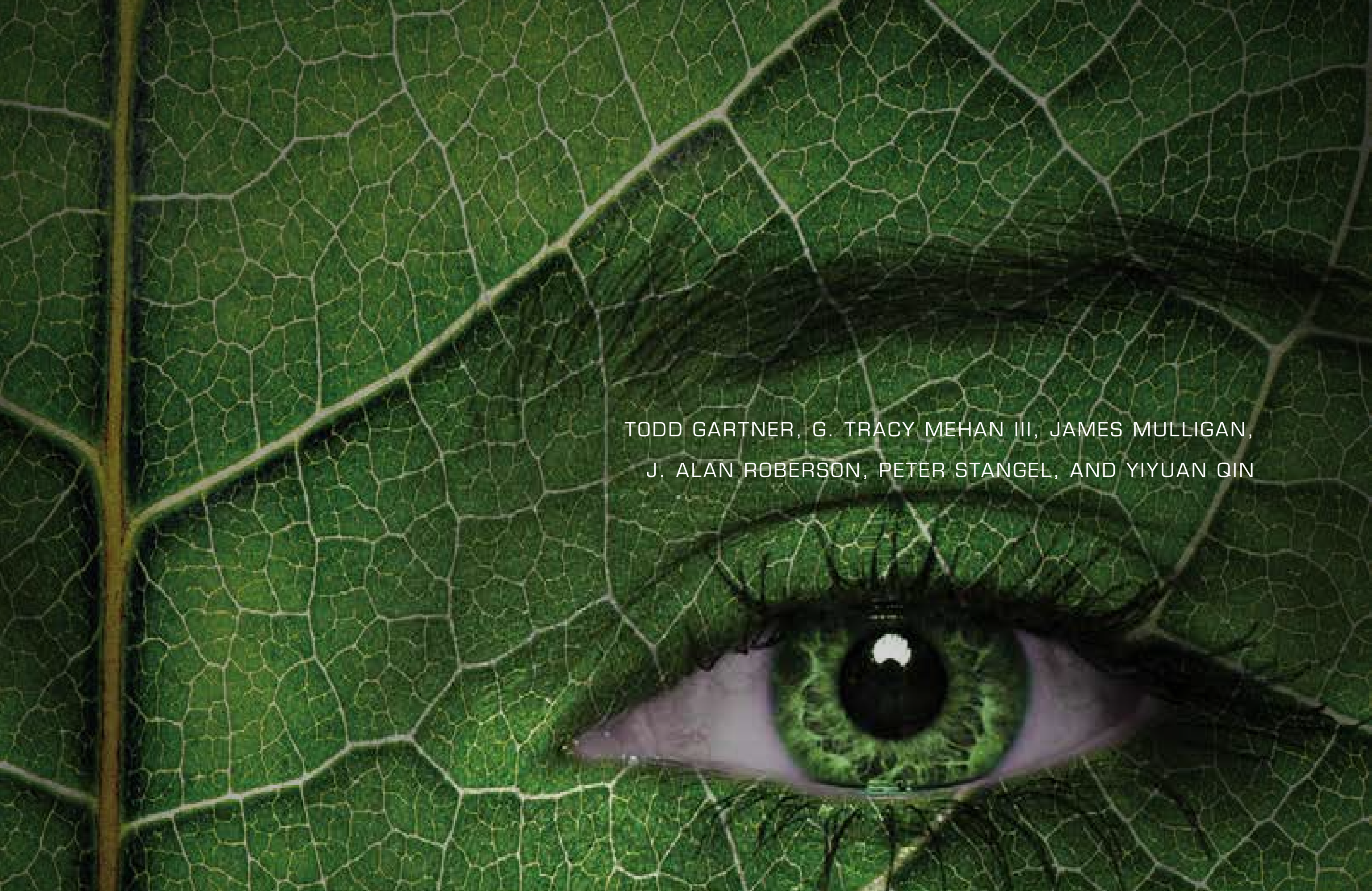

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Protecting forested watersheds is smart economics for water utilities

PROTECTING AND SUSTAINABLY MANAGING FORESTED WATERSHEDS IS AN APPROACH THAT, WHEN USED AS A COMPLEMENT TO TRADITIONAL INFRASTRUCTURE, MAY NOT ONLY REDUCE COSTS BUT ALSO HELP SECURE NEW FUNDING STREAMS.

The breathtaking $1 trillion estimated price tag to repair and expand our nation's drinking water infrastructure is both sobering and compelling (LaFrance, 2013). To address this costly issue, some water utilities and the communities they serve are turning to a solution nearly as old as our nation itself—protecting forested watersheds. Increasing evidence suggests that healthy forests produce water that is less expensive to treat, transport, and store. These same forests also provide a plethora of other cultural, economic, and environmental benefits. And with real estate prices in many areas being lower as a result of the Great Recession, now is the time to protect and sustainably manage the lands and forests that supply our potable water.

The stakes are high. According to the 2008 report of the National Research Council, Hydrologic Effects of a Changing Forest Landscape (NRC, 2008), "the forests cycle water from precipitation through soil and ultimately deliver it as streamflow that is used to supply *nearly two-thirds of the clean water supply in the United States*." Changes in forested headwaters, including tributary streams

TABLE 1 Examples of natural infrastructure strategies and complementary built infrastructure

Watershed	Major Issues	Natural Infrastructure Strategy	Complementary Built Components
Crooked River watershed—Portland, Maine	Forest conversion for development and need to maintain filtration avoidance waiver	Conversation easements, land acquisition, and best management practices as a cost-avoidance strategy in a healthy watershed	Ozonation, chlorination
La Cache Poudre and Big Thompson River watersheds—Fort Collins and Greeley, Colo.	Costly sedimentation and flood risks associated with catastrophic wildfire in forested watershed	Wildfire risk management as a cost-avoidance strategy in the face of extreme and costly disruptive events	Off-river reservoir, presedimentation basin, ability to blend water from reservoir and Poudre, flocculation, sedimentation, filtration
McKenzie River watershed—Eugene, Ore.	Loss of forested riparian buffers to residential development, and associated water quality decline and incremental increases in treatment costs	Forested riparian buffers as a cost-reduction strategy in a nonregulatory setting in a healthy watershed	Chlorination, coagulation and flocculation, sedimentation, filtration
Upper Neuse River Basin—Raleigh & Durham, N.C.	Substantial degradation from development in heavily forested landscape leading to Clean Water Act requirements and high treatment costs; reservoir siltation against backdrop of flood and drought risk	Protection of forested riparian buffers, wetlands, and floodplains as a regulatory compliance, cost reduction, and risk mitigation strategy in a degraded watershed	Ozonation, coagulation, two-stage filtration (activated carbon and sand filters), UV, and chlorination; multiple reservoirs

feeding into rivers, "influence the quantity and quality of downstream water sources; in this way, forests and water are closely intertwined."

Recent advancements in our understanding of the benefits provided by healthy, well-managed forests provide water systems nationwide with a new approach to tackle America's imposing drinking water infrastructure needs. By harnessing forests as "natural infrastructure" to complement traditional "gray" (built infrastructure) approaches, utilities can help keep costs down, reduce future risks to water supply, enhance resilience to climate change, and provide a suite of ancillary benefits for their customers: the air we breathe; the places we play and enjoy; wood, paper, and hundreds of other forest-derived products; family-supporting jobs; and the wildlife with which we share our landscapes.

Recognizing that such an approach to securing drinking water and other watershed services is cost-effective, stakeholders and water utilities in a number of communities nationwide are looking to natural infrastructure as part of a solution to growing challenges. Table 1 illustrates the importance of forests and other ecosystems to potable water providers in a variety of ecological, financial, and regulatory settings. Although the context is unique for each of these watersheds, the utilities share opportunities to capture cost savings by investing in forest-based natural infrastructure, often as part of an integrated approach, alongside essential built infrastructure.

THE SCIENCE IS CLEAR

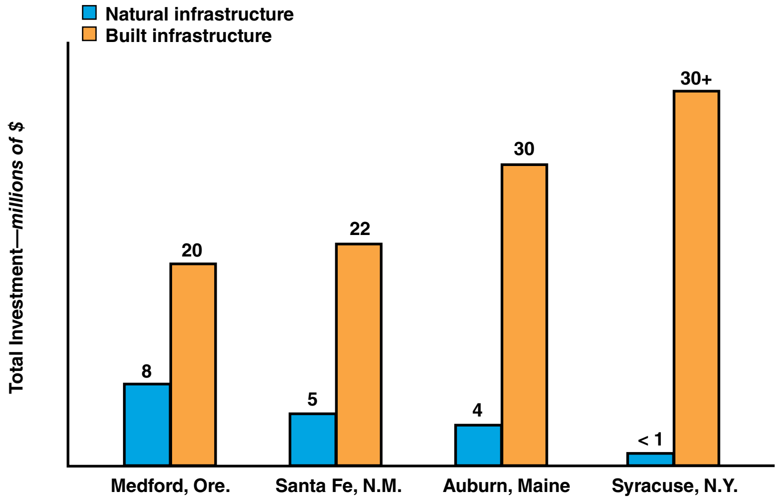
Forests have a number of characteristics that qualify them alongside retention ponds, filtration technology, and presedimentation basins as critical water infrastructure. With sturdy, long-lived roots, multilayered canopies, and varied soil composition, forests help to regulate water yield and peak flow, as well as mitigate sedimentation and nutrient loading.

Strong root systems of forests anchor soil against erosion (Geyer et al, 2000; Beeson & Doyle, 1995). Multilayered forest canopies provide rain and snow interception (Brooks et al, 2003; Briggs & Smithson, 1986), and the forest litter layer promotes infiltration of water into the soil, providing a barrier that slows downslope water movement (Dudley & Solton, 2003). These characteristics minimize stormflow peaks and associated erosion for all but the most intense storm events. Furthermore, forests help minimize sediment and pollutant delivery to streams and give ample opportunity for nutrient uptake by plants and microbes in the soil (de la Crétaz & Barten, 2007; Vitousek & Reiners, 1975).

Forests help produce water of the highest quality in the country (Jones et al, 2009; Freeman et al, 2008; Boyer et al, 2002; USDA, 2002). In the event of forest conversion and disturbance, the benefits from forests diminish, leaving communities at risk of flood, drought, increased treatment cost, and greater possibility of water contamination. Therefore, maintaining healthy, forested landscapes and implementing best practices in forestry management can be effective strategies for promoting source water quality and regulating flow.

Keep in mind that the sustainable management of forests is paramount to this approach. Preserved forests—those without active management—have their place. But in most cases, sustainable timber harvest is necessary and desirable to maintain forest health and protection from forest pests, diseases, catastrophic fires, and other threats. Sustainable timber harvest also helps support thriving rural economies. A well-managed forest that provides competitive economic returns is far more likely to remain a forest, as

FIGURE 1 Comparison of financial merits of integrated natural and built infrastructure alternatives for desired ecological outcomes



opposed to some other land use that may have detrimental effects on water quality and quantity.

THE ECONOMICS ARE COMPELLING

Just as forests and water are closely intertwined, forests and water treatment, transport, and storage are increasingly linked from an economic perspective. A growing body of research suggests that high-quality source water and well-regulated flow can lead to cost savings (Freeman et al, 2008). By maintaining high source water quality through natural infrastructure investments, treatment plants may avoid capital costs for some of the processes in conventional treatment, such as coagulation, flocculation, sedimentation, and more advanced treatment processes like membrane filtration and activated carbon. Reduced sedimentation in source water also prevents sediment buildup in reservoirs and potential water intake clogging, leading to decreased maintenance costs such as dredging and repairing. Finally, treatment plants with high-quality raw water may also save on variable costs because more chemicals such as coagulants, disinfectants, and pH adjusters are needed when water quality degrades.

Jim Taft (2013), executive director of the Association of State Drinking Water Administrators, describes a recent study by the US Environmental Protection Agency of six communities that concluded that "on average, every $1 spent on source-water protection saved an average of $27 in water treatment costs" (Winiecki, 2012). Taft notes that several other studies have also confirmed "that improved source water quality relates to lower treatment and chemical costs" (Freeman et al, 2008; Postel & Worldwatch Institute, 2005; Forster and Murray, 2001; Dearmont et al, 1998; Holmes, 1988; Espey et al, 1997; Forster et al, 1987).

AWWA and the US Endowment for Forestry and Communities (USEFC) are collaborating on new research and applied experiments to further clarify the relationship among watershed health, water quality, and water treatment costs—part of a growing partnership to help water utilities become more involved with forested watershed protection. Protecting forested watersheds won't address the entire drinking water infrastructure need, but it is one strategy that can significantly help reduce long-term costs to consumers.

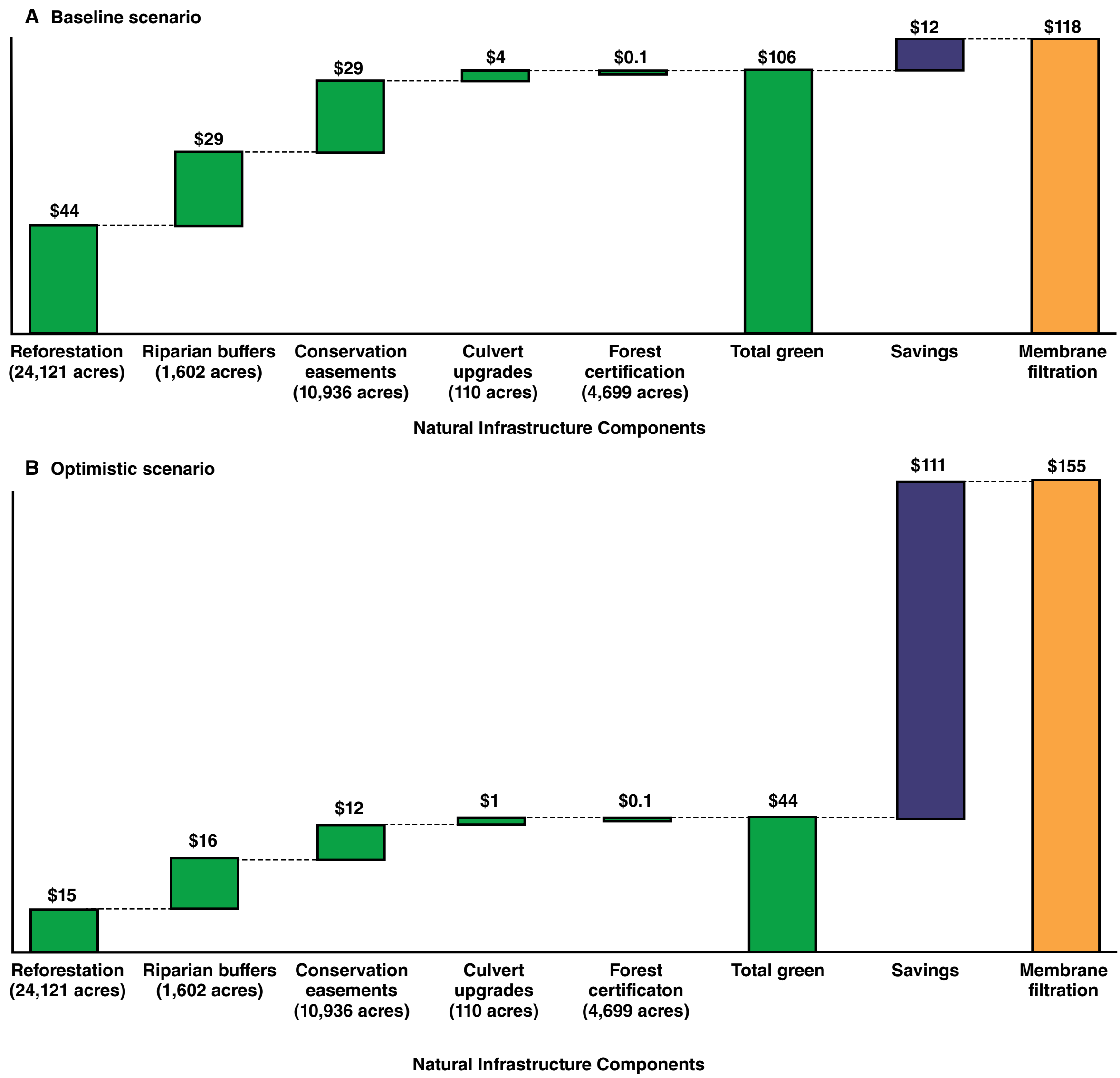
GREEN INFRASTRUCTURE COMPLEMENTS GRAY INFRASTRUCTURE

Because of aging water utility infrastructure, a growing population, growing affluence, and increasing threats to forested watersheds from climate change and other factors, water quality managers are paying closer attention to the benefits of forests as a least-cost option compared with, say, costly engineered solutions. This is not an either-or proposition. Society will always need well-financed, effective, and well-engineered gray infrastructure. But, as economists are always telling us, the action is at the margin, and great benefits—economic and environmental—are to be found in the complementarity of green and gray solutions.

The mother of all such efforts is the New York City source water–protection initiative to protect its upstate watersheds. Instead of spending $8–10 billion on a new filtration plant, it is spending less than $2 billion on land protection and a variety of forest and agricultural best management practices. Boston also manages tens of thousands of forested acres around its reservoir with a staff of 160 completely financed by ratepayers. The avoided costs for both communities are huge. These eminently sensible programs were enabled by a filtration avoidance waiver authorized under the Safe Drinking Water Act.

Other watershed-level economic studies show that the cost of natural infrastructure options to achieve water management objectives is competitive with the gray infrastructure alternatives (Figure 1). Some of these studies examine natural infrastructure investments that reduce or eliminate the need for an upfront capital cost. Others look at natural infrastructure as a mechanism to eliminate or reduce certain operating costs for a utility. In some cases, natural infrastructure is used not to reduce costs but to provide greater community benefits for a given

FIGURE 2 Preliminary green–gray analysis for Portland, Maine



investment because forests help sustain people's livelihoods, provide space for recreation, and boost resilience to natural hazards, to name a few (Schmidt & Mulligan (2013) in Gartner et al, 2013). These examples illustrate the potential economic benefits to communities of all sizes and geographies that merit consideration by utility managers throughout the country.

An increasingly used type of investment analysis (cost–benefit analysis or cost-effectiveness analysis, depending on the situation) that provides a basis for considering both natural infrastructure (green) and built infrastructure (gray) alternatives is the "green–gray analysis" (Talberth et al (2013) in Gartner et al, 2013). Although still in its infancy, green–gray analysis has demonstrated the potential to present natural infrastructure investments in a manner commensurate with conventional infrastructure investments so that the two can be compared by public investment analysts (Figure 2). This suggests that, once fully developed, a green–gray analysis methodology can be a standard part of infrastructure investment decisions for a wide variety of settings.

Despite the limitations and challenges in measuring marginal benefits, economic analyses to date have demonstrated the clear potential for cost-effectiveness of a wide range of natural infrastructure options relative to built infrastructure alternatives.

WATERSHED PROTECTION: IT'S DÉJÀ VU ALL OVER AGAIN

Protecting forested watersheds is not a new idea. The rediscovery of the water quality benefits of forests is a bit like going back to the future. As Yogi Berra famously said, "It's déjà vu all over again."

Back in the late 19th century, Philadelphia acquired 9,000 acres to protect its potable water, and the land remains protected as a city park to this day. In 1889, Seattle started acquiring land in the forested Cedar River Watershed to filter water for its utility, eventually owning and managing 90,000 acres. This eliminates the need for a new filtration system—maybe several systems, given the passage of time as well as associated operations and maintenance costs.

Utilities in New England have long protected and sustainably managed their forested watersheds. The South Central Connecticut Regional Water Authority in New Haven owns 27,000 acres of land to protect its ten active reservoirs and seven groundwater supply aquifers. Manchester (New Hampshire) Water Works owns 8,000 acres around Lake Massabesic, the source of its drinking water, and generates revenues from timber harvesting, which allows it to reimburse local communities for the loss of tax revenue.

Devastating wildfires in 1996 and 2002 helped the Denver Water Board realize just how important their forested watersheds are. Management of post-fire sedimentation for the utility in the aftermath of these blazes exceeded $26 million. Furthermore, insect infestations, lack of funding for management, and climate change will continue to make their watershed, and many others, highly vulnerable to fire and degradation. Denver took a bold step to get ahead of the curve and inked an agreement with the US Department of Agriculture Forest Service to reduce fuel loads and accelerate reforestation in critical parts of the watershed. The water utility and the Forest Service are splitting the $33 million price tag. Comparable investments are now under way in similarly plagued communities such as Salt Lake City, Utah; San Francisco, Calif.; and Flagstaff, Ariz.

The World Resources Institute (WRI), Earth Economics, and Manomet Center for Conservation Sciences synthesized the work of 56 experts with experience in source water protection across the American landscape in Natural Infrastructure: Investing in Forested Landscapes for Source Water Protection in the United States (2013). The report may be downloaded, gratis, from WRI's website (www.wri.org/publication/natural-infrastructure).

The Natural Infrastructure report outlines the business case, scientific underpinnings, and means of identifying and seizing opportunities to work with utilities, stakeholders, political leaders, and conservation organizations to design, finance, and implement forest management measures, at scale, to defer or avoid expensive investments in gray infrastructure and reduce ongoing treatment costs. Whether through the use of fee-simple purchases, acquisition of conservation easements, or the subsidizing of sustainable forest practices by private landowners, water quality goals are achieved in tandem with habitat protection, a natural hydrologic flow regime, and sequestration of carbon. The value-added proposition extends far beyond cost-effectiveness to encompass a suite of environmental and conservation benefits. These examples and case studies, along with other resources, are available to help water utilities address their reluctance when it comes to venturing into new practices of investing in natural infrastructure.

Source water protection under the Safe Drinking Water Act is the analogue to watershed protection under the Clean Water Act but is more tightly focused on potable water. It is part of a multibarrier approach to protecting water supplies up to, and including, water treatment. It is preventive in nature, which is less expensive than treatment after the fact.

> A well-managed forest that provides competitive economic returns is far more likely to remain a forest.

FUNDING WATERSHED PROTECTION AND MANAGEMENT

As the relationship between watershed health, water quality, and water treatment costs becomes increasingly compelling, the biggest challenge for water utilities may be accommodating watershed protection and management costs. Budgets are tight, and traditional infrastructure needs are enormous. At first blush, adding a new cost for watershed health may seem impractical. But when viewed as a complement to traditional treatment practices, and in light of the potential for considerable cost-savings to rate-payers, funding for watershed health is a smart and responsible move.

Sustainably managing forested watersheds and protecting them from conversion to other uses or directing others to do so may be foreign to water utilities that are more accustomed to traditional, built infrastructure to address water treatment. This challenge should not be underestimated, but it is not insurmountable by any means.

Fortunately, as dozens of utilities across the country engage in watershed protection and management, solutions for cost and expertise are rapidly developing. Although the outcome—sustainable management and protection from development of forested watersheds—is always the same, the path to achieving this goal

TABLE 2 Summary of natural infrastructure financial mechanisms

Finance Mechanism	Typical Revenue Allocation: Land Acquisition	Easements	Land Management Activities	Typical User of Finance Mechanism	Potential Scale of Investment
Direct investment by governments and utilities					
Rates	X	X	X	Utility	Medium
Municipal bonds (revenue-backed)	X	X		Utility	High
Municipal bonds (general obligation)	X	X	X	Government	High
Rates surcharges	X	X	X	Utility	Medium
Earmarked proceeds	X	X	X	Government	Low to high
Development impact fees	X	X	X	Government	Low
Reverse auction	X	X	X	Government	Low
State revolving funds	X	X	X	Utility	Medium
Farm bill programs			X	Government	Medium
Water Infrastructure Finance and Innovation Authority	TBD	TBD	TBD	Utility	High
Private investment capital		X	X	Utility, government	Low
Indirect investment by governments and utilities					
Property tax incentives			X	Government	Medium
Voluntary donations by individual and the private sector					
Voluntary surcharge	X	X	X	Private sector, NGO, utility	Low
Online crowdsource platforms	X	X	X	NGO	Low
Auction	X	X	X	NGO	Low to medium
Corporate sponsorship	X	X	X	Utility	Low
Market-based mechanisms					
Nutrient trading		No additional revenue		Government, NGO	Medium
Mitigation banking		No additional revenue		Government	Low to medium
Tradable development rights		No additional revenue		Government	Medium
Forest banking		No additional revenue		Private sector	Low
Carbon market	X	X	X	Utility, government, NGO	Low to medium
Certification and labeling programs			X	Private sector, government	Low

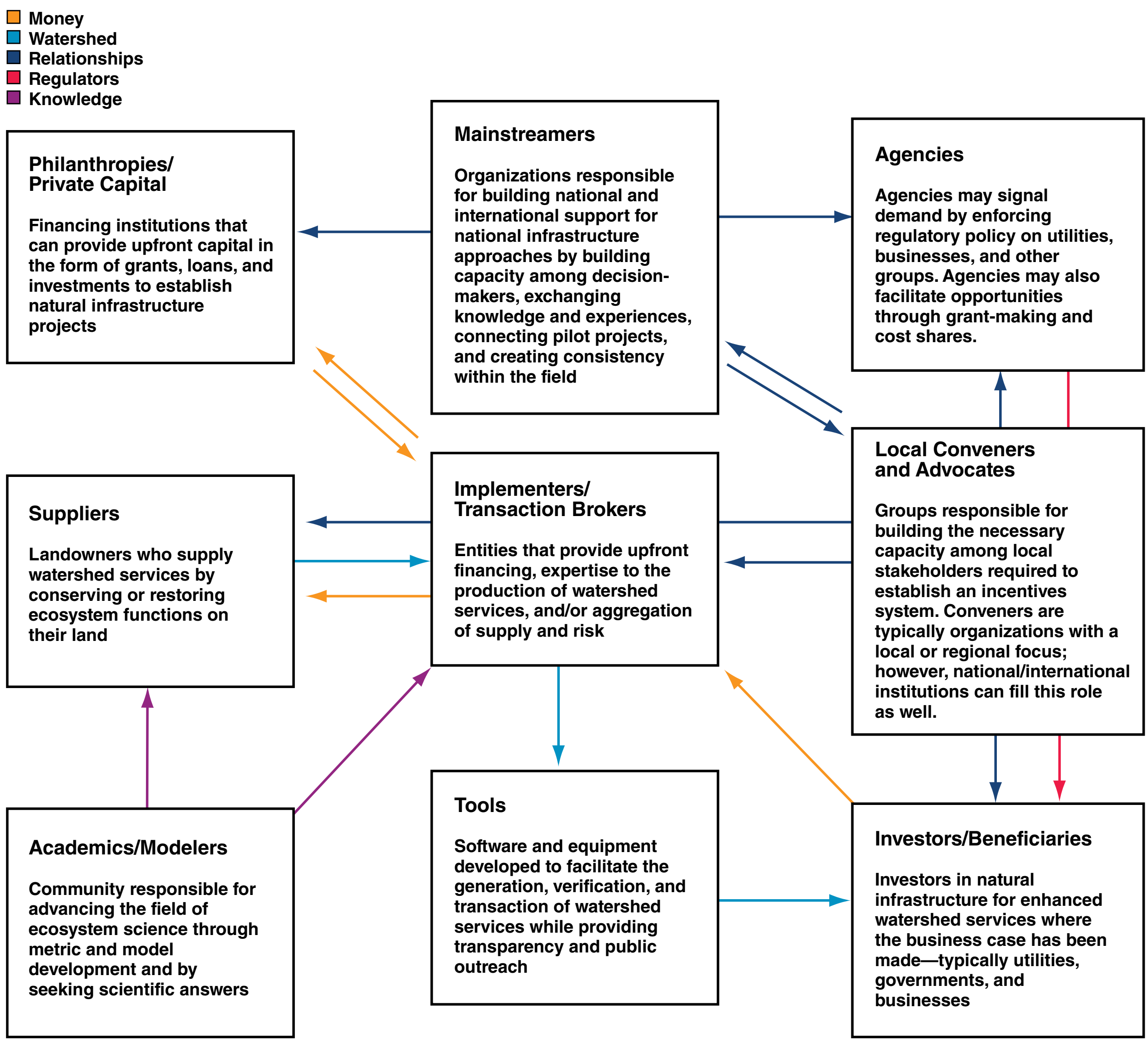
NGO—nongovernmental organization, TBD—to be determined

is as varied as the communities in which the utilities are found.

In the Upper Neuse River Basin in North Carolina's Piedmont region, the City of Raleigh established a nutrient impact fee—a one-time charge collected on new water and sewer hookups. This was followed by a permanent watershed protection fee on public water bills of one penny per 100 gallons, which generates $1.3 million annually. The average household pays about 40 cents monthly. These measures have generated $7.5 million since 2005 to address water quality issues within the utility's watershed. Durham, N.C., increased its water rates to fund land protection in 2011 to protect areas upstream of its two water supply reservoirs. Growth and development, with resulting forest degradation that could lead to Clean Water Act requirements, higher treatment costs, reservoir siltation, and flood and drought risk are key drivers in this watershed. The USEFC and the USDA Natural Resources Conservation Service co-funded much of the work that led to Raleigh's achievement. This partnership was designed to seek and implement sustained funding programs that would link water consumers with water producers—in this case, the private forest-land owners who collectively own and manage most of Raleigh's watershed.

Central Arkansas Water (Little Rock) collects approximately $1 million per year by means of a dedicated fixed fee collected from its customers

FIGURE 3 The "actor network" in successful natural infrastructure efforts



Source: Gartner et al, 2013

as does Salt Lake City, which generates $1.5 million annually. The average household pays about $0.45 and $1.50 per month, respectively. San Antonio finances its source water–protection program from a ⅛-cent sales tax, passed by its voters.

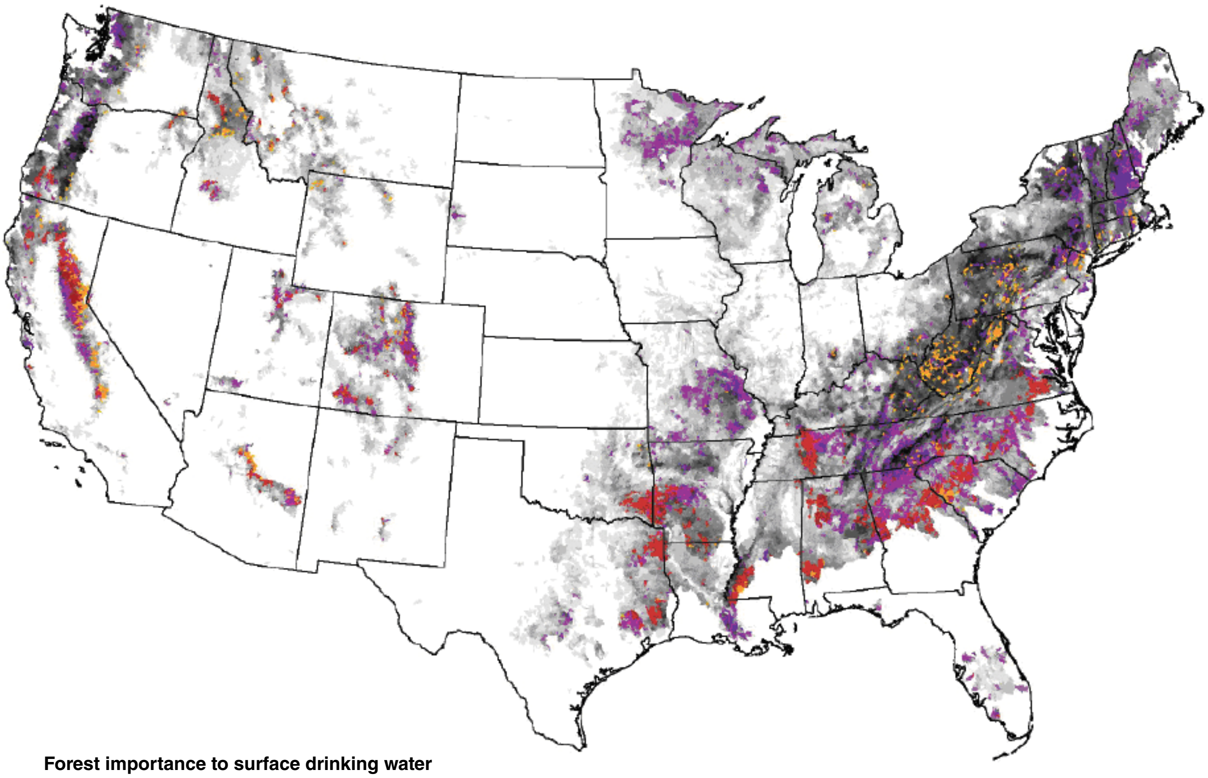
Flagstaff pursued a $10 million bond issue, approved at the ballot box, to finance its forest and watershed management program in the face of forest fires in Arizona. Denver's massive commitment, discussed earlier, is funded directly from its base budget as is San Francisco's funding in light of the forest fire problem in its watershed.

There is an emerging vanguard of water utilities and others who are making sustained financial commitments to source water protection in forested landscapes for a variety of reasons, be it forest fires, suburban sprawl, or demographic shifts (Table 2).

The choice of a sustainable, long-term funding source is important for reasons that are not hard to comprehend. The nation's population continues to expand, and American's lifestyles are, generally, affluent. Thus, more development, deforestation, spread of impervious surfaces (roads, sidewalks, parking lots, and roofs), and the resultant degradation of water quality. Land values are not getting any cheaper. It will take significant investments over time to keep treatment and capital costs in manageable territory in the out years.

The decision about how to fund source water protection at scale is, quintessentially, a local political decision on the part of utilities and the communities they serve. In some places the customers may support

FIGURE 4 Forest importance to surface drinking water and watersheds with high risk—top 10%



Source: USDA, 2011

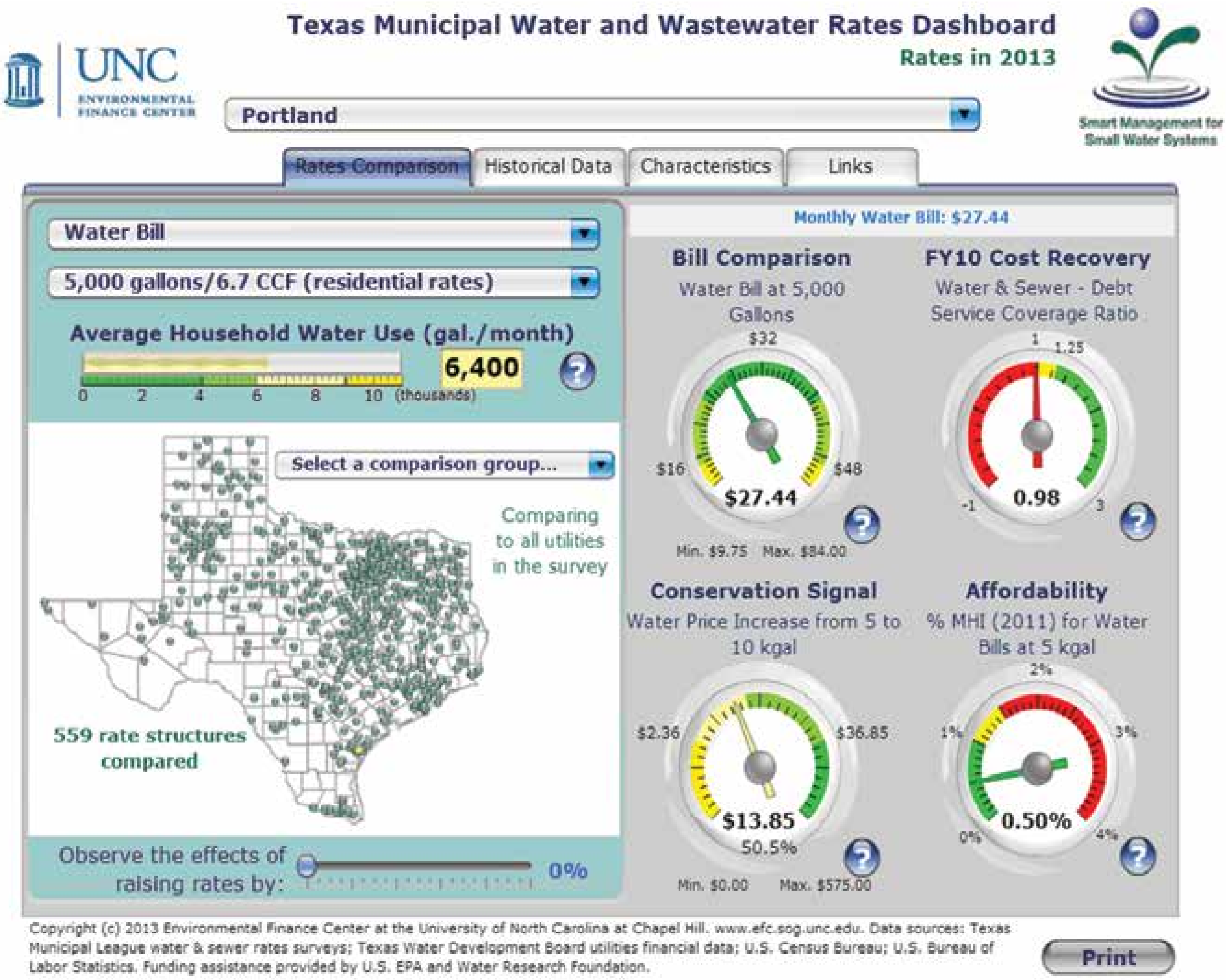
water rates robust enough to allow for necessary expenditures from the base capital budget. In other places, a watershed or user fee may make economic sense in providing funds upfront so that utilities are not faced with paying to remove pollutants after storms wash loose sediment into streams or contaminants that exceed legal limits.

MANAGING FORESTED WATERSHEDS: WHO YOU GONNA CALL?

For most engineers, forested watershed protection and management may be outside their comfort zones. Unfamiliarity with watershed protection strategies, much less the process for prioritizing lands with the biggest potential to affect water quality, can be a significant hurdle. As this practice becomes increasingly common, however, expertise is readily found. Ecologists and hydrologists, market-based conservation experts, policy experts, third-party verifiers, and model and tool developers all bring important expertise and capacity to a program. The Natural Infrastructure report illustrates the relationship among a variety of stakeholders and experts (Figure 3; Gartner et al, 2013). More and more utilities now employ watershed protection experts, and many land trusts and conservation groups routinely consider water quality issues as part of their business.

Taking advantage of peer-to-peer contacts within the water utility community is the simplest way to learn how others have been successful. The USEFC, WRI, and others stand ready to help connect interested water utilities with partners who can advise on watershed issues as well as funding solutions.

Although many water utilities choose to own and manage their forested watersheds, this is not the only path. Existing, well-managed forests may be kept in that state through payments to landowners that reward them for practices that benefit water quality. Incentive payments to private landowners to encourage good management practices has proved extremely effective for wildlife and game management, for example, and could certainly be extended to water



This screen shot shows a water bill rate comparison for Portland, Ore., using the Municipal Water and Wastewater Rates Dashboard from the University of North Carolina Environmental Finance Center.

quality issues. The well-proven conservation easement allows landowners to retain their land and generate revenue while protecting land from development at a much lower cost than outright acquisition.

More than 10 million families own 264 million acres—35%—of America's forests (USDA, 2008). Many of these families need some financial return from the forests to keep them intact and well managed, and to resist short-term financial gains from inappropriate harvest or development that could seriously affect water quality. Payment for watershed services is one approach that could help ensure the long-term health of drinking water supplies and save water consumers money.

PUBLIC OPINION ON DRINKING WATER

Not surprisingly, the public is very supportive of efforts to protect drinking water supplies even if it entails having to pay more to do so. Organizations such as The Nature Conservancy (TNC) and The Trust for Public Land (TPL) are leaders in advancing community-driven efforts to protect land for recreation, open space, wildlife, and watershed protection. One common approach is to help communities develop conservation ballot measures that allow voters to decide if they would like to devote funding to land and water protection for any number of benefits. According to the TPL website, this approach has been very successful. In the 2013 elections, for example, voters passed 53 of 68 ballot measures proposed (68%), approving more than $797 million for conservation purposes (www.landvote.org). Since 1988, this strategy has resulted in nearly $60 billion being approved for conservation purposes by voters. The approach works when the economy is good or bad, and in red states and blue states.

TPL has done extensive polling to better understand what motivates people to support conservation ballot issues. In 2012, TPL conducted 17 state and local public opinion surveys throughout the United States. In each survey, they posed a question asking likely voters whether they would be more or less likely to support a conservation finance ballot measure if it included funding for an array of purposes. When asked about "water supply/drinking water," 62% strongly supported and 90% supported such measures. When asked about "water quality/clean water," 36% strongly supported and 76% supported such measures. Public support for water-related issues dwarfs interest for issues such as wildlife habitat, multiuse trails, open space, and land for parks and recreation. These results are consistent with TPL's summary of poll findings during the past decade, which consistently rank drinking water and water quality as the number-one and number-two purposes in more than 200 surveys during that period.

ANCILLARY BENEFITS

Sustainably managed forested watersheds provide many other economic, cultural, and environmental benefits. A well-managed forest will provide income from timber harvest, putting money in the pocket of the forest owners, and also those associated with the industry: forestry consultants, loggers, truckers and other forms of transportation, and mill owners. Putting money in the pockets of those who own and benefit from sustainably managed forests is one market-driven approach to helping ensure that forested watersheds remain forested. According to the American Forest & Paper Association (www.afandpa.org), the forest industry generates about 4.5% of the total annual US manufacturing gross domestic product and is among the top 10 manufacturing-sector employers in 47 states. In rural areas in particular, forest-based jobs are essential to the local economy. A high demand for products from sustainably managed forests will help ensure that forested watersheds are not converted to other uses that may have detrimental impacts on water quality.

Forested watersheds that allow public access are often popular sites for recreation, from hunting and fishing to birding and hiking. Even where access is not permitted, such protected lands are valued as open space. The forests in watersheds are also excellent carbon sinks and help regulate climate. They provide a valuable habitat for fish and wildlife, and are a backbone of nature-based tourism in many places.

PROVIDING SOLUTIONS

Taking on forested watershed protection and management with all the other short- and long-term challenges that face on a daily basis may seem daunting. It does require new expertise and it does require adjusting budgets or creating new funding streams. There are, however, many organizations willing to help you and support your process for getting involved.

The USEFC, AWWA, the Weyerhaeuser Family Foundation, and the Sustainable Forestry Initiative are jointly supporting outreach efforts to water utilities around the country to help connect the dots with regard to forested watershed protection. The organizations mentioned in this article—TPL, TNC, and WRI, among many others—are producing ground-breaking partnerships and research that makes the case for forested watershed protection more appealing.

Additionally, as the science underpinning the water-related benefits of natural infrastructure and relevant data advances rapidly, software, online platforms, and other tools are becoming increasingly available, facilitating investments in natural infrastructure on a large scale (Gartner et al, 2013). WRI's world-leading mapping tool, Aqueduct, identifies global water risks (Reig et al, 2013); the Forest to Faucets Partnership of the USDA Forest Service looks to recognize opportunities for forest conservation and restoration actions related to water quality (USDA, 2011; Figure 4); the Ecosystem Crediting Platform of the Willamette Partnership (2014) helps track and monitor program transparency; and the Municipal Water and Wastewater Rates Dashboard from the University of North Carolina Environmental Finance Center (2014) is designed to communicate the value of source water–protection investments to the utility rate base (see the screen shot on page 62).

America's drinking water infrastructure needs are daunting—so daunting, in fact, that traditional funding strategies may not be adequate to meet the need. Protecting and sustainably managing forested watersheds is an approach that, when used as a complement to traditional "gray" infrastructure, may not only reduce costs but may also help secure new funding streams. And because keeping costs as low as possible while ensuring superior water quality for your customers is of paramount importance, watershed protection is a strategy worth considering.

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REFERENCES

Beeson, C.E. & Doyle, P.F., 1995. Comparison of Bank Erosion at Vegetated and Non-Vegetated Channel Bends. *Journal of the American Water Resources Association*, 31:6:983. http://dx.doi.org/10.1111/j.1752-1688.1995.tb03414.x.

Boyer, E. & Goodale, C.L., 2002. Anthropogenic Nitrogen Sources and Relationships to Riverine Nitrogen Export in the Northeastern U.S.A. *Biogeochemistry,* 57:58:137. http://dx.doi.org/10.1023/A:1015709302073.

Briggs, D.J. & Smithson, P., 1986. *Fundamentals of Physical Geography*. Rowman & Littlefield, Totowa, NJ.

Brooks, J.R.; Schulte, P.J.; Bond, B.J.; Coulombe, R.; Domec, J.-C.; Hinckley, T.M.; McDowell, N.; & Philips, N, 2003. Does Foliage on the Same Branch Compete for the Same Water? Experiments on Douglas-Fir Trees. *Trees—Structure and Function,* 17:2:101. http:/dx.doi.org/10.1007/s00468-002-0207-1.

Dearmont, D.; McCarl, B.A.; & Tolman, D.A., 1998. Costs of Water Treatment Due to Diminished Water Quality: A Case Study in Texas. *Water Resources Research,* 34:4:849. http://dx.doi.org/10.1029/98WR00213.

De la Crétaz, A. & Barten, P.K., 2007. *Land Use Effects on Streamflow and Water Quality in the Northeastern United States*. CRC Press, Boca Raton, Fla.

Dudley, N. & Stolton, S., 2003. Running Pure: The Importance of Forest Protected Areas to Drinking Water. World Bank & WWF Alliance for Forest Conservation and Sustainable Use, Washington.

Espey, M.; Espey, J.; & Shaw, W.D., 1997. Price Elasticity of Residential Demand for Water: A Meta-analysis. *Water Resources Research,* 33:6:1369. http://dx.doi.org/10.1029/97WR00571.

Forster, D.L. & Murray, C., 2001. Farming Practices & Community Water Treatment Costs (no. AEDE-FR-0003). Ohio State University Department of Agricultural, Environmental, and Development Economics, Columbus.

Forster, D.L.; Bardos, C.P.; & Southgate, D.D., 1987. Soil Erosion and Water Treatment Costs. *Journal of Soil and Water Conservation,* 42:5:349.

Freeman, J.; Madsen, R.; & Hart, K., 2008. Statistical Analysis of Drinking Water Treatment Plan Costs, Source Water Quality, and Land Cover Characteristics. www.forestsforwatersheds.org/storage/Freeman%202008%20DW%20costs.pdf (accessed June 2013).

Gartner, T.; Mulligan, J.; Schmidt, R.; & Gunn, J., 2013. Natural Infrastructure: Investing in Forested Landscapes for Source Water Protection in the United States. World Resources Institute, Washington.

Geyer, W.R.; Morris, J.T.; Prahl, F.G.; & Jay, D.A., 2000. Interaction Between Physical Processes and Ecosystem Structure: A Comparative Approach. In *Estuarine Science: a Synthetic Approach to Research and Practice* (J.E. Hobbie, editor), 177-206. Island Press, Washington.

Holmes, T.P., 1988. The Offsite Impact of Soil Erosion on the Water Treatment Industry. *Land Economics,* 64:4:356. http://dx.doi.org/10.2307/3146308.

Jones, J.A.; Achterman, G.L.; Augustine, L.A.; Creed, I.F.; Ffolliot, P.F.; McDonald, L.; & Wemple, B.C., 2009. Hydrologic Effects of a Changing Forested Landscape—Challenges for the Hydrological Sciences. *Hydrological Processes,* 23:18:2699. http://dx.doi.org/10.1002/hyp.7404.

LaFrance, D., 2013. AWWA Statement on American Society of Civil Engineers Infrastructure Report Card, Mar. 13, 2013. www.Allonewater.com (accessed March 2013).

NRC (National Research Council), 2008. *Hydrologic Effects of a Changing Forest Landscape*. National Academies Press, Washington.

Postel, S. & Worldwatch Institute, 2005. Liquid Assets: The Critical Need to Safeguard Freshwater Ecosystems. Worldwatch Institute, Washington.

Reig, P.; Shiao, T.; & Gassert, F., 2013. Aqueduct Water Risk Framework. Working paper. World Resources Institute, Washington. www.wri.org/publication/aqueduct-waterrisk-framework (accessed May 2014).

Schmidt, R. & Mulligan J., 2013. Section 1.3: Demonstrations of the Business Case. Natural Infrastructure: Investing in Forested Landscapes for Source Water Protection in the United States. World Resources Institute, Washington.

Taft, J., 2013. Box 3: Natural Infrastructure and Safe Drinking Water. In *Natural Infrastructure: Investing in Forested Landscapes for Source Water Protection in the United States.* World Resources Institute, Washington.

Talberth, J.; Gray, E.; Yonavjak, L.; & Gartner T., 2013. Section 1.2: Green-Gray Analysis. Natural Infrastructure: Investing in Forested Landscapes for Source Water Protection in the United States. World Resources Institute, Washington.

University of North Carolina Environmental Finance Center, 2014. Municipal Water and Wastewater Rates Dashboard. www.efc.sog.unc.edu/reslib/item/north-carolina-water-and-wastewater-rates-dashboard (accessed June 2014).

USDA (US Department of Agriculture), 2011. From the Forest to the Faucet: Drinking Water and Forest in the US. Forest Services. USDA, Washington.

USDA, 2008. Family Forest Owners of the United States, 2006. Gen Tech. Rep. NRS-27. Forest Service, Northern Research Station. USDA, Newtown Square, Pa.

USDA, 2002. Southern Forest Resource Assessment. Forest Service, Southern Research Station. USDA, Asheville, N.C.

Vitousek, P.M. & Reiners, W.A., 1975. Ecosystem Succession and Nutrient Retention: A Hypothesis. *BioScience*. 25:6:376. http://dx.doi.org/10.2307/1297148.i.

Willamette Partnership, 2014. Ecosystem Crediting Platform. http://willamettepartnership.ecosystemcredits.org (accessed May 2014).

Winiecki, E., 2012. Economics and Source Water Protection. http://yosemite.epa.gov/r10/water.nsf/c6e3c862e806dd688825688200708c97/04a73c144395fda18825702e00650eb2/$FILE/Economics_of_SWP_E_Winiecki_EPA.ppt#8 (accessed May 2013).

ADDITIONAL RESOURCES

Integrated Watershed Management: Principles and Practice, Second Edition. Heathcote, I.W., 2009. Catalog No. 20742.

Watershed Management for Drinking Water Protection. C. Davis, editor, 2008. Catalog No. 20675.

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