sector and property managers by developing implementation strategies with key stakeholders and tailoring messaging to highlight the key benefits of interest for their sites. In addition, with new land development codes, public and private parcels may be required to maintain additional stormwater on site, based on impervious surface cover. This will likely increase private interest in stormwater management, and prioritizing projects with multiple benefits can help contribute to citywide goals.

Connecting RCPP with citywide resilience planning efforts: The City of Austin is focused on increasing climate resilience throughout the city, with efforts led by the Office of Sustainability. WPD and Austin Water can engage with this citywide planning effort and examine how the RCPP can contribute to community and environmental resilience in the face of climate change. For example, the RCPP may provide distributed emergency water supplies to residents. Framing the RCPP within this context may elucidate additional potential benefits and help with engaging additional supports and residents.

Implementing the RCPP to improve equity and build community resilience: The RCPP is currently being implemented as a pilot in a single watershed. However, additional phases of this work can identify where and how to implement the program that can maximize benefits to communities with the greatest need. In addition to the direct benefits of the program, the implementation strategy can help to build community resilience. WPD is exploring how partnering with neighborhood associations, local businesses, and NGOs can help communities develop stronger networks and build resilience.

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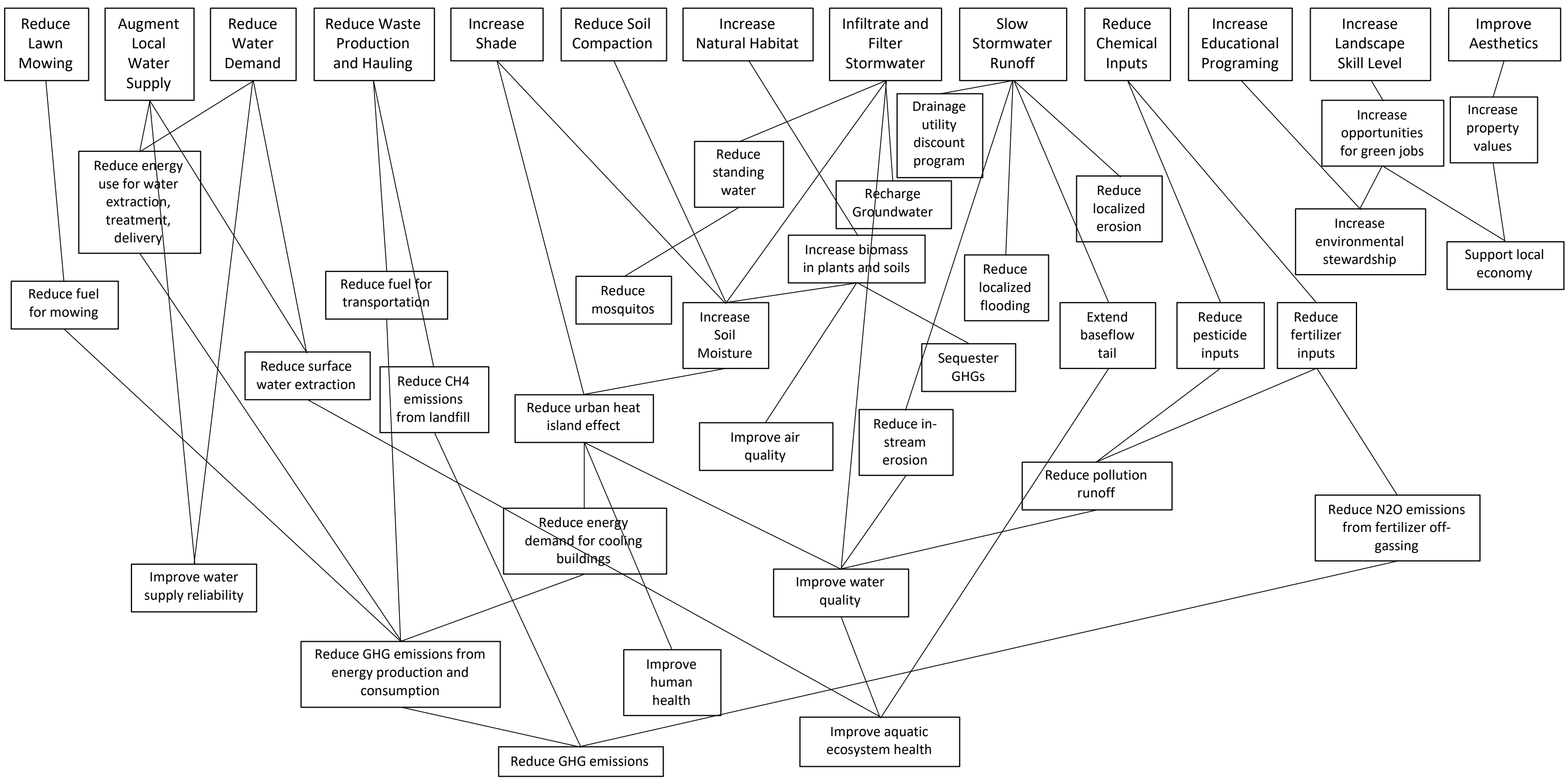
Appendix A

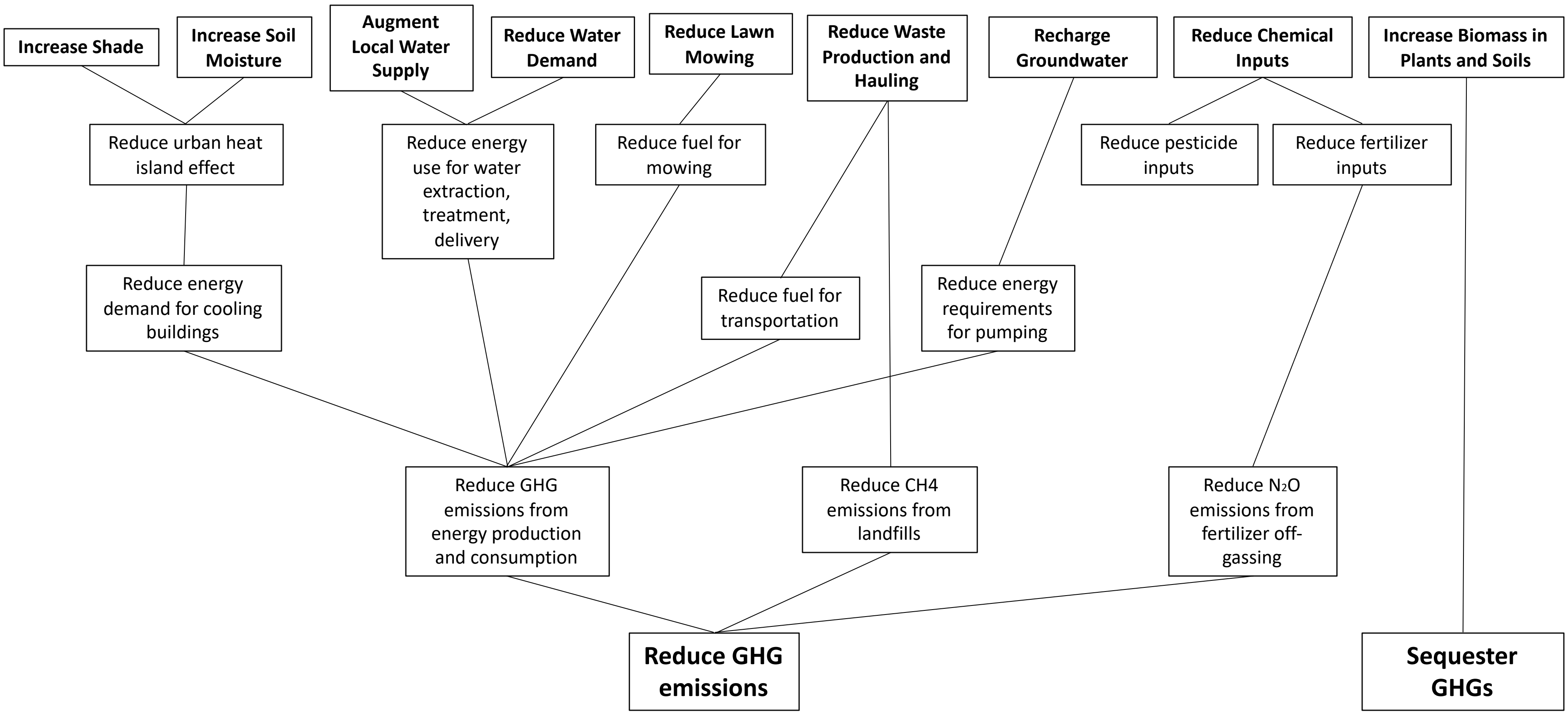
FLOW CHARTS OF PHYSICAL PROCESSES AND BENEFITS OF THE RAIN CATCHER PILOT PROGRAM

(a) Flow chart demonstrating the relationship between processes and potential outputs from the Rain Catcher Pilot Program.

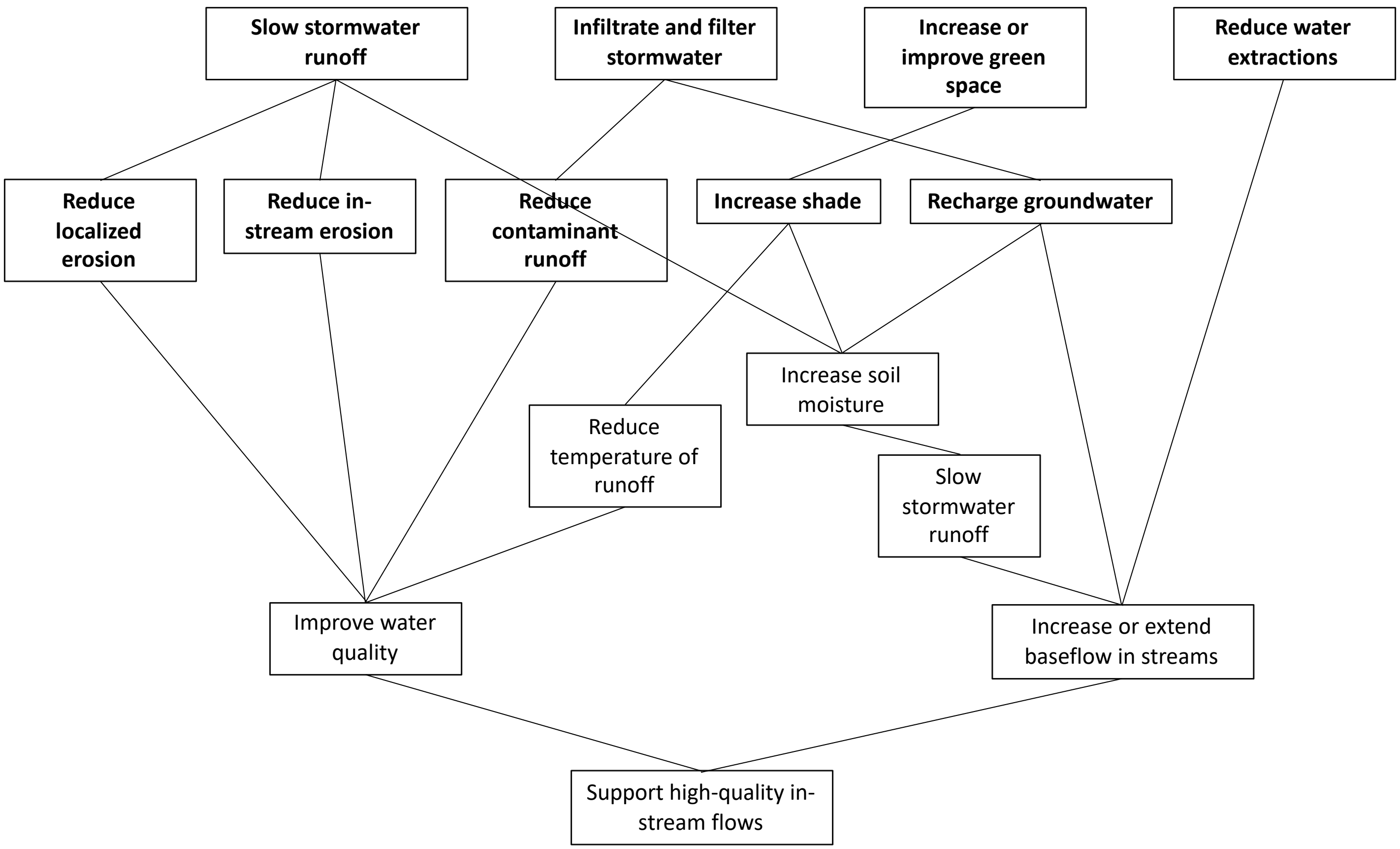


(b) Flow chart demonstrating the relationship between processes and a particular benefit of interest. These diagrams can be developed for any of the key benefits identified to show stakeholders how the project leads to a benefit.

Outcome of Interest: GHG Concentrations



Outcome of Interest: High Quality In-Stream Flows



Appendix B

ENERGY SAVINGS FROM OFFSETTING POTABLE WATER DEMAND

The Water-Energy Simulator (WESim) is a model that allows users to determine the energy required for municipal water systems and their greenhouse gas footprints. WESim breaks the water system into eight phases, from extraction to wastewater discharge (Table B1). Volumes going through each of these phases are accounted for by summing the flow through individual facilities. The energy intensity of each of these phases is estimated or directly calculated through energy bills.

Table B1. Water System Steps Outlined in the Water-Energy Simulator (WESim)

Step	Explanation	Facility example
Extraction	Energy used to extract water. This is primarily a factor with groundwater.	Groundwater pump
Water Conveyance	Energy used to bring water from extraction to treatment.	Aqueduct
Water Treatment	Energy used to treat water to potable standards.	Water treatment plant
Water Distribution	Energy for bringing water from the water treatment plant to the customers.	Potable distribution
Wastewater Collection	Energy used to collect post-consumed water.	Sewer pumps
Wastewater Treatment	Energy used to treat wastewater to discharge standards.	Wastewater treatment plant
Wastewater Discharge	Energy used to discharge treated wastewater.	Discharge pumps
Operations	Energy used to maintain infrastructure, employees, and the transportation of non-water necessities.	Shipments of treating chemicals
Customer End Use	Energy used for domestic or commercial clients to modify water.	Water heating

Installing cisterns may offset potable water demand, but it will not affect wastewater treatment or consumer end use energy because landscape irrigation is not directed through wastewater flows and does not require heating. In addition, Austin's water source, the Colorado River, does not require substantial energy for extraction and conveyance because treatment plants are adjacent to the river. As a result, only the energy used in treatment and distribution needs to be considered for the cistern project. We estimated energy required for distribution based on the combined flow of all water treatment plants and estimated energy intensity, which is provided by WESim's energy intensity estimate tool and is based on the median energy intensity from 41 utilities. Data on the volume of water treated and energy intensity was downloaded from Austin's Open Data Portal.

The model estimates that for every thousand gallons of potable water offset by the RCPP, Austin Water will reduce energy use by 2.4 kWh (Table B2). In addition, Austin Energy will reduce GHG emissions by 0.0017 tons of CO2-eq. These ratios allow for a calculation of the energy and GHG savings with an estimate of the potable water offsets from different adoption scenarios. Widespread adoption could lead to large energy savings due to the high energy intensity of water treatment.

Table B2. Energy Intensity of Treatment and Distribution from WESim

Facility Name	Flow (MGD)	Source Energy Intensity (kWh / 1000 gallons)	Site Energy Intensity (kWh / 1000 gallons)	Source Emissions (tons CO2-eq / 1000 gallons)
Water Treatment				
Ullrich	63	6.1	1.8	0.0013
Davis	53	6.1	1.8	0.0013
Water Treatment Plant 4	25	6.6	2.0	0.0014
Average Water Treatment	*47*	*6.3*	*1.9*	*0.0013*
Distribution				
Potable Water Distribution	142	1.8	0.54	0.0004
Total			**2.4**	**0.0017**

Note: Source/site energy converted using WESim defaults.

Data on water treatment was downloaded from Austin's Open Data Portal. For water volume treated at each water treatment plant, the Gallons of Water and Wastewater Treated dataset was used. For the energy use of each of those plants, the Energy Consumption for All Plants dataset was used. In the dataset, months that lacked data for either water or energy were excluded. Using these datasets, we determined average monthly water consumption and energy intensity for Ullrich, Davis, and Water Treatment Plant 4 (Table B3).

Table B3. Data on Average Energy Intensity and Water Treatment Volume from Each Treatment Plant in Austin, Texas

Plant	Average Intensity (kWh / MG)	Average Treatment Volume (MG / month)
Ullrich	1820	1920
Davis	1830	1620
Water Treatment Plant 4	1980	782

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