EARTH ECONOMICS

The Benefits of Community-Driven Green Infrastructure

Technical Report | Water Wise Gulf South

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Upper Ninth Ward Bunny Friend Neighborhood Association

HEALTHY Community SERVICES Building Healthier Communities by Going Green

GREATER TREMÉ CONSORTIUM, INC.

WATERWISE GULF SOUTH

DANA BROWN & Associates

INSTITUTE FOR Sustainable Communities

THE KRESGE FOUNDATION

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Earth Economics is a leader in ecological economics and has provided innovative analysis and recommendations to governments, tribes, organizations, private firms, and communities around the world.

Earth Economics acknowledges that we operate on the lands of the Coast Salish peoples, specifically the ancestral homelands of the Puyallup Tribe of Indians, and the 1854 Medicine Creek Treaty. Earth Economics and Water Wise Gulf South would also like to acknowledge that the efforts we have engaged in for this work occur on the unceded ancestral homelands of the Sovereign Nation of the Chitimacha Tribe of Louisiana.

Table of Contents

Introduction

Communities across the nation are increasingly turning to green infrastructure solutions as part of a multi-pronged stormwater management strategy. Green infrastructure refers to a suite of installations that mimic natural processes to slow and reduce the stormwater volume flowing into traditional stormwater drainage systems. Every gallon diverted from flowing directly to existing drains eases the pressure on conveyance systems and reduces the severity of urban flooding caused by storm drain backups. New Orleans is especially vulnerable to flooding and stands to benefit in numerous ways from the continued installation of distributed green infrastructure.

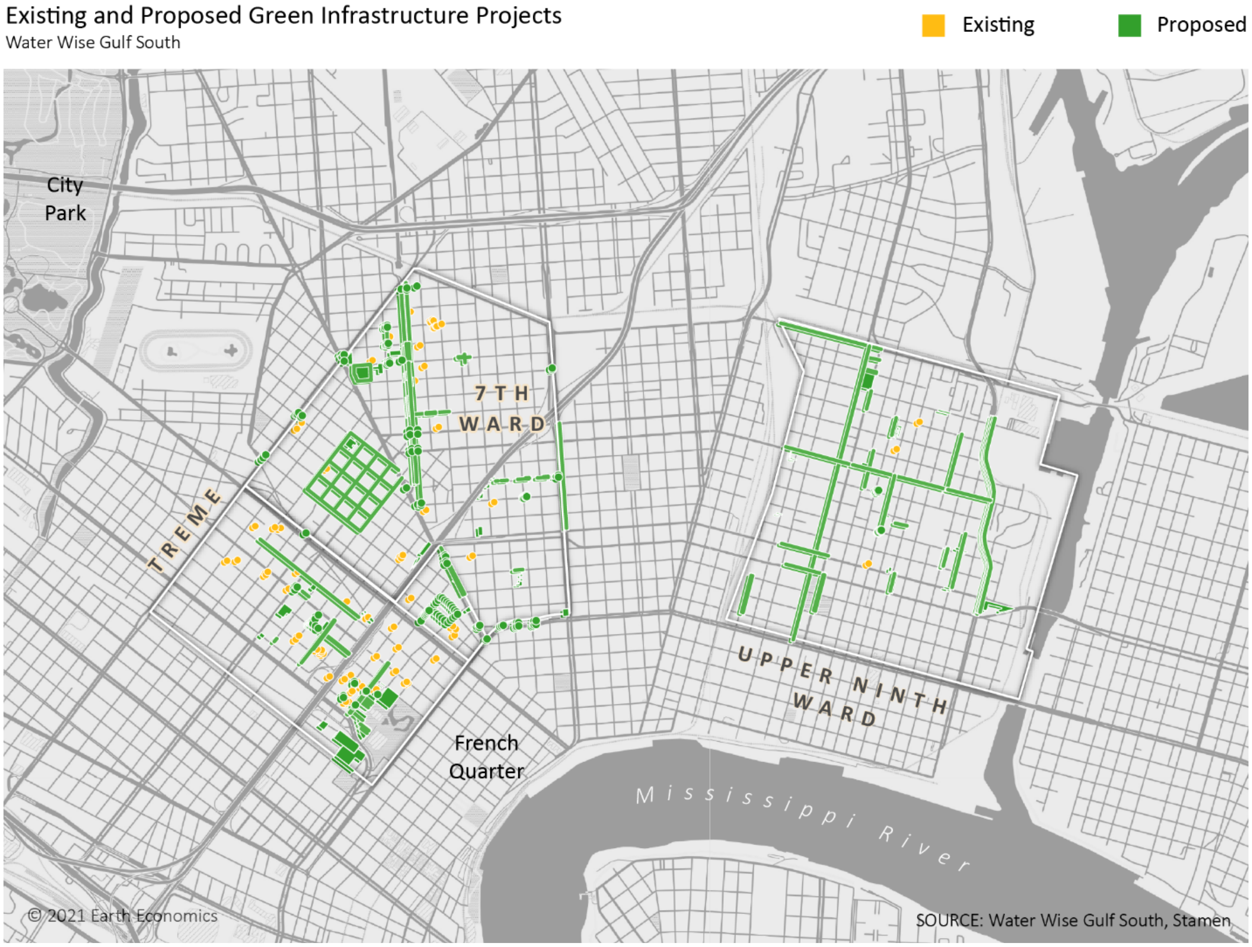
Water Wise Gulf South (WWGS) in partnership with Greater Tremé Consortium/Water Wise Tremé, Healthy Community Services/Water Wise 7th Ward, and Upper 9th Ward Bunny Friend Neighborhood Association/Water Wise Upper 9th Ward has been installing green infrastructure projects in New Orleans since 2013.[1] The Water Wise model relies on a partnership approach between community-based organizations that strive to reduce repetitive flooding, subsidence, and climate change impacts while also improving water quality. The partnership empowers diverse community members to implement green infrastructure solutions, addressing community concerns through educational and training support as well as community-building events.

WWGS supports community-driven green infrastructure solutions that mitigate repetitive flooding and subsidence as well as improving water quality and reducing climate change impacts like sea-level rise. WWGS empowers individuals, neighbors, and communities through training and other events. As of 2020 the neighborhood organizations have conducted workshops, planted over 160 trees, and implemented over 142 green infrastructure projects that have added more than 48,450 gallons of stormwater retention capacity. As the accompanying fact sheet shows, these neighborhood groups have completed other projects since 2020 that store thousands more gallons of stormwater. These projects include rain gardens, concrete removal, French drains, rain barrels, stormwater planter boxes, pervious pavement, and bioswales. Figure 1 shows completed projects and planned green infrastructure installations in these neighborhoods. To interact with this information and view the map in more detail please visit https://arcg.is/1XzC1v0.

Earth Economics (EE) analyzed the value of current and future green infrastructure installations by Greater Tremé Consortium, Healthy Community Services, and Upper 9th Ward to ground WWGS's advocacy with data-driven evidence for engagement with the City of New Orleans and prospective funders to increase installations of community-driven biophilic solutions. This report supplements a fact sheet of the analysis by providing additional context and references.

[1] Visit waterwisegulfsouth.org to learn more about Water Wise Gulf South and their activities

Figure 1. Map of Proposed and Completed WWGS Green Infrastructure Projects



Site Overview: Flooding in New Orleans

Flooding is a long-standing issue for New Orleans (NOLA). Situated within the Mississippi River Delta, much of the city has developed in the lowland areas by Lake Pontchartrain and in drainage bowls along the river where water collects (Figure 2).

Engineering efforts over the past few centuries have tried to keep the city dry using levee systems.[2] These levees help mitigate river and lake flooding in conjunction with pumps that push water outside the levee boundaries, primarily into Lake Pontchartrain.[3] This approach requires extensive stormwater drainage infrastructure and energy-intensive pumping. However, this aging infrastructure cannot effectively pump out all water when needed, resulting in frequent flooding, particularly in low-lying areas of the city that historically have been home to low-income communities of color. Small-scale urban flooding is also a regular nuisance in neighborhoods that lack adequate storm drains and other drainage infrastructure, or

[2] Sewerage & Water Board of New Orleans, "Stormwater - Drainage System Overview & Map," Stormwater, April 20, 2020, https://www.swbno.org/Stormwater/Overview.

[3] Waggonner & Ball Architects, "Greater New Orleans Urban Water Plan: Vision" (New Orleans, LA: Greater New Orleans, Inc. (GNO, Inc.), 2013), 53, https://livingwithwater.com/blog/urban_water_plan/reports/.

where blocked storm drains, illegal driveways that impair the drainage system, and extensive impervious concrete surfaces exist.[4]

Figure 2. Digital Elevation Model (5m resolution) of WWGS Neighborhoods

Much of NOLA sits below sea level, and the land continues to sink via a process called subsidence. Communities in the city's low-lying areas continue to sink, driven by the decomposition and drying of former wetland soils combined with the continuous pumping of groundwater.[5] The city's complex engineering system and environmental conditions—NOLA receives over 60 inches of rainfall each year[6]—set the stage for NOLA's unique flooding challenges.

Climate change impacts like more intense and frequent storm events or increasing extreme heat pose major threats to the NOLA community now and into the future. As Hurricane Katrina showed, heightened flooding risks are an environmental justice concern as flooding impacts and disaster responses in NOLA

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[4] Water Wise Gulf South, "Water Wise Upper 9th Ward," March 31, 2020, https://waterwisegulfsouth.org/water-wise-9th-ward/.

[5] Lei Zou et al., "Evaluating Land Subsidence Rates and Their Implications for Land Loss in the Lower Mississippi River Basin," Water 8, no. 1 (January 2016): 10, https://doi.org/10.3390/w8010010.

[6] Waggonner & Ball Architects, "Greater New Orleans Urban Water Plan: Vision."

are not evenly distributed.[7] Low-income and communities of color are the hardest hit by storms and receive less support.[8]

The flooding these communities face stems from a history of racially discriminatory local policies and disparities in public investments in these neighborhoods.[9] For WWGS communities, the development of the I-10 corridor is a mark of environmental racism as it separated areas of economic opportunity and investment while creating new environmental hazards.[10]

Background: Green Infrastructure for Stormwater Management

In practice, green infrastructure installations mimic natural processes to slow and reduce the amount of stormwater flowing into drains. Planners and community groups nationwide are increasingly turning to diverse green infrastructure solutions to mitigate urban flooding because of their cost savings, efficacy, cross-compatibility with existing infrastructure, and other co-benefits.[11]

Economic Benefits of Green Infrastructure

Successful green infrastructure development occurs when projects are strategically integrated with existing infrastructure. For New Orleans, which features some of the country's oldest stormwater infrastructure,[12] green infrastructure helps ease the demands placed upon an aging and overtaxed system. By continuing to complement existing gray infrastructure with additional green infrastructure installation, the need for investments in large-scale projects to increase drainage pipe size or pumping capacity can be minimized even as increasing rainfall volumes are projected for the rest of the century.[13] As the following examples show, green infrastructure mitigates stormwater runoff from entering over-burdened drainage systems, thereby providing savings for utilities.

In Providence, Rhode Island, green infrastructure projects have removed nine million gallons of stormwater annually from a combined sewer system. The subsequent reduction in combined sewer overflows (CSO) saves the utility up to $9,000 each year in operating costs for CSO abatement.[14] Similarly,

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7 John R. Logan, "The Impact of Katrina: Race and Class in Storm-Damaged Neighborhoods" (Providence, RI: Brown University, 2006), https://s4.ad.brown.edu/Projects/Hurricane/report.pdf.

8 Stacy Seicshnaydre et al., "Rigging the Real Estate Market: Segregation, Inequality, and Disaster Risk" (New Orleans, LA: The Data Center, April 5, 2018), https://www.datacenterresearch.org/reports_analysis/rigging-the-real-estate-market-segregation-inequality-and-disaster-risk/.

9 Craig E. Colten, "Basin Street Blues: Drainage and Environmental Equity in New Orleans, 1890–1930," *Journal of Historical Geography* 28, no. 2 (April 1, 2002): 237–57, https://doi.org/10.1006/jhge.2001.0400.

10 Tulane School of Architecture, "The Elevated I-10 Claiborne Avenue Expressway Severed the Historic African-American Tremé Neighborhood in the Late 1960s and Continues to Spark Controversy Today.," June 16, 2015, https://architecture.tulane.edu/preservation-project/timeline-entry/1435.

11 R.M. Roseen, T.V. Janeski, J.J. Houle, et al. "Forging the Link: Linking the Economic Benefits of Low Impact Development and Community Decision." University of New Hampshire Stormwater Center, Virginia Commonwealth University, and Antioch University New England. July 2011.

12 Sewerage & Water Board of New Orleans, "Using Green to Aid the Grey: The Sewerage & Water Board and Green Infrastructure," Green Infrastructure, 2019, https://www.swbno.org/Projects/InteractiveGuideToGreenInfrastructure.

13 City of New Orleans, "Climate Action for a Resilient New Orleans" (New Orleans, LA: Mayor's Office of Resilience and Sustainability, 2017), https://www.nola.gov/nola/media/Climate-Action/Climate-Action-for-a-Resilient-New-Orleans.pdf.

14 R.M. Roseen, T.V. Janeski, J.J. Houle, et al. Forging the Link: Linking the Economic Benefits of Low Impact Development and Community Decision. University of New Hampshire Stormwater Center, Virginia Commonwealth University, and Antioch University New England. July 2011

utilities in Portland, Oregon have saved $100,000 per year in conveyance demands by managing stormwater with green infrastructure.[15]

On a larger scale, New York City (NYC) has already saved $1.5 billion, 22 percent less than a gray infrastructure only approach, by incorporating green infrastructure into its municipal stormwater infrastructure planning.[16] An important benefit is that these investments encourage infiltration of water into the ground, which reduces the need for pumping and saves energy costs. The resulting surplus funds are redistributed to contract labor and supplies, creating additional jobs.[17]

In yet another example, Earth Economics recently conducted a benefit-cost analysis (BCA) of the Well Farm Project green infrastructure stormwater management installation in Peoria, Illinois. The study found that the installation will capture 1.3 million gallons of stormwater per year, save at least $197,340 in stormwater costs over the next 30 years, sequester 840 metric tons of carbon dioxide, and save $8,000 in public health expenses by filtering out harmful air pollutants.[18]

Even within NOLA, proposed green infrastructure has been projected to generate significant economic returns. In partnership with Impact Infrastructure through the 100 Resilient Cities program, Earth Economics completed a Triple Bottom Line benefit-cost analysis of the proposed 25-acre Mirabeau Water Garden urban park. The park design uses green infrastructure to mitigate neighborhood flooding during heavy rain events by storing and encouraging the infiltration of 10 million gallons of stormwater. In addition to reduced flood risk, the analysis quantified other park benefits including education, public health, subsidence avoidance, habitat, and carbon sequestration. The analysis found that each dollar invested in the project would return $6 in economic, social, and environmental benefits.

Green Infrastructure Has Lower Capital and O&M Costs

Green infrastructure can be a cost-effective solution from both a capital investment and operations & maintenance (O&M) perspective, particularly when planned with existing gray infrastructure systems. By capturing and slowing water where it lands, green infrastructure reduces downstream strain on centralized conveyance and treatment systems. Green infrastructure projects tend to store more gallons of stormwater per dollar invested than conventional gray infrastructure.[19] Additionally, O&M costs tend to be similar or lower than gray infrastructure as a percentage of capital costs. Green infrastructure

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[15] Jeffery Odefey et al., "Banking on Green: A Look at How Green Infrastructure Can Save Municipalities Money and Provide Economic Benefits Community-Wide" (Washington DC: American Rivers, the Water Environment Federation, the American Society of Landscape Architects and ECONorthwest, April 2012), https://www.americanrivers.org/conservation-resource/banking-on-green/.

[16] Greg Browder et al., "Integrating Green and Gray: Creating Next Generation Infrastructure" (Washington DC: World Bank & World Resources Institute, March 21, 2019), https://www.wri.org/publication/integrating-green-gray.

[17] New York City Department of Environmental Protection, "NYC Green Infrastructure Plan: A Sustainable Strategy for Clean Waterways" (New York, NY: NYC Department of Environmental Protection, 2010), https://www1.nyc.gov/assets/dep/downloads/pdf/water/stormwater/green-infrastructure/nyc-green-infrastructure-plan-2010.pdf. See especially Figure 11: O&M Costs to the City of CSO Control Scenarios.

Noah Enelow et al., "Jobs & Equity in the Urban Forest" (Portland, OR & Oakland, CA: Ecotrust & Policy Link, February 2017), https://ecotrust.org/media/Jobs-and-Equity-in-the-Urban-Forest_final-report_3_8_17.pdf.

[18] Emily Nonko, "In Peoria, Green Infrastructure as a Path to Social Equity," Next City, November 20, 2019, https://nextcity.org/daily/entry/in-peoria-green-infrastructure-as-a-path-to-social-equity.

[19] Ed MacMullan and Sarah Reich, "The Economics of Low-Impact Development: A Literature Review" (Eugene, OR: ECONorthwest, November 2007), https://owl.cwp.org/mdocs-posts/macmullen-2007-econorthwest-economics-literature-review1/.

capital costs are estimated to be five to 30 percent, and 25 percent less over the project lifetime compared to conventional practices.[20] In Germantown, Wisconsin, low-impact design—which incorporates green infrastructure elements—generates around $600,000 in savings compared to conventional stormwater management design.[21] Similarly, adopting pervious asphalt in Greenland, New Hampshire saved developers $930,000 in costs for piping and storage, a 26 percent difference compared to conventional design.[22]

Green Infrastructure Is Cost-Effective and Adaptable

Green infrastructure is also cost-effective due to its storage potential and its ability to be implemented incrementally. Green infrastructure projects can often store more gallons of stormwater per dollar invested than conventional gray infrastructure. Compared to making select investments in several large-scale, expensive gray infrastructure upgrades, distributed green infrastructure projects can be financed and installed incrementally over time and space while prioritizing a city's most pressing areas of flooding concern.[23]

Green infrastructure installation is most successful and cost-effective when decision-making is community-driven.[24] Community engagement in NOLA is critical for guiding implementation, and community-wide distributed installations can contribute to the climate action goal of creating a "Culture of Awareness and Action."[25]

Earth Economics Analysis: Methods and Findings

Vulnerability to Urban Flood Events in NOLA

The growing urban flooding problem is apparent with increasing calls to 311, NOLA's non-emergency helpline. Between 2012 and 2018, helpline tickets for street flooding and drainage-related services in Council Districts C and D increased by 46 percent.[26] Climate science predicts that the intense rainfall events that cause urban flooding will become more common throughout the Gulf.

Urban flood damage in New Orleans often happens at a scale too small to trigger the disaster declarations that release state and federal funds, which means that damages must be covered by individual insurance claims. The ability to cover flood damage with insurance remains an issue for households in the area. In 2016, the Federal Emergency Management Agency (FEMA) revised its Special Flood Hazard Area (SFHA) maps to reflect the strength of the fortified post-Katrina flood defenses. The

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[20] Claudia Copeland, "Green Infrastructure and Issues in Managing Urban Stormwater" (Washington DC: Congressional Research Services, May 2, 2016), https://fas.org/sgp/crs/misc/R43131.pdf.

[21] Environmental Protection Agency, 2007. Reducing Stormwater Costs through Low Impact Development (LID) Strategies and Practices, December 2007, EPA 841-F-07-006 37.

[22] U.S. EPA, "Case Studies Analyzing the Economic Benefits of Low Impact Development and Green Infrastructure Programs Case Studies Analyzing the Economic Benefits of Low Impact Development and Green Infrastructure Programs," 2013.

[23] Stuart R. Gaffin, Cynthia Rosenzweig, and Angela Y. Y. Kong, "Adapting to Climate Change through Urban Green Infrastructure," Nature Climate Change 2, no. 10 (October 2012): 704–704, https://doi.org/10.1038/nclimate1685.

[24] Megan Heckert and Christina D. Rosan, "Developing a Green Infrastructure Equity Index to Promote Equity Planning," *Urban Forestry & Urban Greening*, Special Section: Power in urban social-ecological systems: Processes and practices of governance and marginalization, 19 (September 1, 2016): 263–70, https://doi.org/10.1016/j.ufug.2015.12.011.

[25] City of New Orleans, "Climate Action for a Resilient New Orleans."

[26] City of New Orleans, "311 Calls (Historic Data: 2012-2018)," City of New Orleans Open Data, January 7, 2019, https://data.nola.gov/City-Administration/311-Calls-Historic-Data-2012-2018-/3iz8-nghx.

result was that more than 50 percent of homes were no longer required to hold National Flood Insurance Program (NFIP) policies.[27]

Homeowners can turn to either NFIP or supplemental private flood insurance for recovering flood losses. However, less financially secure households may not be able to afford or retain flood insurance, especially if these rates increase. Renters often do not have the same recourse to respond effectively to flood damage. Although homeowner's insurance is mandatory, renter's insurance is not; in both cases, policies to cover flood damage are extra. Renters are often less financially secure than homeowners since they typically lack home equity—the foundation from which wealth is often built. They are thus more vulnerable to flood damages, as they are less likely to have flood coverage and generally have fewer resources to address flood-related losses.

Maps in Figures 3 and 4 show the rates of rental, ownership, and vacancy in the Tremé, 7th Ward, and 9th Ward neighborhoods with American Community Survey (ACS) data from the U.S. Census. Spatial analysis using ACS data finds that over 60 percent of households in Tremé, the 7th Ward, and the 9th Ward are renter-occupied, with this rate increasing following trends of unaffordability and gentrification (table 1).[28] Renters, as a group, tend to be lower-income, which also means they are less able to bear the increased costs from repeat flood events that drive displacement.[29]

Table 1: Changes in the Proportion of Renter-Occupied Housing, 2010–2018

	Tremé	7th Ward	Upper 9th Ward	Orleans Parish
Change in proportion of renter-occupied housing (%)	+0.4%	+3.9%	+5.6%	+2.9%

[27] Kailath, Ryan. "New Maps Label Much of New Orleans Out of Flood Hazard Area." All Things Considered. WWNO, New Orleans, Louisiana, 30 September. 2016. Radio.

[28] Jason Richardson, Bruce Mitchell, and Jad Edlebi, "Gentrification and Disinvestment 2020: COVID-19 Struck a Nation That Was Already Mostly Struggling. Do Opportunity Zones Benefit or Gentrify Low-Income Neighborhoods?" National Community Reinvestment Coalition (NCRC), June 2020, https://ncrc.org/gentrification20/.

[29] Christopher Dolbom, Scott A. Hemmerling, and Joshua A. Lewis, "Community Resettlement Prospects in Southeast Louisiana: A Multidisciplinary Exploration of Legal, Cultural, and Demographic Aspects of Moving Individuals and Communities" (New Orleans, LA: Tulane Institute on Water Resources Law & Policy, 2014), https://thewaterinstitute.org/assets/docs/publications/9_23_2014_Community-Resettlement-Prospects-in-Southeast-Louisiana.pdf.

Figure 3. Percent of Renter-Occupied Households in WWGS Neighborhoods

Figure 4. Percent of Vacant Units in WWGS Neighborhoods

Measuring the Costs of Urban Flooding

Accounting for the costs of neighborhood-scale urban flooding is a challenge because it is frequently caused by events smaller than a 100-year flood—the typical threshold used for mapping, regulation, and insurance purposes.[30] These frequent, lower-impact events are not generally modeled or tracked, even though over time their cumulative costs may rival those of larger, less-frequent flood events.[31] The burden of this repetitive flooding is disproportionately borne by those with the fewest resources to cope with the impacts.[32]

Costs to the individual include:

- Damage to structures and property[33]
- Lost wages or business income due to missed work[34]
- Time and money spent on cleanup[35]
- Longer commutes due to flood closures[36]
- Health-related costs from mold-induced respiratory issues[37]
- Stress and mental health impacts of repeated flooding[38]
- Reduced access to emergency services, public transit, schools, etc.[39]
- Increased risk of injury and death (slips, falls, drownings)[40]

Costs to the public include:

- Decreased economic activity[41]
- Decreased real estate value[42]
- Business closures[43]

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30 G.E. Galloway et al., "The Growing Threat of Urban Flooding: A National Challenge" (College Park, MD & Galveston, TX: University of Maryland Center for Disaster Resilience & Texas A&M University Center for Texas Beaches and Shores., 2018), https://today.tamu.edu/wp-content/uploads/sites/4/2018/11/Urban-flooding-report-online.pdf.(p. 11)

31 Federal Emergency Management Agency (FEMA), "Building Community Resilience with Nature-Based Solutions: A Guide for Local Communities" (Washington DC: FEMA, 2020), https://www.fema.gov/sites/default/files/2020-09/fema_Riskmap-nature-based-solutions-guide-2020_071520.pdf.

32 Galloway et al., "The Growing Threat of Urban Flooding: A National Challenge."(p. 11)

33 Harriet Festing et al., "The Prevalence and Cost of Urban Flooding: A Case Study of Cook County, IL" (Chicago, IL: Center for Neighborhood Technology (CNT), May 2014), https://www.cnt.org/publications/the-prevalence-and-cost-of-urban-flooding.

34 Ibid.

35 Ibid.

36 Waggonner & Ball Architects, "Greater New Orleans Urban Water Plan: Vision."

37 Festing et al., "The Prevalence and Cost of Urban Flooding: A Case Study of Cook County, IL."

38 Ibid.

39 Todd Alexander Litman, "Lessons from Katrina and Rita What Major Disasters Can Teach Transportation Planners" (Victoria, BC: Victoria Transport Policy Institute, April 13, 2006), https://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.1073.4842&rep=rep1&type=pdf.

40 Federal Emergency Management Agency (FEMA), "Reducing Damage from Localized Flooding: A Guide for Communities," (Washington DC: FEMA, 2015), https://www.fema.gov/pdf/fima/FEMA511-complete.pdf

41 Miyuki Hino et al., "High-Tide Flooding Disrupts Local Economic Activity," *Science Advances* 5, no. 2 (February 15, 2019): 1–9, https://doi.org/10.1126/sciadv.aau2736.

42 Galloway et al., "The Growing Threat of Urban Flooding: A National Challenge."

43 Festing et al., "The Prevalence and Cost of Urban Flooding: A Case Study of Cook County, IL."

- Discharge of contaminants (heavy metals, nutrients like nitrogen and phosphorus) to adjacent water bodies[44]

WWGS Green Infrastructure and the Urban Flooding Problem

Water Wise Neighborhood Champions have installed green infrastructure projects at private residences, small businesses, churches, community centers, vacant lots, and in public rights-of-way. As of 2020, this collaboration has planted over 160 trees and implemented over 142 other green infrastructure projects that have added over 48,450 gallons of stormwater retention capacity to the neighborhoods. These projects include rain gardens, concrete removal, French drains, rain barrels, stormwater planter boxes, pervious pavement, and bioswales.

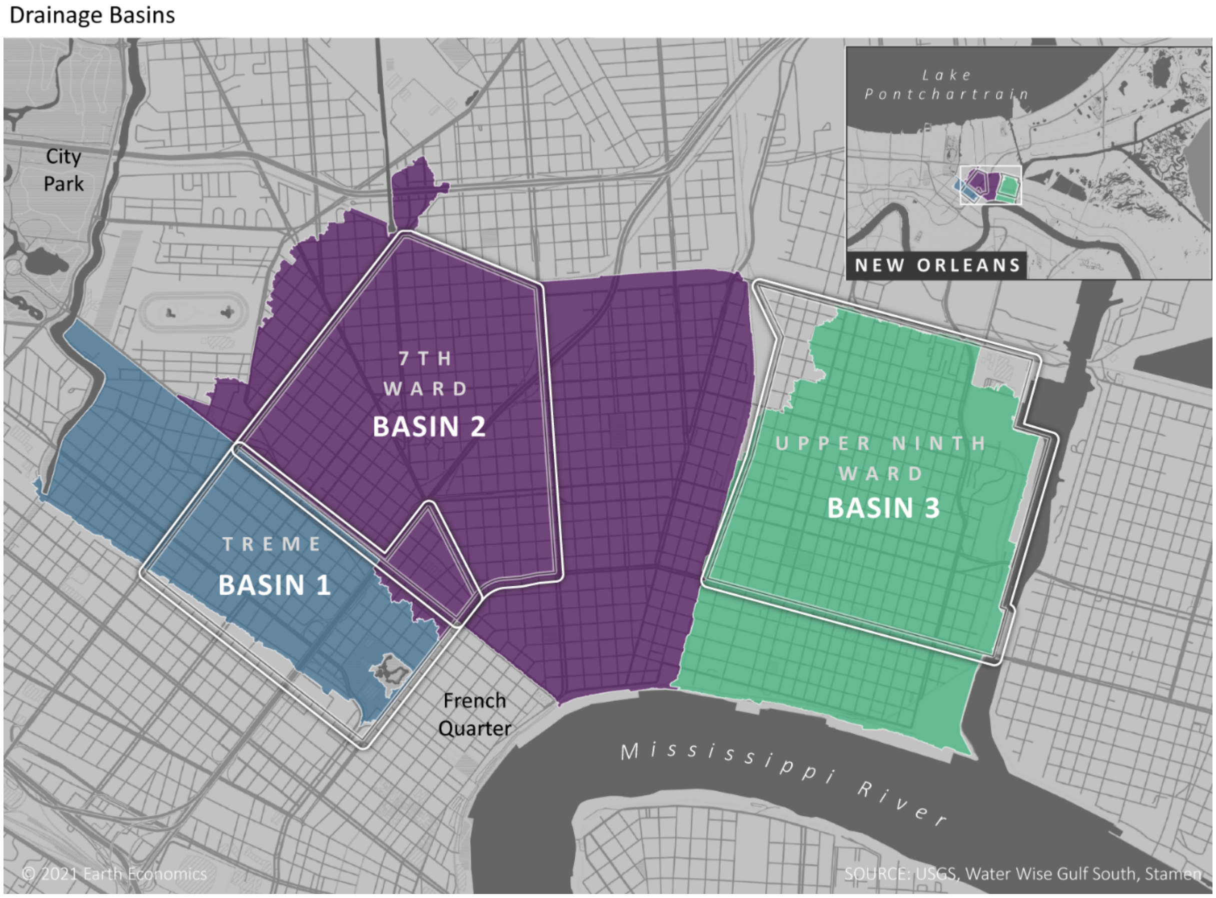
Through a series of trainings, workshops, and events, WWGS has worked to empower individuals and communities to participate in the visioning of future green infrastructure projects for community improvements. One product of this work is the *Community Lookbooks*, which details plans for installing a much broader suite of small- and large-scale green infrastructure projects.

Scaling up green infrastructure is important because the bigger it is, the better it works. Every additional gallon that does not flow directly to the drainage system eases pressure on the system and reduces the extent of urban flooding from storm drain backups. In total, proposed WWGS projects could store approximately 6.5 million gallons of water, increase green space by 45 acres, and cost $32 million for installation and $1.5 million in annual maintenance.

Because New Orleans lies in a basin surrounded by levees, all water that enters the city must eventually be pumped out. According to a fact sheet from the New Orleans Sewer and Water Board, the existing pumping and drainage system is capable of handling one inch of rain for the first hour, and half an inch of rain for every subsequent hour. This estimate reflects the capacity of pumps and drainage canals, but also the current mix of pervious versus paved surfaces and existing stormwater detention capacity. Therefore, any storm that exceeds the capacity of the existing drainage system should produce localized flooding, beginning with the most flood-prone neighborhoods and drainage basins, and spreading to other neighborhoods/basins and increasing in severity with increased rainfall intensity or duration.
WWGS is proposing to add aboveground green infrastructure projects that will store and slow stormwater, shifting the ratio of pervious and impervious surfaces in the city and helping alleviate the urban flooding problem created by intense rainfall events.

[44] L. Darnell Weeden, "Hurricane Katrina and the Toxic Torts Implications of Environmental Injustice in New Orleans," *John Marshall Law Review* 40, no. 1 (2007 2006): 1–41, https://heinonline.org/HOL/Page?handle=hein.journals/jmlr40&id=9&div=&collection=.

Figure 5. Drainage Basins of WWGS Neighborhoods at 1m Resolution



Understanding where stormwater would flow if it were not diverted by WWGS green infrastructure projects is the key for examining flood reduction impacts. The 5-meter digital elevation model presented in Figure 2 suggests how water moves when it reaches the landscape, but it is possible to understand this in greater detail. By delineating micro drainage basins at 1-meter resolution (Figure5) and then locating each proposed green infrastructure project from the *Community Lookbooks* within each drainage, it is possible to understand the magnitude and location of the flood reduction benefits.

The proposed projects are split between three neighborhoods but in reality, they are scattered across multiple micro sub-basins, as shown above.

To place the rainfall captured by these proposed green infrastructure projects in context, we calculate their storage capacity as a percentage of total rainfall generated by a typical but intense rainstorm: one that deposits three inches of rain over an hour. In a given year in New Orleans, such a storm has a 10 to 20 percent chance of occurring.[45]

[45] National Oceanic and Atmospheric Administration's (NOAA) National Weather Service, "NOAA Atlas 14 Point Precipitation Frequency Estimates: LA," Hydrometorological Design Studies Center Precipitation Frequency Data Server (PFDS), April 21, 2017, https://hdsc.nws.noaa.gov/hdsc/pfds/pfds_map_cont.html.

By comparing the storage capacity of all projects in a single basin against the total runoff generated, we can begin to understand the magnitude of the flood-reducing benefits of the proposed green infrastructure projects.

- **7th Ward**. The proposed green infrastructure projects located in this drainage basin will collect over 1.6 million gallons—approximately 1 percent of the total stormwater generated in the basin by the modeled rain event.
- **Upper 9th Ward**. The proposed green infrastructure projects located in this drainage basin will collect 2.2 million gallons—approximately 2 percent of the total stormwater generated in the basin by the modeled rain event.
- **Tremé**. The proposed green infrastructure projects located in this drainage basin will collect 2.7 million gallons—approximately 5 percent of the total stormwater generated in the basin by the modeled rain event.

These estimates do not include recent tree planting efforts. They are also conservative estimates; they do not include the water storage capacity of street tree plantings, whose storage capacity is calculated not on a per-event basis, but on an annual basis. By absorbing water into their root systems, holding water in their canopies, and keeping rainfall away from nearby impervious surfaces, street trees are one of the most effective green infrastructure solutions for reducing local flooding. The stormwater storage capacity of street trees amounts to an additional 1 million gallons of water storage each year.

See Appendix 1 for more information on this method.

When green infrastructure is implemented at scale across the watershed, the benefits multiply. Stormwater retention decreases water runoff and the area of flooding during peak flow events; flood modeling finds that widespread green infrastructure adoption could lead to as much as an 8 percent reduction in the floodplain area for 2-year storm events.[46]

Ecosystem Services Benefits from Green Infrastructure

NOLA is surrounded by extensive wetlands that provide benefits worth millions of dollars, including flood risk reduction, shoreline stabilization, hurricane buffering, climate change adaptation and mitigation, recreation, tourism, and job creation benefits. Landcover changes associated with green infrastructure projects provide additional ecosystem services benefits for climate stability, disaster risk reduction, water quality, and water capture. Transforming impervious surfaces to green spaces with green infrastructure to mimic the function of wetlands enhances the benefits residents receive from the little green space in these neighborhoods. Green infrastructure projects built on public and private land in the metropolitan area help to store stormwater locally, reducing the burden on NOLA's stormwater infrastructure and improving local quality of life.

Adding green features to the landscape works in concert with existing drainage to reduce urban flooding, and it also offers communities important environmental co-benefits. Green spaces in the 7th Ward, Tremé, and Upper 9th Ward neighborhoods perform economically valuable functions each year, from reducing flood risk to stabilizing shorelines to providing recreational opportunities. These benefits are called ecosystem services.

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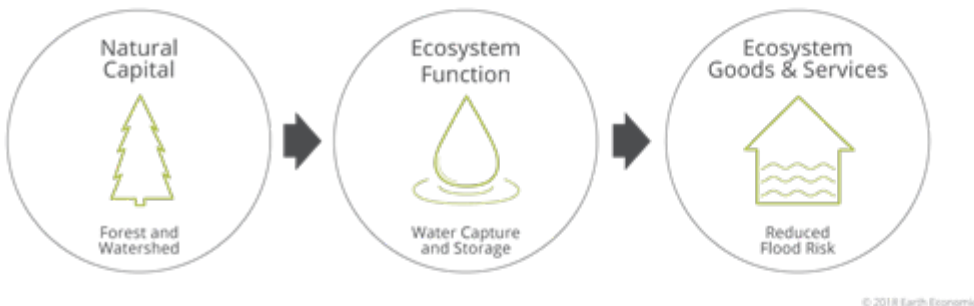
[46] Atkins, "Flood Loss Avoidance Benefits of Green Infrastructure for Stormwater Management," Reports and Assessments (Washington, DC: United States Environmental Protection Agency, December 2015), https://www.epa.gov/green-infrastructure/flood-loss-avoidance-benefits-green-infrastructure-stormwater-management.

Ecosystem Services Valuation

Earth Economics has over twenty years of experience conducting comprehensive benefit-cost analyses that incorporate the non-market economic value of natural capital assets. Natural capital is defined as naturally occurring ecosystems such as wetlands, forests, and pastures, as well as the plant and animal communities they support. The benefits derived from the ecosystem functions produced by natural capital are known as ecosystem goods and services, such as water supply, carbon sequestration and storage, and flood-risk reduction (see Figure 6). Following the Millennium Ecosystem Assessment, 21 ecosystem services can be categorized into four main categories: provisioning services, regulating services, information services, and supporting services.

Figure 6. Example Link Between Natural Capital and Ecosystem Goods and Services



Over the past half-century, scholars specializing in environmental and natural resource economics have developed a diverse toolkit of primary valuation techniques to assess the economic contribution of ecosystem goods and services. In some instances, this value is partially captured by markets; consumers buy products directly provided by nature, such as water or fish. For these goods and services, formal markets can reflect their contribution to human well-being. Yet there are also benefits for which markets do not exist. To estimate the value of these "non-market" benefits (e.g., clean air, aesthetic appreciation), economists must apply other techniques, such as travel cost analysis, hedonic pricing, and contingent valuation.

Broadly speaking, ecosystem services describe the benefits people receive from natural capital. Natural capital refers to resources like plants, animals, soils, minerals, and energy resources. Like other forms of capital, natural capital provides a flow of goods and services. These goods and services are the basis of all other economic activity as they provide water, clean air, food, flood risk reduction, and other critical services. For example, during storm events, natural capital like grasses and trees capture and store excess stormwater runoff, reducing flood risk to human life and property.

Categories of Ecosystem Services

Ecosystem services are often grouped into four categories:

- ***Provisioning services*** provide the physical materials which society uses. Community gardens grow food. Rivers provide drinking water as well as fish for food.
- ***Regulating services*** are benefits obtained from the natural control of ecosystem processes. Intact ecosystems provide climate regulation, water quality and delivery, and soil erosion prevention. They also keep disease organisms in check.
- ***Supporting services*** provide the habitats that support food webs and all life on the planet.

- ***Information services*** allow humans to interact meaningfully with nature. These services include providing spiritually significant species and natural areas, natural places for recreation, and opportunities for scientific research and education.

Benefit Transfer Methodology

To value ecosystem goods and services, Earth Economics employs the benefit transfer method (BTM), in which estimates of economic value are based on primary valuation studies of similar goods or services produced in comparable conditions (e.g., climate, terrain, soils, species). BTM is often the only practical, cost-effective option for producing reasonable estimates of the wide range of services provided by ecosystems.

The application of BTM begins by identifying critical attributes of a landscape that determine ecological productivity and expected benefits. Primary valuations of similar ecosystems, geographies, and communities are then identified and assessed for their comparability with land cover types within the WWGS study area. Estimates from primary studies are then standardized (i.e., adjusted to common units, correcting for any inflation between the period of research and the present) to ensure "apples-to-apples" comparisons. In this sense, BTM is similar to a property appraisal, in which the features and pricing of similar nearby properties are used to estimate value prior to a sale. Though each process has its limitations, they are rapid and efficient approaches to generating reasonable values for making investment and policy decisions.

To apply BTM for a full set of ecosystem services/land cover type combinations, this analysis used Earth Economics' Ecosystem services Valuation Toolkit (EVT). Studies within EVT have gone through multiple reviews and are standardized for use in BTM. Our analysts used several criteria to select appropriate primary studies for WWGS neighborhoods, including geographic location and the ecological and demographic characteristics of the original primary study sites.

The Ecosystem Services Values of Added Green Space

Table 2. Ecosystem Services Benefits Estimates ($ / year) in 2019 dollars

Neighborhood	Existing Ecosystem Services	Added Greenspace from WWGS Projects
7th Ward	$410,000 - 6,380,000	$460,000 - 6,750,000
Tremé	$240,000 - 3,600,000	$280,000 - 3,780,000
Upper 9th Ward	$500,000 - 6,900,000	$540,000 - 7,220,000

This table compares the ecosystem services benefits of the ecosystem services provided by existing areas of greenery (i.e., lawns, grasslands, wetlands, trees) and the additional benefits of the proposed landcover changes from the green infrastructure projects highlighted in the *Community Lookbooks*. The proposed green infrastructure projects will increase the ecosystem services benefits by $47,000 to $375,000 in the 7th Ward, $38,000 to $182,000 in the Tremé and $46,000 to $291,000 in the Upper 9th Ward.

See Appendix 2 for the studies that informed this valuation.

Additional Co-Benefits of Green Infrastructure

Green infrastructure provides additional co-benefits beyond managing stormwater and minimizing the direct impacts of flooding in communities.

These benefits include:

- Reduced urban heat island effect [47]
- Workforce benefits[48]
- Re-established native species / vegetation[49]
- Improved physical health from recreation and mental health[50] from reduced stress[51]
- Improved air quality[52]
- Other difficult to quantify cultural, aesthetic, and habitat-related ecosystem services benefits

Re-establishing vegetation and protecting existing green areas is one effective way to generate environmental benefits. For example, live oaks can store up to 1,000 gallons of water per day and bald cypress can store up to 880 gallons of water per day.[53] Native vegetation is resilient to storms, adapted to the climate and wet conditions, and able to thrive in various green infrastructure functional designs. These ecosystems are also culturally significant. Bald cypress and river cane, for example, are vital to the Chitimacha Tribe of Louisiana.[54]

Investing in green infrastructure projects can support the City of New Orleans Climate Plan[23] , specifically through the support of the community-wide climate action goals of addressing climate impacts like increased rainfall intensity and increased temperatures.

In summary, green infrastructure can:

- Help existing drainage infrastructure systems by reducing the amount and rate at which stormwater runoff enters the system.
- Mitigate the effects of rising temperatures and in particular the acute effects of urban heat islands by offering shade and green spaces to cool down when it is hot. The cooling effect of trees and green space in urban areas also helps lower building and transportation energy costs.
- Reduce energy use by reducing the amount of water drainage pumps must move.

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[47] Ranhao Sun et al., “Cooling Effects of Wetlands in an Urban Region: The Case of Beijing,” *Ecological Indicators* 20 (September 1, 2012): 57–64, https://doi.org/10.1016/j.ecolind.2012.02.006.

[48] Sara Lamback et al., “Exploring the Green Infrastructure Workforce,” NatureWORKS Issue Brief (Boston, MA: Jobs for the Future, 2017), https://www.jff.org/resources/exploring-green-infrastructure-workforce/.

Thrive New Orleans, “Thrive Works Green,” 2020, https://www.thrivenola.org/ndr/.

[49] Sustaining Our Urban Landscape (SOUL), “SOUL’s Native Trees,” 2020, https://soulnola.org/tree-recommendations/.

[50] Marc G. Berman et al., “Interacting with Nature Improves Cognition and Affect for Individuals with Depression,” *Journal of Affective Disorders* 140, no. 3 (November 1, 2012): 300–305, https://doi.org/10.1016/j.jad.2012.03.012.

[51] Iana Markevych et al., “Exploring Pathways Linking Greenspace to Health: Theoretical and Methodological Guidance,” *Environmental Research* 158 (October 1, 2017): 301–17, https://doi.org/10.1016/j.envres.2017.06.028.

[52] Halley L. Brantley et al., “Field Assessment of the Effects of Roadside Vegetation on Near-Road Black Carbon and Particulate Matter,” *Science of The Total Environment* 468–469 (January 15, 2014): 120–29, https://doi.org/10.1016/j.scitotenv.2013.08.001.

[53] Sustaining Our Urban Landscape (SOUL), “SOUL’s Native Trees.”

[54] Sovereign Nation of the Chitimacha, “Chitimacha Baskets,” Text, Improving the Quality of Life for Our Members & the Community: Tribal Government, May 17, 2013, http://www.chitimacha.gov/history-culture/chitimacha-baskets.

The increased visibility of green spaces and sustainable implementations throughout the city support the goal of creating a culture of awareness and action for promoting a more climate-resilient NOLA.

Financing and Investing in Community-Led Green Infrastructure

As New Orleans builds back from disasters and redevelops neighborhoods, it has an opportunity to invest in green infrastructure to complement its existing traditional infrastructure. As this report has demonstrated, cities are investing in green infrastructure as an adaptable and cost-effective solution to flooding. In New Orleans, scaling up green infrastructure with community support should lessen the impacts of flooding on aging infrastructure, and also support the city's climate action goals.

Although there are currently a number of programs that support rain barrel installation (Green Light New Orleans), tree planting (SOUL), or removing paving (Urban Conservancy's Front Yard Initiative), scaling up green infrastructure will require additional funds.

The following programs can be accessed to help support this investment:

- FEMA Flood Mitigation Assistance Grants (FMA)
- FEMA Pre-Disaster Mitigation Building Resilient Infrastructure and Communities Grants (BRIC)
- HUD Community Development Block Grant (CDBG)
    - Funds can be used to incorporate green elements into CDBG projects
- Environment Protection Agency Section 319 Grants
    - For nonpoint-source pollution reduction projects
- EPA Clean Water State Revolving Fund (SRF)
    - Offers loans to local governments at lower interest rates than municipal bonds
    - Administered through the Louisiana Department of Environmental Quality

Conclusion

The proposed projects have been designed to meet the site-specific needs of these neighborhoods—an essential element of any successful green infrastructure project. These projects offer flood reduction and other green benefits to the neighborhoods that reflect local priorities and values. Offering both lower costs than traditional gray infrastructure approaches and a wide range of benefits, site-specific green infrastructure projects have routinely proven to be cost-effective. By working with community groups, local governments are able to tap a variety of state and federal funds that support these projects.

Appendix 1. Percentage of Stormwater Averted, Detailed Calculation

Modeling the relative efficacy of the proposed GI projects at the neighborhood scale consists of five general steps:

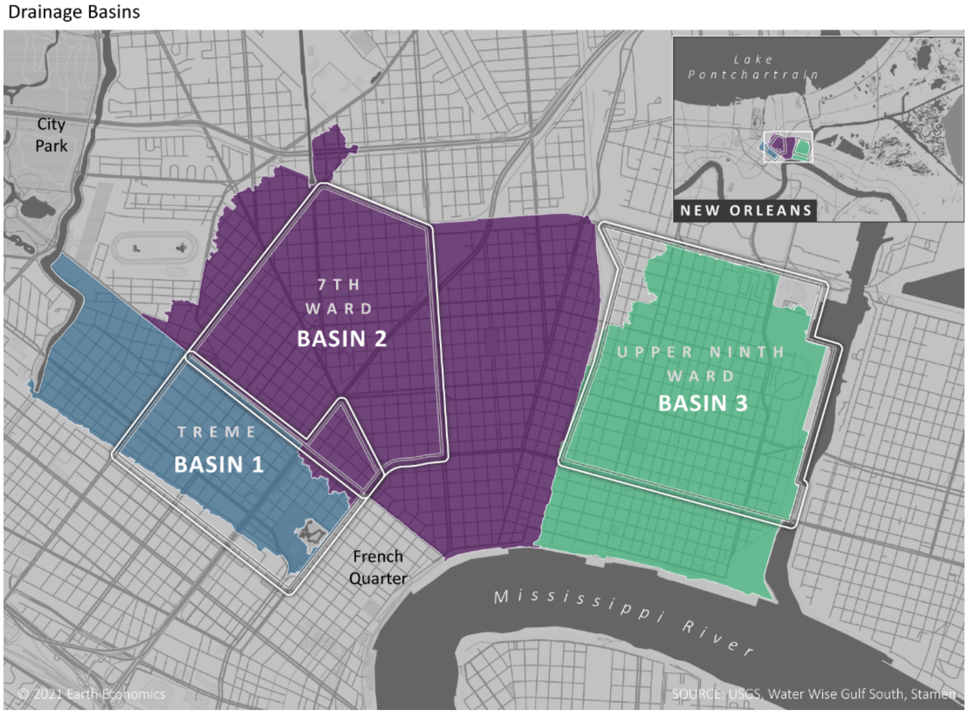
Step 1. Model storage as a percent of total rainfall for **a given rain event**

This analysis is built on the example of a 5-10 year rain event ([NOAA Atlas 14]) that produces 3 inches of rain in one hour in New Orleans. Such a storm has a 10 to 20 percent chance of occurring in a single year. This scenario was chosen because it exceeds the commonly understood capacity of the pumping system in New Orleans: one inch during the first hour, and half an inch in each subsequent hour. This modeled rain event would be expected to produce the localized neighborhood-scale flooding that is the subject of this study.

Step 2. Identify the number of major basins in the neighborhood, and **identify their area**

While delineating at 1m resolution produces multiple drainage basins, the proposed GI projects all fall within a single, large drainage basin that covers most of each neighborhood, and extends into others (see the map below).

Drainage Basins



GI projects for Tremé occur within basin #1, which has an area of 1.0 square miles. Projects for the 7th Ward occur within basin #2, which has an area of 2.9 square miles. Projects for the Upper 9th Ward occur within basin #3, which has an area of 1.7 square miles.

Notice that all three drainage basins are larger than the neighborhoods; this explains, in part, why localized flooding is felt acutely.

Step 3. Identify the total storage capacity of the proposed projects—excluding street trees—contained by each neighborhood basin

Basin 1 (Tremé): 25 proposed projects will store a total of 2,697,380 gallons of stormwater. Note that three projects identified in the *Lookbooks* as Tremé were reclassified into Basin 2 (7th Ward).

Basin 2 (7th Ward): 48 proposed projects will store a total of 1,620,696 gallons of stormwater. Note that three projects identified in the *Lookbooks* as Tremé were reclassified into Basin 2 (7th Ward).

Basin 3 (Upper 9th Ward): 43 proposed projects will store a total of 2,174,527 gallons of stormwater.

Step 4. Use the USGS rainfall calculator to estimate total stormwater runoff generated in each basin by the modeled rainfall event (Step 1)

Basin 1 (Tremé): 52,135,680 gallons of stormwater.

Basin 2 (7th Ward): 151,193,472 gallons of stormwater.

Basin 3 (Upper 9th Ward): 88,630,656 gallons of stormwater.

Step 5. Compare total storage (Step 3) against total runoff (Step 4) to illustrate the magnitude of the flood attenuation benefits of installing the proposed GI projects

Basin 1 (Tremé): 2,697,380 gallons of storage / 52,135,680 total gallons of stormwater = 2%

Basin 2 (7th Ward): 1,620,696 gallons of storage / 151,193,472 total gallons of stormwater = 1%

Basin 3 (Upper 9th Ward): 2,174,527 gallons of storage / 88,630,656 total gallons of stormwater = 5%

Appendix 2. Ecosystem services Valuation Literature

Studies that informed this ecosystem services valuation include:

Harrison, G. L. 2014. Economic Impact of Ecosystem servicess Provided by Ecologically Sustainable Roadside Right of Way Vegetation Management Practices. Florida Department of Transportation.

Ko, J. 2007. The Economic Value of Ecosystem servicess Provided by the Galveston Bay/Estuary System. Texas Commission on Environmental Quality.

Barnes, S. R., Bond, C., Burger, N., Anania, K., Strong, A., Weilant, S., Virgets, S. 2017. Economic Evaluation of Coastal Land Loss in Louisiana. Economic Evaluation of Coastal Land Loss in Louisiana 4(1): 1-39.

Costanza, R., Pérez-Maqueo, O., Martinez, M. L., Sutton, P., Anderson, S. J., Mulder, K. 2008. The Value of Coastal Wetlands for Hurricane Protection. Ambio: A Journal of the Human Environment 37(4): 241-248.

Petrolia, D. R., Interis, M. G., Hwang, J., Hidrue, M. K., Moore, R. G., Kim, T. 2012. America's Wetland? A National Survey of Willingness to Pay for Restoration of Louisiana's Coastal Wetlands. Marine Resource Economics 29(1): 17-37.

Brander, L. M., Koetse, M. J. 2011. The value of urban open space: Meta-analyses of contingent valuation and hedonic pricing results. Journal of Environmental Management 92: 2763-2773.

Bergstrom, J. C., Stoll, J. R., Titre, J. P., Wright, V. L. 1990. Economic Value of Wetlands-Based Recreation. Ecological Economics 2: 129-147.

McPherson, E. G., Simpson, R. D. 2002. A Comparison of Municipal Forest Benefits and Costs in Modesto and Santa Monica, California, USA. Urban Forestry & Urban Greening 1(2): 61-74.

Breaux, A., Farber, S. C., Day Jr., J. W. 1995. Using Natural Coastal Wetlands Systems for Wastewater Treatment: An Economic Benefit Analysis. Journal of Environmental Management 44: 285-291.