

# Estimating Multiple Benefits from Stormwater Capture Projects- Why and How

*Water Reuse Action Plan Action 3.3*

September 7, 2021



# Building Capacity to Capture and Reuse Stormwater

## Water Reuse Action Plan (2020)

- WRAP partnerships help advance integrated water management and recycling
- 45+ actions with implementation plans
- Action 3.3 focuses on advancing stormwater capture and use



# Understanding SCU Opportunities & Challenges

- Webcast series to explore key issues affecting SCU
  - 4 webcasts and 1 technical meeting 2021
- ***Today's webcast focuses on evaluation of multiple benefits***
- National meeting at Johnson Foundation at Wingspread September 2021
- Meeting report and followup actions



# Today's Webcast

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## Introductions

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### **Multiple Benefits As The Springboard**

- Anne Thebo, Pacific Institute

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### **Current Approaches to Evaluating Benefits**

- T.J. Moon, Los Angeles County  
- Spencer Joplin, CA State Water Resources Control Board

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### **How Can We Estimate Multiple Benefits?**

- Sybil Sharvelle, Colorado State University  
- Janet Clements, Corona Environmental  
- Katie Spahr, Water Research Foundation

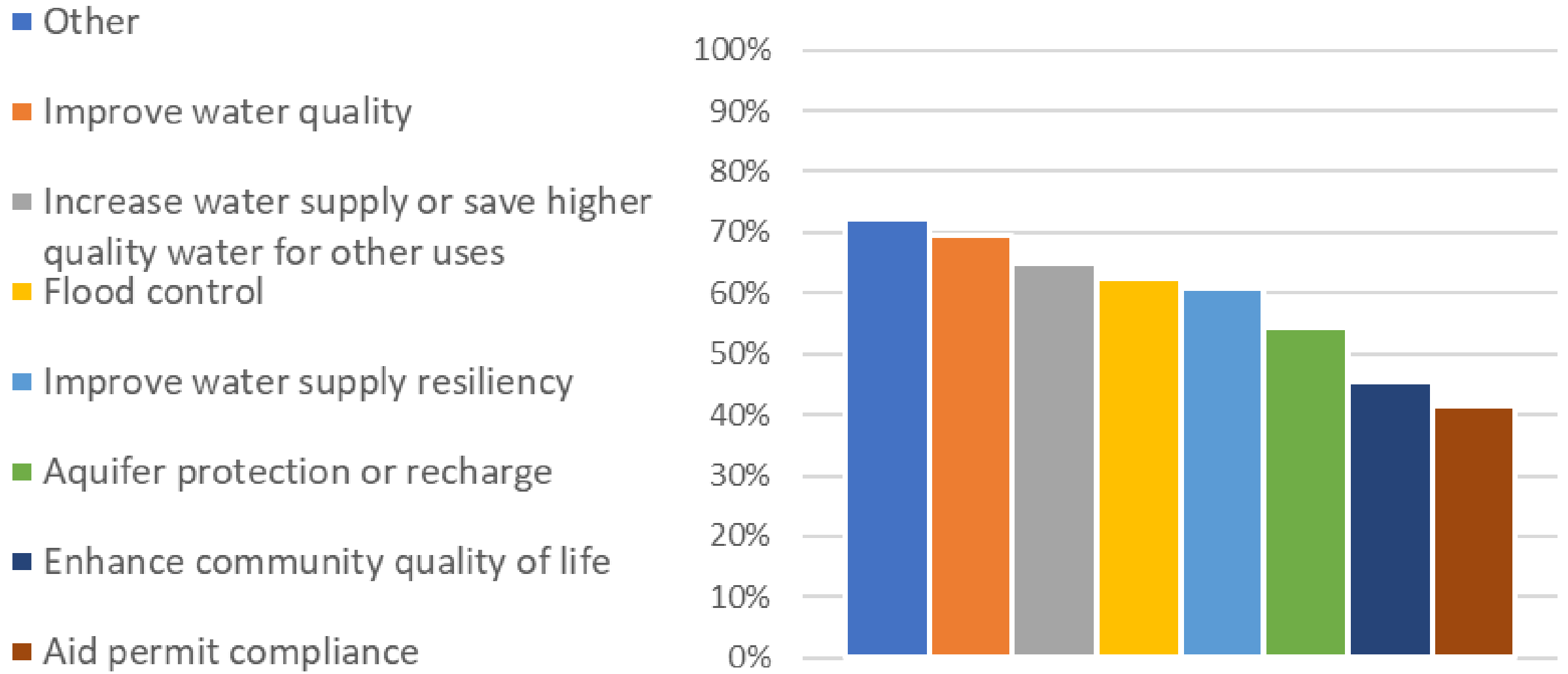
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### **Where Do We Go From Here?**

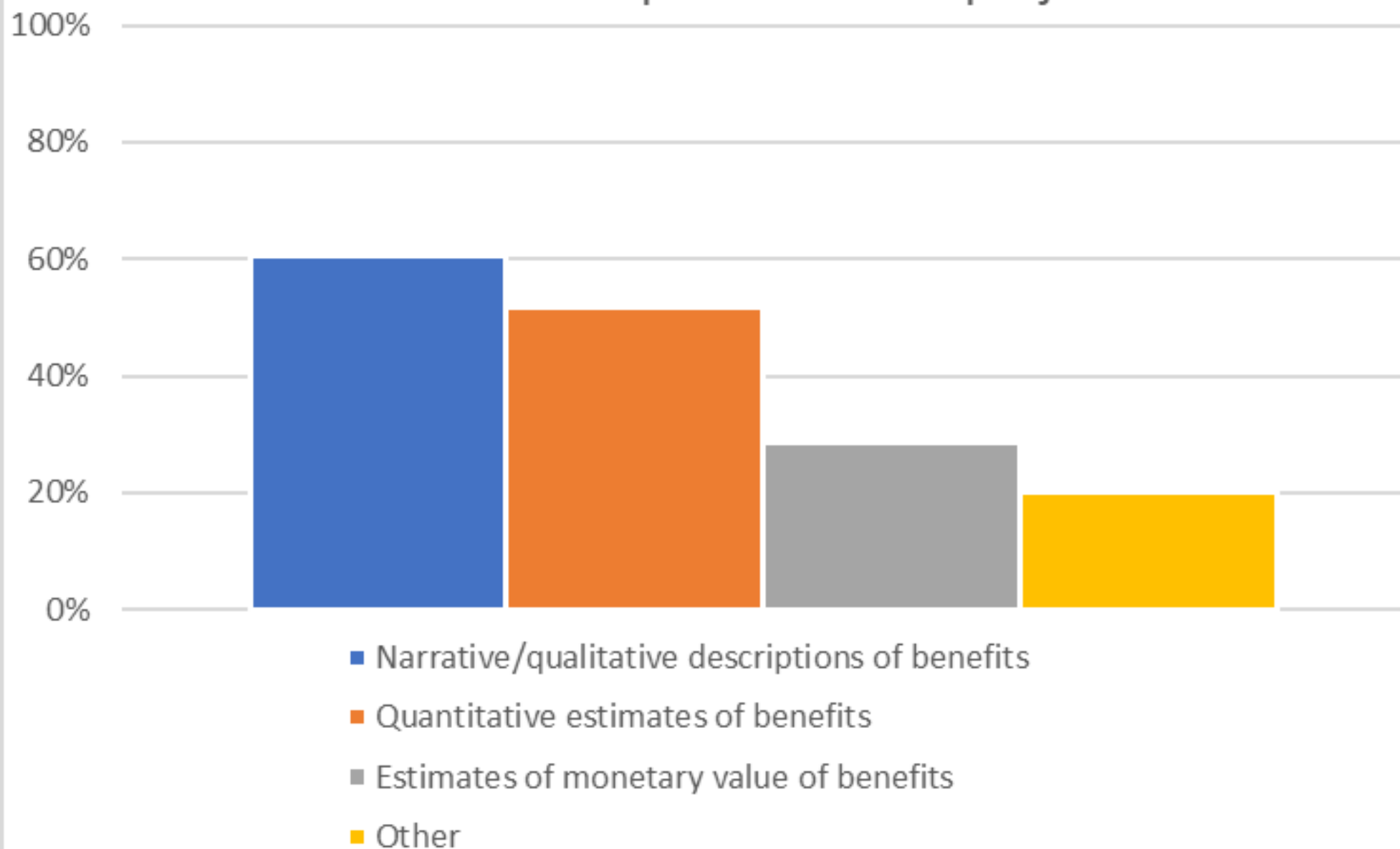
# What We Heard From You

- About 400 Registrants
- > Half from West, 10% each from East, South, Southwest
- Quarter each from local agencies, states, and consultants
- 2/3 from water limited areas
- Most want several kinds of help with benefits evaluation:
  - Examples of how others do it
  - Matching benefits methods with different audiences
  - New benefit evaluation tools

# What benefits do you think stormwater capture and use projects can provide your community?



## How do you currently evaluate the benefits of stormwater capture and use projects?



# Estimating Multiple Benefits from Stormwater Capture Projects – Why and How?

## Multiple Benefits as the Springboard

EPA Webinar Series  
September 7, 2021

**Anne Thebo, Ph.D.**  
Senior Researcher, Pacific Institute





# Today's Webinar

Why Should We Look at the Multiple Benefits?



Current Approaches to Evaluating Benefits



How Can We Estimate Multiple Benefits?



Where Do We Go From Here?

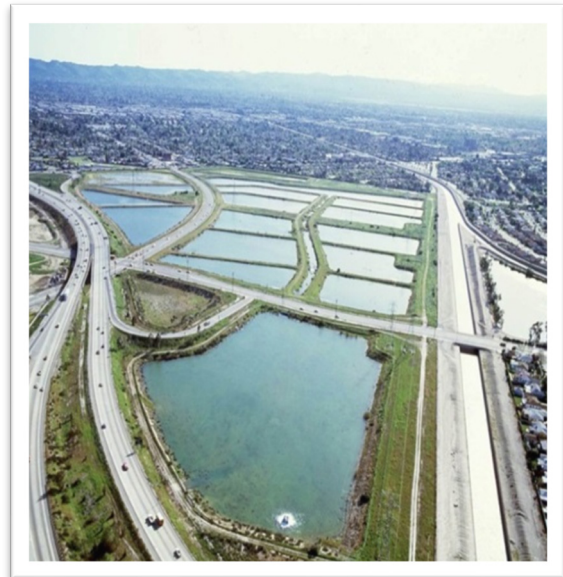
# Why Should We Look at the Multiple Benefits of Stormwater Capture and Use?

- Benefits motivate action, but costs are a common barrier
- Benefits can build public support, motivate integrated approaches, and build co-funding opportunities

# What do we mean by 'stormwater capture'?

Decentralized

Centralized



Household Rain garden  
(Portland, OR)  
Source: City of Portland

Bioretention Bed in Greenstreet  
(Queens, NY)  
Source: NYC Parks

Rory M. Shaw Wetlands Park  
(Los Angeles County)  
Source: Maven's Notebook

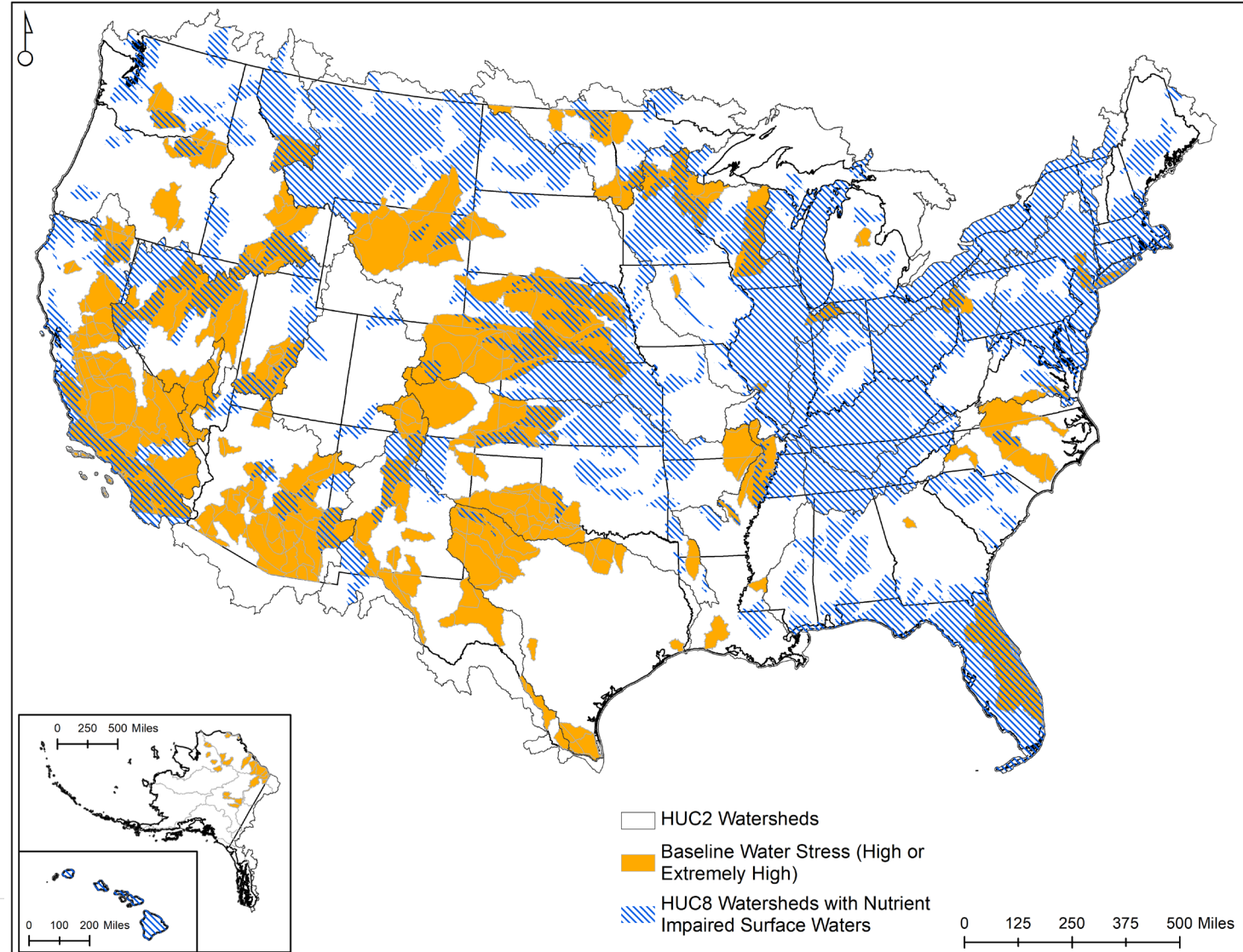
Tujunga Spreading Grounds  
(Los Angeles County)  
Source: LADWP

Multiple Scales, Direct and Indirect Reuse, Wide Ranging Geographies, and

*Diverse Project Drivers*

# What Benefits Have Historically Motivated Stormwater Capture?

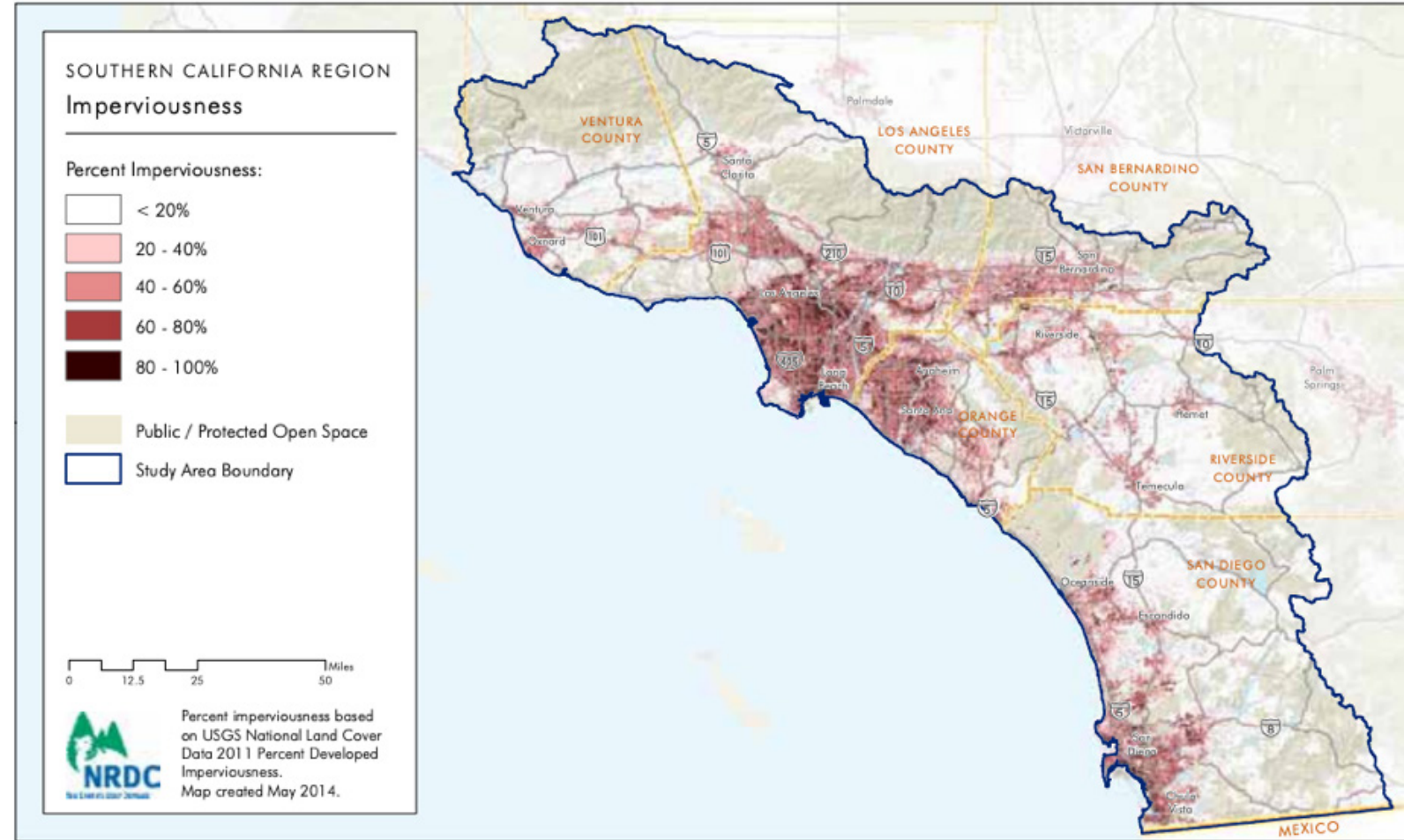
- Water Supply
- Water Quality Improvement
- Flood Management



Data: Water Stress Indicator (WRI AQUEDUCT v3.0); 303(d) Listed Waters (USEPA)

# Abundant, but Underrealized Opportunities for Stormwater Capture

- Opportunity for 420,000 to 630,000 AFY in Bay Area and Southern California (NRDC and Pacific Institute 2014)
- Up to 34,000 MAFY stormwater potentially available for capture in the U.S. (EPA 2004; Aguilar and Brown 2020)
- U.S. Urban Water Use is Approximately 47,000 MAFY (USGS 2020)



Source: NRDC and Pacific Institute.  
Stormwater Capture Potential in Urban  
and Suburban California. June 2014.

# Stormwater Can Be Less Expensive than Other Alternative Supplies

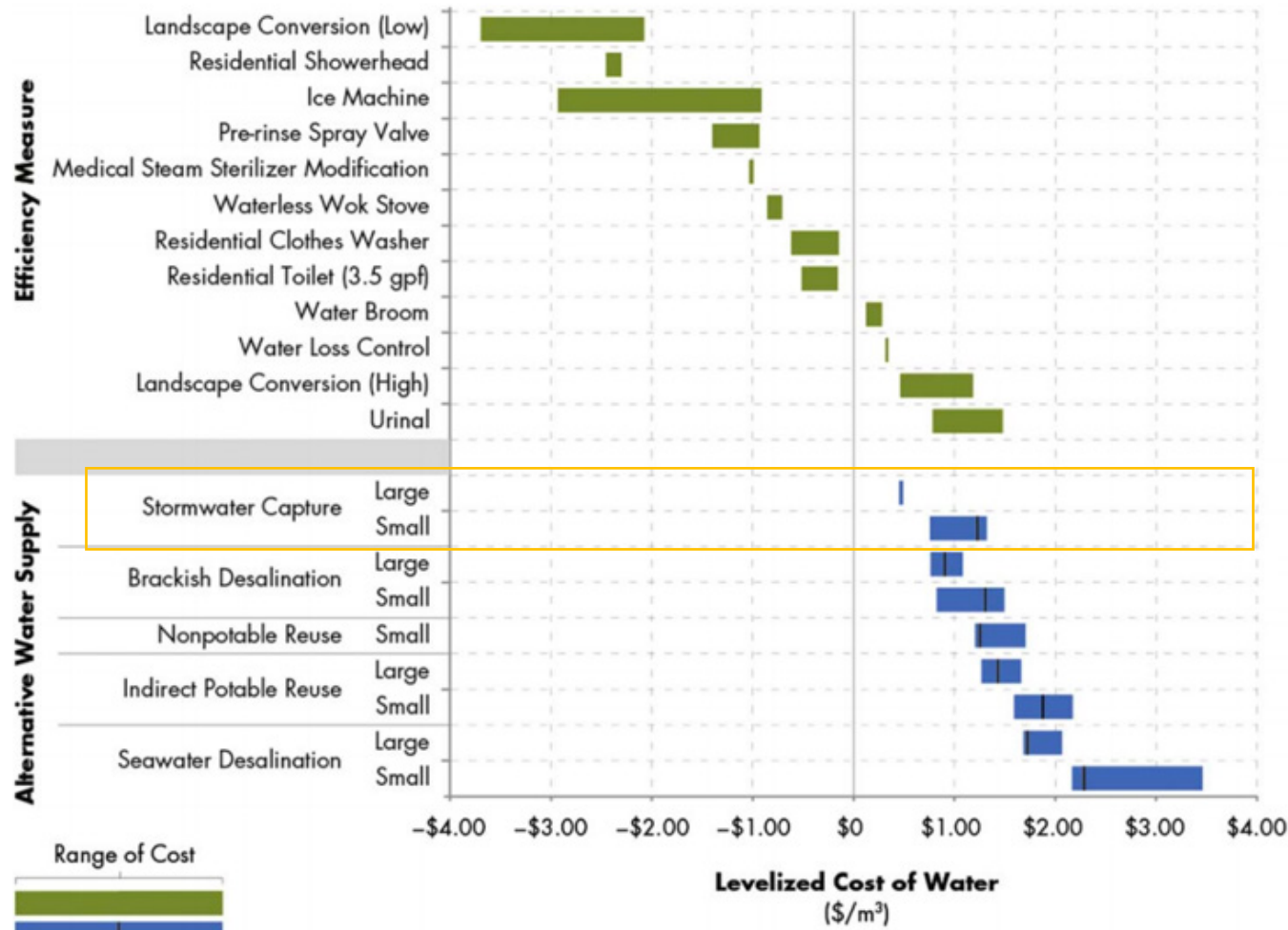
## Median Costs per Acre-Foot

Cooley, et al. (2019)

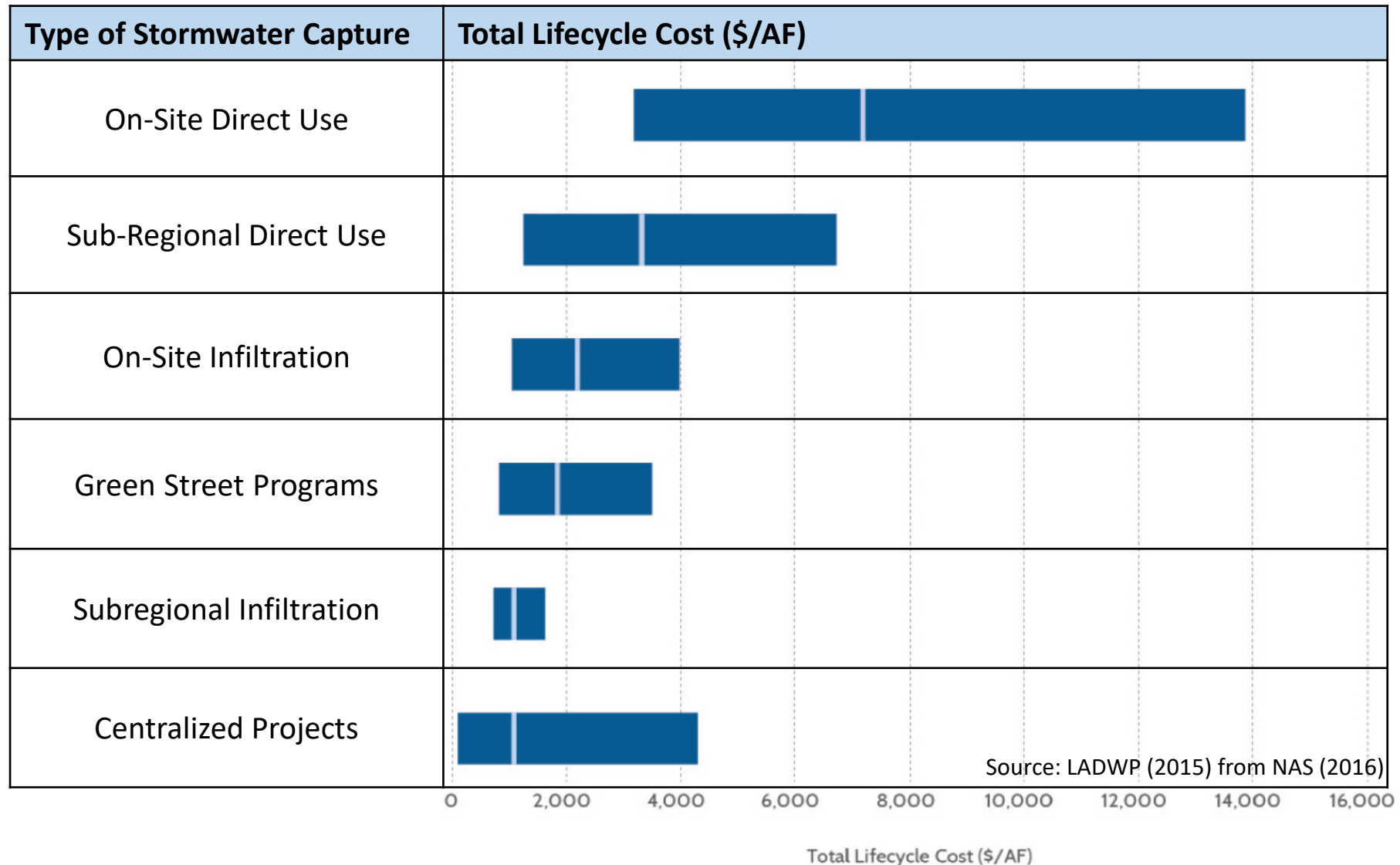
- Large (> 6,500 AFY): \$590 / AF
- Small (< 1,500 AFY): \$1,500 / AF

Perone and Rohde (2016)

- Managed aquifer recharge: \$1,550 / AF (between \$410 to \$2,660 / AF)



# Lifecycle Costs Vary Across Different Types of Stormwater Capture



# Stormwater Capture Exists as Part of the Broader Water System

To accurately compare water projects, we need to systematically evaluate the benefits and costs of each water management option, as well as understand who benefits and who pays.





# Austin's Rain Catcher Pilot Program

## Project Goals

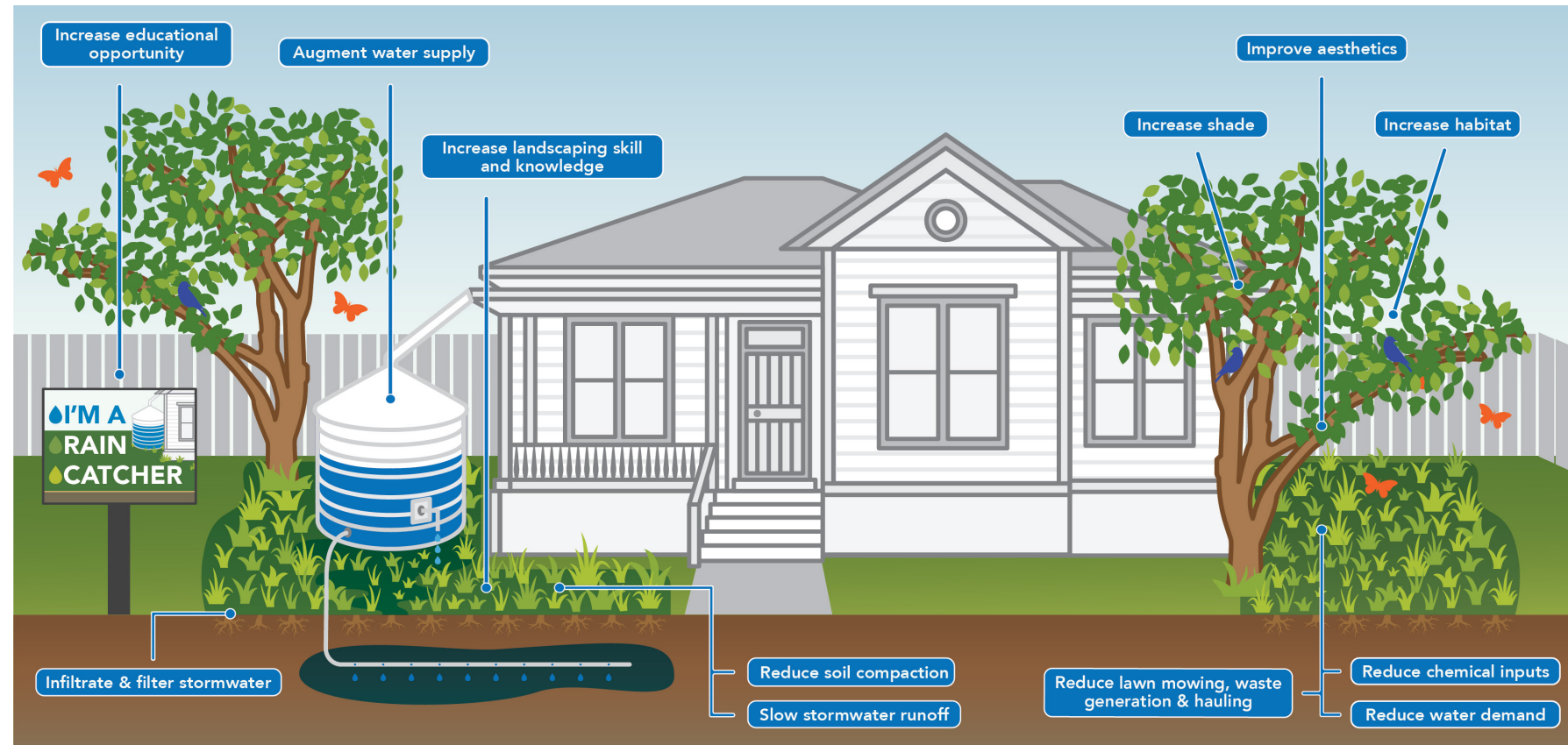
Reduce erosive events, improve instream flows, engage with residents

## Project Options

Rain cisterns, rain gardens, trees

## Project Partners

Austin Water  
Austin WPD  
Local NGOs



*How can multiple benefits increase engagement with other city departments, homeowners, and local NGOs?*

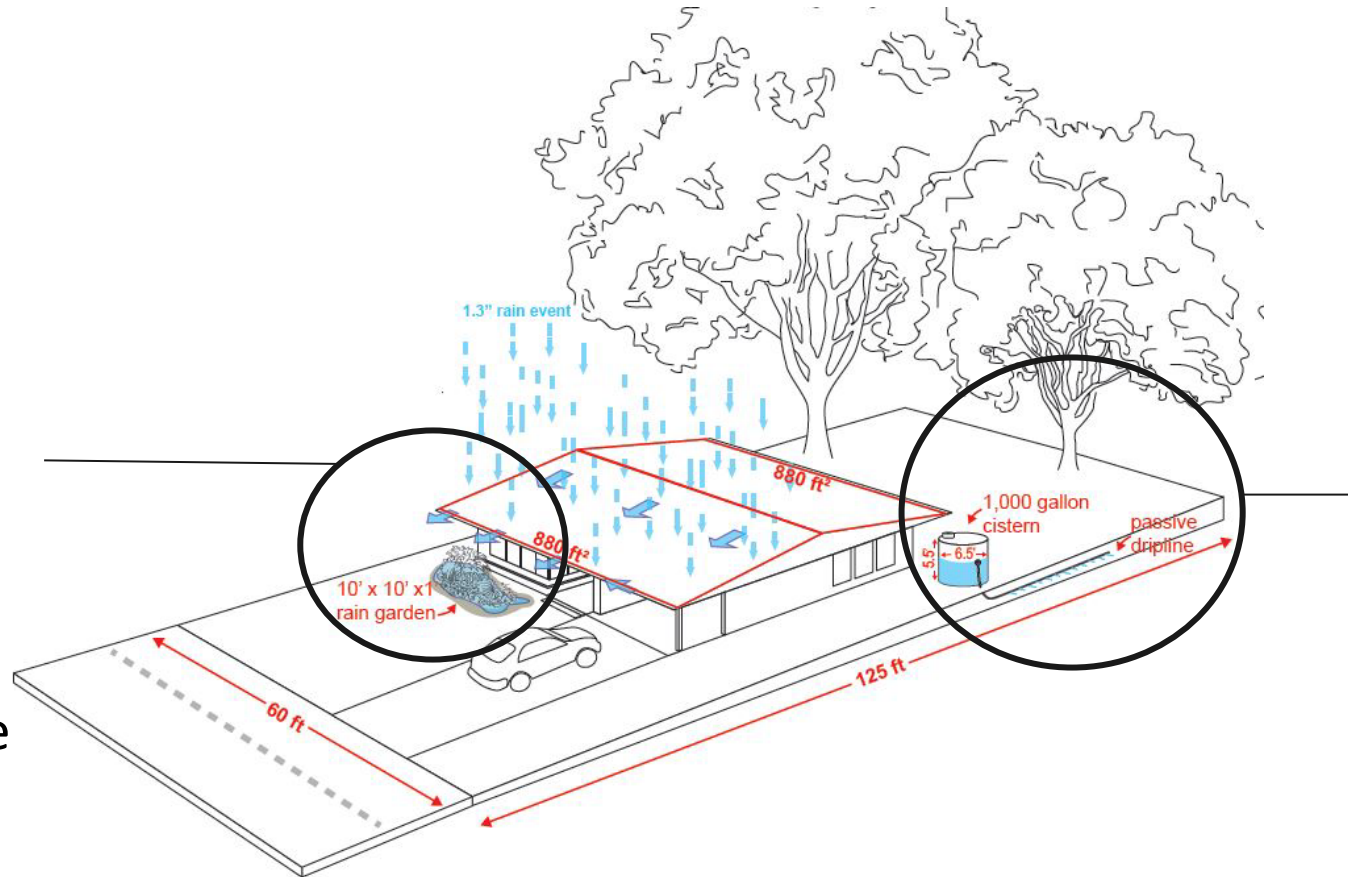
# Connecting Benefits with Beneficiaries

Theme	Benefit	Stakeholder Interested
<b>Water</b>	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
<b>Energy</b>	Energy for water treatment and delivery	Austin Energy, Austin Water
	Energy related to heating/cooling buildings	Austin Energy, residents
<b>Land and Environment</b>	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
<b>Community Benefits</b>	Reduce urban heat island effect	Parks and Recreation Department, Development Services Department (Forestry), Public Works Department, Office of Sustainability, WPD, Environmental NGOs, residents



# Rain Catcher Rebates from Two City Departments

Austin Water's  
Rainscape Rebate  
\$0.30 per sq. ft.  
PLUS  
Austin WPD  
stormwater rebate  
\$1 per gallon

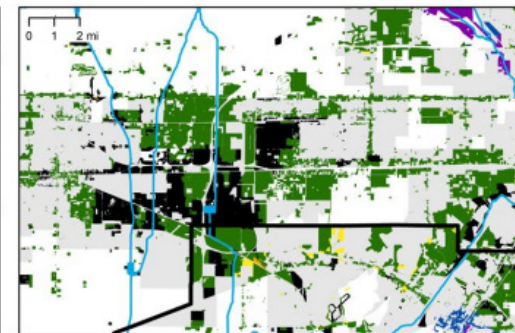
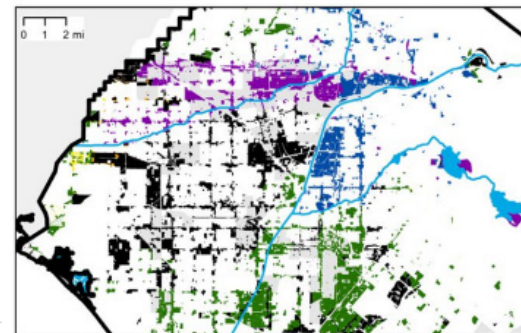
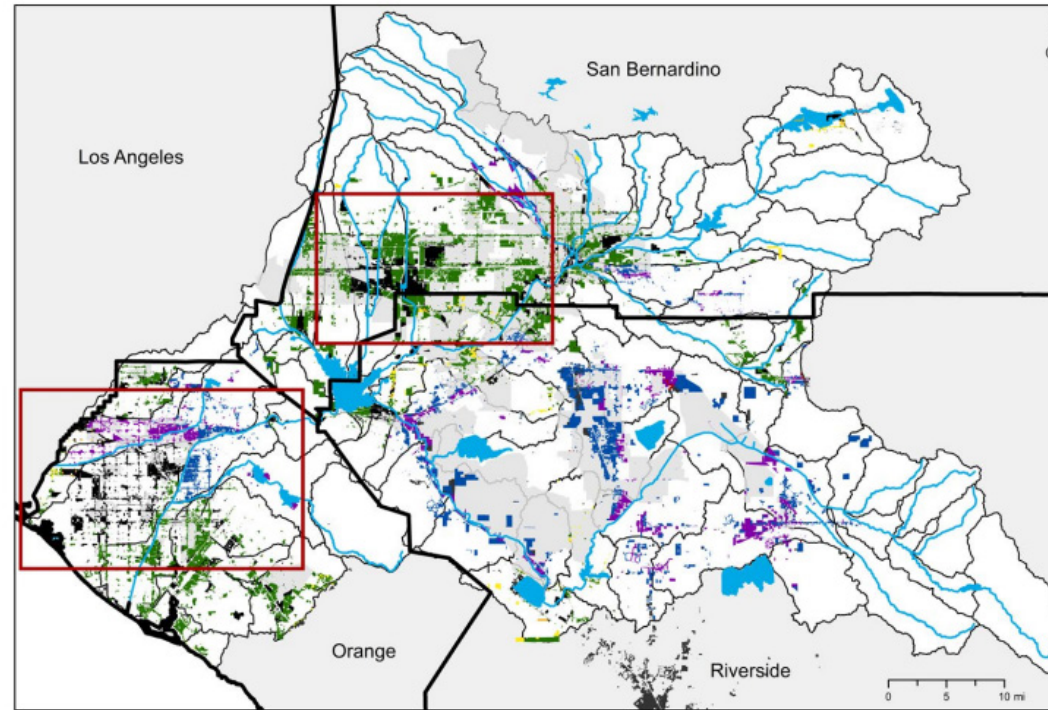


Austin Water's  
Rainwater Harvesting  
Rebate  
\$0.5 - \$1.00 / gallon  
PLUS  
Austin WPD  
stormwater rebate  
\$1 per gallon

# Can Multiple Benefits Help Motivate Private Sector Investment in Landscape Improvements (Including Stormwater Capture)?

Analysis at watershed and parcel scale:

- Water supply
- Water quality
- Flood risk mitigation
- Disadvantaged communities



# Incorporating Multiple Benefits Into Funding Programs

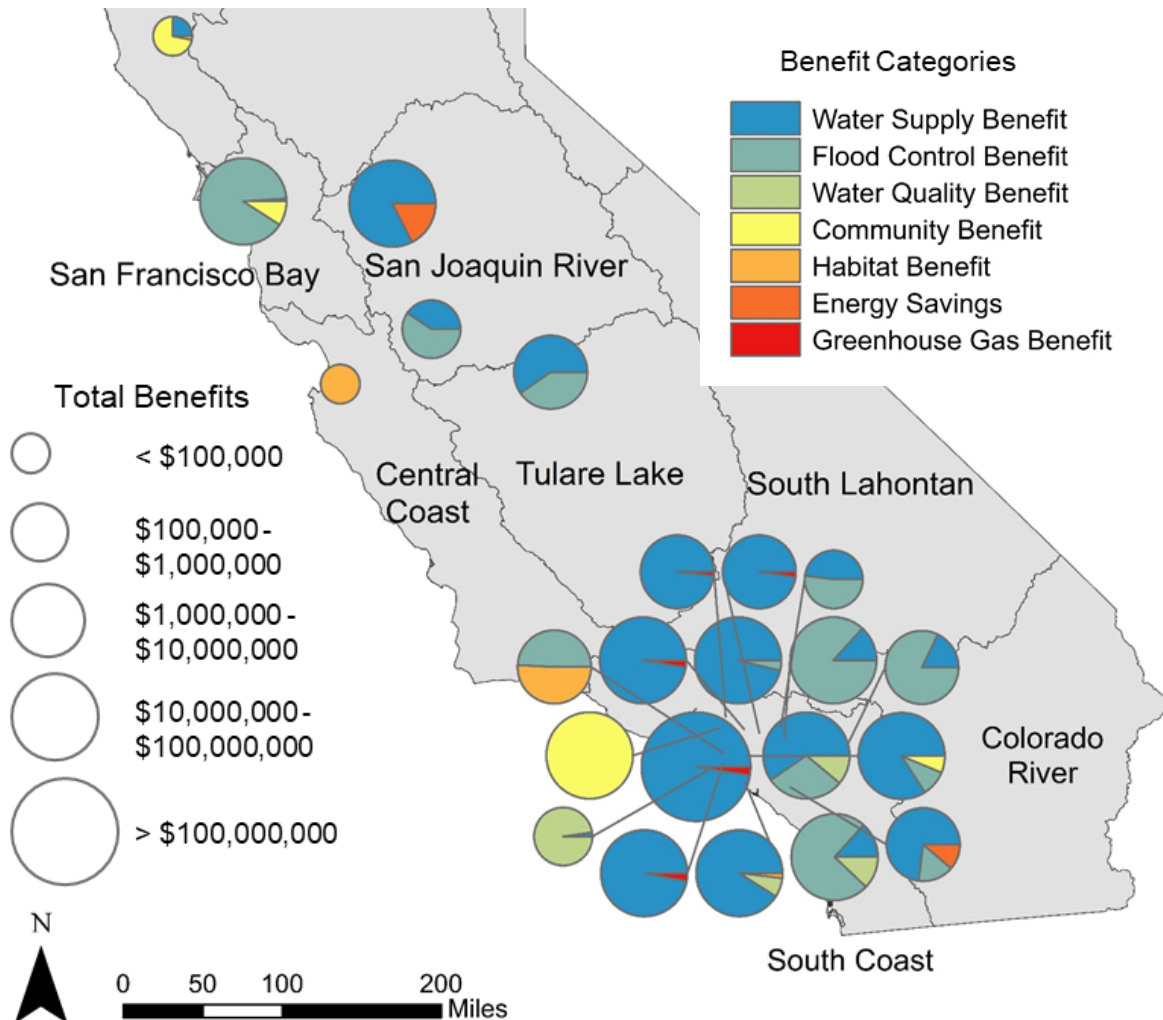
## Benefits of Stormwater Capture Cited In California Prop 1E and 84 Proposals

Benefit	Benefit Metric (2018 USD)
Water Supply	<ul style="list-style-type: none"><li>• Avoided cost of purchasing imported supplies</li><li>• Cost savings for water users relative to the status quo</li><li>• Revenue from sales of water to other users</li><li>• Avoided operations and maintenance costs</li></ul>
Flood Damage Reduction	<ul style="list-style-type: none"><li>• Avoided flood damage to residential and non-residential properties</li><li>• Avoided loss of revenue and wages from flood disruptions to business</li><li>• Avoided emergency response costs</li><li>• Reduced insurance premiums</li><li>• Avoided public safety and health impacts</li></ul>
Water Quality	<ul style="list-style-type: none"><li>• Avoided cost of water treatment</li></ul>
Energy and/or Electrical Savings	<ul style="list-style-type: none"><li>• Avoided or reduced energy use from groundwater pumping or surface water transfers</li></ul>
Community Benefits	<ul style="list-style-type: none"><li>• Added public active and passive recreation space (acres of space)</li><li>• Increased property values</li></ul>
Habitat	<ul style="list-style-type: none"><li>• Economic value of ecosystem services of wildlife habitat</li><li>• Value of in stream flows</li></ul>
Greenhouse Gases Avoided	<ul style="list-style-type: none"><li>• Avoided greenhouse gas emissions (metric tons of CO<sub>2</sub>e per year)</li><li>• Carbon sequestration (metric tons of CO<sub>2</sub>e per year)</li></ul>
Avoided Costs	<ul style="list-style-type: none"><li>• Avoided lowest-cost project alternative</li><li>• Avoided operations and maintenance, including groundwater pumping</li></ul>

<https://doi.org/10.1371/journal.pone.0230549.t004>

Source: Diringier et al. 2019

# Value and Diversity of Stormwater Capture Related Benefits Identified in Prop 84 and 1 Proposals

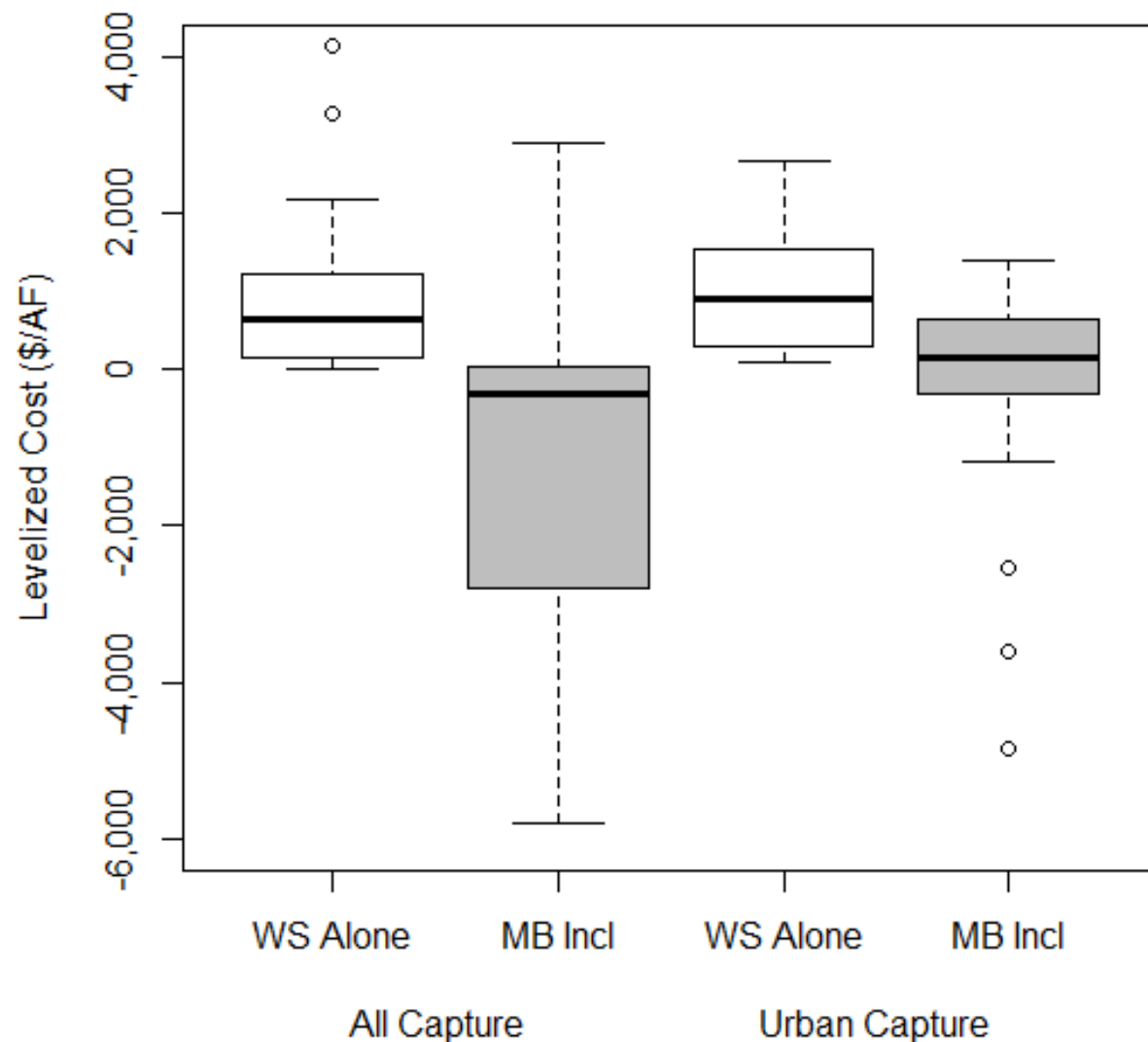


Stormwater capture is economically feasible, but prioritizing projects that yield the greatest benefits is challenging.

Incorporating multiple benefits provides opportunities to:

- Develop standardized project proposals,
- Allow funders to determine the net benefits,
- Co-fund projects,
- Optimize investments in water.

# Including a Greater Range of Benefits in Benefit-Cost Analyses Can Reduce the Effective Cost of Stormwater Capture



Stormwater capture costs decreased when multiple benefits were included

# Incorporating multiple benefits can improve decision making



Optimize investment of time, money, and resources



Identify opportunities to share costs



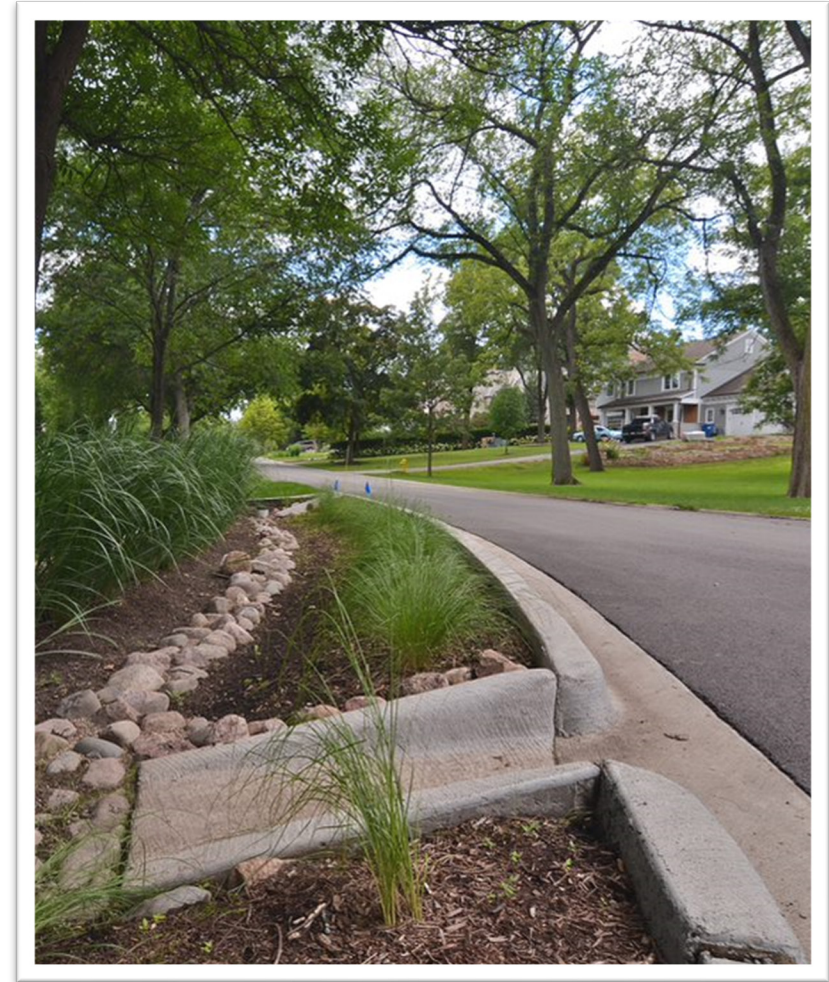
Building community support for a project or program



Minimize adverse and unintended consequences



Promote equitable and transparent decisions





# Thank You!

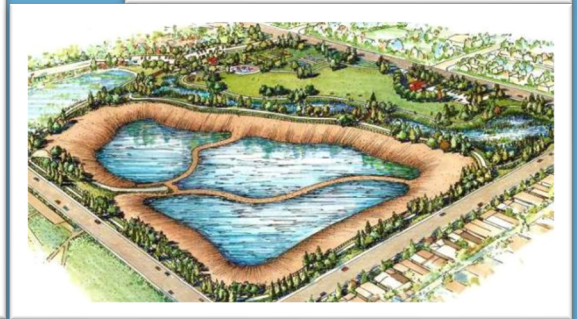
## Contact Information

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# Evaluating Stormwater Capture Project Benefits in Los Angeles County

September 7, 2021

# Evaluating Benefits



- 2012 Los Angeles MS4 Permit encouraged the development of multi-benefit, regional stormwater capture projects
- How do you balance all the potential multi-benefits?
  - Water Quality
  - Water Supply
  - Community Enhancements
- Can you assign monetary value?
- Is one formula appropriate for all projects

# Safe Clean Water Program – Scoring Criteria



- Stakeholder Advisory Group consisting of environmental groups, water supply, MS4 agencies, regulators developed scoring criteria in 2017-2018
- Watershed Management Modeling System (WMMS) – Water Quality model developed by LA County was instrumental in determining metrics to evaluate most benefits
- November 2018 – Safe Clean Water Program passed
  - Generates ~\$280M towards stormwater capture projects
- Scoring Committee has evaluated over 120 Multi-Benefit Projects

# Safe Clean Water Program – Scoring Criteria

## Water Quality (50 Points)

### Water Quality

- Cost Effectiveness – 24-hour Capacity (acre-feet) / Construction Cost
  - Ratio of 1 or greater was determined to be optimal
- Performance Effectiveness – WMMS generated pollutant reduction results

## Water Supply (25 Points)

### Water Supply

- Cost Effectiveness – Total Life-Cycle Costs / Total Water Supply Benefit (ac-ft)
- Water Supply – Annual Water Supply Benefit (ac-ft) generated by WMMS

## Community Investment (25 Points)

### Community Investments

- Metrics - Flooding, recreational, access
- Community Support

## Leveraging Funds (10 Points)

# Ladera Park Stormwater Capture Project



## Water Quality

- Capacity 5.1 ac-ft (Infiltration)
- Construction Cost: \$5.9 M
- Ratio: 0.86

## Water Supply

- No Recharge Potential (Near Coast)
- Dry Weather runoff (1 cfs) is used for water harvesting/treatment

## Community Enhancements

- Bioswales
- Demonstration Garden/ Shade Structure
- Education Outreach

**Total Score: 69**

# Roosevelt Park Stormwater Capture Project



## Water Quality

- Capacity – 8.0 ac-ft (Infiltration)
- Construction Cost: \$9.7 M
- Ratio: 0.82

## Water Supply

- Recharge Potential in Los Angeles River – 80 ac-ft/year

## Community Enhancements

- Education Garden
- Bioswales/Native Landscaping
- Exercise Equipment
- Skate Park
- Soccer Field

**Total Score: 67**

# Gates Canyon Park Stormwater Capture Project



## Water Quality

- Capacity – 3.5 ac-ft (On-site Treatment)
- Construction Cost: \$8.9 M
- Ratio: 0.39 (Not Cost-Effective in comparison)

## Water Supply

- No recharge potential due to geological constraints
- Water Harvesting System (35 ac-ft/year)

## Community Enhancements

- New park amenities
- Reduced irrigation costs

**Total Score: N/A.** Didn't meet base score



# County of Los Angeles Stormwater Projects

Project Name	Type	Note	Construction Costs	24- hour Capacity (ac-ft)	Water Supply (ac-ft/year)	Safe Clean Water Program Score
Ladera Park	Infiltration Wells & Irrigation Reuse	No Recharge Potential	\$5.9M	5.1	22	69
Roosevelt Park	Infiltration Wells & Gallery	Recharge Potential	\$9.7M	8.0	80	67
Gates Canyon Park	Infiltration Wells & Irrigation Reuse	High Treatment Cost	\$8.9M	3.5	35	N/A

# Conclusions

1. Every project has different challenges/opportunities
  - Geotechnical constraints & Water Supply Opportunities vary
  - Water Treatment Projects are most expensive
  - Dry Weather vs. Wet Weather Projects
  - Difficult to use a singular formula that applies to all projects
2. Recommend comparing similar projects per region
  - Project in areas where groundwater recharge is possible provide “more” benefit compared to areas that don’t recharge
3. Community Enhancements are difficult to compare/evaluate
  - Need further stakeholder engagement to develop agreed upon quantification
  - Metrics are being developed by Safe Clean Water Program team – expected in June 2022
4. Developing stormwater BMP models help evaluate benefits

# Questions

The seal of the County of Los Angeles is visible in the top right corner of the slide. It features a circular design with the words "COUNTY OF LOS ANGELES" around the perimeter and a central emblem.

TJ Moon  
LA County Public Works  
[tmoon@dpw.lacounty.gov](mailto:tmoon@dpw.lacounty.gov)

# Funding Perspective on Project Benefits

Presenter: Spencer Joplin, P.E.  
Water Resource Control Engineer

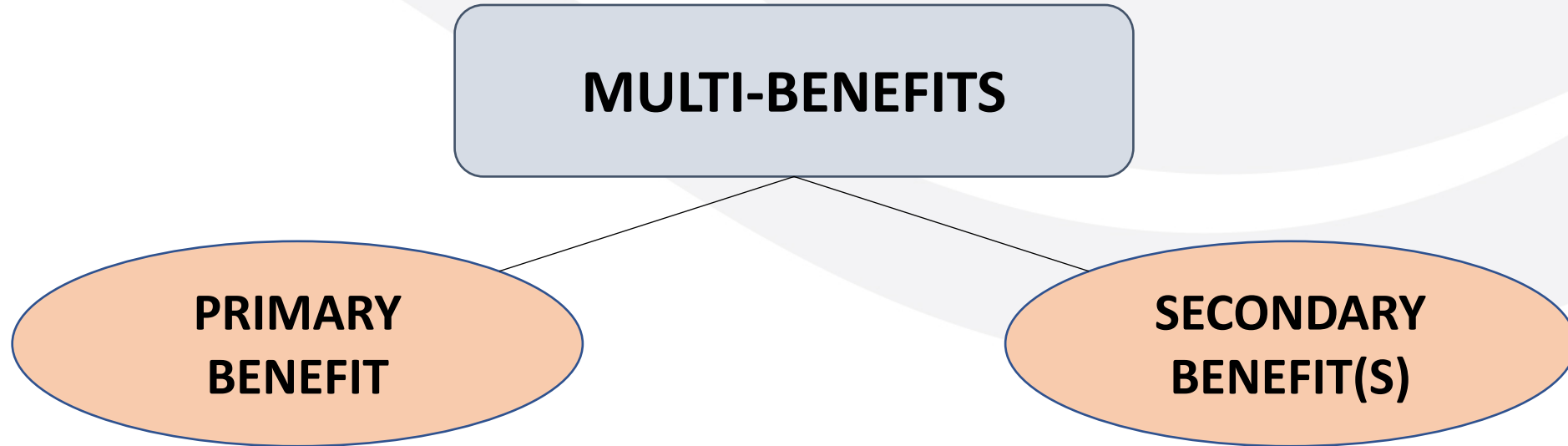


Storm Water Grant Program, September 2021

# Outline

- Grant Program Requirements (for Project Benefits)
- How benefits are presented in an application
- How benefits are evaluated by the Grant Program Staff

# Grant Program Requirements



- Only one (1) Primary Benefit per Project
- Water Supply/Quality – Preferred/Incentivized
- Must be a quantifiable benefit

- Up to two (2) Secondary Benefits per Project (for scoring purposes)
- Not required to be a quantifiable benefit; However, quantification expected (when feasible) depending on the type of benefit claimed

# Examples of quantifiable benefits

Benefit	Example	Metric Units
<b>Water Quality</b> while contributing to compliance with applicable permit and/or TMDL requirements	<ul style="list-style-type: none"> <li>Increased filtration and/or treatment of runoff</li> <li>Nonpoint source pollution control</li> <li>Reestablished natural water drainage and treatment</li> </ul>	<ul style="list-style-type: none"> <li>Load Reduction: lb/day, kg/day.</li> <li>Concentration: mg/l, µg/l, MPN/ml.</li> <li>Unit cost: \$/lb, \$/kg, \$/MPN.</li> <li>Treatment capacity: MGD, AFY.</li> </ul>
<b>Water Supply</b> through groundwater management and/or runoff capture and use	<ul style="list-style-type: none"> <li>Water supply reliability</li> <li>Water conservation</li> <li>Conjunctive use</li> </ul>	<ul style="list-style-type: none"> <li>Volume Captured: MGD, AFY</li> <li>Unit Cost: \$/AF (along with volume)</li> </ul>
<b>Flood Management</b>	<ul style="list-style-type: none"> <li>Decreased flood risk by reducing runoff rate and/or volume</li> <li>Reduced sanitary sewer overflows</li> </ul>	<ul style="list-style-type: none"> <li>Rate: CFS.</li> <li>Area protected: acres.</li> <li>Volume: CF, AF</li> <li>Storm: x-year storm, inches in 24 hours.</li> </ul>
<b>Environmental</b>	<ul style="list-style-type: none"> <li>Environmental and habitat protection and improvement, including:               <ul style="list-style-type: none"> <li>wetland enhancement/creation;</li> <li>riparian enhancement; and/or</li> <li>instream flow improvement</li> </ul> </li> <li>Increased urban green space</li> <li>Reduced energy use, greenhouse gas emissions, or provides a carbon sink</li> </ul>	Size and/or Rate <ul style="list-style-type: none"> <li>acres</li> <li>cubic feet per second (cfs)</li> <li>carbon sequestration (megagrams of carbon per area)</li> </ul> Other <ul style="list-style-type: none"> <li>area units of landscape and buffer</li> <li>measure of improved hydrology</li> <li>number of biotic structure</li> <li>number of physical structures</li> <li>reduced temperature (degrees)</li> </ul>
<b>Community</b>	<ul style="list-style-type: none"> <li>Enhanced and/or created recreational and public use areas</li> <li>Community involvement</li> <li>Employment opportunities provided</li> </ul>	<ul style="list-style-type: none"> <li>Size</li> <li>size of population served</li> <li>number of people</li> <li>number of jobs</li> <li>acres</li> </ul>

# How are Benefits presented in an Application?

## Annual Benefit Quantities Analysis

- Driving force behind projects
  - (i.e. water shortages, WQ impairments)
- Methodology for quantifying claimed Benefits and supporting documentation
- Description of Non-quantifiable Benefits
- Table Summary of Primary and Secondary Benefits (including quantification)

## Cost-Benefit Analysis

### INPUT:

- Itemized volumetric benefit quantities for each BMP Type (amount captured, treated, infiltrated/used)
- Estimated Useful Life of each BMP Type
- Capital Costs of each BMP Type
- Annual O&M Costs of each BMP Type

### OUTPUT:

- Unit (Dollar/Acre-Foot) Cost



# Typical Quantification Methods

- Water Balance
- Modeling Tools or Software
- Calculations

# How are Benefits evaluated?

- Scoring of Benefits driven by the scoring criteria/rubric within the Program Guidelines (Adopted by the Board)
- Do claimed benefits address Program preferences/priorities?
- Are benefits quantified (when applicable) and supported with technical analysis?
- Geographical scale of benefits
  - (i.e. project addressing regional or watershed scale issues vs. local issues)
- Unit Cost-Benefit in comparison with other proposals

# CONTACT INFORMATION

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Phone: 916.319.9436



*Connecting world class research with real-world water challenges*

**Colorado State University**

***Co-Benefits Assessment in the CLASIC tool***  
Sybil Sharvelle

# Co-Benefits Assessments – Spectrum of Analysis

Lists of Co-Benefits

Monetary estimates

**Qualitative**

**Quantitative**



Low input data needed  
Local considerations less important

Complex input data needed  
Local considerations very important

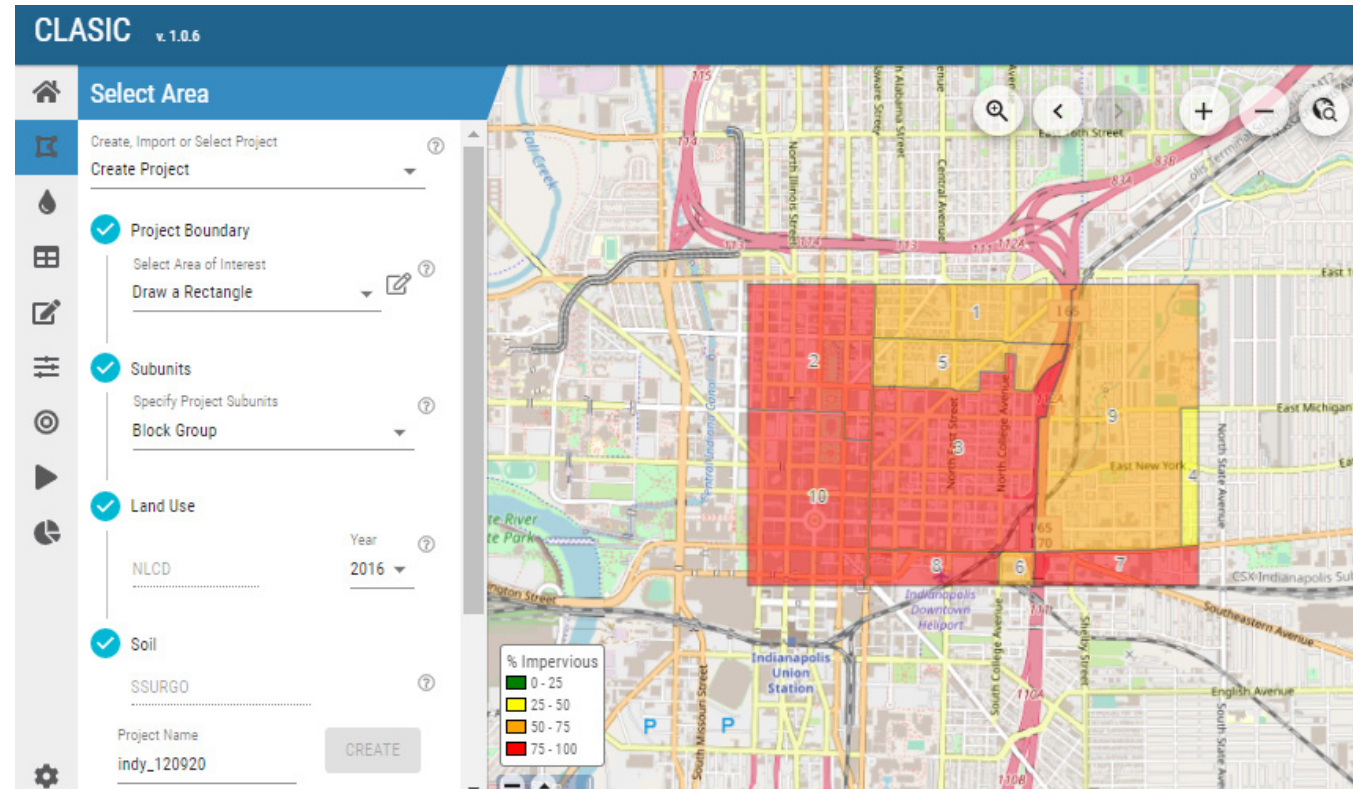
# Vision of CLASIC Decision Support System

*The CLASIC tool is a user-informed screening tool which utilizes a lifecycle cost framework to support stormwater infrastructure decisions on extent and combinations of green, hybrid green-gray and gray infrastructure practices.*



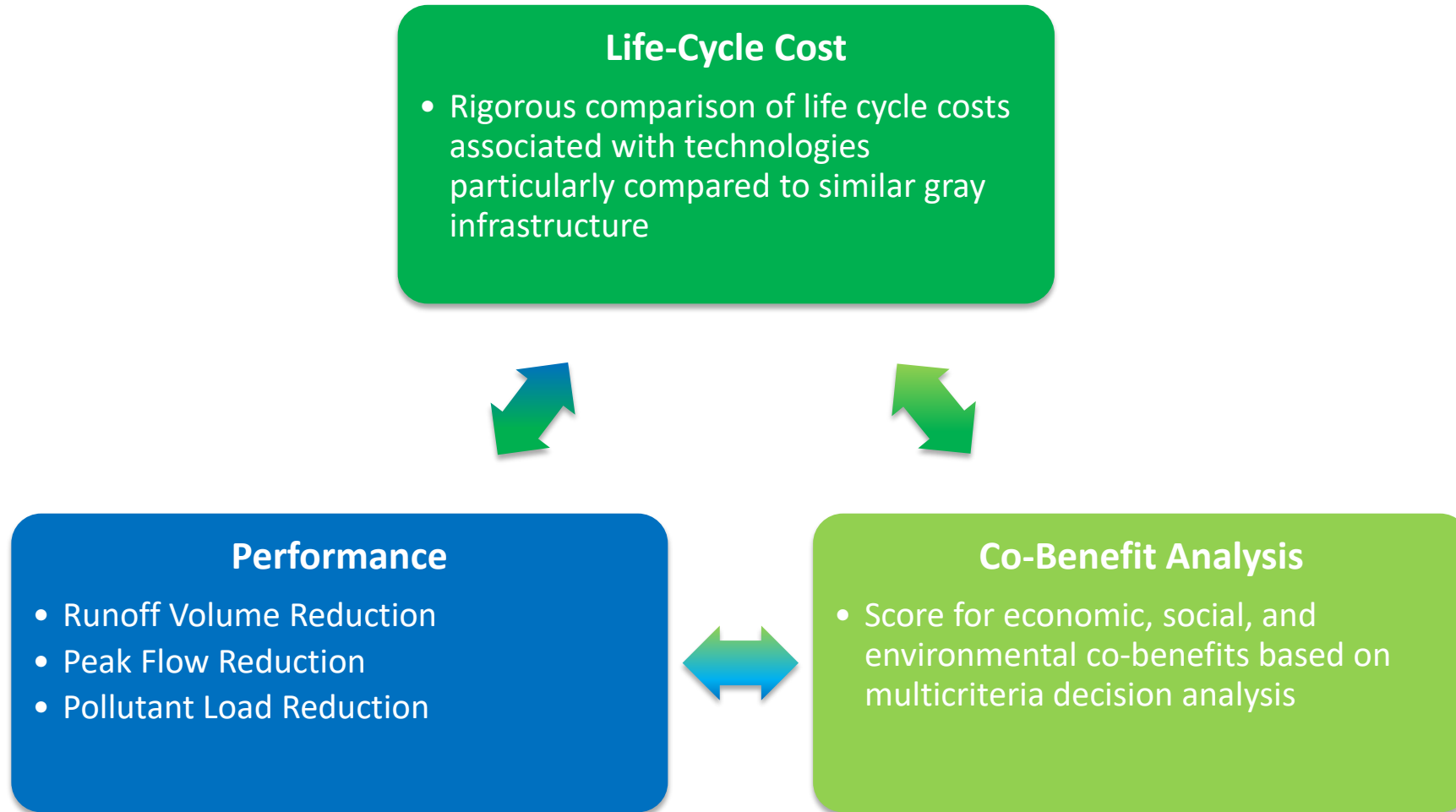
# Web Based Decision Support System:

[clasic.erams.com](http://clasic.erams.com)



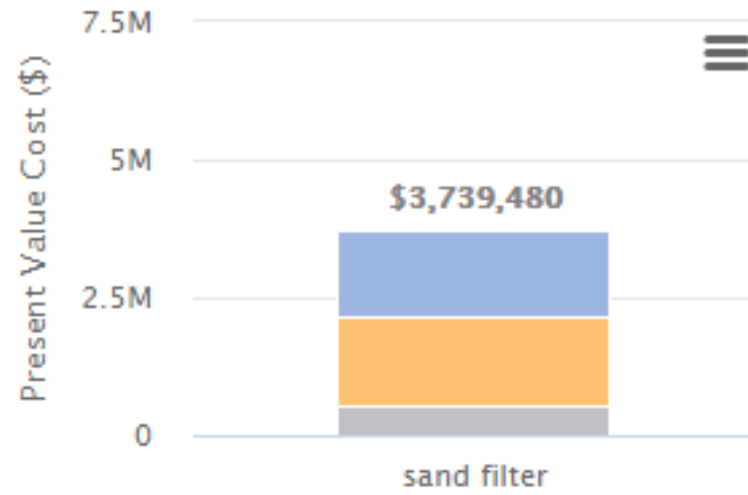
GIS Interfaced for automated data collection of CLASIC inputs (area characteristics)

# Three Basic Outputs for User Allows for Integrated Assessment





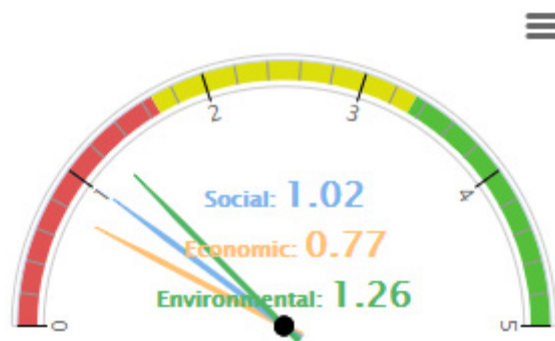
## Sand Filter



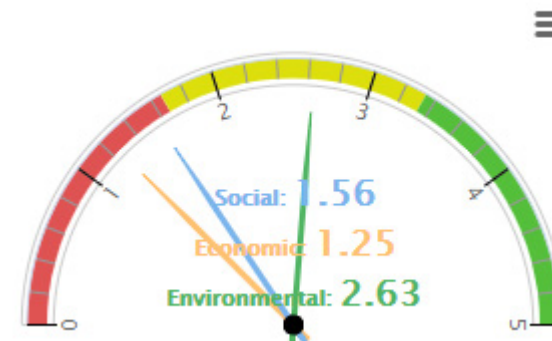
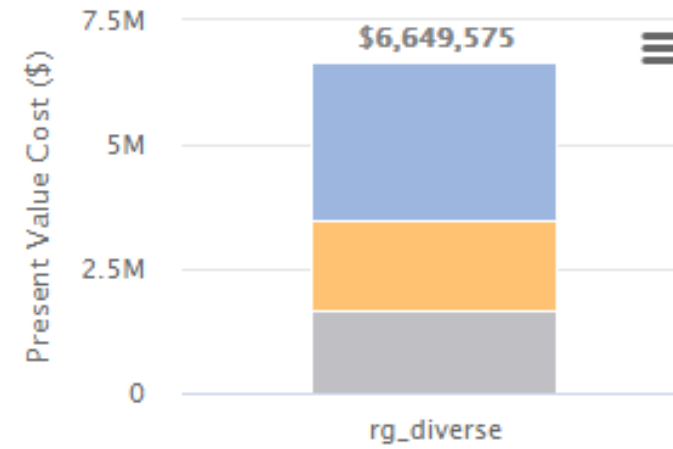
● Construction

● Maintenance

● Rehabilitation



## Rain Garden with Diverse Vegetation



# Co-Benefits Assessments – Spectrum of Analysis

Lists of Co-Benefits

Monetary estimates

**Qualitative**

**Quantitative**



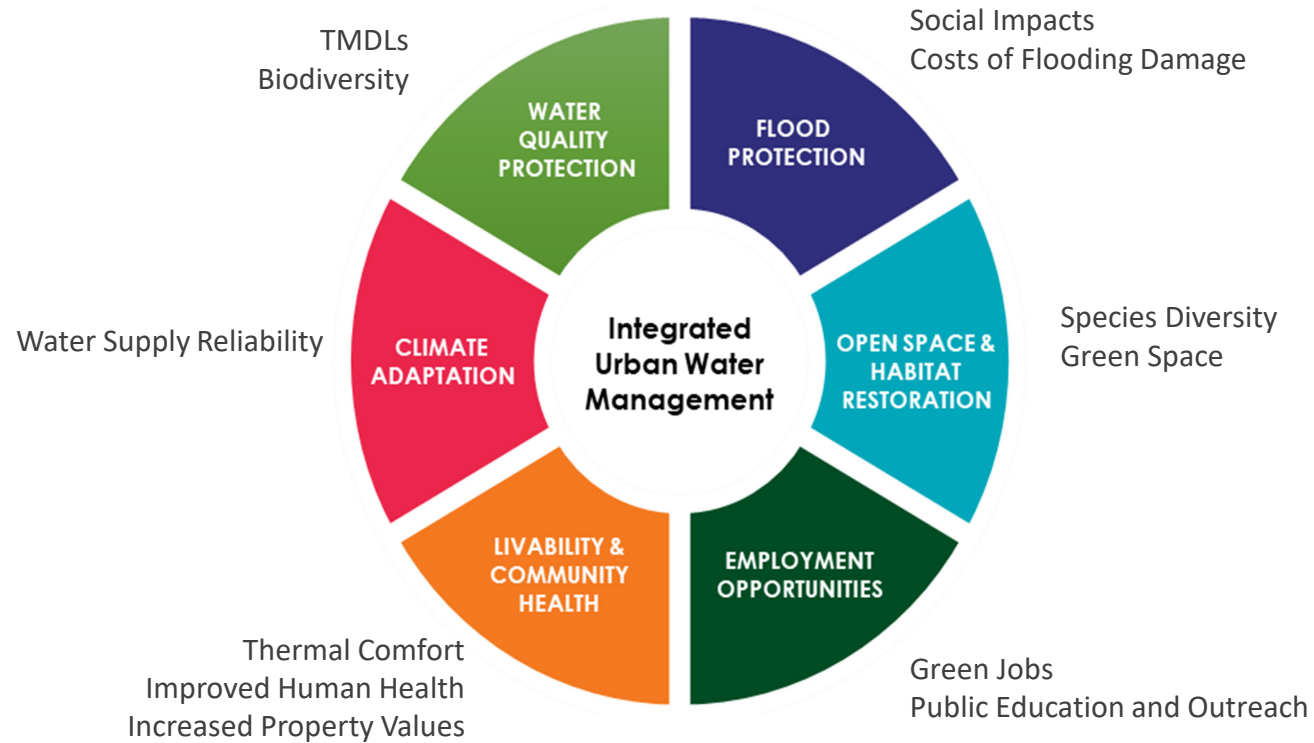
Low input data needed  
Local considerations less important

Complex input data needed  
Local considerations very important



CLASIC

# Co-Benefit Analysis in CLASIC Tool



User selects importance factors (1 – 4) for each indicator

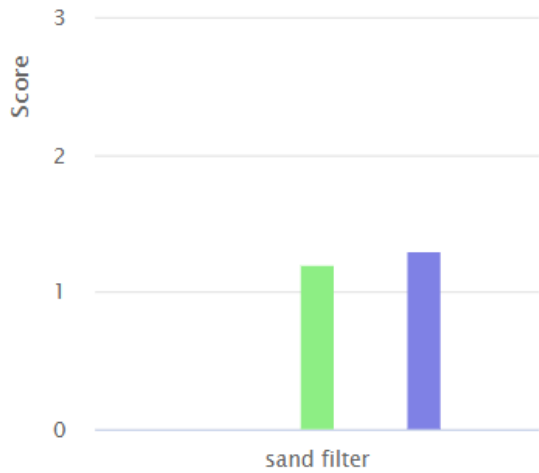
### Economic Indicator Importance ^

- Economic Indicators**
  -
- Property Values
- Costs from Illness
- Avoided Cost from Combined Sewer Treatment
- Potential Impacts from Nuisance Floods
- Building Energy Eff.
- Avoided Water Treatment
- Employment Opportunity

# Quantitative Data used to Assign Indicator Ratings

For each indicator, relative rating between 1 - 5 is assigned to enable a comparative analysis between scenarios  
(Multi-Criteria Decision Analysis)

Co-Benefit Indicators	Approach	CLASIC parameters used for estimation
<b>ECONOMIC</b>		
Property Values	Directly correlated to area of added green space	SCM area (acre) only when vegetated is selected and technology is added to captured impervious
Costs from Illness	Ozone, PM10, nitrogen dioxide, sulfur dioxide, and carbon monoxide removal by each herbaceous plants and trees is estimated. Pollutant removal is used in conjunction with cost of illness treatment associated with each pollutant.	Diverse Vegetated SCM area (acre); Number of trees added; Area of Green Roof
Avoided Costs from Combined Sewer Treatment	Runoff volume	Average annual precipitation that becomes runoff (in/yr)



● Health Impacts From Air Quality

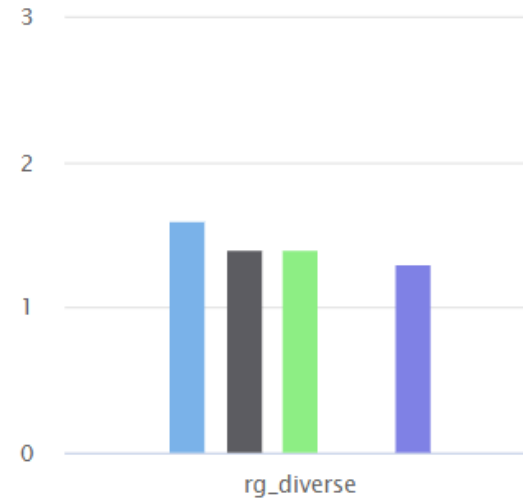
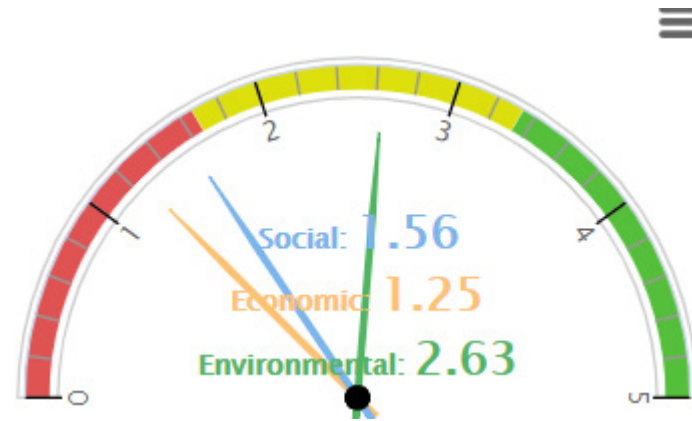
● Mental Health

● Thermal Comfort

● Increased Supply from Harvested Stormwater

● Public Awareness of Stormwater and Water Systems

Social ▼



# Summary

- Co- Benefits Analyses range from qualitative to quantitative (monetary)
  - More extensive data inputs required for monetary estimate
- CLASIC utilizes multi-criteria decision analysis approach to provide relative comparisons of co-benefits between scenarios with few user inputs



**Welcome to the GSI TBL Tool**

This Tool allows you to quantify and monetize the Triple Bottom Line (TBL) benefits of Green Stormwater Infrastructure (GSI).

In subsequent tabs, you will provide inputs necessary to develop the GSI scenario you would like to evaluate. You will also enter key inputs necessary to quantify and monetize the GSI benefits relevant to your community. Each benefit is represented by a separate tab/benefits module.

Throughout this Tool, only enter values into Cells shaded in **GREEN**. Generally, you should not enter values into cells shaded in **GRAY** (although there are exceptions). Results are shown in cells that are shaded in **ORANGE**.

To successfully navigate the Tool, the **MACROS ASSOCIATED WITH THIS FILE MUST BE ENABLED**. Simply hit the Enable Content button at the top of the screen to enable macros.

## Framework and Tool for Quantifying the Triple Bottom Line Benefits of Green Stormwater Infrastructure



Enter TBL GSI Tool



THE  
Water  
Research  
FOUNDATION

**CORONA**  
ENVIRONMENTAL CONSULTING

**Kennedy/Jenks**  
Consultants

**Janet Clements**  
**Director, Water Economics and Planning**  
**Corona Environmental Consulting**

September 7, 2021



# Project Objective

Develop economic framework and Excel-based tool to help practitioners *quantify* and *monetize* the *Triple Bottom Line benefits* of GSI and compare them to *costs*.



# What is Triple Bottom Line Analysis?

Comprehensive **benefit-cost analysis** that accounts for:

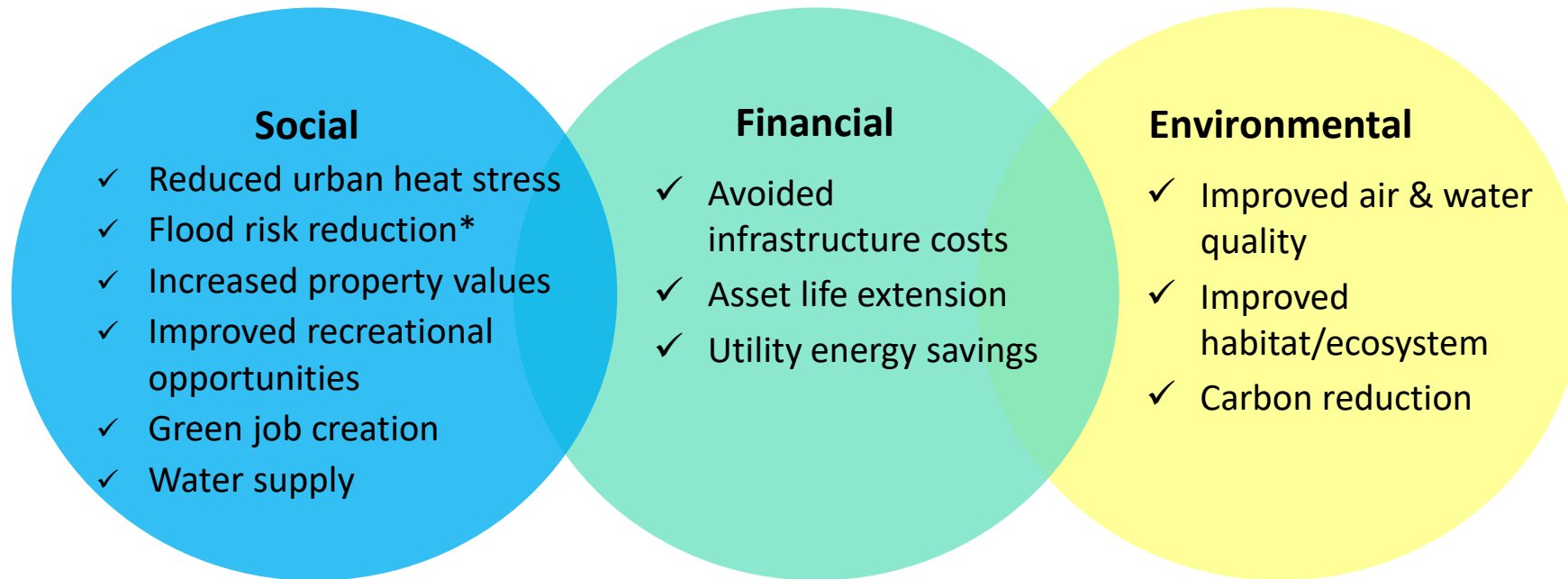
- *financial*
- *social*
- *environmental*

**benefits and costs** of a project or program **over time**, and to **whom they accrue**.



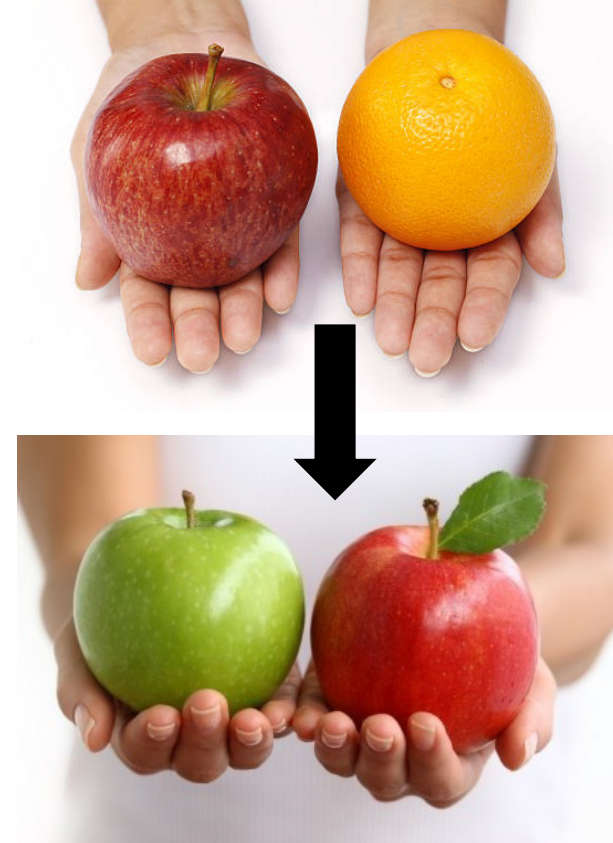
# Economic Aspects of GSI

A broader *economic* (TBL) perspective can reveal that GSI provides greater benefits for communities.



# Why is Quantitative/Monetized TBL Information Needed?

- Build support for GI internally
- Identify stormwater management alternatives that maximize community value
- Compete for scarce funding
- Leverage private capital and alternative funding
- Support alternative project delivery models
- Gain community support and buy-in



# Framework and Tool

- Standard economic valuation methods
- Default (regional) values/allows for user customization
- Neighborhood, city, watershed scale
- Excel-based Tool, guidance, report, extensive technical documentation



# Establishing a GSI Scenario

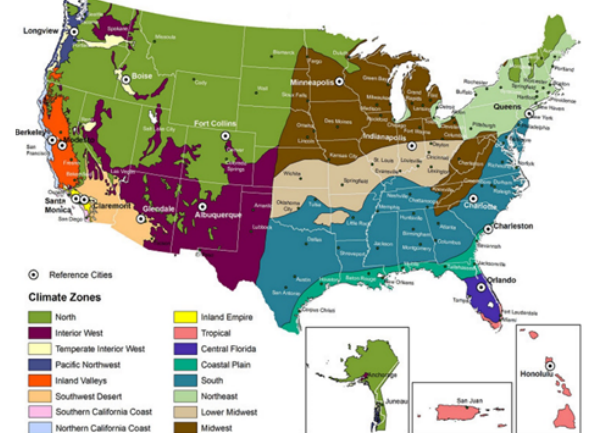
## GSI Practices - Enter Acres Managed or Number of BMPs

<u>GSI Practice (BMP)</u>	<u>CLASIC BMP Name</u>	<u>Effective Impervious Acres Managed</u> (acres)	<u>Number of BMPs</u>	<u>Volume Capacity by BMP type</u> (cft)	<u>Calculated BMP Area (Footprint)</u> (square feet)	<u>Annual Runoff Volume</u> (cft)
Rain gardens	Rain gardens		-	-	-	-
Bioretention facilities	Infiltration trenches	708.4	802	2,520,062	4,408,272	79,279,098
Green roofs	Green roofs	57	598	202,505	2,987,534	6,370,642
Tree planting/street trees	*	151.2	118,000	548,700	82,962,564	16,916,421
Permeable pavement	Permeable pavement	329	329	1,170,385	7,165,620	36,819,344
Cisterns - rainwater harvesting	Rainwater harvesting	8.29	45	30,080		927,373
Rain barrels - rainwater harvesting	Rainwater harvesting	11.48	1,000	7,352.9		1,284,583
Constructed wetland	*		-	-	-	-
Wet ponds	Wet pond		-	-	-	-
Biofiltration/grass or vegetated swale	Grass swale		-	-	-	-
		1,265		4,479,085		141,597,462

\* CLASIC does not address "Tree planting/street trees" or "constructed wetland"

# Benefit Modules: Energy Savings

- Building energy savings (trees and green roofs)
- Avoided stormwater pumping and treatment
- Avoided drinking water treatment and distribution

A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U																																																																
<div style="background-color: #e1f5fe; padding: 10px; border: 1px solid #cfcfcf;"> <h2 style="margin: 0;">\$ Energy Savings</h2> <ul style="list-style-type: none"> <li>- Reduced heating and cooling for buildings</li> <li>- Avoided stormwater pumping and treatment</li> <li>- Avoided drinking water treatment and distribution</li> </ul> </div>					<p><b>Benefit Value Summary</b></p> <table border="1" style="width: 100%; border-collapse: collapse;"> <tr> <td>Annualized Value</td> <td style="text-align: right;">\$ 26,603</td> </tr> <tr> <td>Present Value</td> <td style="text-align: right;">\$ 835,968</td> </tr> <tr> <td>analysis period (years)</td> <td style="text-align: right;">50</td> </tr> </table>					Annualized Value	\$ 26,603	Present Value	\$ 835,968	analysis period (years)	50																																																																					
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<p><b>Building Energy Savings - Trees</b></p> <table style="width: 100%; border-collapse: collapse;"> <tr> <td style="width: 20%; border: 1px solid #ccc;">90</td> <td style="width: 10%;"></td> <td style="width: 40%;">Number of trees added</td> <td style="width: 30%;"></td> </tr> <tr> <td style="border: 1px solid #ccc;">Midwest</td> <td></td> <td>Climate Zone</td> <td></td> </tr> <tr> <td style="border: 1px solid #ccc;">Minnesota</td> <td></td> <td>State</td> <td></td> </tr> </table> <p><b>Electricity Savings at Full Tree Growth (30 years)</b></p> <table style="width: 100%; border-collapse: collapse;"> <tr> <td style="border: 1px solid #ccc;">267</td> <td style="width: 10%;"></td> <td style="width: 30%;">kWh</td> <td style="width: 10%;">Average Annual Electricity Savings Per Tree</td> <td style="width: 40%;"></td> </tr> <tr> <td style="border: 1px solid #ccc;">12.5</td> <td></td> <td>(cents/kWh)</td> <td>Average Cost of Electricity (Residential and Commercial)</td> <td></td> </tr> <tr> <td style="border: 1px solid #ccc;">\$ 33.21</td> <td></td> <td>\$ / year</td> <td>Value of Electricity Savings Per Year Per Tree</td> <td></td> </tr> <tr> <td style="border: 1px solid #ccc;">\$ 2,989</td> <td></td> <td>\$ / year</td> <td>Value of Electricity Savings Per Year for all Trees</td> <td></td> </tr> </table> <p><b>Natural Gas Savings at Full Tree Growth (30 years)</b></p> <table style="width: 100%; border-collapse: collapse;"> <tr> <td style="border: 1px solid #ccc;">36.47</td> <td style="width: 10%;"></td> <td style="width: 30%;">(Therms)</td> <td style="width: 10%;">Average Annual Natural Gas Savings Per Tree</td> <td style="width: 40%;"></td> </tr> <tr> <td style="border: 1px solid #ccc;">3.53</td> <td></td> <td>Thousand Cubic Feet Conversion</td> <td></td> <td></td> </tr> <tr> <td style="border: 1px solid #ccc;">9.58</td> <td></td> <td>(\$/K Cubic Feet)</td> <td>Average Cost of Natural Gas</td> <td></td> </tr> <tr> <td style="border: 1px solid #ccc;">\$ 33.79</td> <td></td> <td>\$ / year</td> <td>Value of Natural Gas Savings Per Year Per Tree</td> <td></td> </tr> <tr> <td style="border: 1px solid #ccc;">\$ 3,041</td> <td></td> <td>\$ / year</td> <td>Value of Natural Gas Savings Per Year for all Trees</td> <td></td> </tr> </table> <p><b>Building Energy Savings - Green Roofs</b></p> <table style="width: 100%; border-collapse: collapse;"> <tr> <td style="border: 1px solid #ccc;">MN MINN</td> <td style="width: 10%;"></td> <td style="width: 40%;">Reference State/City</td> <td style="width: 50%;"></td> </tr> <tr> <td style="border: 1px solid #ccc;">435,600</td> <td></td> <td>square foot</td> <td>Square footage of green roof added</td> </tr> </table> <p><u>Green Roof Parameters</u></p>																				90		Number of trees added		Midwest		Climate Zone		Minnesota		State		267		kWh	Average Annual Electricity Savings Per Tree		12.5		(cents/kWh)	Average Cost of Electricity (Residential and Commercial)		\$ 33.21		\$ / year	Value of Electricity Savings Per Year Per Tree		\$ 2,989		\$ / year	Value of Electricity Savings Per Year for all Trees		36.47		(Therms)	Average Annual Natural Gas Savings Per Tree		3.53		Thousand Cubic Feet Conversion			9.58		(\$/K Cubic Feet)	Average Cost of Natural Gas		\$ 33.79		\$ / year	Value of Natural Gas Savings Per Year Per Tree		\$ 3,041		\$ / year	Value of Natural Gas Savings Per Year for all Trees		MN MINN		Reference State/City		435,600		square foot	Square footage of green roof added
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<p>Introduction   Results.Dashboard   Key.Inputs   GSI.Scenario   Costs.Timeline   1.Avoided.Infrastructure.Costs   2.Avoided.Replacement.Costs   <b>3.Energy.Savings</b>   4.Water.Supply   5.Air.Quality</p>																																																																																				

# GSI Benefit/Cost Results

- Benefits by Triple Bottom Line (TBL) category
- Benefits over time

## Analysis Assumptions

Analysis Period  Years  
 Discount Rate

## Present Value - All Benefits and Costs

	Total over study period	Annualized values
Benefits	\$ 27,893,556	\$ 1,673,975
Costs	\$ 21,532,600	\$ 1,292,235
<b>Benefit-Cost Ratio</b>	1.295	

## Benefit Categories

### Financial

- Avoided infrastructure and treatment costs
- Avoided replacement costs
- Energy savings

### Environmental

- Water quality improvements
- Carbon emissions reduction and sequestration
- Ecosystem benefits

### Social

- Improved air quality
- Water supply benefits
- Improved aesthetics (property values)
- Reduced heat stress
- Increased recreation
- Green job creation

### Other

- Other benefits (enter to the right)

## Benefits Calculated Outside Tool

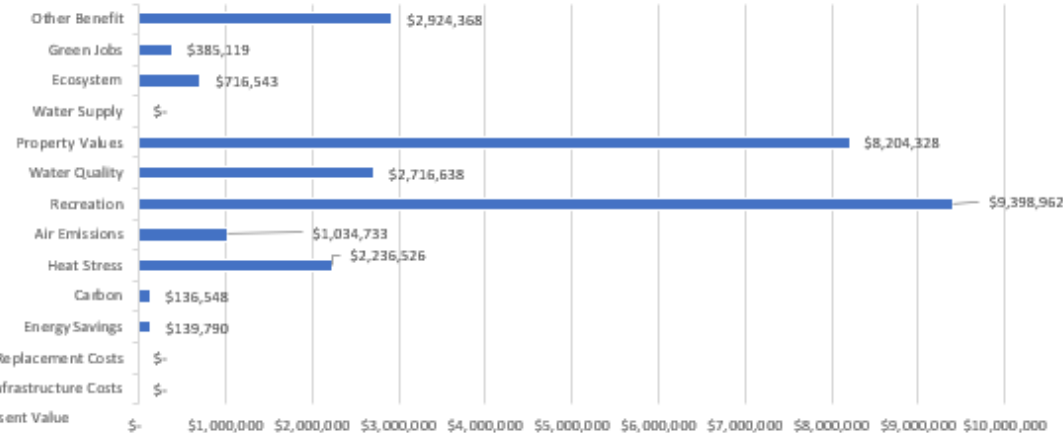
### Average annual (non-discounted)

\$ 175,500

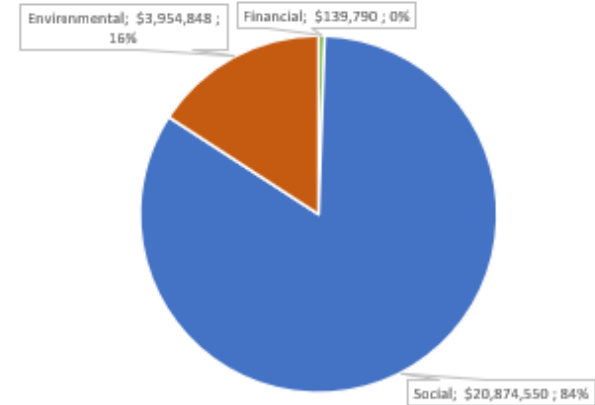
### TBL Benefit Type

Other

Present Value Benefits by GSI Category



TBL Accounting of GSI Benefits - Present Value





# Case Studies

- **St. Paul (MI)** – Green/Gray Alternatives evaluation; 34-acre site; Autocase comparison
- **Lancaster (PA)** – Citywide Stormwater Management Plan; CNT/AR comparison
- **Seattle (WA)** – Neighborhood Improvement; Incorporates MODA analysis
- **Cleveland (OH)** – 9 grant-funded projects

	Saint Paul, MN	Lancaster, PA	Seattle, WA	Cleveland, OH
Description	Compares benefits and costs of two alternatives – gray- and GSI-based approaches – for mixed-use, 134-acre redevelopment site.	Evaluates benefits and costs of a citywide GSI-based stormwater management plan implemented over 25-years.	Examines benefits and costs of three ROW bioretention projects in high priority watershed.	Evaluates benefits and costs of multiple grant funded GSI projects in combined sewer are of District.
Project proponents	Capitol Region Watershed District/City of Saint Paul	City of Lancaster	Seattle Public Utilities	Northeast Ohio Regional Sewer District.
Key highlights	Results compared to similar analysis using <a href="#">Autocase</a> tool. Compares incremental costs / benefits of gray and GSI scenario.	Results compared to a similar analysis developed using <a href="#">CNT/American Rivers Guide</a> .	Incorporates <a href="#">MODA</a> framework that SPU uses to assess GSI project priorities / benefits.	Includes customized property value analysis and analyzes distributed projects.
GSI scenario	Centralized GSI corridor; 4.8 acres of bioretention; 300 trees, large retention pond / wetland system; 10-acres of green space. Stream restoration links development site to recreation/natural area.	Manages 1,265 IA / 1,060 MG of runoff/year through GSI: bioretention (56%); permeable pavement (26%); trees (13%); green roofs (4.5%); RWH (1%).	ROW bioretention projects managing 6 impervious acres; includes 89 trees, pedestrian/safety improvements, and community gathering space.	Nine distributed projects including bioretention, permeable pavement, and underground systems.
Avoided infrastructure		★		★
Avoided maint./replace.		★		★
Energy savings	★	★	★	★
Water supply		★		★
Air quality	★	★	★	★
Heat stress	★	★		
Recreation	★	★	★	
Enhanced aesthetics	★	★	★	★
Green job creation	★	★	★	★
Water quality/habitat	★		★	
Carbon reduction	★	★	★	★
Terrestrial ecosystem	★	★	★	★
Flood risk reduction	★			
Total PV benefits (\$M)	\$27.9 (GSI); \$15.1 (gray); (28-year PV)	\$521.8 (50-year PV)	\$8.98 (50-year PV)	\$3.49 (40-year PV)
Total PV costs (\$M)	\$21.5 (GSI); 18.8 (gray) (28-year PV)	\$241.5	\$5.87	2.40
Benefit-cost ratio	1.3 (GSI); 0.8 (gray)	2.16	1.53	1.455

# Key Research Gaps and Next Steps

- Quantification: Flood risk reduction, habitat creation, urban heat stress benefits
- How to design, locate, and implement GSI to achieve benefits
- Incremental benefits and costs  
(what are the price points for achieving benefits?)
- Informing/integrating with funding and financing options/  
alternative project delivery models
- Equity implications
- Alternative frameworks for non-quantified benefits

**Contact:** Janet Clements

[jclements@coronaenv.com](mailto:jclements@coronaenv.com)

# Assessing Co-benefits and Moving Towards Multi- functional Design

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KATIE SPAHR, PH.D., P.E.

RESEARCH PROGRAM MANAGER, THE WATER RESEARCH FOUNDATION

PRESENTING GRADUATE WORK PERFORMED UNDER

DR. TERRI HOGUE, COLORADO SCHOOL OF MINES

# Integrated Decision Support Tool (i-DST) Project

Develop an integrated, scalable, decision support tool (called i-DST) for grey, green, and hybrid infrastructure for nationwide implementation

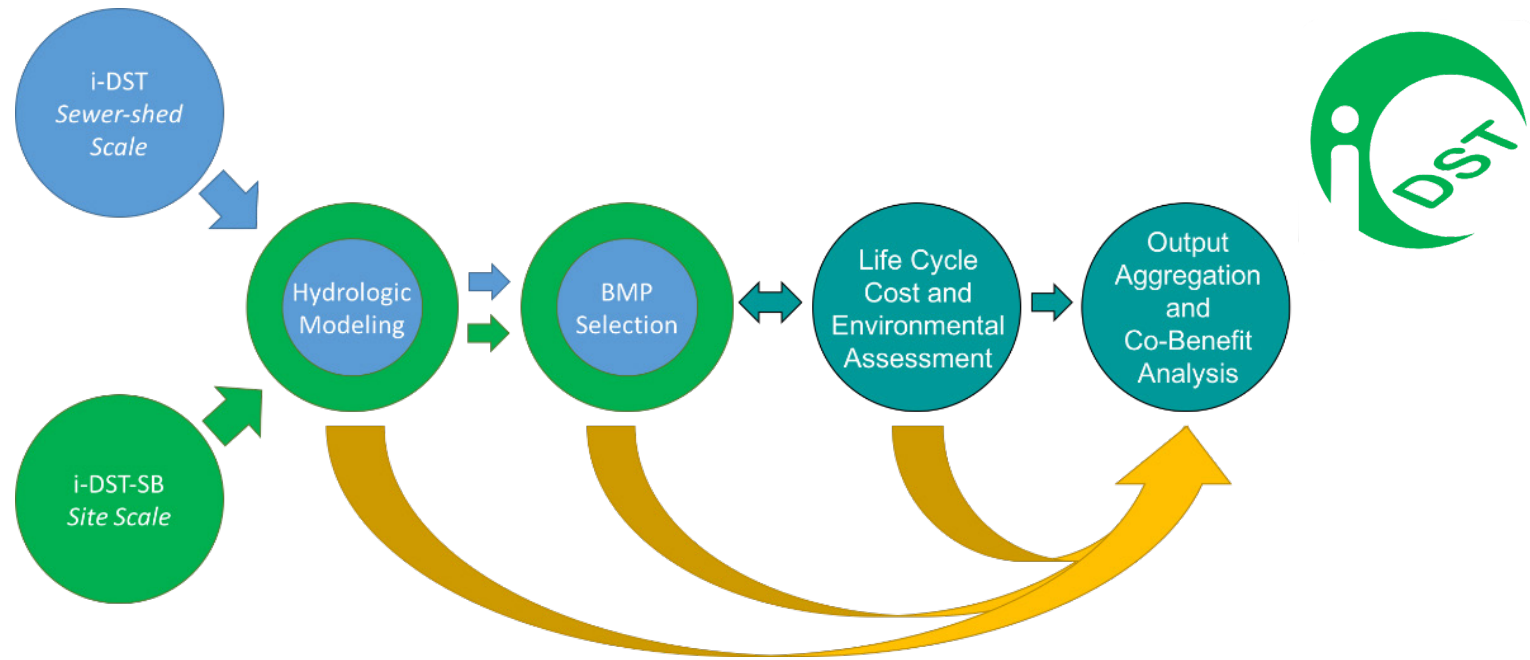
Planning-level tool – suitable for project prioritization (not design)



EPA National Priorities: Life Cycle Costs of Water Infrastructure Alternatives (RFP: EPA-G2015-ORD-D1)

[idst.mines.edu](http://idst.mines.edu)

Board Image from the Noun Project



Conceptual model of tool components



Multi-institutional collaboration



Science Advisory Board

# State of the co-benefit literature

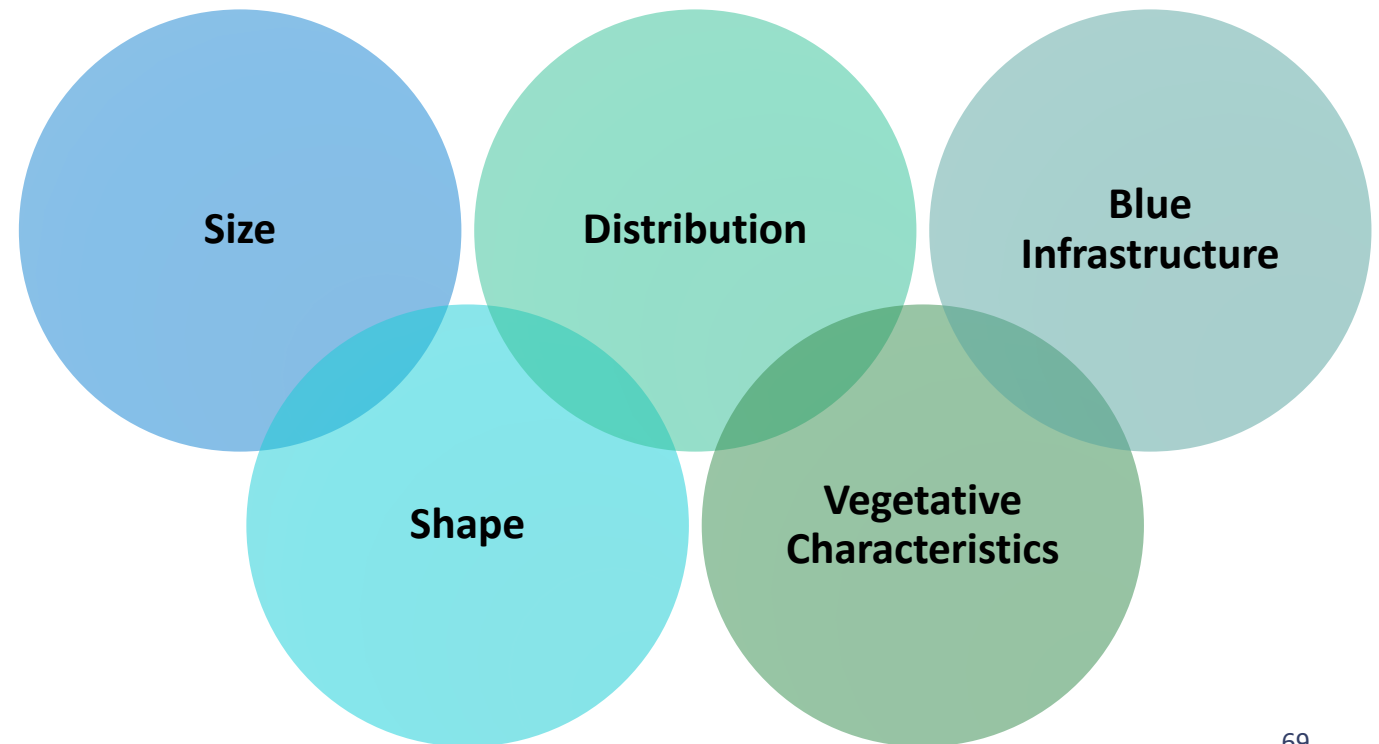
“This global systematic review highlights the minimal evidence on human health and social well-being relating to green infrastructure for stormwater and flood management”

-Venkataramanan et al. (2019)

“In small parks ... pollutant removal by vegetation is unlikely to make the major contribution to improved air quality in their interiors”

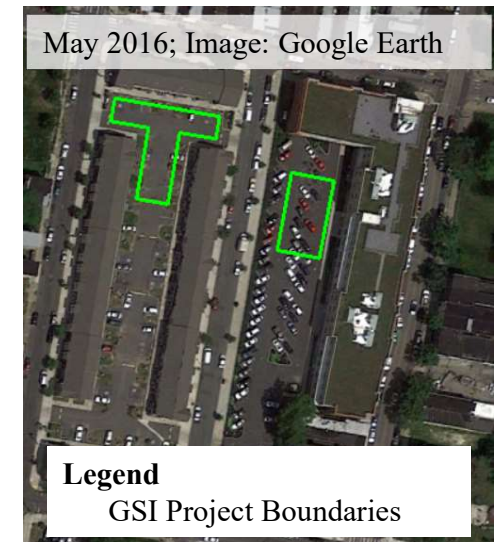
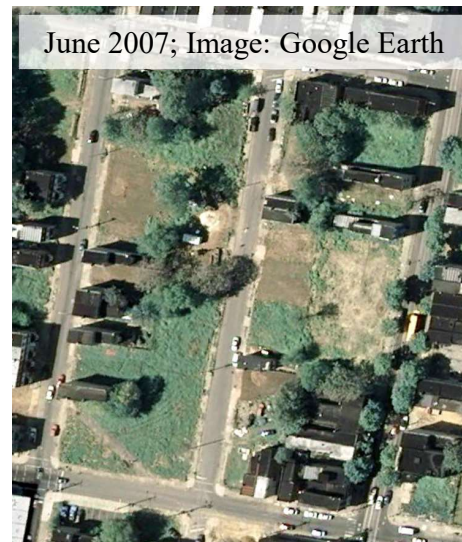
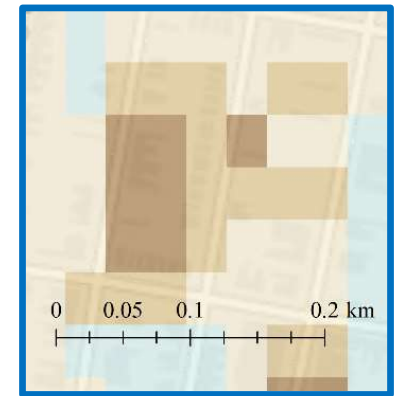
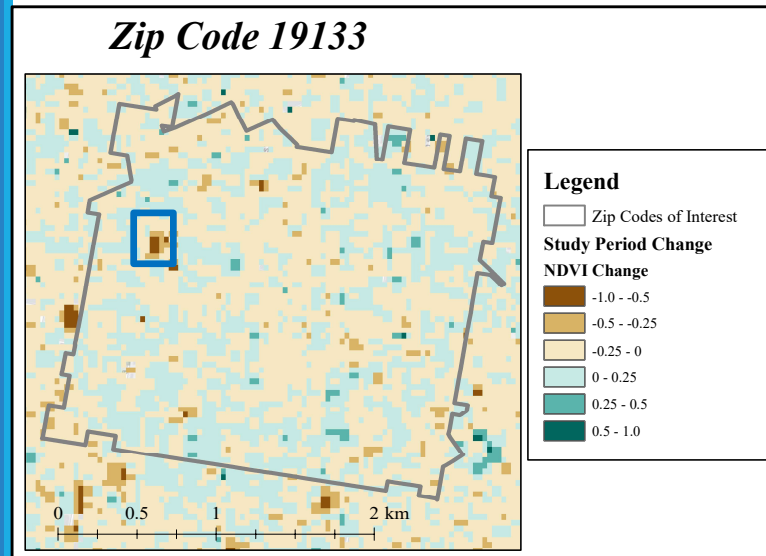
-Xing & Brimblecombe (2020)

Benefit	Reference
Improved air quality	(Xing & Brimblecombe, 2020)
Human health and well-being	(Venkataramanan et al., 2019)
Property values	(Mazzotta, Besedin, & Speers, 2014)
Urban cooling	(Yu et al., 2020)



Previous work using high resolution vegetation modeling showed that GSI installation is not offsetting development in Philadelphia.

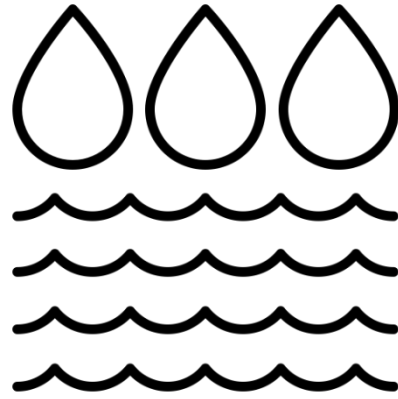
(Spahr et al., 2020)



For the i-DST, we focused on 13 benefits

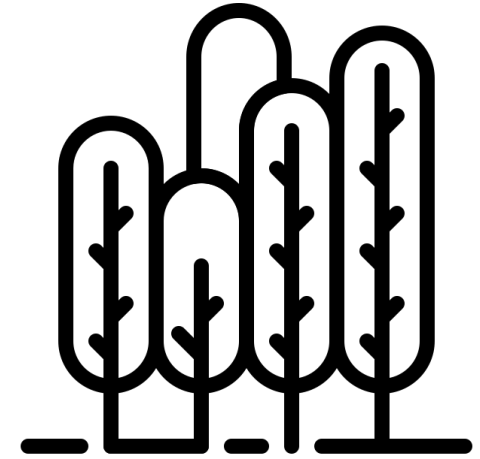
Benefits were analyzed by driver:

Hydrologic processes or vegetation



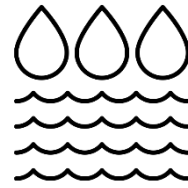
### Hydrologic-process-based Benefits

- Improved water quality
- Reduced impacts from flooding
- Reduced burden on existing infrastructure
- Increased local groundwater resources
- Cistern-specific benefits
- Increased aquatic biodiversity



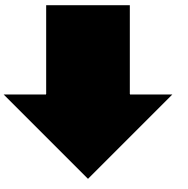
### Vegetation-based Benefits

- Increased recreational opportunities
- Increased terrestrial biodiversity
- Increased property values
- Neighborhood beautification
- Human health and well social well being
- Improved air quality
- Neighborhood cooling



## Hydrologic-process-based Benefits

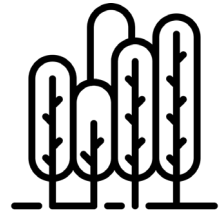
Straightforward to measure through stormwater modeling



Benefit	Metric	Lower Value Preferred?	BR	IT	PP	UDS	UIS	VS
-	Total capital cost	Yes	1.00	0.06	0.54	0.48	0.26	0.00
Vegetated benefits	Total potential vegetated area	No	0.26	0.00	-	-	-	1.00
Reduced impacts from flooding	Flow exceedance frequency	Yes	0.32	0.39	0.39	1.00	0.61	0.00
Increased groundwater resources	Total groundwater recharge potential	No	0.00	0.12	0.07	-	1.00	0.65
Neighborhood Cooling	Total evapotranspiration	No	1.00	0.82	0.88	-	-	0.00
Improved water quality	Average annual load of total phosphorus at outlet	Yes	0.00	0.01	0.09	1.00	0.07	0.09

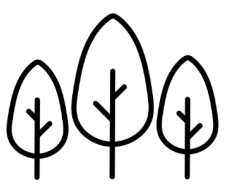
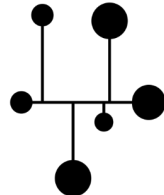
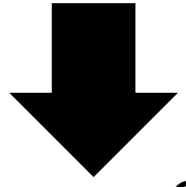
Key: ← More preferred →

## i-DST SUSTAIN



## Vegetation-based Benefits

Require knowledge of surrounding urban green infrastructure



## 4 Cs: Community, context, connectivity, canopy

Different benefit drivers require different benefit assessments



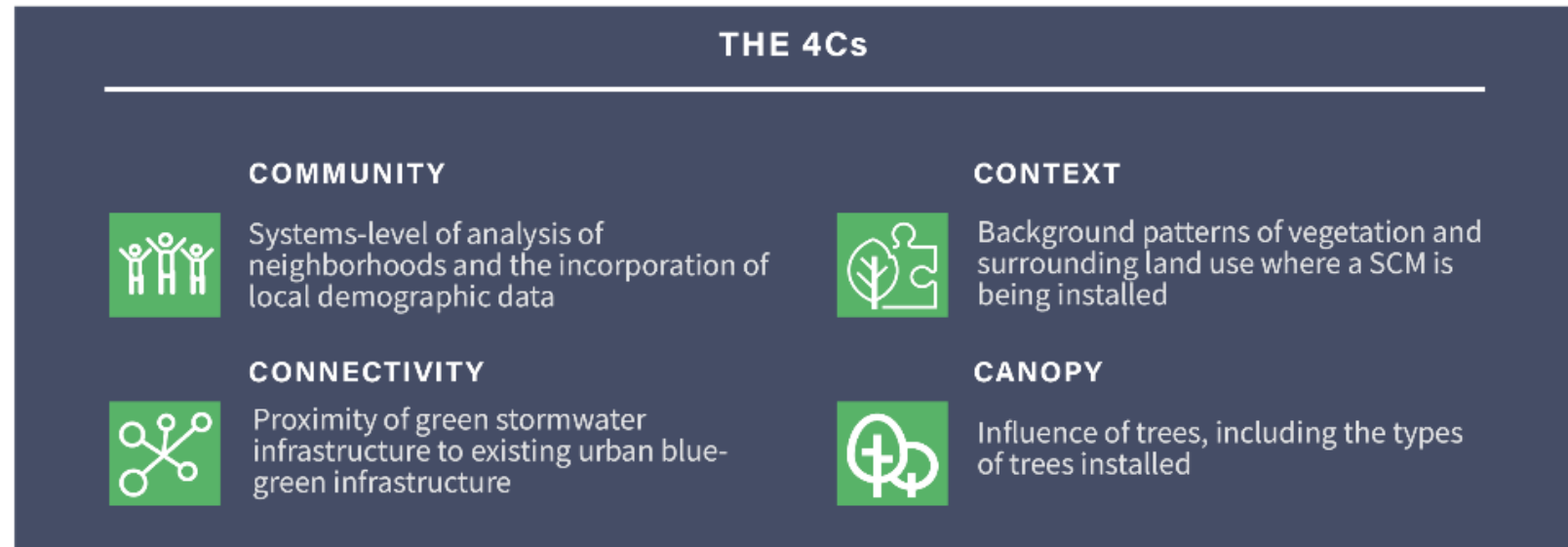
# The 4Cs

Conceptual framework to be used to help practitioners assess trade-offs between benefits

Pulled from common themes in the vegetated benefit literature

Promotes and supports scientifically sound decisions and multi-functional planning

(Spahr et al., 2021)



# i-DST Benefit Factsheets

## • Summarize literature

## • Identify trade-offs

## • Jumping off point for stormwater managers

## • Will be hosted on i-DST website

**Benefit Guidance Factsheet**

### INCREASED PROPERTY VALUES

**Functional description:** Adding vegetation using greener stormwater control measures (SCMs) can increase property values of adjacent lots.

**STATE OF THE LITERATURE**

The impact of green stormwater infrastructure (GSI) on property values is measured using hedonic pricing modeling. The results of the models are variable, as shown in the table on the right. A 2014 meta-analysis of hedonic pricing studies found that expected property value increases are dependent on the size, quantity, and location of the green infrastructure installed [1]. As shown in the graph on the right, not all green infrastructure types studied are the same as the GSI included in the i-DST.

**ASSESSING THE IMPACT OF SCMS ON PROPERTY VALUES USING THE 4Cs**

**COMMUNITY** Some developments with SCMs can result in higher tax rates that reduce returns for other taxpayers. In fact, all elements of a property may yield increased property values, increased property values to the generalization and displacement [1].

**CONTEXT** The installation of a multi-use detention basin instead of a park or a pocket park impact on adjacent property values. The impact of a park had a negative impact on property values [2].

**CONNECTIVITY** The impact of GSI on property values increases on the per lot area [3].

**CANOPY** Most of the existing literature focuses on the impact of permeable pavement [1, 4, 5]. These studies mention other green infrastructure types including the i-DST, but do not account for the installation of trees [6].

**KEY CONSIDERATION(S) FOR SCM INSTALLATION**  
Monitor other stakeholders. Consider scope of project for property stakeholders. Includes trees, SCMs, etc.

**Benefit Guidance Factsheet**

### HUMAN HEALTH AND SOCIAL WELL-BEING

**Functional description:** Managing stormwater runoff and identifying along with adding vegetation using stormwater control measures (SCMs) can result in personal and community human health and social well-being benefits.

**STATE OF THE LITERATURE**

Green stormwater infrastructure (GSI) can potentially improve community public health through increased interactions with vegetation [1]. In a comprehensive review of the literature, the authors found that human health and social well-being outcomes, the authors found that the studies connected GSI to mental health or physical health outcomes [2]. The authors go on to encourage "experts in social science, public health, and program evaluation to be integrated into interdisciplinary green infrastructure research" [2]. These efforts could include an evaluation of how the "availability of the form, structure or composition of urban nature" impacts mental or physical health [3]. This type of research will be critical for practitioners' understanding of how different configurations and scales of urban nature, including GSI, influence human health and social well-being so that future design interventions can be informed and optimized by these findings.

**ASSESSING THE IMPACT OF SCMS ON HUMAN HEALTH USING THE 4Cs**

**COMMUNITY** While there are many potential positive impacts of SCMs on human health and social well-being, the highest potential for human health outcomes is likely to be through the installation of green infrastructure that improves air quality and reduces noise [1].

**CONTEXT** Environmental psychology do not found that visual appearance of green infrastructure has a positive impact on human health outcomes, especially in situations with a steady high stress level [2].

**CONNECTIVITY** It is important to have both parks and green infrastructure in a community. A study of parks and green infrastructure in a city found that parks and green infrastructure yield similar results.

**CANOPY** Air pollution removal by a tree canopy is highly dependent on the species of the tree canopy. A study of parks and green infrastructure in a city found that parks and green infrastructure yield similar results.

**KEY CONSIDERATION(S) FOR SCM INSTALLATION**  
Focus on parks that provide positive and improve social equity.

**Benefit Guidance Factsheet**

### INCREASED BIODIVERSITY

**Functional description:** Adding vegetation and blue infrastructure to neighborhoods can improve urban habitats for aquatic and terrestrial flora and fauna.

**STATE OF THE LITERATURE**

Improving landscape connectivity is the main focus of studies looking to increase terrestrial biodiversity. Many studies use landscape analysis with a least-cost path approach to determine the best landscape connections [1, 2]. Depending on the species of animals, connectivity and optimization of natural green spaces is a vital to regional GSI can result in increased terrestrial biodiversity [3, 4]. After a city study in the US found that urban landscape could provide critical habitat for monarch butterflies, other pollinators, and other wildlife species [5]. Pollinators in particular thrive in the urban environment due to their "highly mobile spatial and temporal requirements" for habitat, allowing them to find suitable foraging habitats, other pollinators, and other wildlife species [5]. Pollinators in particular thrive in the urban environment due to their "highly mobile spatial and temporal requirements" for habitat, allowing them to find suitable foraging habitats, other pollinators, and other wildlife species [5].

**ASSESSING THE IMPACT OF SCMS ON INCREASED BIODIVERSITY USING THE 4Cs**

**COMMUNITY** Some developments with a large number of urban habitat connectivity and community connectivity can result in increased biodiversity [1]. The impact of a park had a positive impact on biodiversity [2].

**CONTEXT** The impact of a park had a positive impact on biodiversity [2]. The impact of a park had a positive impact on biodiversity [2].

**CONNECTIVITY** A study of a park corridor found that parks and green infrastructure in a city found that parks and green infrastructure yield similar results.

**CANOPY** In addition to supporting pollinators and other wildlife species, tree canopy can also provide shade and reduce urban heat island effect [3].

**KEY CONSIDERATION(S) FOR SCM INSTALLATION**  
Focus on parks that provide positive and improve social equity.

**Benefit Guidance Factsheet**

### INCREASED RECREATIONAL OPPORTUNITIES

**Functional description:** Green or blue infrastructure used for stormwater management can provide recreational opportunities through access to vegetated spaces or water features.

**STATE OF THE LITERATURE**

There are multiple ways green stormwater infrastructure (GSI) can enhance passive and active recreation. Most of the existing literature focuses on installing GSI in parks and connecting stormwater control measures (SCMs) to create urban recreation corridors. Many cities in the US have leveraged existing parks as a means to manage stormwater. A 2014 study by the Trust for Public Lands found that more than 5,000 acres of parks in 48 major cities had been used for stormwater management [1]. SCMs can be installed to "vegetate existing parks to enhance the design and functionality of these parks" [2]. Incorporating GSI into park planning allows municipalities to leverage and plan around existing parks to create green corridors. When evaluated at a single installation level, smaller vegetated SCMs, like infiltration cells, are more likely to mirror the vegetated benefits of informal green spaces, like vacant lots, than larger GSI like parks. At the smaller scale, vegetated SCMs can offer residents an alternative experience to formal recreation [3]. Other research links a larger system of about blue and green infrastructure, SCMs can optimize residents' exposure to urban vegetation [4].

**ASSESSING THE IMPACT OF SCMS ON RECREATIONAL OPPORTUNITIES USING THE 4Cs**

**COMMUNITY** The impact of GSI on recreational opportunities is highly dependent on the location of the GSI. The impact of a park had a positive impact on recreational opportunities [1].

**CONTEXT** The impact of a park had a positive impact on recreational opportunities [1]. The impact of a park had a positive impact on recreational opportunities [1].

**CONNECTIVITY** The impact of GSI on recreational opportunities is highly dependent on the location of the GSI. The impact of a park had a positive impact on recreational opportunities [1].

**CANOPY** The impact of a park had a positive impact on recreational opportunities [1]. The impact of a park had a positive impact on recreational opportunities [1].

**KEY CONSIDERATION(S) FOR SCM INSTALLATION**  
Consider the impact of GSI on recreational opportunities.

**Benefit Guidance Factsheet**

### IMPROVED AIR QUALITY

**Functional description:** Vegetation can improve air quality through greenery, uptake of pollutants via leaf stomata, provision of air mixing through dispersion and interaction of airflow patterns.

**STATE OF THE LITERATURE**

Studies that assess the interaction between green infrastructure and air pollution tend to focus on air capture in parks [1]. There is no scientific consensus about the size and/or composition of urban green spaces required to improve air quality in fact. The removal of atmospheric pollutants by vegetation is one of the most common climate solutions systems, yet, the best supported evidence [2]. Air quality mitigation is primarily performed by trees which uptake gaseous pollutants via leaf stomata and intercept airborne particles on the plant surface [3]. Even though particular matter is intercepted, it can be re-introduced into the atmosphere and environment [3].

**ASSESSING THE IMPACT OF SCMS ON IMPROVED AIR QUALITY USING THE 4Cs**

**COMMUNITY** The impact of GSI on air quality is highly dependent on the location of the GSI. The impact of a park had a positive impact on air quality [1].

**CONTEXT** The impact of a park had a positive impact on air quality [1]. The impact of a park had a positive impact on air quality [1].

**CONNECTIVITY** The impact of GSI on air quality is highly dependent on the location of the GSI. The impact of a park had a positive impact on air quality [1].

**CANOPY** The impact of a park had a positive impact on air quality [1]. The impact of a park had a positive impact on air quality [1].

**KEY CONSIDERATION(S) FOR SCM INSTALLATION**  
Consider the impact of GSI on air quality.

**Benefit Guidance Factsheet**

### NEIGHBORHOOD BEAUTIFICATION

**Functional description:** Adding vegetation via grass, permeable, small trees and woody details can improve the appearance of neighborhoods.

**STATE OF THE LITERATURE**

Improved community aesthetics is the installation of vegetated features is another selling point for green stormwater infrastructure (GSI) programs, especially in areas where practitioners are looking to revitalize neighborhoods [1]. Studies of urban green spaces have found that aesthetic preference increases with the number of trees and amount of flowers, water and that "in green spaces, aesthetic preference is related to the use of the space" [2]. The impact of a park had a positive impact on neighborhood aesthetics [3].

**ASSESSING THE IMPACT OF SCMS ON NEIGHBORHOOD BEAUTIFICATION USING THE 4Cs**

**COMMUNITY** The impact of GSI on neighborhood aesthetics is highly dependent on the location of the GSI. The impact of a park had a positive impact on neighborhood aesthetics [1].

**CONTEXT** The impact of a park had a positive impact on neighborhood aesthetics [1]. The impact of a park had a positive impact on neighborhood aesthetics [1].

**CONNECTIVITY** The impact of GSI on neighborhood aesthetics is highly dependent on the location of the GSI. The impact of a park had a positive impact on neighborhood aesthetics [1].

**CANOPY** The impact of a park had a positive impact on neighborhood aesthetics [1]. The impact of a park had a positive impact on neighborhood aesthetics [1].

**KEY CONSIDERATION(S) FOR SCM INSTALLATION**  
Consider the impact of GSI on neighborhood aesthetics.

**Benefit Guidance Factsheet**

### NEIGHBORHOOD COOLING (URBAN HEAT ISLAND MITIGATION)

**Functional description:** Increased impervious surfaces lead to higher land surface temperatures in urban areas, often called the urban heat island (UHI) effect. Vegetation and standing ponds in stormwater control measures (SCMs) can provide cooling benefits through transpiration and evaporation.

**STATE OF THE LITERATURE**

The magnitude of the cooling effect from blue-green infrastructure is impacted by a myriad of variables including tree latitude, climate, and land use characteristics of the surrounding area [1]. The impact of urban cooling qualitative factors on parks and canopy. What are the cooling impacts of all types of urban green infrastructure (UGI), measures like a mix of tree canopy, permeable pavements, and impervious materials [2]. Most analysis is performed at a smaller than city scale and results are more specific [3]. A meta-analysis has found that, on average, parks and trees can cool the day. 4.5 degrees per hour have been found to reduce air temperature [3]. Some studies have found that smaller parks actually contribute to the urban heat island effect of the surrounding neighborhood [4]. Trees and larger green spaces, like parks, study provide more cooling than smaller, ground-level installations like bioswales and infiltration [5]. The cooling from blue infrastructure such as ponds is needed to be similar to vegetative cooling [6]. In addition, more trees need to be performed to understand cooling contributions of green infrastructure on larger scales on different climates and land uses.

**ASSESSING THE IMPACT OF SCMS ON NEIGHBORHOOD COOLING USING THE 4Cs**

**COMMUNITY** The impact of GSI on neighborhood cooling is highly dependent on the location of the GSI. The impact of a park had a positive impact on neighborhood cooling [1].

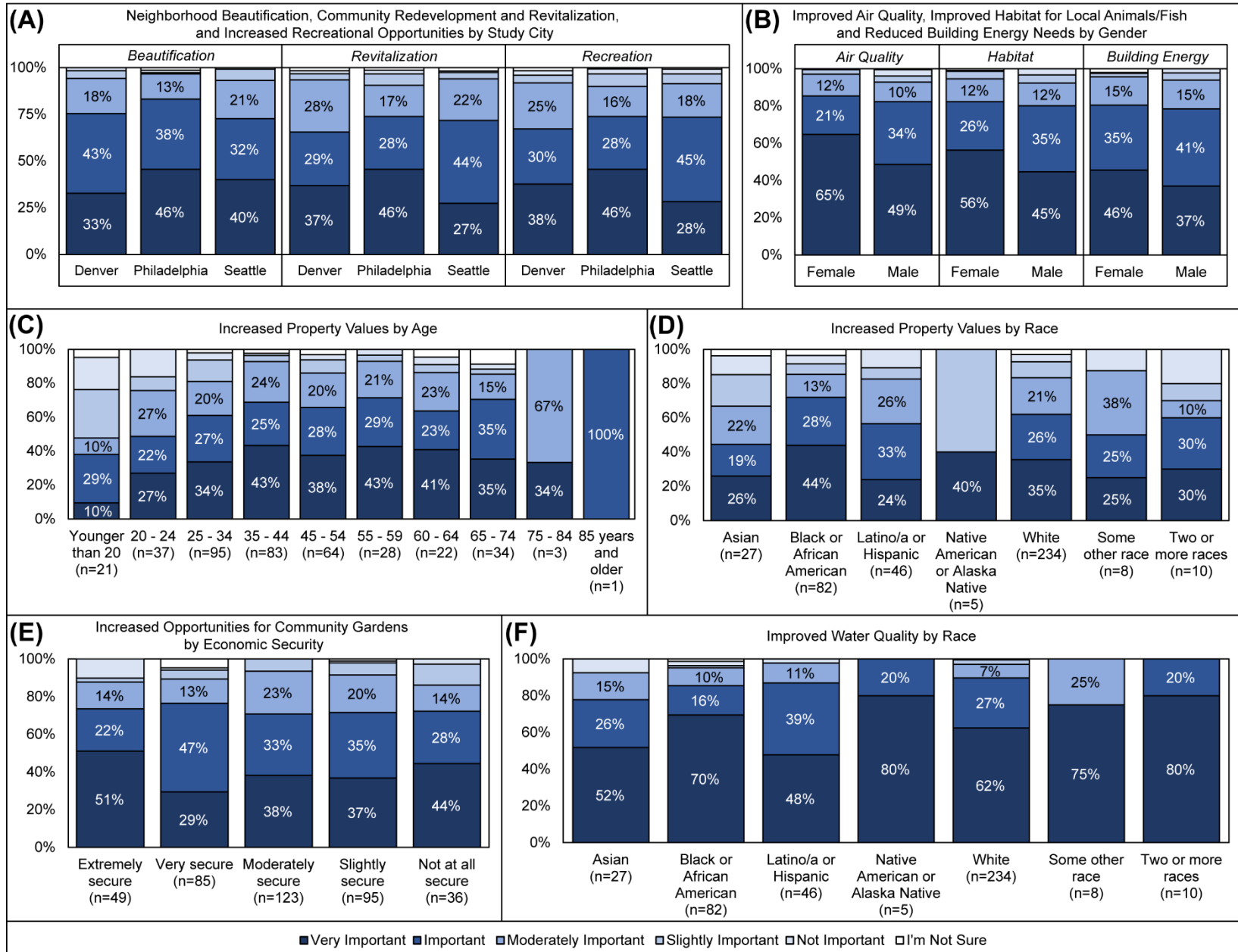
**CONTEXT** The impact of a park had a positive impact on neighborhood cooling [1]. The impact of a park had a positive impact on neighborhood cooling [1].

**CONNECTIVITY** The impact of GSI on neighborhood cooling is highly dependent on the location of the GSI. The impact of a park had a positive impact on neighborhood cooling [1].

**CANOPY** The impact of a park had a positive impact on neighborhood cooling [1]. The impact of a park had a positive impact on neighborhood cooling [1].

**KEY CONSIDERATION(S) FOR SCM INSTALLATION**  
Consider the impact of GSI on neighborhood cooling.

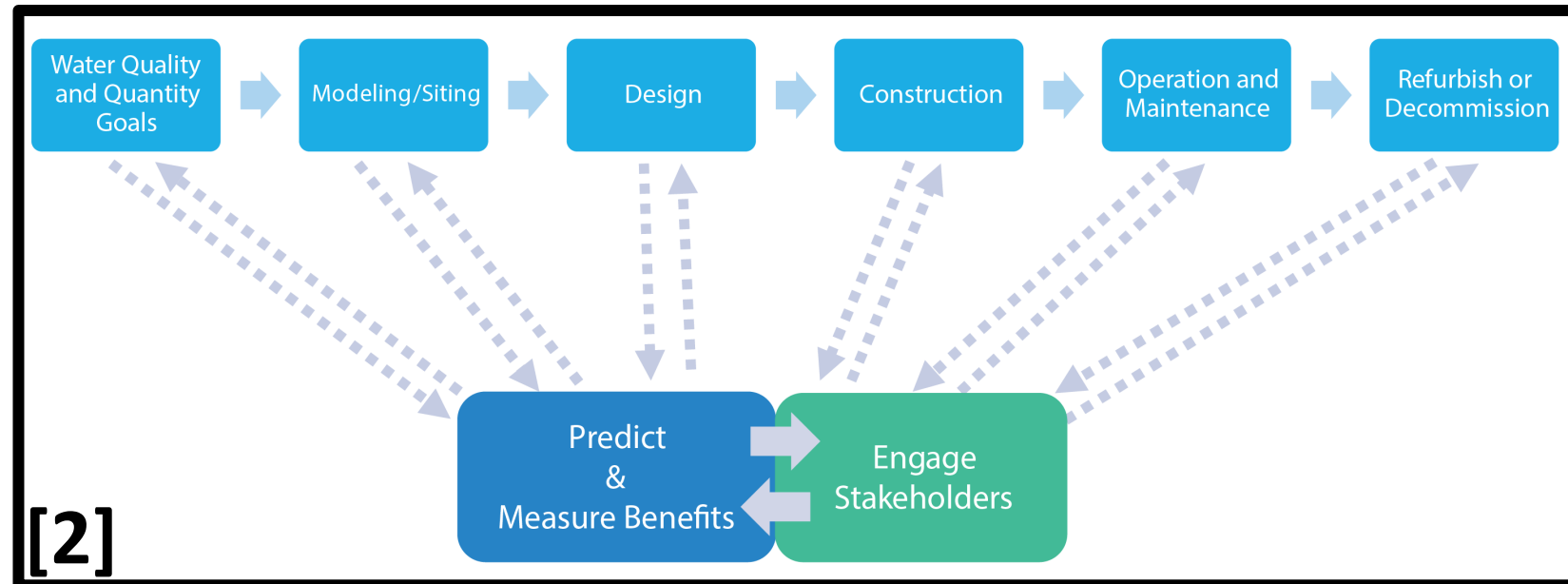
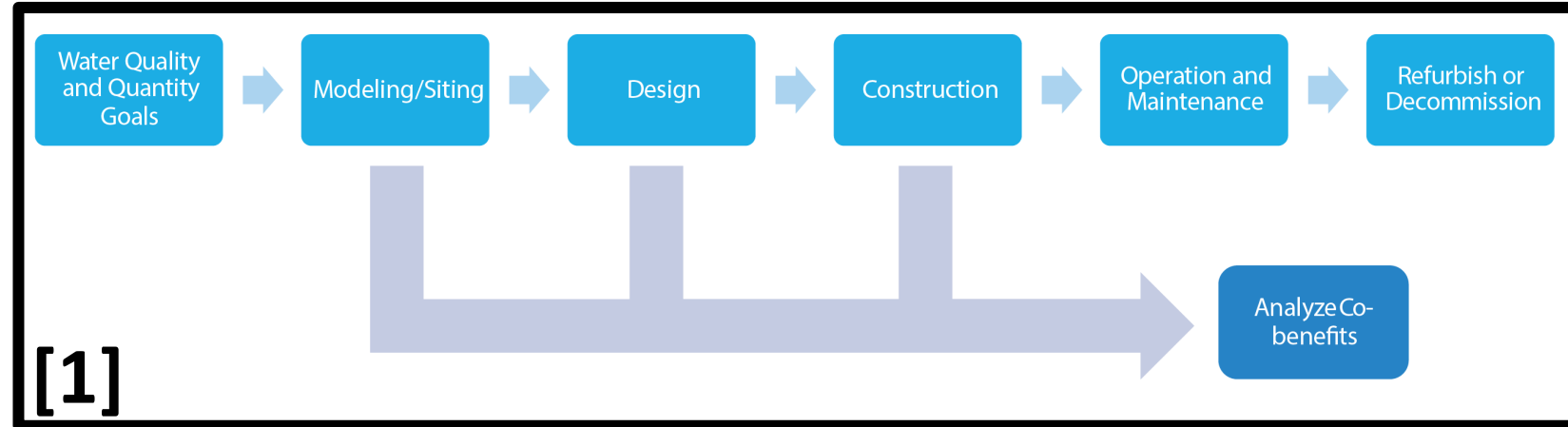
Preference for co-benefits varies over location and demographics.



(Spahr et al., *In press*)

# Shifting to Multi-functional Design

Moving away from post-processing analysis [1] to using benefit assessments to help each stage of the design process [2].



We need your help  
setting the  
research agenda  
for stormwater  
capture and use!

WRF Project 4841: Assessing the State of  
Knowledge and Research Needs for  
Stormwater Harvesting

Project Lead by Carollo Engineers

Please fill out this quick survey:

<https://www.surveymonkey.com/r/stormwaterharvesting>

Will drop link into the chat

# References

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- Mazzotta, M., Besedin, E., & Speers, A. (2014). A Meta-Analysis of Hedonic Studies to Assess the Property Value Effects of Low Impact Development. *Resources*, 3(1), 31–61. <https://doi.org/10.3390/resources3010031>
- Spahr, K.M., Bell, C. D., McCray, J. E., & Hogue, T. S. (2020). Greening up stormwater infrastructure: Measuring vegetation to establish context and promote cobenefits in a diverse set of US cities. *Urban Forestry and Urban Greening*, 48. <https://doi.org/10.1016/j.ufug.2019.126548>
- Spahr, K. M., J. M. Smith, J.E. McCray, T.S. Hogue, “Public preference for green stormwater infrastructure and ancillary cobenefits: How opinions vary across city, race, and educational attainment” *Journal of Sustainable Water in the Built Environment*. In Press.
- Spahr, K. M., Bell, C. D., Gallo, E.M., McCray, J. E., & Hogue, T. S. (2021) Incorporating a multiple benefit analysis into a stormwater hydrologic decision support tool at planning level. *Journal of Sustainable Water in the Built Environment*. 7(3). <https://doi.org/10.1061/JSWBAY.0000952>
- Venkataramanan, V., Packman, A. I., Peters, D. R., Lopez, D., McCuskey, D. J., McDonald, R. I., ... Young, S. L. (2019). A systematic review of the human health and social well-being outcomes of green infrastructure for stormwater and flood management. *Journal of Environmental Management*, 246, 868–880. <https://doi.org/10.1016/j.jenvman.2019.05.028>
- Xing, Y., & Brimblecombe, P. (2020, February 1). Trees and parks as “the lungs of cities.” *Urban Forestry and Urban Greening*, Vol. 48, p. 126552. <https://doi.org/10.1016/j.ufug.2019.126552>
- Yu, Z., Yang, G., Zuo, S., Jørgensen, G., Koga, M., & Vejre, H. (2020, March 1). Critical review on the cooling effect of urban blue-green space: A threshold-size perspective. *Urban Forestry and Urban Greening*, Vol. 49, p. 126630. <https://doi.org/10.1016/j.ufug.2020.126630>

# Where Do We Go From Here?

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For more information, please visit:

> EPA's Water Reuse Action Plan Home Page:

<https://www.epa.gov/waterreuse/water-reuse-action-plan>

> Action 3.3 page on the WRAP Online Platform:

<https://www.epa.gov/waterreuse/national-water-reuse-action-plan-online-platform?action=3.3>

***Thank You For Joining Us!***