GREEN STORMWATER INFRASTRUCTURE FOR AFFORDABLE HOUSING IN YONKERS, NY

TECHNICAL REPORT

MULFORD Affordable Housing Development

MHACY Municipal Housing Authority for the City of Yonkers

GROUNDWORK Hudson Valley

GROUNDWORK USA

EARTH ECONOMICS

Green Stormwater Infrastructure for Affordable Housing in Yonkers, NY: Technical Report

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This technical supplement provides information on methods and data sources shared in the accompanying fact sheet, "The Benefits of Green Infrastructure for Affordable Housing | Yonkers, NY." This work was supported by The Kresge Foundation.

Contributors

Earth Economics

Carson Risner, Research Analyst
Laura Villegas, Senior Research Analyst
Olivia Molden, Project Director
Ken Cousins, Research Principal
Alice Lin, GIS Specialist
Kameron Eck, Intern

Groundwork USA

Lawrence Hoffman, Senior Manager of GIS and Data Services

Groundwork Hudson Valley

Brigitte Griswold, former Executive Director
Ellen Theg, Chief of Operations
Oded Holzinger, Executive Director

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.

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Introduction

Groundwork Hudson Valley has collaborated with the Municipal Housing Authority for the City of Yonkers (MHACY) on plans for incorporating green stormwater infrastructure at several affordable housing projects.[1] The sites are, *Dr. James O'Rourke Townhouses, Francis Reagan Townhouses, Kris Kristensen Homes, Joseph F. Loehr Court, Msgr. Cajetan J. Troy Manor,* and *William A. Walsh Homes*. Each of these sites will include one or more of the following features: bioretention basins, tree pits, mulched areas, or new lawns. Features were selected for their water retention capabilities to reduce localized flooding events.

Analysis of current planning finds that the project will add about two acres of bioretention areas and almost one acre of new lawn. The valuation study of the ecosystem services produced on the current and planned MHACY sites in Yonkers conducted by Earth Economics shows there are significant *quantifiable* co-benefits associated with MHACCY's proposed GI interventions. This technical report outlines the methods and data sources used to estimate values shared in public materials.

[1] See Groundwork Hudson Valley's Climate Safe Neighborhoods program for more information www.groundworkhv.org/programs/transforming-places/climate-safe-neighborhoods/

Methods and Data

Earth Economics researchers quantified the magnitude of selected social, environmental, and fiscal[2] benefits associated with six of the *Climate Safe Neighborhood* projects. These benefits were translated into monetary terms using well-documented and widely applied valuation methods, based on the Millennium Ecosystem Assessment framework (MEA, 2003). To complement this analysis, Earth Economics also applied their *Green Infrastructure Jobs Tool* to approximate the number of local jobs project spending would support.

Ecosystem Services

Ecosystem services are benefits to humans that derive from ecosystem functions, such as air and water filtration, regulation of stormwater and urban runoff, or outdoor recreational experiences (Figure 1).

Figure 1. Capital Functions

The MEA framework defines and categorizes 21 ecosystem services into four main categories (see Table 1): provisioning services, regulating services, supporting services, and information services.

- **Provisioning** services are often referred to natural resources
- **Regulating** services produce benefits through natural biological and chemical processes
- **Supporting** services provide habitat and refugia for living organisms
- **Information** services support meaningful human-nature interactions.

Valuation and the Benefit Transfer Method

Ecosystem service valuation is the process of quantifying the monetary value of these benefits. Some ecosystem services are traded in markets (e.g., traded foods, carbon credits, and natural fibers), and for these, there are mechanisms to assign or impute a monetary value using market prices. However, many other ecosystem benefits are known as "non-market" goods and services.

Most valuation methods fall under one of three larger categories: direct market valuation, stated preference methods, and revealed preference methods. Direct market valuation is used when markets exist for the particular benefit that's being measured. For example, urban forests are known to moderate the effects of heavy rain events and regulate urban runoff by storing water. Using the *avoided cost method* (see table 2), researchers can estimate the damage that might be incurred in the absence of such

[2] In this report, the terms economic benefits and community investments are used interchangeably.

forests. Storing water decreases runoff and ultimately reduces flood risk for those downstream, which can be quantified as the avoided damage (including public health costs) expected to have taken place if the runoff was at previous levels (i.e., without forest cover).

Over the past several decades, economists have developed a range of methods to determine the value of non-market benefits such as scenic beauty, a sense of belonging, the enjoyment of urban biodiversity, and the public health benefits provided by improved air and water quality. Table 2 presents descriptions and examples of these methods.

*Table 1. The MAE Framework for Ecosystem Service Valuation**

Service	Economic Benefit to People
Provisioning	
Energy and Raw Materials	Fuel, fiber, fertilizer, minerals, and energy
Food	Food crops, fish, game, and fruits
Medicinal Resources	Traditional medicines, pharmaceuticals, and assay organisms
Ornamental Resources	Materials for clothing, jewelry, handicraft, worship, and decoration
Water Storage	Long-term reserves of usable water stored in surface waters, and both shallow and deep aquifers
Regulating	
Air Quality	Providing clean, breathable air
Biological Control	Providing pest, weed, and disease control
Climate Stability	Stabilizing climate at local and global levels through evapotranspiration, shading, carbon sequestration and storage, and other processes
Disaster Risk Reduction	Mitigating impacts from natural hazards such as floods, hurricanes, fires, and droughts
Pollination and Seed Dispersal	Pollinating wild and domestic plant species via wind, insects, birds, or other animals
Soil Formation	Building soils through decomposition or sediment deposition
Soil Quality	Maintaining soil fertility and the capacity to process organic inputs
Soil Retention	Retaining arable land, slope stability, and coastal integrity
Water Quality	Removing pollutants via soil filtration and metabolization by microbial and vegetative communities
Water Capture, Conveyance, and Supply	Intercepted precipitation that becomes surface and subsurface water flows
Navigation	Maintaining adequate depth in surface waters to support recreational and commercial vessel traffic
Supporting	
Habitat	Providing diverse shelter and refugia to maintain biological diversity
Information	
Aesthetic Information	Compelling natural views, sounds, and smells
Cultural Value	Meaningful spiritual and historic engagement with nature; sense of place
Science and Education	Natural systems as a focus for the creation and transfer of knowledge
Recreation and Tourism	Enjoying the natural world and outdoor activities

**Adapted from Daly and Farley 2004, de Groot 2002, and Boehnke-Henrichs et al. 2013.*

Table 2. Economic Benefit Valuation Methods

Method	Description	Example
Direct Market Valuation		
Market price	Valuations are directly obtained from the prices paid for the good or service in markets	The price of energy sold on open markets, minus the costs incurred to produce that energy (known as producer surplus)
Replacement cost	Cost of replacing a given benefit provided by functioning green infrastructure with a built solution	The cost of replacing a raingarden's natural filtration capacity with a water filtration plant
Avoided cost	Economic losses that would be incurred if a particular form of green infrastructure were removed or its function significantly impaired	Costs related to flooding (e.g., life losses, building and road damages, missed workdays, etc.) that would be mitigated by GI that reduces flood extents
Revealed Preference Approaches		
Travel cost	Costs incurred in the traveling required to consume or enjoy a benefit provided by green infrastructure	People who travel to visit an urban park must value that experience at least as much as the cost of traveling there
Hedonic pricing	Benefits (or costs) of green infrastructure manifested through the impact of different factors on observed market prices	Property values near lakes and parks tend to exceed similar properties without such nearby amenities, all else being equal
Stated Preference Approaches		
Contingent valuation	Value elicited from survey instruments that pose hypothetical continuous valuation scenarios	What people are willing to pay to protect water quality
Discrete choice	Value elicited from survey instruments that present a series of discrete hypothetical alternatives	Whether people prefer to pay a larger fee to restore environmental quality or a smaller fee to limit pollution

Benefit Transfer Methods

Other common approaches used in ecosystem service valuation are called **benefit transfer methods** (BTM), by which previous estimates of ecosystem service values are applied to locations within common attributes and contexts. In practice, BTM begins by identifying valuation studies of landcover types similar to those being studied (e.g., open greenspace) in locations with attributes comparable to those of the study area (e.g., climate, land use) to ensure "apples-to-apples" comparison. Valuation estimates from the original studies are then converted to dollar-per-year-per-area (e.g., square feet), and multiplied by the extent of each combination of landcover and attributes that are present in the study area.

Every candidate study is reviewed by analysts who were not involved in the initial selection process, to ensure that studies are appropriate for the ecosystems, ecosystem services, and attributes of the study area. Since the Climate Safe Neighborhoods projects are exclusively urban, studies conducted in rural areas have been excluded. Studies are also restricted to those conducted in similar geographic areas (e.g., New York) to ensure that beneficiaries are also similar. When more than one study is deemed appropriate, researchers can report both minimum and maximum values to show the variability of valuation estimates for each ecosystem service and landcover-attribute combination. However, in this study findings are presented as averages. Table 3 shows the ecosystem services valued here, the corresponding valuation method, and the data or literature sources used in the valuation processes.

Table 3. Summary of benefit, valuation methodology, and related notes

Benefit	Ecosystem Service	Valuation method	Data/ literature source
Social	Aesthetic	BTM; Hedonic Price Method	Peper et al., 2007
	Urban Heat Mitigation	Avoided cost	Earth Economics' Urban Heat Mitigation Mapping tool; HCUPnet (2022); CDC (2022); DAYMET (2022); EPA (2022)
	New Jobs	BTM	Earth Economics' GI Jobs tool
	Education/ Workforce development*	N/A	N/A
	Social Cohesion*	N/A	N/A
	Noise reduction*	N/A	N/A
	Avoided road closures when sewage systems overflow*	N/A	N/A
Environmental	Reduced erosion, avoided topsoil loss*	N/A	N/A
	Stormwater management	BTM	TPL, 2022
	Wastewater management	BTM	TPL, 2022
	Air quality	BTM	Gopalakrishnan et al., 2018;
	Carbon sequestration	BTM	City of Calgary, 2019; Flynn and Traver, 2013; Kavehei et al., 2018
	Avoided CO2 emissions	BTM	USDA, 2018
	Reduced building energy use	BTM; Avoided cost	USDA, 2018
Fiscal	Avoided road repair*	N/A	N/A
	Avoided repair/maintenance*	N/A	N/A

** Not included due to data limitations and study assumptions.*

Results

This study examined selected social, environmental, and economic benefits associated with the green infrastructure features that characterize six of the affordable green housing projects. The results reveal that the value of these benefits to local residents could be substantial, depending on the specific implementation of the proposed projects. Below are estimated values[3] for selected monetizable ecosystem services, organized by green infrastructure feature types.

Most elements of green infrastructure provide a broad range of ecosystem goods and services—many more than have been estimated in this report. Accordingly, these totals can be considered conservative, rather than comprehensive estimates.

Table 4 shows the value of ecosystem services provided by bioretention areas, trees, and areas of open space and grassland.

Table 4. Summary of Ecosystem Service Value by feature.

Feature	Annual Ecosystem Service Value (USD 2022)
Bioretention	$179,600/acre
Grassland	$70/acre
Urban trees*	$750/tree

** As provided by fully mature trees. Because it takes time for saplings to reach maturity, the full value of this ecosystem service will not be realized immediately.*

The stormwater management services provided by bioretention areas are substantial ($179,000 per acre, per year), based on the *2022 Feasibility Study* prepared by MKM Landscape Architecture PC. Table 5 reports the water capture efficiency of bioretention infrastructures for each project site.

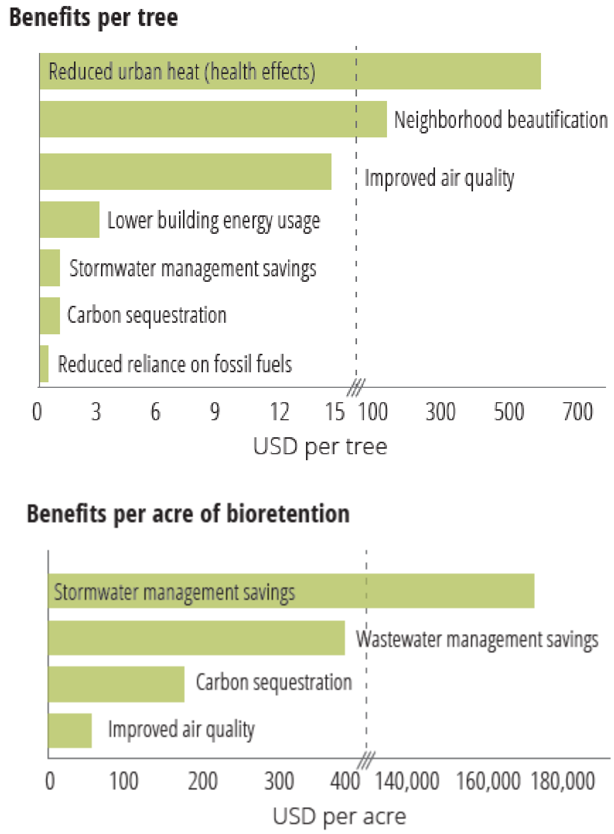
Table 5. Water capture by bioretention features at each project site.

Site	Bioretention area (acres)*	Water captured (gallons)*
Dr. James O'Rourke Townhouses	0.92	93,700
William A. Walsh Homes	0.28	66,100
Francis Reagan Townhouses	0.18	70,900
Joseph F. Loehr Court	0.12	20,900
Kris Kristensen Homes	0.04	20,000
Msgr. Cajetan J. Troy Manor	0.10	17,600

Source: MKM Landscape Architecture PC, 2022
*Values have been rounded.

[3] All values have been rounded

Figure 2. Summary of results for per unit per year benefits



Ecosystem Services Values by Project Feature

The section below presents detailed descriptions of how each ecosystem service value was derived, organized by project features (i.e. trees, bioretention, grassland). It is worth noting that whenever a range of values was available, Earth Economics chose the most conservative estimate.

Feature: Trees

Urban Heat Mitigation

Urban green space and trees can reduce urban heat through evapotranspiration and by providing shade. To calculate the economic value of such cooling effects, Earth Economics applied its proprietary Urban Heat Mitigation Mapping (UHMM) tool, which estimates the savings in hospitalization costs and avoided loss of life amongst those 65 and older that can be attributed to urban forests. Changes to urban heat extremes are estimated based on a health impact function that is used by the U.S. Environmental Protection Agency (EPA) for the *Environmental Benefits Mapping and Analysis Program* (BenMAP). Other inputs include Census tract data, mortality data from the Center for Disease Control and Prevention, morbidity data from the *Hospitalization Cost and Utilization Project*, and forest cover (at 30-meter resolution) as reported in the National Land Cover Dataset. Outputs from this tool include avoided hospitalization costs and avoided deaths per year associated with the ability of urban tree canopy to moderate extreme heat. These estimates are standardized as annual per-tree values, with the EPA's

Value of a Statistical Life (VSL) measure to approximate the "economic value of human life losses" ($7.4 million per person).

For this project, Earth Economics used the most conservative values associated with the New York City metropolitan area. Table 6 below summarizes lower-bound outputs from the UHMM tool for New York City. The annual urban heat mitigation value per tree is roughly $610 (2022 USD).

Table 6. Output from Urban Heat Mitigation Mapping tool, New York City

Benefit category	Value per tree (2022 USD)
Avoided hospitalizations (people 65 and over) per year	19
Avoided mortality (people 65 and over) per year	24
Avoided hospitalization costs per year	$2
Avoided loss in human life per year (VSL)	$606

Aesthetics

Well-maintained green spaces with trees help to beautify built landscapes. In this study, Earth Economics focused on the aesthetic value of trees, based on the *New York City Municipal Forest Resource Analysis* conducted by Peper et al. (2007). The authors applied a hedonic price study to New York City, reporting an aesthetic annual value per tree of approximately $130 (2022 USD).

Air Quality

Urban trees improve air quality by directly removing air pollutants. To estimate direct pollutant removal by urban trees, Earth Economics used the per-tree estimates specific to New York City presented a report on the *Urban Forest of New York* (Nowak et al., 2018). The authors calculated pollutant removal by NYC's trees using data from weather data and pollution monitors for ozone, nitrogen dioxide, sulfide dioxide, and PM2.5. The monetary value of removal of these pollutants was estimated using EPA's BenMAP tool, which measured the savings from avoided human health impacts (e.g. cost of illness, value of statistical life, loss of wages). Earth Economics adjusted the findings reported in Nowak et al. (2018) to arrive at an annual value of air quality improvement of around $15 (2022 USD) per tree.

Avoided CO_2 Emissions

Urban trees can also help to reduce air pollutant emissions by reducing energy consumption in nearby buildings, thereby reducing pollution from power generation. Nowak et al. (2018) estimated the emissions avoided by the cooling effects of nearby trees using USDA's i-Tree. They estimated that NYC's urban forest lowers carbon emissions by 43,000 tons of CO2e, or 11,800 of C, per year. Using the Interagency Working Group's Social Cost of Carbon (SCC) estimates of $160/ton (2022 USD), this translates to $0.40 per tree, per year (2022 USD).

Energy Savings

Trees reduce building energy use through shade provision and evapotranspiration. Beyond the emissions avoided by lower energy demand, stakeholders benefit from lower energy bills. Again, Earth Economics relied on per-tree values from Nowak et al. (2018). Using U.S. Energy Information Administration data and USDA's i-Tree tool to estimate annual energy savings, that report estimated the annual value of energy savings attributed to NYC's 6,977,000 trees is $20.5 million (2022 USD), or roughly $3 per tree, per year (2022 USD).

Carbon Sequestration

Trees reduce the amount of carbon in the atmosphere as they grow by absorbing carbon. In their study of the Urban Forest of New York City, Nowak et al. (2018) used the i-Tree Eco Model to estimate the net carbon sequestered by NYC's urban trees. They estimated the number to be approximately 36,000 tons per year (132,000 annual tons of CO2e). To translate this to monetary value, authors multiply tree carbon values by the SCC. The resulting annual value net carbon sequestered by NYC's trees is nearly $7.8 million (2022 USD), or roughly $1 per tree, per year (2022 USD).

Stormwater Management (Avoided Runoff)

Trees intercept rainfall and absorb surface waters through their roots. Nowak et al. (2018) calculated avoided runoff to be 69 million cubic feet per year. They estimated the monetary value of that avoided runoff at $0.08 (2022 USD) per cubic foot, based on estimated average national water treatment and runoff control costs. The overall value of avoided runoff attributable to NYC's urban forests is $5.5 million (2022 USD), or roughly $1 per tree, per year (2022 USD).

Feature: Bioretention

Air Quality

Green bioretention features can improve urban air quality and human health. To estimate the monetary value of improved air quality associated with these project features, Earth Economics used the urban shrublands values reported by Gopalakrishnan et al. in their 2018 study of air quality and human health impacts in the United States. Those authors used the i-Tree Eco model to estimate the air pollution removal capacity of grasslands and shrublands for nitrogen dioxide, ozone, sulfur dioxide, and PM2.5. Again, the monetary value of these benefits were derived from EPA's BenMAP program, based on avoided emergency room visits, hospital admissions, etc. This values air quality improvements from bioretention areas at around $55 per acre per year (2022 USD).

Carbon Sequestration

Bioretention features are designed to mimic the ability of natural ecosystems to capture and store water. Yet because these features are vegetated, they also sequester carbon. We calculated the average unit value (tons per square foot per year) of three studies on the biophysical performance of bioretention projects as our sequestration rate (Flynn & Traver, 2013; Kavehei et al., 2018; City of Calgary, 2019). To translate this into monetary value per acre, we multiplied that value by the SCC of $160 per ton (2022 USD) and convert area units, resulting in an average of roughly $175 per acre per year.

Stormwater Management

Many forms of green stormwater infrastructure (GSI) are designed to facilitate infiltration of runoff into groundwater, reducing the need for additional grey stormwater infrastructure. The 2022 feasibility study developed by MKM Landscape Architecture PC estimates that the across a combined 1.64 acres, the projects would capture 289,189 gallons of water per year (see table 5), a rate of 176,252 gallons per acre per year. To translate this to monetary value, Earth Economics used the avoided cost method reported in the Trust for Public Land report *The Economic Benefits of Parks in New York City* (2022). That study recorded average unit construction costs across 13 GSI projects in New York state, ranging from $0.38 to $1.49 for each gallon captured. Using the midpoint value of building stormwater infrastructure of $1.02 per gallon (USD 2022), Earth Economics estimated that the bioretention features of these projects avoid $179,000 in additional infrastructure costs (2022 USD).

Wastewater Management

The ability of bioretention features to absorb runoff also reduces wastewater treatment costs. Again, Earth Economics followed an avoided cost approach based on the costs reported in the 2022 TPL study. They estimated that treating a gallon of wastewater costs New York City between $0.0019 and $0.0021. Using the annual water capture rate of 176,252 per acre (see above), the value of avoided wastewater treatment is around $380 per acre, per year (2022 USD).

Feature: Grasslands

Air Quality

Grasslands and shrublands each improve air quality and human health. Following the approach used to value the air quality benefits of bioretention features, Earth Economics used values reported by Gopalakrishnan et al. (2018). For grass features of the project sites, Earth Economics estimated air quality improvements of roughly $70 per acre, per year (2022 USD).

Additional Jobs

The proposed projects offer new employment opportunities that can be separated into direct, indirect, and induced effects. Direct effects include those hired to install, operate, and maintain each project site. Indirect effects are jobs in industries that supply and support companies which implement projects (e.g. plant nurseries, insurance). Induced effects are jobs in the industries associated with employee spending (e.g. groceries, housing). Earth Economics has developed a database of such effects for various green infrastructure project types, known as the *GI Jobs Tool*. Estimates in the database have been drawn from the project implementation literature and adjusted to local wage rates.[4] Table 8 shows the total new jobs supported per $1,000,000 spending on construction and O&M activities.

Table 8. Jobs supported per $1,000,000 spending on bioretention features.

	Direct	Indirect	Induced	Total
Construction	7	2	4	13
O&M	8	2	4	14

Limitations

This analysis has been primarily limited by the availability of data, especially regarding the maintenance costs and workforce development opportunities associated with Groundwork paid youth programs. Earth Economics researchers also found gaps in the ecosystem services valuation literature for features relevant to the proposed projects, including the effects on nuisance flooding,[5] soil and water quality improvements, habitat integrity and connectivity, urban biodiversity, and ambient noise reductions.[6]

[4] For additional details on the GI Jobs tool, please contact the authors.

[5] Low level (<1 ft^2), often frequent, inundation events that disrupt everyday activities and cause minor property damage.

[6] A 2010 Study by the Center for Neighborhood Technology, estimating noise mitigation benefits of green stormwater infrastructure strategies suggests noise reduction associated with various green infrastructure types (e.g. porous pavement, green roof, street hedgerows) can be comparable and in some instances surpass benefits associated with conventional noise walls (CNT, 2020).

Future engagements can add clarity on the degree to which the green infrastructure features at each location limit nuisance flooding and associated costs, such as reduced road damage, fewer road closures, and public health benefits associated with a reduction in sewage overflows.

The precision of this analysis may also be limited by the application of benefit transfer methodology, which generalizes estimates from similar study sites. Because no two locations are identical (true also of variation within research areas), it is assumed that benefit transfer introduces a degree of error. Earth Economics follows best-use practices when selecting peer-reviewed studies to minimize such effects. More significant is the limited understanding of the relationships between nuisance flooding and NBS.

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