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TO: NRDC
FROM: ECONorthwest
SUBJECT: GREEN INFRASTRUCTURE ECONOMIC BENEFITS AND FINANCING LITERATURE REVIEW

This memo provides a review of the recent literature on the economic benefits of green infrastructure. It also provides recent studies that provide insights into solutions for financing green infrastructure projects. The identified studies are generally sorted to highlight those that are themselves most heavily referenced, an indication of their relevance to the overall effort of gaining a better understanding of the potential benefits of green infrastructure. This review focused on studies from 2007 and after, because an earlier review on the topic by ECONorthwest addressed studies released prior to 2007.

SUMMARY OF FINDINGS

The most recent literature reiterates the now established notion that green infrastructure is not only a cost-effective way to reduce stormwater runoff, but that it also provides a number of additional economic benefits that grey infrastructure alternatives generally do not provide. We can also draw a number of common themes from this recent literature.

- While each case is highly site-specific, the recent literature reaffirms the accepted view that green infrastructure can be a cost-effective tool in reducing stormwater runoff.
- Green infrastructure can provide economic benefits that grey infrastructure alternatives do not.
- In some cases, the most cost-effective approach to reducing stormwater runoff may be a blend of green and grey infrastructure.
- Many of the economic benefits of green infrastructure are not quantifiable, but that doesn't mean they don't have value.
- Not all BMPs are created equal. The cost-effectiveness of green infrastructure varies by location and technique.
- Households may value the direct and indirect benefits of green infrastructure, but many individuals and professionals do not recognize the value of green infrastructure itself. This may create social and attitudinal preference barriers to implementation.

BENEFIT-COST ANALYSES AND COST-EFFECTIVENESS

Table 1 below presents a summary of the common economic benefits valued in the recent green infrastructure literature.

Table 1: Common Economic Benefits Valued in Selected Literature

	Stormwater Management	Environmental Quality	Community Livability	Regulatory Management	Ecosystem Services
Londoño and Ando (2011)	√	√			
EPA (2010)	√	√	√	√	√
Roseen et al (2011)	√	√	√		
CNT (2010)	√	√	√		√
Gunderson et al (2011)	√	√			
Gunderson et al (2011b)	√			√	
Jaffe et al (2010)	√	√			
Sullivan et al (2010)		√		√	
Montalto et al (2007)				√	

- Source: ECONorthwest staff
- Notes: This list of economic benefits is not comprehensive. An interested reader may find a more comprehensive list of economic values of green infrastructure from CNT (2010).
- Benefits of stormwater management include: reduced water treatment needs, reduced grey infrastructure needs, reduced flooding costs
- Benefits of environmental quality include: increased groundwater recharge, improved air quality, improved air quality, reduced atmospheric CO2, reduced urban heat island, lower home cooling expenses, and climate change adaptation
- Benefits of community livability include: improved aesthetics, increased public and educational opportunities, reduced noise pollution, improved community cohesion
- Benefits of ecosystem services include: channel protection and integrity, increased recreational opportunities, improved habitat
- Benefits of regulatory management include a municipalities' increased ability to meet regulatory requirements, including CSOs under NPDES permits and TMDL restrictions.

The following annotated bibliography provides a review of relevant recent reports on the economics of green infrastructure, with a particular focus on those studies on cost and benefit analyses. The bibliography is divided into three categories. First, we present cutting edge and foundational literature that either examines the economic benefits of green infrastructure in innovative ways or provides a comprehensive and rigorous analysis that policy makers and researchers will likely rely on in future discussions. Second, we present those studies which are of good quality and notable. These are recent studies with sound economic analysis, with findings that future research will likely build upon. Third, we present one study with findings that we should interpret with caution.

Widely Known and Referenced

Londoño, C. and A. Ando. 2011. "Valuing Preferences over Stormwater Management Outcomes Given State-Dependent Preferences and Heterogeneous Status Quo." Agricultural

& Applied Economics Association's 2011 AAEA & NAREA Joint Annual Meeting. Pittsburgh, Pennsylvania. July.
Using a choice-experiment survey of households in Champaign-Urbana, Illinois, this paper estimates the values of multiple attributes of stormwater management outcomes and identifies households' willingness-to-pay for different attributes of stormwater management controls. The paper finds that households have a positive willingness-to-pay for reductions in flooding frequency, and in particular basement flooding, and improved environmental quality. The paper also finds that an individuals' WTP values depend on his or her status quo condition.

Environmental Protection Agency. 2010. "Green Infrastructure Case Studies: Municipal Policies for Managing Stormwater with Green Infrastructure." EPA-841-F-10-004. August.
This report presents the common trends in how 12 local governments developed and implemented stormwater policies to support green infrastructure. The paper presents a range of benefits derived from green infrastructure for the social, economic, and environmental conditions of a community. The paper also presents and discusses a variety of municipal incentive programs.

Stratus Consulting Inc. 2009. "A Triple Bottom Line Assessment of Traditional and Green Infrastructure Options for Controlling CSO Events in Philadelphia's Watersheds." Final Report. City of Philadelphia Water Department. August.
This paper presents a cost-benefit analysis of Philadelphia's grey and green infrastructure CSO control alternatives under consideration, with a particular emphasis on triple bottom line aspects, including their respective abilities to provide environmental, social, public health, and other goods. The paper focuses, in particular, on the benefits and external costs of these alternatives. The paper finds that LID-based green infrastructure approaches provide a wide array of important environmental and social benefits to the community, benefits which traditional infrastructure alternatives generally do not provide.

Center for Neighborhood Technology. 2010. "The Value of Green Infrastructure: A Guide to Recognizing Its Economic, Environmental, and Social Benefits."
This guide outlines the full-range of potential economic benefits of green infrastructure investments, by type of practice. The guide examines the steps necessary to calculate the performance benefits of green infrastructure techniques and, where possible, demonstrates simplified examples that estimate the magnitude and value of these benefits.

MacMullan, E. and S. Reich. 2007. "The Economics of Low-Impact Development: A Literature Review." ECONorthwest. November.
This report describes the methods economists use when measuring the costs and benefits of low impact development and conventional stormwater controls and summarizes the literature that identifies and measures the economic costs and benefits of managing stormwater using LID. The report's intended audience is municipal officials, stormwater managers, ratepayer stakeholders and other non-economists. The review found that most economic studies of LID focused on comparing costs between green and grey projects. Many limited their comparison to installation and ignored O&M. Few studies attempted to compare apples to apples and recognize the additional benefits green infrastructure projects provide.

Good Quality and Notable

Roseen, R., T. Janeski, J. Houle, M. Simpson, and J. Gunderson. 2011. "Forging the Link: Linking the Economic Benefits of Low Impact Development and Community Decisions." University of New Hampshire Stormwater Center, the Virginia Commonwealth University, and Antioch University New England. July.
This paper presents the economic benefits, including construction and project life-cycle costs, of green infrastructure to municipalities, commercial developers, and others. The paper also presents ways in which green infrastructure can build community resiliency in water management to climate change.

Gunderson, J., R. Roseen, T. Janeski, J. Houle, and M. Simpson. 2011. "Cost-Effective LID in Commercial and Residential Development." Stormwater. March-April.
This paper examines the cost-effectiveness of two LID projects—one on a residential development and one on a large-scale commercial development. Both projects displayed environmental quality improvements, including a measurable improvement in water-quality and lower home cooling expenses, and stormwater management benefits, including reduced flooding costs and avoided grey infrastructure costs.

Gunderson, J., R. Roseen, T. Janeski, J. Houle, and M. Simpson. 2011b. "Economical CSO Management." Stormwater. May.
Using case studies, this paper shows how green infrastructure can help cities and municipalities reduce stormwater runoff volumes entering combined systems and lower treatment costs. They conclude that using a blend of grey and green infrastructure strategies to manage CSOs can be more economically viable than using grey infrastructure alone.

Jaffe, M., M. Zellner, E. Minor, H. Ahmed, M. Elberts, H. Sprague, S. Wise, and B. Miller. 2010. "Using Green Infrastructure to Manage Urban Stormwater Quality: A Review of Selected Practices and State Programs." Illinois Environmental Protection Agency. September.
This paper reviews the peer-reviewed scientific reports and articles related to green infrastructure in Illinois and five other states. The authors examine whether green infrastructure is as effective as conventional controls in reducing total suspended solids and total nitrogen in receiving water bodies and the effectiveness of these techniques on reducing runoff volumes and peak flow discharge compared to conventional controls. The authors use an economic model to find green infrastructure techniques result in a substantial cost-savings in both construction and life-cycle costs compared to conventional controls. The authors also address some of the indirect benefits of green infrastructure, including ecosystem services.

Sullivan, M., B. Busiek, H. Bourne, and S. Bell. 2010. "Green Infrastructure and NPDES Permits: One Step at a Time." Water Environment Federation.
This paper describes the benefits of green infrastructure, particularly in the context of NPDES permits and GI's role in controlling CSOs. The paper provides several examples of case studies where municipalities are incorporating green infrastructure into requirements under their NPDES permits.

Thurston, H., M. Heberling, and A. Schrecongost. 2009. Environmental Economics for Watershed Restoration. Boca Raton, FL: CRC Press, Taylor & Francis Group.

This book provides guidance to watershed groups interested in incorporating economic valuation for prioritizing watershed restoration projects or to justify the expenses of such projects. The book's intended audience is stakeholders with little to no background in economics who are interested in these issues and want to understand the economics more fully.

Montalto, F., C. Behr, K. Alfredo, M. Wolf, M. Arye, and M. Walsh. 2007. "Rapid assessment of the cost-effectiveness of low impact development for CSO control." Landscape and Urban Planning doi: 10.1016/j.landurbplan.2007.02.004.
This paper presents a model for assessing the cost-effectiveness of green infrastructure for reducing CSOs in municipalities. The paper does not present other types of economic benefits associated with green infrastructure. The paper finds differing level of cost-effectiveness between settings, but also concludes that under a variety of performance and cost scenarios, green infrastructure may be a cost-effective alternative for municipalities to consider in their efforts to reduce CSOs.

LimnoTech and Casey Trees. 2007. "The Green Build-out Model: Quantifying the Stormwater Management Benefits of Trees and Green Roofs in Washington, DC." EPA Cooperative Agreement CP-83282101-0. April.
This paper presents the Green Build-out Model, a planning tool that quantifies the cumulative stormwater management benefits of trees and green roofs in the District of Colombia. The paper compares two planning scenarios with the Green Build-out Model: an "intensive greening" scenario, which considered putting trees and green roofs wherever physically possible, and a "moderate greening" scenario, which considered putting trees wherever practical and reasonable. With a variety of findings, the paper concludes that trees, green roofs, and large tree boxes provide substantial benefits to the District as reductions in stormwater runoff and untreated discharges in sewer systems.

Sands, K. and T. Chapman. "Rain Barrels—Truth or Consequences." Milwaukee Metropolitan Sewerage District. Milwaukee, Wisconsin.
This paper describes the use and function of rain barrels. It also tests the performance of this green infrastructure technique against some benefit assumptions, including water quality issues.

Eckles, K. "A Public Works Perspective on the Cost vs. Benefit of Various Stormwater Management Practices." City of Woodbury.
In this presentation, Karen Eckles evaluates the costs and benefits of various BMPs on a project level and site-specific basis. She finds pollutant loading that is direct to and treated by a particular BMP and the amount of time that BMP is physically treating stormwater heavily influence its cost-effectiveness. She also finds that passive systems are the least cost-effective BMP alternatives, while active systems are a very cost-effective way to remove phosphorous from stormwater at low levels.

Needs More Attention

Jaffe, M. 2010. "Reflections on Green Infrastructure Economics." Environmental Practice 12(4): 357-365. December.
This paper uses economic modeling in Illinois to show that the benefits of green infrastructure related to flood and pollution risk-mitigation exceed their direct construction and maintenance costs. The paper also finds that green infrastructure is cost-effective in managing urban

stormwater when compared to conventional grey infrastructure under a number of development scenarios. The paper makes a case against valuing the indirect economic benefits when conducting benefit-cost analyses of green infrastructure, because of the uncertainty and analytical complexity of such studies. The author believes economic studies can find cost-effectiveness in green infrastructure without examining indirect benefits.

Note:

We should interpret these conclusions with caution. While in many cases the direct economic benefits of green infrastructure may greatly outweigh their costs, there are cases where it is the indirect benefits that make green infrastructure a more cost-effective and viable alternative to traditional alternatives. Moreover, the fact that many of these indirect benefits are difficult or impossible to quantify does not mean that they do not have value nor does it preclude policy makers from considering these benefits qualitatively when they weigh alternatives. In fact, the accepted professional guidelines for conducting economic analyses require policy makers to consider the full range of non-market values, including indirect and unquantifiable values, in any economic valuation of a policy decision.[1]

INCENTIVES AND FINANCIAL MECHANISMS

The annotated bibliography below reviews reports and information sources on the financing of green infrastructure, including financing mechanisms, incentives, and programs.

Thurston, H., M. Taylor, W. Shuster, A. Roy, and M. Morrison. 2010. "Using a reverse auction to promote household level stormwater control." Environmental Science & Policy 13: 405-414.
The paper hypothesizes that it may be more cost effective for smaller communities to use stormwater incentives, instead of traditional, large infrastructional best management practices, to control runoff at the parcel level. The paper tests the effectiveness of a procurement auction as the coordinating mechanism for encouraging installation of parcel-scale rain gardens and rain barrels in the Midwest. The paper finds that even relatively minimal financial incentives can result in homeowners' willingness-to-accept stormwater management practices on their properties.

Weston Solutions. 2010. "Rain Barrel/Downspout Disconnect Best Management Practice Effectiveness Monitoring and Operations Program: Final Report." City of San Diego, Stormwater Department, Pollution Prevention Division. San Diego, CA. June.
This paper uses six watershed management areas within the City of San Diego to test the effectiveness of a rain barrel downspout disconnect (RBDD) best management practices. The paper assess the effectiveness of the RBDD system and determines the cost-effectiveness of implementing RBDD systems as a qualifying watershed water quality activity under San Diego's MS4 Permit.

Huber, M., D. Willis, J. Haynes, and C. Privette. 2010. "Incentive Policies to Promote the Use of Enhanced Stormwater BMPs in New Residential Developments." Southern Agricultural Economics Association Annual Meeting. Orlando, FL. February.

[1] For more information on guidelines for conducting economic analysis, see: EPA. Guidelines for Preparing Economic Analysis. Washington, DC. 2010.

This paper presents the conceptual framework for the Stormwater Banking Program (SBP), which allows a developer to build at a greater density in exchange for paying a portion of their participation profits to the SBP and installing green infrastructure, as an alternative to traditional stormwater controls. The authors argue the SBP increases developers' profits; raises additional revenue that officials can use to retrofit outdated and/or poorly functioning BMPs in existing developments; and achieves stormwater runoff control well above the minimum regulatory requirement on new developments.

Environmental Protection Agency. 2009. "Managing Wet Weather with Green Infrastructure—Municipal Handbook: Incentive Mechanisms." EPA-833-F-09-001. June.
The paper comprehensively lists the types and places where municipalities around the United States are currently using incentive mechanisms. The paper organizes the types of these incentives in five categories, including: stormwater fee discount, development incentives, grants, rebates and installation financing, and awards and recognition programs.

Meder, I. and E. Kouma. 2009. "Low Impact Development for the Empowered Homeowner: Incentive Programs for Single Family Residencies." December.
This paper outlines the experience of the City of Lincoln, which implemented three incentive programs to improve stormwater quality with green infrastructure techniques. The paper notes these programs have created a citywide awareness of and interest in green infrastructure among homeowners.

Roy, A., S. Wenger, T. Fletcher, C. Walsh, A. Ladson, W. Shuster, H. Thurston, R. Brown. 2008. "Impediments and Solutions to Sustainable, Watershed-Scale Urban Stormwater Management: Lessons from Australia and the United States." Environmental Management 42: 344-359.
This paper compares the experiences of Australia and the United States to identify seven major impediments to sustainable urban stormwater management. The paper offers several examples of successful, regional green infrastructure techniques. The paper also identifies solutions to each of the listed impediments that should encourage implementation of green infrastructure techniques.

Struck, S. 2008. "Incentives for Adoption of Low Impact Development Approaches on a Larger Scale." ASCE Conference Proceedings. World Environmental and Water Resources Congress 2008: Ahupua'a Proceedings of the World Environmental and Water Congress 2008.
This paper proposes developers use a watershed sustainability index based on holistic water management strategies that would provide a framework for evaluation and a transparent rating system for new and redevelopment projects. The watershed index, which an expert panel would develop, would define a set of standards and apply a numerical "credit" method to measure the degree to which a development meets these standards. The author also proposes that an independent, third-party verify the scoring process of a development's design and incorporation of these techniques.

Bitting, J. and C. Kloss. "Managing Wet Weather with Green Infrastructure—Municipal Handbook: Green Infrastructure Retrofit Policies."
This paper explores the policies and incentives that municipalities use to facilitate green infrastructure among homeowners and developers. The paper presents these policies by type of technology, but notes that approaches for one green infrastructure technique are applicable to another or there is overlap among goals and outcomes. The paper concludes with common

themes from successful green infrastructure retrofit policy and recommendations for policy makers looking to implement incentives through policy.

Dietz, M., J. Clausen, and K. Filchak. 2004. "Education and Changes in Residential Nonpoint Source Pollution." Environmental Management 34(5): 684-690.
This paper examines whether educating homeowners and implementing best management practices can improve stormwater quality in a suburban neighborhood. The paper uses a paired watershed design to test the effectiveness of these practices. The paper finds some changes in measured behavior and some improvements in measurable water quality parameters.

BARRIERS TO GREEN INFRASTRUCTURE

The annotated bibliography below reviews papers that discuss the common economic and social barriers to widespread implementation of green infrastructure techniques.

LaBadie, K. 2010. "Identifying Barriers to Low Impact Development and Green Infrastructure in the Albuquerque Area." The University of New Mexico. Albuquerque, NM. May.
Using a focus group of local professionals, this study identifies barriers to the widespread implementation of green infrastructure in the Albuquerque region. The study reveals these professionals display a preference for well-known, low cost techniques, but also that these professionals have a lack of knowledge about other techniques or an uncertainty over their effectiveness. Based on these discussions, the study makes six recommendations for overcoming barriers, particularly in the semi-arid conditions of New Mexico.

Stockwell, A. 2009. "Analysis of Barriers to Low Impact Development in the North Coast Redwood Region, California." Humboldt State University. December.
Using a literature review and interviews with stormwater professionals, this paper examines the barriers to green infrastructure on the North Coast. It finds these barriers include: institutionalized conventional practices, budget and staff constraints, and challenging local conditions.

Souto, L. 2009. "Overcoming Barriers to Changing the Landscape." Managing Wet Weather with Green Infrastructure Conference. Ft. Myers, FL. June.
In this presentation, Leesa Souto introduces a variety of social and attitudinal preference barriers to low impact development, including: appearance preferences, disconnection to landscape, perceived capability, and social norms. The author also discusses a variety of strategies to address these barriers.

Godwin, D., B. Parry, F. Burris, S. Chan, and A. Punton. 2008. "Barriers and Opportunities for Low Impact Development: Case Studies from Three Oregon Communities." Oregon State University, Sea Grant Extension Program. Corvallis, OR.
This paper, based on discussions from a workshop involving local decision-makers and residents in three Oregon communities, addresses the barriers to implementing green infrastructure practices, the need for education on green infrastructure, and the audiences to which policy makers should direct these efforts. The paper presents several findings and opportunities based on themes that emerged from these discussions.

OTHER

The annotated bibliography below presents some other useful and notable recent studies related to the economics of green infrastructure.

Morgan, T., K. Riley, R. Tannebring, and L. Veldhuis. 2011. "Evaluating the Impacts of Small-Scale Urban Greenspace: A Case Study of Harlem Place in Los Angeles." Donald Bren School of Environmental Science & Management, University of California, Santa Barbara. May.
This paper examines the net effects of small-scale interstitial greenspace in downtown Los Angeles, where greenspace is nearly non-existent. The authors use literature reviews, GIS data, and modeling to assess the economic, ecological, and social effects of integrating small-scale greenspace into downtown LA. This project is not final.

Vandermuelen, V., A. Verspecht, B. Vermeire, G. Van Huylenbroeck, and X. Gellynck. 2011. "The use of economic valuation to create public support for green infrastructure investments in urban areas." Landscape and Urban Planning. Article in Press.
This paper describes a model that municipal officials can use to describe the value of green infrastructure techniques in economic terms. The paper presents monetary valuation techniques, with an emphasis on site-specific considerations, including benefit-cost analysis and multiplier analysis. The paper concludes that using this model will help to justify policy support for and investment in green space.

U.S. Green Building Council and Berkebile, Nelson, Immenschuh, McDowell. 2011. "Multi-Variate Study of Stormwater BMPs: 2008 Green Building Research Fund Grants." Final Report. Kansas State University. March.
This paper presents the results of monitoring of several BMPs with the objective of improving these practices for effective onsite stormwater management. For each BMP, the paper documents water quality parameters, soil infiltration rates, soil sampling, facility sizing, performance baselines and measures, and costs.