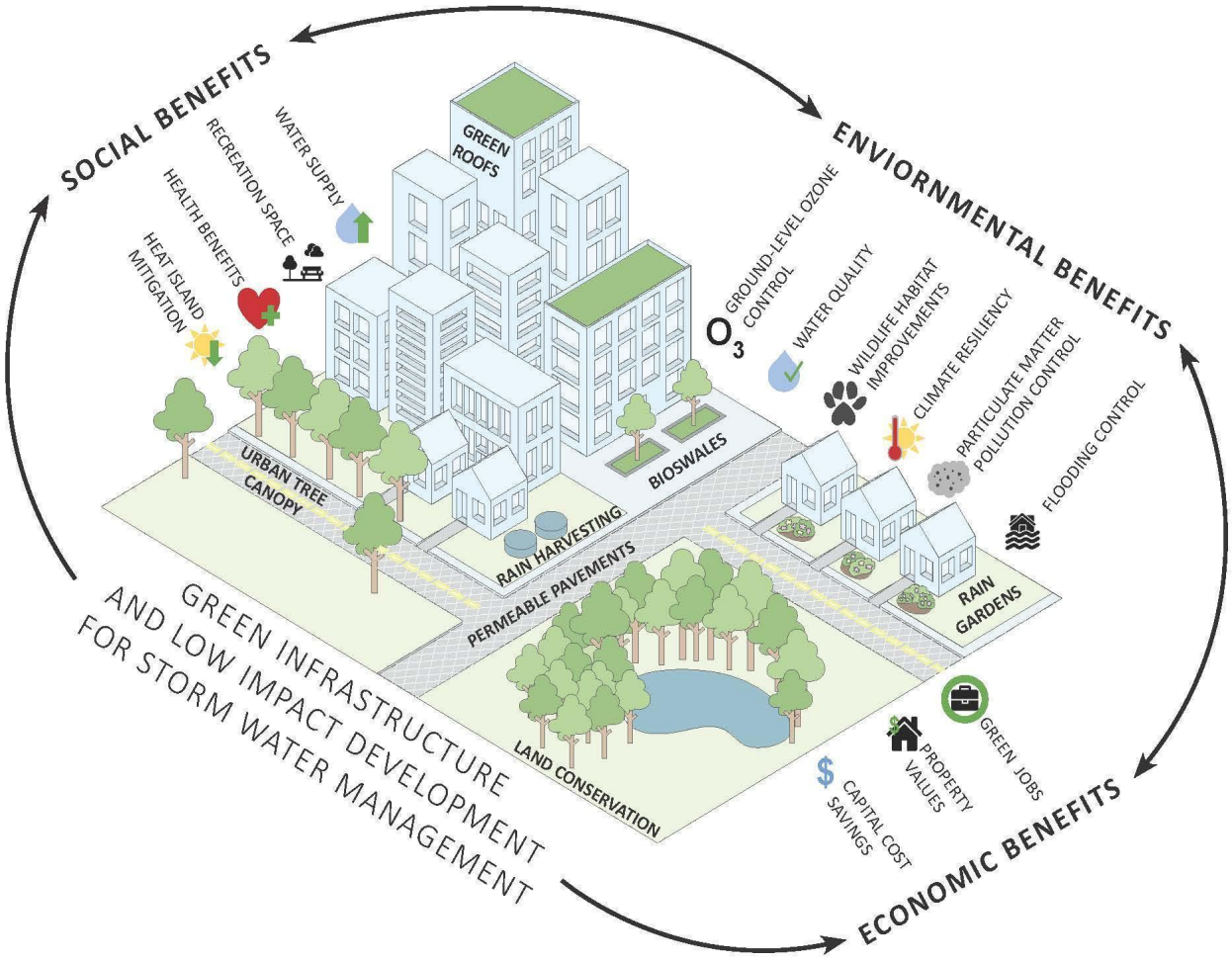
Optimizing Green Infrastructure and Low Impact Development to Mitigate Impacts on Freshwater Systems

A Strategic Framework for The Sea Grant Network



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Executive Summary

Runoff from stormwater carries pollutants, such as particulates, nutrients, pesticides, other synthetic organic chemicals, toxic metals, pathogens, and contaminants of emerging concern into water bodies degrading water quality and resulting in damages to both freshwater and marine ecosystems. Impairments to these ecosystems produce negative economic, social, and environmental impacts on communities. Although stormwater best management practices (BMPs) encompass green infrastructure (GI) and low impact development (LID) to address issues related to both volume and chemical composition of urban runoff, significant concerns in treating runoff pollutants such as the uncertainties on performance, implementation and maintenance costs, and the potential for accumulation of or leaching of metals and other pollutants remain.

This report is a strategic document that identifies research priorities and actions for the Sea Grant Network and its partners to optimize the deployment of innovative GI/LID techniques through science and catalyzed collaboration. Through a three-pronged approach: an extensive literature review, a regional stakeholder survey, and two stakeholder advisory group (SAG) workshops, we have identified key knowledge gaps and challenges concerning the deployment of GI/ LID and provided recommendations and strategies to address them:

- Four (4) key **Research Focus Areas** to advance the implementation of GI/ LID are:
  1. Sustainable design, installation, and maintenance;
  2. Relevant and credible cost-benefit information;
  3. Accelerated resilience and adaptation to climate change impacts; and
  4. Efficient and inclusive planning and management.
- **Extension**: Provide useful resources and tools to all stakeholders, especially the public, developers, and local officials to raise awareness and advance the support for and integration of GI/ LID in retrofits and new development.
- **Education**: Train diverse stakeholders on the science, social, economic, and environmental benefits and proper installation, operation, and maintenance of GI/ LID.
- **Partnerships**: Engage scientific communities with local communities, non-governmental organizations, and government to assure that all technical, financial, and regulatory resources are utilized to advance the deployment of GI/ LID.

These strategies are expected to guide the Sea Grant Network's efforts in its research, education and outreach, extension, and partnerships in developing and deploying innovative GI/LID techniques to treat stormwater runoff into freshwater systems and improve the integrity of freshwater and ultimately marine ecosystems.

Table of Contents

1. Introduction

1.1 Background

Freshwater systems in the U.S., such as streams, lakes, groundwater, and wetlands, suffer from periodic influx of a variety of contaminants from urban and agricultural runoff. Traditional and emerging runoff pollutants find their way to freshwater systems and ultimately to coastal waters via both nonpoint and point sources such as agriculture, stormwater, and combined sewer overflows (CSOs). Land use changes can alter runoff magnitude and pattern and reshape flow discharge. Stormwater runoff carries a multitude of chemical and microbial contaminants to freshwater systems and degrades the integrity of aquatic ecosystems, which gives rise to complex economic and social challenges, particularly to socially underrepresented and economically disadvantaged groups, who primarily reside in urban areas ((Pew Research Center, 2018).

Traditional stormwater pollutants typically include oxygen-demanding materials, metals, nutrients, pathogens, synthetic organic chemicals (SOCs), and sediments that create a myriad of environmental problems. For example, nutrients, such as nitrogen (N) and phosphorus (P) in runoff, can contaminate surface water and groundwater and cause a wide array of environmental and public health problems including eutrophication in water bodies, ammonia poisoning of aquatic life, and nitrate pollution in drinking water (Galloway et al., 2003; Voisin et al., 2018). Nutrients are primarily derived from fertilizers and other organic and inorganic pollutants from motor oil and road dust in urban areas (Hart et al., 2004; Mallin et al., 2009; Wada et al., 2020). In addition to traditional pollutants, recent attention has been given to contaminants of emerging concerns (CECs) such as antibiotics and hormones from CSO effluents in urban areas and Concentrated Animal Feeding Operations (CAFOs) in rural areas, per- and polyfluoroalkyl substances (PFAS) and micro- or nano-plastics from wastewater treatment facilities. Fate and transport of these CECs in urban stormwater and agricultural runoff, their chemical and biological impacts on the receiving freshwater systems, and their ultimate effects on ecological and human health with resulting economic and social damages are yet to be adequately and comprehensively studied.

Traditional stormwater management approaches primarily focus on peak flow reductions without addressing water quality (Burns et al., 2012). Newer stormwater best management practices (BMPs) encourage designs that address both quantity and quality issues. Green infrastructure (GI) and low impact development (LID) are BMPS of particular interest since they address both challenges and are inherently more sustainable and typically more adaptable to changing conditions.

1.2 Definitions

There are a variety of definitions for GI and LID. For this report we will use the National Green Infrastructure Certification Program's definition of green infrastructure as: "stormwater management practices that protect, restore, or mimic the natural water cycle" (EnvironCert, 2021). GI uses existing natural landscapes (e.g., wetlands and forests) and nature-based features (e.g., vegetated rooftops, rain gardens, pervious surfaces, native landscaping, and broader habitat restoration) to reduce runoff and abate and/or trap pollutants. In contrast, LID emphasizes the use of small-scale, decentralized stormwater control measurements to preserve or closely mimic some site-specific pre-development hydrologic responses to storms such as increasing infiltration and mitigating runoff (Burns et al., 2012). Examples of GI/LID techniques include bioretention cells, rain gardens, bioswales, permeable pavements, infiltration basins and trenches, and green roofs.

1.3 Implementation of GI/ LID

Public works departments at the municipal and county levels, together with various transportation agencies, are the entities that are typically tasked with managing stormwater. These entities are required to manage stormwater under various federal and state stormwater regulations (Grabowski et al., 2022). The U.S. Environmental Protection Agency (EPA) develops federal stormwater rules, while different states may go beyond the federal requirements in their local regulations. The EPA (and often states as well) provide guidance, tools, and information on planning, design, maintenance, and funding for GI (USEPA, 2022a). For example, EPA's "Green Streets, Green Jobs, Green Towns (G3) Initiative" provides support for small to medium-sized communities in urbanized watersheds to reduce stormwater runoff

through the use of GI (USEPA, 2021a). In October 2013, EPA released its "Green Infrastructure Strategic Agenda" outlining its actions to promote effective implementation (USEPA, 2021b). The Green Infrastructure Federal Collaborative, initiated by the EPA in May of 2021, fosters engagement and cooperation among federal agencies that actively work to promote the implementation of GI through their policies and programs. Members include the U.S. Army Corps of Engineers, U.S. Department of Agriculture, U.S. Department of Commerce, U.S. Department of Homeland Security, U.S. Department of Housing and Urban Development, U.S. Department of the Interior, U.S. Department of Transportation, and U.S. EPA (USEPA, 2022b).

In addition to federal and state programs, there are several non-governmental organizations that support GI/ LID BMPs. The National Green Infrastructure Certification Program (NGICP) provides the base-level skill set support for the proper construction, inspection, and maintenance of GI through certification (EnvironCert, 2021). The Nature Conservancy supports cities to accelerate their use of GI to manage stormwater runoff by developing financing tools that attract private capital to support these projects (*Green Infrastructure for Cities*, 2022). The Water Research Foundation (WRF) provides annual updates of its International Stormwater Best Management Practices Database of the most monitored and reported BMP types available (WRF, 2021). In 2021, WRF published a report and an Excel-based tool providing a systematic approach for quantifying and monetizing the financial, social, and environmental benefits of GI/ LID at the community, watershed, or neighborhood scale (Clements et al., 2021).

Collaboration, partnerships, and the utilization of the myriad of regulatory, technical, and financial resources will help ensure further implementation of GI/ LID as stormwater BMPs.

1.4 Project purpose and process

The development of this strategic document is part of the project *Optimizing Green Infrastructures and Low Impact Developments to Mitigate Runoff and Pollution Impacts on Freshwater Systems* funded in 2021 by the National Sea Grant Office. The purpose of the project is to optimize the deployment of innovative GI/LID techniques to mitigate stormwater runoff and reduce negative impacts on freshwater systems by evaluating the existing science, expanding research, and catalyzing collaboration of the Sea Grant Network and stakeholders.

The utilization of GI/ LID in freshwater watersheds will have profound and positive benefits on the health of our coastal ecosystems, a primary goal of the National Sea Grant Program.

The project consists of two components. Component I was a scoping study that identified key challenges, knowledge gaps, research needs, and strategies for the Sea Grant Network in the pursuit to enhance implementation of GI/LID. The study collected information through a comprehensive literature review, a stakeholder survey, discussions with Sea Grant professionals, and two focused stakeholder advisory group workshops. The findings informed this strategic report.

Component II is the development of a competitive research program that will fund up to three projects in the metropolitan areas of the Mid-Atlantic Sea Grant Region (NY-NJ-DE-PA-MD-VA-NC). The research projects will address the knowledge gaps and research needs identified in this report. The outcomes of the research projects will be used to update the strategic framework provided in this report.

2. Summary of findings: knowledge gaps and challenges

2.1 Literature review

A comprehensive literature review was conducted to identify the current knowledge and challenges of GI/ LID techniques, including comparative performance assessments and extensive cost-benefit analyses. The findings from the literature review helped inform the development of the stakeholder survey and guide the discussions with the SAG. Some of the key challenges identified in the literature are poor understanding of GI/ LID performance especially in field studies and under a variety of environmental and climatic conditions, and the lack of regulatory support, financial incentives, and community acceptance. Knowledge gaps identified in the literature include understanding of CECs removal by GI/LID, fate and transport of pollutants under a variety of field conditions, technique optimization, and adequate decision support resources.

2.2 Regional stakeholder survey

The online survey collected information on 220 respondents' knowledge of, involvement in, and opinions on GI/ LID implementation. Most of the respondents were from the consulting, local government, and academic sectors and involved in research, planning, policy, communication, and implementation of GI/ LID. The stakeholders ranked the greatest benefits of GI/LID being improvement of water quality, reduction of stormwater/CSO effluents, and ecological improvements. The greatest concerns and obstacles to GI/ LID implementation perceived by the stakeholders were poor maintenance, costs and available funding, and community acceptance. The identified key knowledge gaps are the lack of demonstrated long-term benefits of GI/LID projects and their performance under varying field conditions. The challenges to widespread implementation of GI/LID projects were availability of funding, lack of understanding of GI/LID and community acceptance, and proper maintenance. The identified research needs include development of project optimization and design-support tools, determination of the best mechanisms to enhance community engagement, especially in underserved and environmentally overburdened communities, and field demonstrations of GI/LID techniques under varying environmental and climatic conditions.

2.3 Stakeholder Advisory Group (SAG) workshops

The stakeholder advisory group (SAG) met virtually on two occasions to review survey findings, discuss research needs, and recommend focus areas for this strategic framework. In the first workshop, participants discussed information gaps, key challenges, and research priority areas. The discussions

were organized around the topics of policy and planning, design and monitoring, implementation and maintenance, and environmental justice. The main conclusions were that there is a need for: community engagement and raising awareness of the long-term co-benefits of GI/ LID, such as improved air quality, reduction of heat islands, flood mitigation, provision of open space, community beautification, and the creation of green jobs; more training for designers, engineers, community members, and maintenance workers; and incentivization of utilizing GI/LID beyond current regulatory requirements. The priority research areas identified were the study of the long-term resilience of GI/ LID to changing climatic conditions including associated shocks and stressors; implementation of GI/ LID projects on a watershed scale to include more field monitoring to determine fate and transport of various pollutants and the impacts on ecological health at the watershed scale; and lifecycle cost-benefit analyses.

In the second workshop, participants reviewed, discussed, and refined the recommendations for this framework in order to prioritize the research needs of projects funded by the competitive research program; effectuate the Sea Grant Network's extension; improve education amongst all stakeholders; and enhance and expand its partnerships. The recommendations call for the attention to the needs of the end-users of the research findings and ask to make research specific and relevant to the communities where the GI/LID projects intend to serve.

3. Recommended Actions for the Sea Grant Network

The literature review, stakeholder survey, and SAG workshops' discussions have identified numerous challenges that have limited the widespread implementation of GI/ LID techniques. These challenges include, but are not limited to, costs/ financing, regulatory support, design and performance, and social barriers to acceptance. To address these challenges and fill recognized knowledge gaps, the recommendations of actions are presented here for each of the following categories: Research, Extension, Education, and Partnerships for the National Sea Grant Network.

3.1 Research

To help the Sea Grant Network manage its resources most effectively, four research areas have been identified to address the identified knowledge gaps and challenges:

- Sustainable design, installation, and maintenance
- Relevant and credible cost-benefit information
- Accelerated resilience and adaptation to climate change impacts
- Efficient and inclusive planning and management

The following priorities have been selected within these research areas.

3.1.1 Sustainable design, installation, and maintenance

To ensure the optimization of GI/ LID projects they must be designed, installed, and maintained through their lifespans in such a way as to protect the environment, consider economic feasibility, and current and future societal concerns and needs. To surmount the identified knowledge gaps and challenges, it is recommended that future research projects: Develop and evaluate the performance of innovative GI/LID design including retrofits, media mixes and reuse thereof, plant-soil combinations, and hybrid designs of green-gray infrastructure. The performance should be evaluated in long-term field evaluations, for both wet and dry seasons, in different ecoregions, and under varying climatic conditions, in addition to lab studies. As far possible, these projects should:

- Investigate designs in ultra-urban areas, especially retrofits,
- Document hydrologic performance,
- Document pollutant fate, transport, and removal efficiencies, especially of CECs,
- Document long-term water quality and groundwater impacts at the watershed scale.

3.1.2 Relevant and credible cost-benefit information

To improve the acceptance of GI/LID it is essential to communicate the direct benefits, co-benefits, and avoided costs associated with GI/ LID compared to costs in a way that is relevant and meaningful to all stakeholders. Therefore, it is a priority that research projects: Identify, quantify, and monetize long-term costs, co-benefits, and avoided costs of GI/LID and compared to gray infrastructure at the community or watershed scale, especially in underserved, environmentally overburdened communities. These analyses should be performed over a long-term temporal and spatial horizon and address socioeconomic and geographical differences. Analysis may include quantifying the benefits to public health, property values, reduction in

urban heat islands, improvement of air quality, job creation, improved passive recreation/ provision of open space, community safety, pollution load reduction, improved regional climate resilience, and flood risk reduction.

3.1.3 Accelerated resilience and adaptation to climate change impacts

Most GI/LID systems are dynamic due to intermittent inundation with stormwater, variations in stormwater chemical composition, fluctuating weather conditions, and climate change related shocks (e.g., hurricanes and floods) and stressors (e.g., sea level rise and land subsidence). To address the knowledge gaps and challenges with GI/ LID projects in relation to resilience and adaptation to climate change impacts, it is recommended that future research projects: Develop and evaluate optimized GI/LID designs and retrofits to handle different climate change challenges, e.g., droughts, dry periods, sea-level rise, and an increased frequency and intensity of storm events and how hydrodynamic stormwater aspects, such as the changes of flow within a storm event and changes in dry periods between storms, including pollutant loading and water quantity, affect GI/LID performance. These research projects should assess how design standards might be adapted to deal with these challenges and how they could vary between geographic regions.

3.1.4 Efficient and inclusive planning and management

To assure that GI/LID projects are most effective at addressing the environmental, economic, and social needs of a community and region there must be inclusivity in the planning for and management of these projects. To that end, it is recommended that research be conducted to: Investigate communities' level of awareness and understanding of and perceptions and attitudes towards different types of GI/LIDs, how these attitudes vary across demographic regions, especially under-served and environmentally overburdened communities, and strategize how the information can be used to foster public acceptance of GI/LID projects in their communities; examine and assess the effectiveness of existing incentives and programs to plan and organize GI/LID initiatives in different socio-economic, urban, suburban, and rural settings at the watershed scale; and investigate how incentives can be enhanced in regulatory or financing programs.

3.2 Extension

The Sea Grant Network has many partners and has demonstrated effective outreach and extension in its endeavors. To support the goals of the framework provided in this document, it is recommended that Sea Grant and its partners enhance its extension and outreach by:

- Offering certification programs and training courses for those involved in GI/LID planning, implementation, maintenance, and monitoring (e.g., engineers, land designers, developers, property owners, planners, government officials, local community groups and local small contractors) to deliver sound information on design, material procurement, construction, monitoring, adaptive management, and maintenance practices.
- Providing demonstration projects in different accessible locations especially schools, municipal properties, new and retrofitted development, and heavy traffic areas. Organize regional and local workshops, and other knowledge sharing events for researchers, practitioners, and the public around these demo sites.
- Focusing on understanding the needs and desires of underserved and environmentally overburdened communities and addressing any concerns they have with the implementation of GI/ LID projects.
- Developing and maintaining a central repository/database for GI/LID information sharing that may include cost-benefit information, community outreach materials, funding opportunities, examples of projects, and decision tools such as plant selection lists for various ecoregions or states.
- Encouraging regulatory agencies to incentivize GI/ LID in their policies and funding programs, especially for underserved and environmentally overburdened communities.

3.3 Education

The extension of the Sea Grant Network can be further enhanced by the opportunities we have identified to provide educational tools and resources. It is recommended that Sea Grant:

- Offer fellowships, scholarships, and internships for GI/LID work (research, design, construction, maintenance, and monitoring).

- Strengthen training on post-construction monitoring and maintenance to not only public work professionals but non-governmental organizations, volunteer corps, and schools.
- Develop curricula and advocate for GI/LID being integrated into science and engineering teaching portfolios at middle and high schools, trade and technical schools, colleges and universities, as well as continuing education programs.

3.4 Partnerships

The recommended actions will be most effective through the expansion and strengthening of the partnerships within the Sea Grant Network, especially partners in underserved and environmentally overburdened communities. The continuous engagement of these partners, even after projects are implemented, is necessary to maintain support for GI/LID projects in these communities. The partnerships we have identified that must be maintained, enhanced, and expanded include, but are not necessarily limited to:

- Nongovernmental and nonprofit organizations
- Community-based and minority leaders and activists (especially in underserved and environmentally overburdened communities)
- Public and private universities and colleges
- Private landowners and developers
- Industry professionals and their organizations
- Local business owners and small contractors
- Federal and state government agencies (including those in the Green Infrastructure Federal Collaborative)
- Surface water management agencies
- Local elected officials
- Local communities and groups representing them (especially underserved and/ or environmentally burdened)
- K-12 schools, including environmental clubs
- Local Green Teams and Environmental Commissions
- Green Infrastructure Leadership Exchange Network
- Land grant extension programs

4. Environmental Justice

The EPA defines environmental justice as "the fair treatment and meaningful involvement of all people regardless of race, color, national origin, or income, with respect to the development, implementation, and enforcement of environmental laws, regulations, and policies" (https://www.epa.gov/environmentaljustice). Woven throughout the recommendations provided in this document is a focus on understanding the needs, concerns, desires, and perspectives of those living in traditionally underserved and environmentally overburdened communities. This includes understanding the costs and co-benefits of GI/LID for their communities, researching the current level of awareness and perspectives on GI/LID, and utilizing these findings to enhance the communities' involvement in decision making and proactive promotion of these types of projects.

This focus of environmental justice as it pertains to improving the implementation of GI/ LID in these communities supports the principles of diversity, equity, and inclusion (DEI) embraced by the Sea Grant Network. The Sea Grant Network and its partners should continue to proactively engage, understand the viewpoints, and serve the diverse populations that are most severely impacted by the cumulative and compounding impacts of aging stormwater and wastewater infrastructure, flooding, industrial pollution, and continuous degradation of water resources due to urban runoff.

5. Conclusion

Some of the recommendations provided in this document are priorities in the forthcoming grant research program and will inform future research needs and education, extension and partnership recommendations for the Sea Grant Network and its programs especially as the pertain to mitigating runoff through the use of GI/LID and, ultimately improving ecological, environmental, and community quality. The recommendations on extension and education will be carried out by the Sea Grant Network and its partners. The framework provided herein will dynamically change as we evaluate the outcomes of the recommendations that are pursued.

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- References

Burns, M. J., Fletcher, T. D., Walsh, C. J., Ladson, A. R., & Hatt, B. E. (2012). Hydrologic shortcomings of conventional urban stormwater management and opportunities for reform. *Landscape and Urban Planning*, *105*(3), 230-240. https://doi.org/10.1016/j.landurbplan.2011.12.012

Clements, J., Henderson, J., & Flemming, A. (2021). *Economic Framework and Tools for Quantifying and Monetizing the Triple Bottom Line Benefits of Green Stormwater Infrastructure*. T. W. R. Foundation.

EnvironCert, I., Inc. (2021). *National Green Infrastructure Certification Program (NGICP)*. Retrieved 5/31/2022 from https://ngicp.org/

Galloway, J. N., Aber, J. D., Erisman, J. W., Seitzinger, S. P., Howarth, R. W., Cowling, E. B., & Cosby, B. J. (2003). The nitrogen cascade. *BIOSCIENCE*, *53*(4), 341-356. https://doi.org/10.1641/0006-3568(2003)053[0341:TNC]2.0.CO;2

Grabowski, Z. J., Mcphearson, T., Matsler, A. M., Groffman, P., & Pickett, S. T. (2022). What is green infrastructure? A study of definitions in US city planning. *Frontiers in Ecology and the Environment*, *20*(3), 152-160. https://doi.org/10.1002/fee.2445

Green Infrastructure for Cities. (2022). The Nature Conservancy. Retrieved 5/31/2022 from https://www.nature.org/en-us/about-us/who-we-are/how-we-work/finance-investing/naturevest/green-infrastructure-for-cities/

Hart, M. R., Quin, B. F., & Nguyen, M. L. (2004). Phosphorus runoff from agricultural land and direct fertilizer effects: A review. *JOURNAL OF ENVIRONMENTAL QUALITY*, *33*(6), 1954-1972. https://doi.org/10.2134/jeq2004.1954

Mallin, M. A., Johnson, V. L., & Ensign, S. H. (2009). Comparative impacts of stormwater runoff on water quality of an urban, a suburban, and a rural stream. *ENVIRONMENTAL MONITORING AND ASSESSMENT*, *159*(1-4), 475-491. https://doi.org/10.1007/s10661-008-0644-4

Pew Research Center. (2018). *What Unites and Divides Urban, Suburban and Rural Communities*.

USEPA. (2021a). *Green Streets, Green Jobs, Green Towns (G3) Program*. Retrieved 5/31/2022 from https://www.epa.gov/G3

USEPA. (2021b). *What is EPA Doing to Support Green Infrastructure?* Retrieved 5/31/2022 from https://www.epa.gov/green-infrastructure/what-epa-doing-support-green-infrastructure-0

USEPA. (2022a). *Green Infrastructure*. Retrieved 5/31/2022 from https://www.epa.gov/green-infrastructure

USEPA. (2022b). *Green Infrastructure Federal Collaborative*. https://www.epa.gov/green-infrastructure/green-infrastructure-federal-collaborative

Voisin, J., Cournoyer, B., Vienney, A., & Mermillod-Blondin, F. (2018). Aquifer recharge with stormwater runoff in urban areas: Influence of vadose zone thickness on nutrient and

bacterial transfers from the surface of infiltration basins to groundwater. *SCIENCE OF THE TOTAL ENVIRONMENT*, *637*, 1496-1507. https://doi.org/10.1016/j.scitotenv.2018.05.094

Wada, K., Simpson, R., Kishimoto, N., & Takei, N. (2020). Motor Vehicle Wash-off Water as a Source of Phosphorus in Roadway Runoff. *Journal of Water and Environment Technology* *18*(1), 9-16.

WRF. (2021). *International Stormwater BMP Database*. The Water Research Foundation. Retrieved 5/31/2022 from https://bmpdatabase.org/