The Economic Value of Riparian Buffers in the Delaware River Basin

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Delaware Riverkeeper Network

FINAL REPORT

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ECONorthwest specializes in economics, planning, and finance. Established in 1974, ECONorthwest has four decades of experience helping clients make sound decisions based on rigorous economic, planning and financial analysis.

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Disclaimer

ECONorthwest completed this project under contract to Delaware Riverkeeper Network.

Throughout the report we have identified our sources of information and assumptions used in the analysis. Within practical limits, ECONW has made every effort to check the reasonableness of the data and assumptions and to test the sensitivity of the results of our analysis to changes in key assumptions.

We gratefully acknowledge the assistance of the many individuals who provided us with information and insight. But we emphasize that we, alone, are responsible for the report's contents. We have prepared this report based on our own knowledge and training and on information derived from government agencies, the reports of others, interviews of individuals, or other sources believed to be reliable. ECONorthwest has not verified the accuracy of such information, however, and makes no representation regarding its accuracy or completeness. Any statements nonfactual in nature constitute the authors' current opinions, which may change as more information becomes available.

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Executive Summary

Riparian buffers are strips of undeveloped land surrounding streams, rivers, ponds and reservoirs. They help to protect water bodies from the impact of adjacent land uses, and provide a suite of crucial ecological services including water purification, flood control, climate regulation, corridors for wildlife movement, and opportunities for outdoor recreation (Table ES1).

Over the past 300 years, nearly half of the Delaware River Basin's original riparian forests have been cleared. Remaining forests are threatened by expanding suburban development. In this report we value losses in ecosystem services that may result from ongoing trends in riparian development and land clearing in the Basin. Specifically, we assess the loss of ecosystem services associated with a 0.6 percent decline (nearly 1,700 acres) in natural riparian land cover within 100 feet of water bodies across the Basin, as occurred between 2001 and 2011. We then project this same rate of development over a 10-year time frame, 2018 to 2028.

Without more effective protection for riparian buffers, we estimate an annualized loss of approximately $981 thousand to $2.5 million in the value of monetized ecosystem services. Translated to a single acre, buffers provide over $10,000 per acre per year in monetized benefits (Table ES2), with additional non-monetized benefits expected to increase this total. Considering these benefits over time, policies that protect riparian corridors represent one of the most efficient investment opportunities facing communities in the Basin.

Total benefits over time, and with extension to even wider buffers, are clearly in the tens of millions of dollars. These benefits are orders of magnitude greater than the one-time costs of protecting these areas before they are developed. Providing these benefits through conservation rather than restoration is particularly cost-effective. The specific benefit categories addressed in this report are:

- Water Quality
- Carbon Storage
- Air Quality
- Flood Prevention
- Property Values
- Wildlife Habitat
- Outdoor Recreation

The connections that riparian corridors provide between fragmented habitats and land parcels are important for both wildlife (enabling dispersal and migration) and humans (a benefit that is increasingly highlighted in regional park and trail plans). Climate change and urbanization will increase the importance and value of buffer services (e.g., by allowing communities in the Basin to adapt to rising recreation demand, increased wastewater and stormwater discharges, and higher peak temperatures affecting streams). Table ES1 summarizes riparian buffer benefits, and Table ES2 summarizes monetary values for a subset of these benefits.

Table ES1. Benefits of Protected Riparian Areas
Source: ECONorthwest with data from multiple sources (see report)

Effect Category	Riparian Buffer Effects	Ecosystem Services
Water Quality	↑ Sediment capture ↑ Nutrient uptake and filtration ↓ Sediment, nitrogen and phosphorus delivered to waterways ↓ Summer water temperatures	↓ Water treatment costs ↑ Drinking water quality ↑ Water clarity ↑ Quality and quantity of water-based recreation ↓ Fish kills and algae blooms ↓ Reservoir and channel dredging
Community Appeal and Livability	↑ Aesthetic conditions surrounding nearby homes (shade, flood protection, noise reduction, privacy) ↑ Visual appeal of riparian recreation areas and water trails	↑ Residential property values ↑ Property tax base ↑ Quality and quantity of land- and water-based recreation
Aquatic Habitat	↑ Aquatic inputs (e.g., leaves, fallen trees, insects) for food and cover ↑ Bank stability ↑ Stream shading ↓ Summer stream temperatures ↑ Dissolved oxygen levels	↑ Recreational fishing opportunities ↑ Commercial fish harvests ↑ Abundance of sensitive aquatic species ↓ Habitat enhancement/replacement costs
Terrestrial Habitat	↑ Habitat for wildlife foraging and breeding ↑ Connections between isolated habitats ↑ Conduits for daily movement to annual migrations	↑ Hunting and wildlife viewing opportunities ↑ Abundance of sensitive wildlife species ↓ Habitat enhancement/replacement costs
Flood Control	↓ Runoff speed ↓ Downstream flood peaks ↓ Sediment loads	↓ Damage to downstream property and crops ↓ Flood insurance premiums ↓ Flood infrastructure and control costs ↓ Risk to human life
Carbon Storage and Air Quality	↑ Capture and storage of carbon, airborne particulates, nitrogen and sulfur dioxides	↑ Improved human health ↓ Healthcare costs ↓ Climate Change effects and extreme weather events ↑ Climate resiliency

Table ES2. Ecosystem Services Provided by Riparian Buffers in the Delaware River Basin, and Per-Unit Values
Source: ECONorthwest with data from multiple sources (see report)

Ecosystem Service Provided	Per-unit Value for Services
Nutrient Retention	$87 to $4,789 per acre per year
Carbon Storage	$4,762 to $8,477 per acre per year
Air Quality	$3 to $132 per acre per year
Aesthetic Values	+1% to +26% Property Price Premium
Flood Mitigation	Qualitative Description
Recreation	$63 per acre per year (lower bound)
Wildlife Habitat	Qualitative Description
Combined Buffer Services	$14/Household/Year

Introduction

Riparian areas occupy only three percent of the landscape but they provide a disproportionately diverse and important set of ecological services to society, and conservation benefits throughout the watershed (Table ES1).[1] These benefits are particularly important when much of the remainder of the watershed is developed, as in the Delaware River Basin.

In this analysis, we consider the potential benefits of protecting and restoring riparian areas across the Delaware River Basin. We begin by providing the economic framework for evaluating the value of ecosystem services provided by riparian zones. Next, we describe the status and recent trends of land cover within the Basin's riparian zones. We then consider the ecological functions of riparian areas and draw on peer-reviewed literature and governmental reports to assign economic values to these services.

The steps in this analysis are:

1. Provide an economic framework based on ecosystem services to assess riparian buffer benefits in the Delaware River Basin.
2. Quantify the existing area of riparian buffers and rates of loss across the Basin
3. Review existing literature on the economic benefits of riparian buffers relevant to the Basin and compile monetary values.
4. Estimate the monetary and non-monetary benefits associated with avoiding further loss of riparian buffers.
5. Consider policy design implications of economic findings, including urgency associated with urbanization trends.

The final results of this analysis are:

- A series of maps detailing the status and trends of riparian buffers in the Delaware River Basin
- A literature review of economic benefits of riparian buffers relevant to the Basin
- Monetary values of ecosystem services of riparian buffers in the Basin by relevant spatial and household units
- Net benefits over time for avoiding continued loss of riparian vegetation

Background on Ecosystem Services and their Economic Value

Ecosystem services are the benefits that humans derive from functional ecosystems. Identifying and accounting for ecosystem services in a systematic way provides a methodical approach for describing the numerous benefits provided by ecosystems. It can also ensure proper

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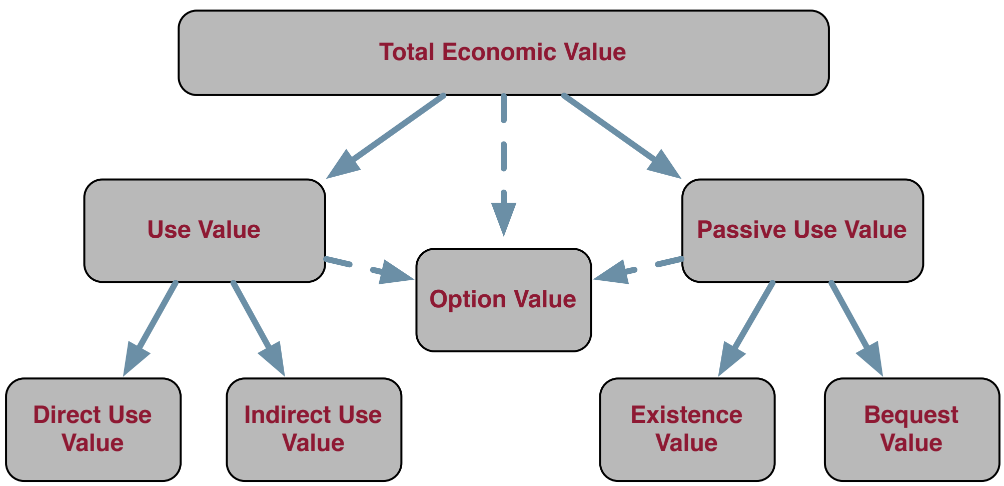
[1] Jones, K.B., Slonecker, E.T., Nash, M.S., Neale, A.C., Wade, T.G. and Hamann, S., 2010. Riparian habitat changes across the continental United States (1972–2003) and potential implications for sustaining ecosystem services. *Landscape Ecology*, *25*(8), pp.1261-1275.

incorporation of demand into the valuation process, recognizing where a particular service is scarce and where it is not. Ecosystem service approaches strive to align valuation with market-based values to reduce criticism and translate benefits into cost-savings terms that will be relevant even to those for whom ecological protection is not an ethical priority. In this section we describe the conceptual framework for ecosystem services, and the techniques used to value them.

Ecosystem services exist only insofar as there is human demand for their supply. Furthermore, the value of ecosystem services is derived from the ways in which humans demand them. Figure 1 demonstrates the various types of economic value for ecosystem services. Total economic value is made up of several components. Direct use value describes the value associated with direct use of an ecosystem service such as breathing clean air or drinking clean water. Indirect use value describes the ecosystem services that precede direct services. Soil fertilization, for example, promotes tree growth, which in turn, plays a role in air purification.

Figure 1. Components of Total Economic Value

Source: ECONorthwest



Passive use values are less obvious but are, in some instances, greater than use values. Existence value describes an individual's demand for the existence of a particular object. Bequest value describes an individual's demand for the future existence of a particular object. Typically, these values are described in terms of an individual's willingness to pay for an object's current or future existence. For example, if an individual is willing to pay a positive sum of money to prevent bald eagle extinction, then she likely is placing existence value on the species. Similarly, if she would be willing to donate a positive sum of money to a conservation fund aimed at maintaining bald eagle health into the future, she likely is placing bequest value on the species.

Option value can fall into either the use or passive use categories. It describes the value of keeping the option open to use a resource or service in the future. For example, some residents of the Basin might feel that the region already has enough riparian habitat, but that there would still be value to additional habitat for the contingency that existing habitat declines, or science reveals a greater need for habitat.

Techniques for Estimating Value of Ecosystem Services

In the absence of well-formed markets, economists have developed techniques for estimating the value of ecosystem services based on the characteristics of the services and the benefiting population. Table 3 summarizes some of the primary techniques for valuing ecosystem services.[2]

Table 3. Techniques Used to Estimate Economic Value of Ecosystem Services
Source: ECONorthwest based on EPA (2009)

Avoided Cost	Estimate the value of a service by identifying and estimating the cost of future projects or programs that would be needed but for the current existence of the service.
Benefit Transfer	Estimate the value of a service at a particular site based on analyses estimating the value of a similar service in another geographic location.
Contingent Valuation	Estimate the value of a service with questionnaires asking respondents how much they would be willing to pay to protect the service, or how much they would be willing to accept to forego the service.
Hedonic Analysis	Estimate the value of a service by comparing property values of multiple households, controlling for several factors, and determining the impact of changes in quantity or quality of the service on property value.
Replacement Cost	Estimate the value of a service by identifying and estimating the cost for projects or programs required to replace the service.
Travel Cost	Estimate the value of a service by calculating the time and money spent by individuals traveling to enjoy or experience the service

Benefit analysis typically progresses from identification of benefits to estimating their monetary value. It is not feasible or appropriate to use dollar values for all potential benefits of riparian areas. Sufficient information is available to assign a dollar value to only a small subset of the total universe of ecosystem goods and services provided by riparian areas in the Basin (Figure 2). Other ecosystem goods and services, such as nutrient cycling, food production, and spiritual fulfillment, provide society with additional benefits, but resist quantification in physical and monetary terms. Other benefits might be theorized to exist, but cannot be identified and verified. Finally, there are potentially other valuable ecosystem goods and services that science does not currently allow us to recognize.

[2] U.S. Environmental Protection Agency. 2009. Valuing the Protection of Ecological Systems and Services: A Report of the EPA Science Advisory Board. Report No. EPA-SAB-09-012.

Figure 2. Hierarchy of Benefit Analysis
Source: ECONorthwest

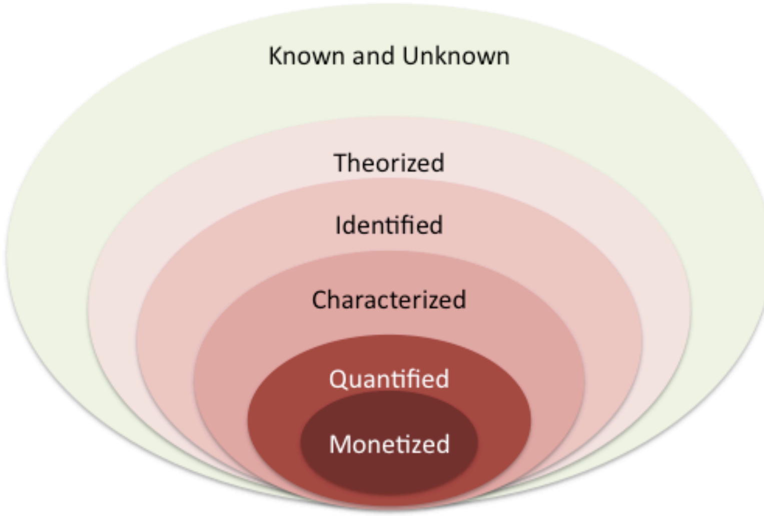


Table ES1 (pg. 7) shows the ecosystem effects and services provided by riparian buffers. Some of these benefits can be reliably measured using market prices, while others are best described by other means. The remainder of this report details the analyses necessary to value these services in the Delaware River Basin.

Riparian Land Cover in the Delaware River Basin

In this section we assess the current extent of intact riparian vegetation and trends in loss and recovery. We use data from the U.S. Environmental Protection Agency's (EPA) Watershed Index Online (WSIO) to describe riparian land cover composition, and trends between 2001 and 2011. The EPA data rely on LANDSAT remote sensing data that classify land cover within 30x30 meter cells. We exclude all watersheds that fall outside the Delaware River Basin.

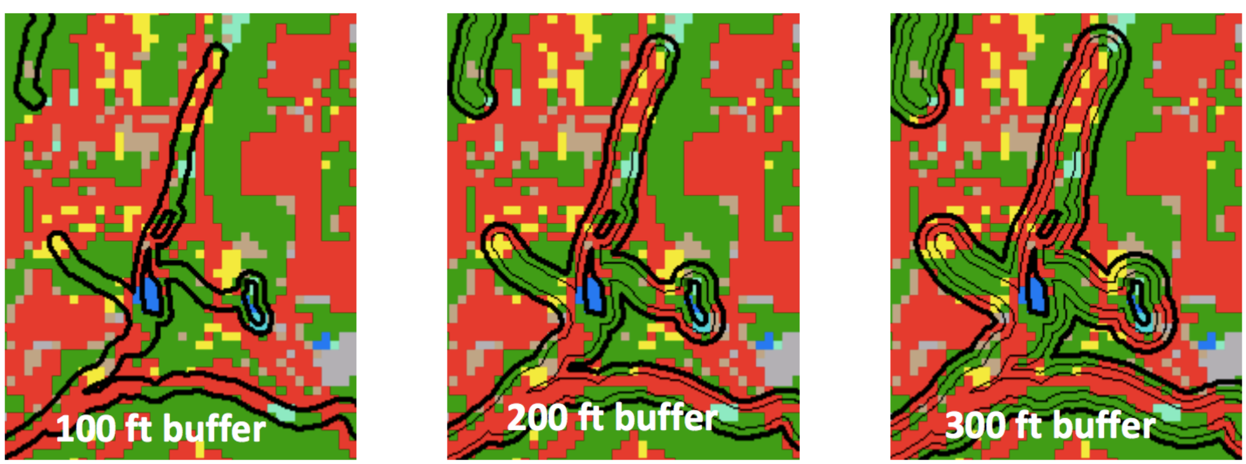
The WSIO data include information on land covers and land uses within the riparian zone, defined as a 108-meter (~ 350 feet) buffer around all surface waters and wetlands. The riparian zone includes the following land cover types:

> *Riparian Zone = Surface Water + Wetlands + Forest (including evergreen forest, deciduous forest, and mixed forests) + Shrub/Scrub + Grassland/Herbaceous + Urban (including high/medium/low intensity development and open space) + Agriculture (including pasture/hay and cultivated crops) + Barren Land*

Given the 30-meter (~100 feet) minimum cell size, LANDSAT data are *"… not of sufficient spatial resolution to adequately map riparian buffer vegetation within the widely accepted 100-ft (30 m) buffer width used as a common reference for buffer effectiveness"*.[3] EPA chose 108 meters (~ 350 feet) as the most accurate width to describe riparian land cover in their dataset.

Figure 3. Resolution of Satellite Imagery and Buffer Width

Source: Center for Land Use Education and Research, 2008. The Status of Connecticut's Coastal Riparian Corridors. University of Connecticut. http://clear.uconn.edu/projects/riparian_buffer/results/CLEAR_%20Summary_021508.pdf



[3] Goetz, S.J., Wright, R.K., Smith, A.J., Zinecker, E. and Schaub, E., 2003. IKONOS imagery for resource management: Tree cover, impervious surfaces, and riparian buffer analyses in the mid-Atlantic region. *Remote sensing of environment*, *88*(1), pp.195-208.

To estimate annual rates of land cover change, we divide the ten-year (2001-2011) change totals by ten. To approximate change in land cover at the policy relevant scale of 100 feet, we assume that land cover composition is the same in the 350- and 100-foot (30 meter) buffer zones and that roughly a third (30m/108m = 27 percent) of the annual/decadal change in the 350-foot zone occurs within the 100-foot zone. Previous analyses have confirmed that trends at 350 feet are representative of trends at 100 feet. For example, a previous study that had access to data at multiple scales (Figure 3) reported similar land cover composition and rates of change in the two buffer widths. The rate of development within in the 100-foot zone was slightly lower than that in the 300-foot zone, which the authors suggest may be a result of recently implemented 100-foot buffer protection policies.[4]

Figure 4 provides a map of the current distribution of riparian buffers in the Delaware River Basin. The data in this map are the basis for the results summarized in Figures 5, 6 and 7. Figure 5 shows the total riparian area within each state in the Basin. Pennsylvania has the most riparian land area in the Basin, and Delaware the least. New York has the highest proportion of natural and forested land within the riparian zone, while Delaware has the lowest (Figure 6 and Figure 7). Almost half of the Basin's historic riparian cover has been lost to agriculture, shopping malls, housing developments, and highways (Figure 7).

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[4] Center for Land Use Education and Research, 2008. The Status of Connecticut's Coastal Riparian Corridors. University of Connecticut.

Figure 4. 350-foot Riparian Buffer Zones in the Delaware River Basin

Source: ECONorthwest with data from the US EPA's Watershed Index Online

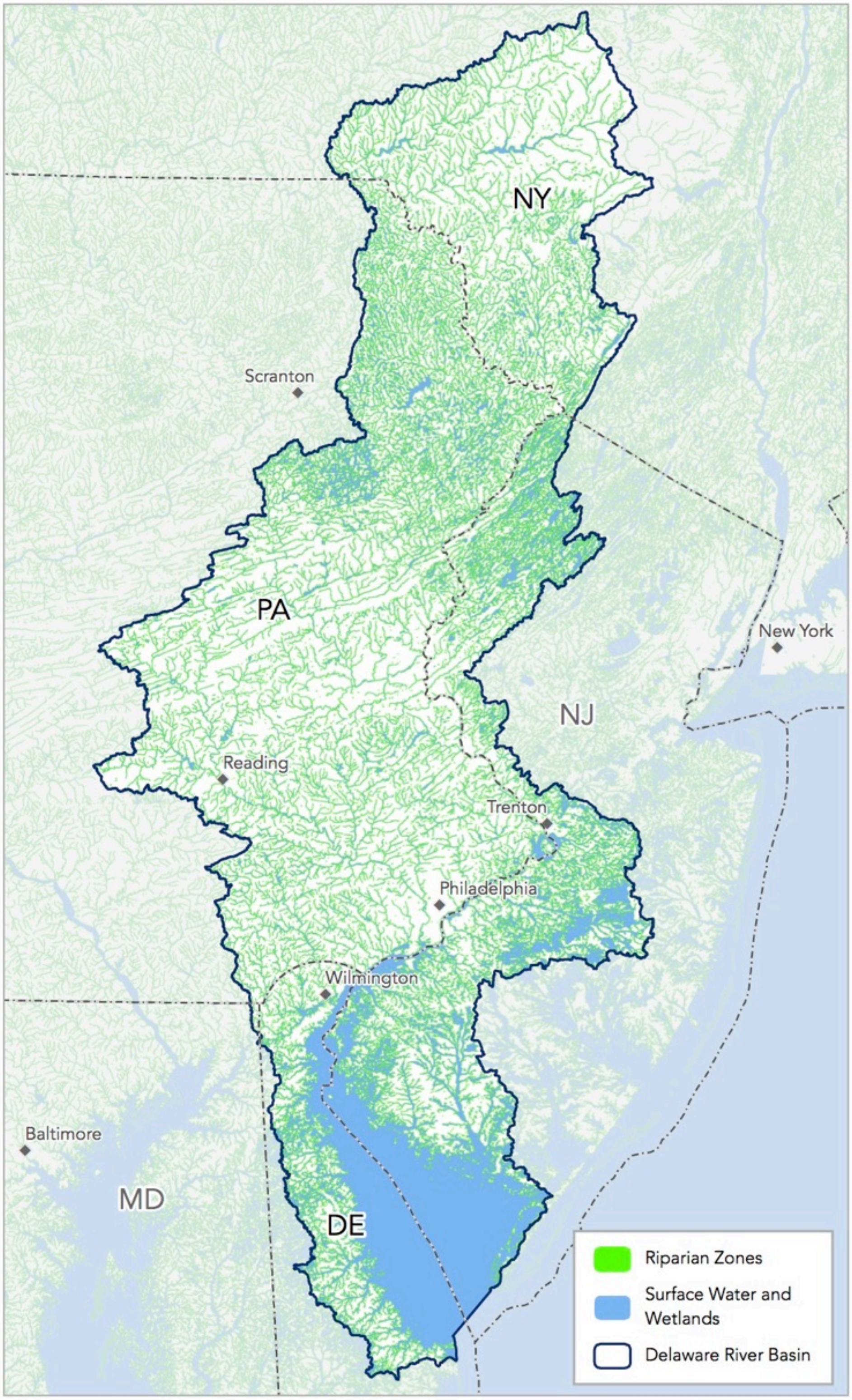


Figure 5. Land Cover Acreages within the Riparian Zone (350-foot Buffer), Delaware River Basin, 2011

Source: ECONorthwest with data from the US EPA's Watershed Index Online

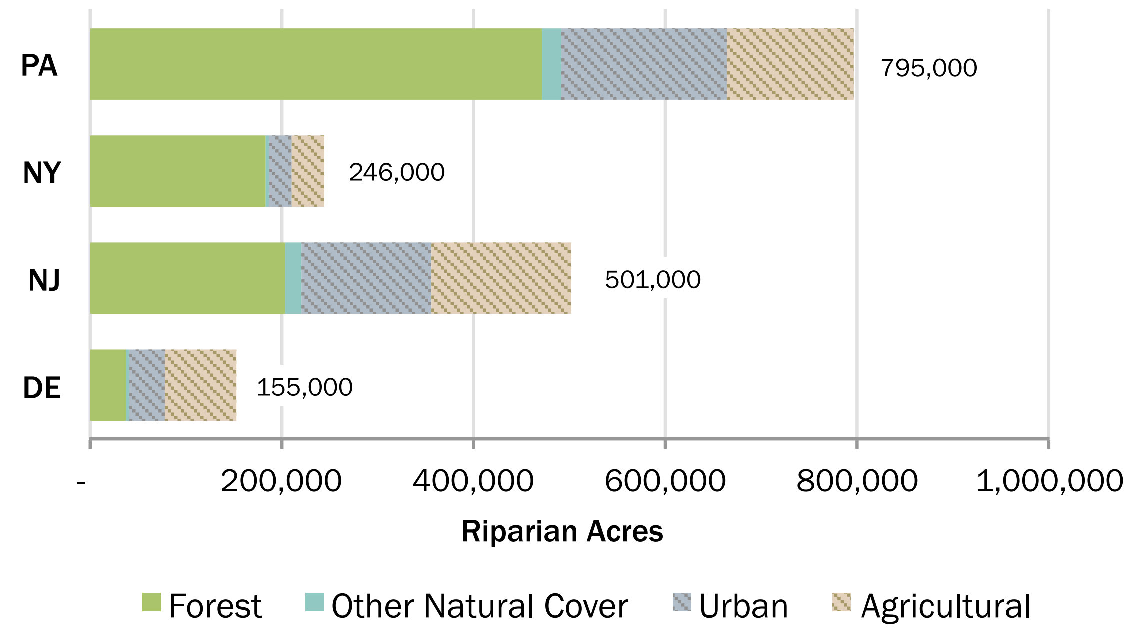


Figure 6. Land Cover Composition within the Riparian Zone (350-foot Buffer), Delaware River Basin, 2011

Source: ECONorthwest with data from the US EPA's Watershed Index Online

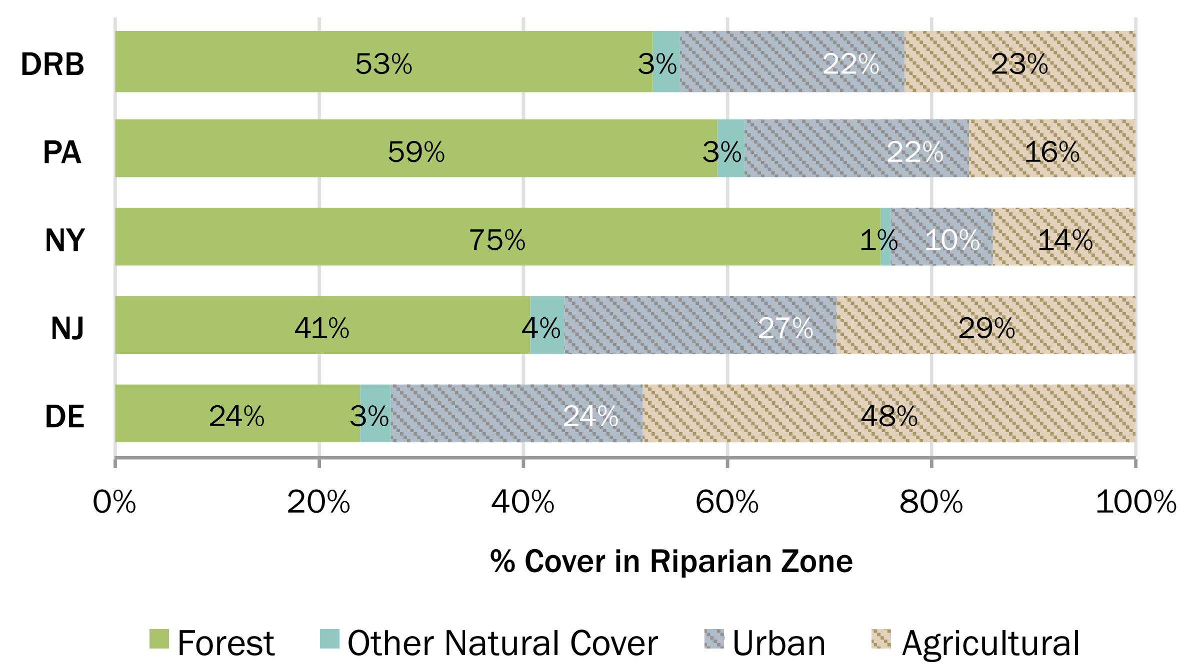
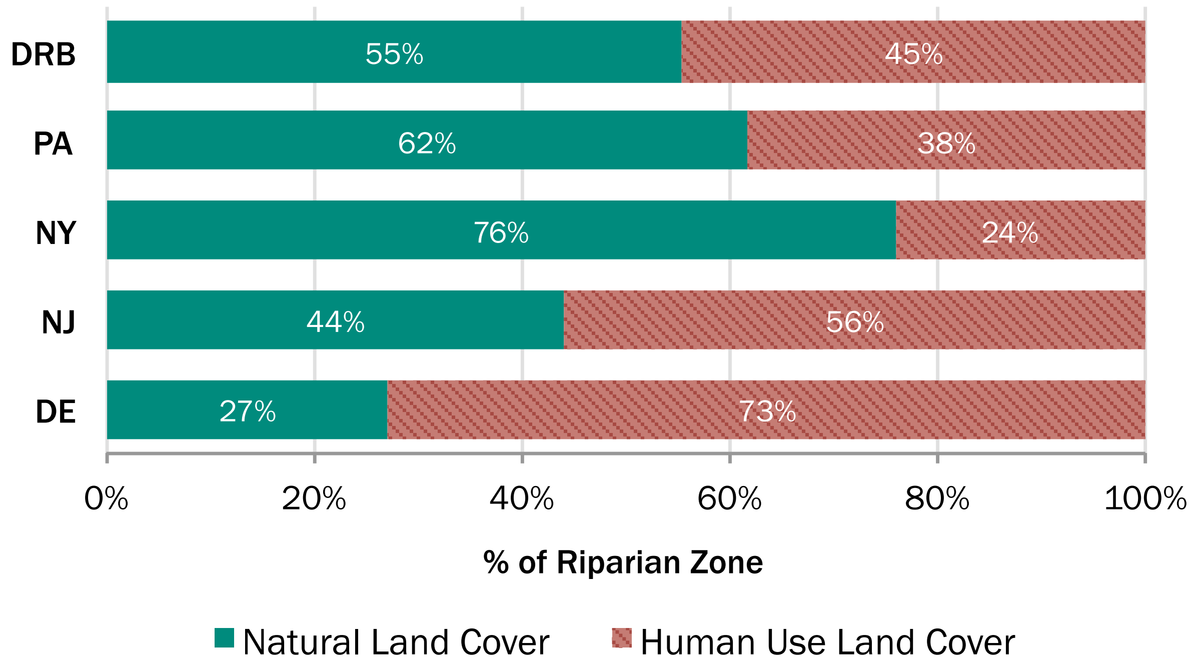


Figure 7. Percent Developed and Undeveloped Cover within the Riparian Zone (350-foot Buffer), Delaware River Basin, 2011

Source: ECONorthwest with data from the US EPA's Watershed Index Online



Trends in riparian land cover are summarized in Figures 8, 9, and 10, as well as Table 4. Urban development (defined on page 18 of this report) in the riparian zone increased between 2001 and 2011, while forests and agriculture declined. Studies of riparian land cover composition and change conducted elsewhere have reported similar trends.[5]

Forested cover and natural cover generally declined in all Basin states, while agricultural use declined in three out of four states (increasing slightly in New York State). WSIO data include watershed-scale totals in 2001 and 2011, but not which land uses replaced others. For example, a watershed may have lost forest on the whole between 2001 and 2011, but the data do not

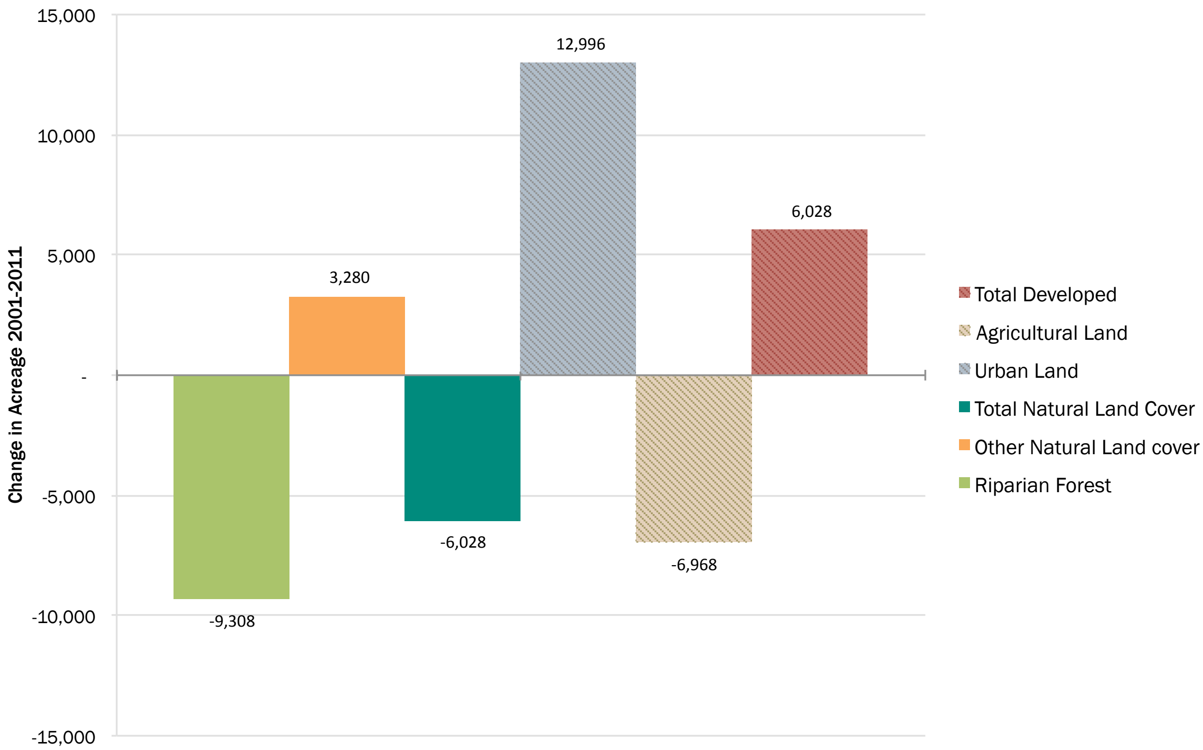
[5] See, for example:

- Center for Land Use Education and Research, 2008. The Status of Connecticut's Coastal Riparian Corridors. University of Connecticut.
- Jones, K.B., Slonecker, E.T., Nash, M.S., Neale, A.C., Wade, T.G. and Hamann, S., 2010. Riparian habitat changes across the continental United States (1972–2003) and potential implications for sustaining ecosystem services. Landscape Ecology, 25(8), pp.1261-1275.
- Newcomb, D.J., Hale, K., Phillipuk, C.R., Schleifer, D. and Stanuikynas, T.J., 2002. Surface Water and Riparian Areas of the Raritan River Basin: A technical report for the Raritan Basin Watershed Management Project.
- Price, W. and Sprague, E., 2011. Pennsylvania's Forests: How They are Changing and Why We Should Care. Pinchot Institute for Conservation.
- Wickham, J.D., Wade, T.G. and Riitters, K.H., 2011. An environmental assessment of United States drinking water watersheds. Landscape Ecology, 26(5), p.605.

specifically report whether those acres transitioned to urban, agriculture, or another natural land cover.

Figure 8. Land Cover Changes in the Riparian Zone (350-foot Buffer) 2001-2011, Delaware River Basin

Source: ECONorthwest with data from the US EPA's Watershed Index Online



Urban land cover includes multiple kinds of human development:[6]

- **Developed, Open Space** - *areas with a mixture of some constructed materials, but mostly vegetation in the form of lawn grasses. Impervious surfaces account for less than 20% of total cover. These areas most commonly include large-lot single-family housing units, parks, golf courses, and vegetation planted in developed settings for recreation, erosion control, or aesthetic purposes.*
- **Developed, Low Intensity** - *areas with a mixture of constructed materials and vegetation. Impervious surfaces account for 20% to 49% percent of total cover. These areas most commonly include single-family housing units, residential yards and lawns.*

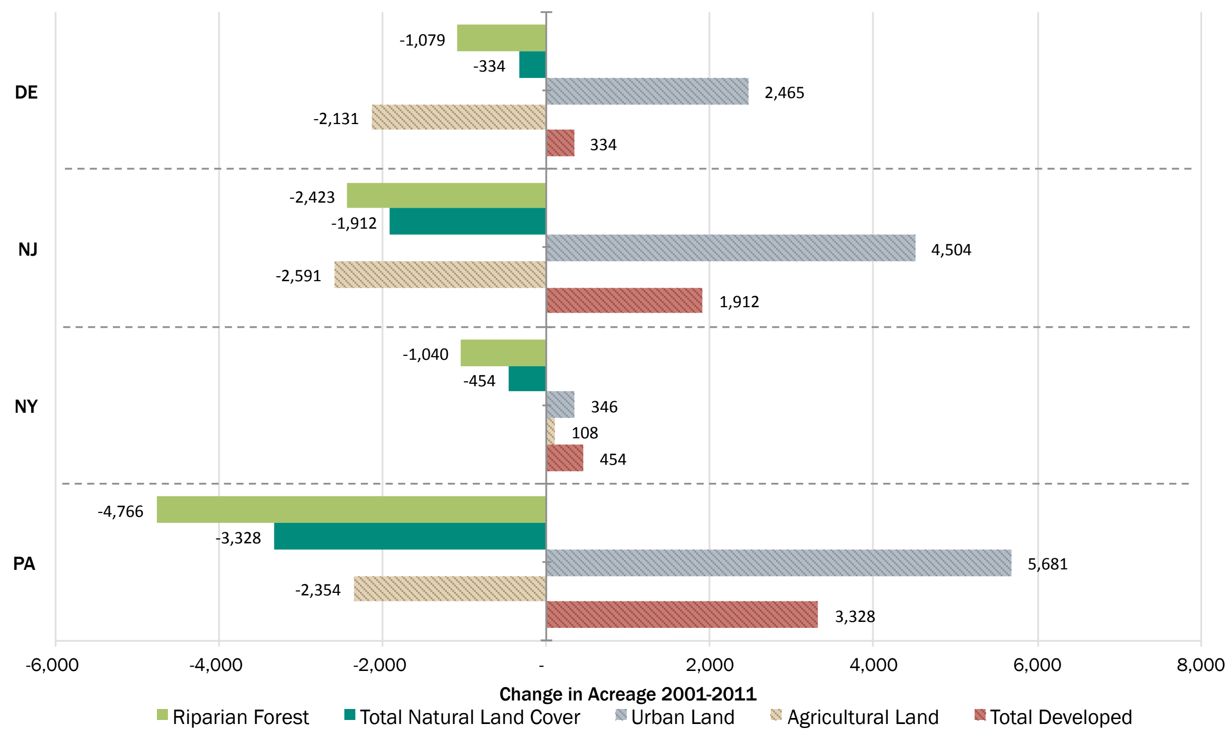
[6] Homer, C.G., Dewitz, J.A., Yang, L., Jin, S., Danielson, P., Xian, G., Coulston, J., Herold, N.D., Wickham, J.D., and Megown, K., 2015, Completion of the 2011 National Land Cover Database for the conterminous United States-Representing a decade of land cover change information. *Photogrammetric Engineering and Remote Sensing*, v. 81, no. 5, p. 345-354

- **Developed, Medium Intensity** - *areas with a mixture of constructed materials and vegetation. Impervious surfaces account for 50% to 79% of the total cover. These areas most commonly include single-family housing units.*
- **Developed High Intensity** - *highly developed areas where people reside or work in high numbers. Examples include apartment complexes, row houses and commercial/industrial. Impervious surfaces account for 80% to 100% of the total cover.*

Urban cover therefore includes both urban and suburban development, as well as roads, utility lines, and lawnscapes. Each of these land cover types has different effects on the environment but the limitations of the land cover data do not allow for us to account for these differences.

Figure 9. Land Cover Changes in the Riparian Zone (350-foot Buffer) by State, 2001-2011, Delaware River Basin

Source: ECONorthwest with data from the US EPA's Watershed Index Online



It's also important to note that not all of the lost riparian forest area was necessarily developed for human uses. Natural land cover types often transition to other natural land cover types. For example, in Pennsylvania nearly 4,800 acres of riparian forest were lost between 2001 and 2011 (Figure 10), but fewer acres of natural land cover were lost overall (-4,800 acres of riparian forest vs. -2,900 acres of natural land cover, overall). Some of these forest acres shifted to shrub/scrub and grasslands.[7]

[7] These trends can be explored with NOAA's Land Cover Atlas (choose watersheds, then the forests tab to see an accounting of which land covers replaced forest cover): https://coast.noaa.gov/ccapatlas/.

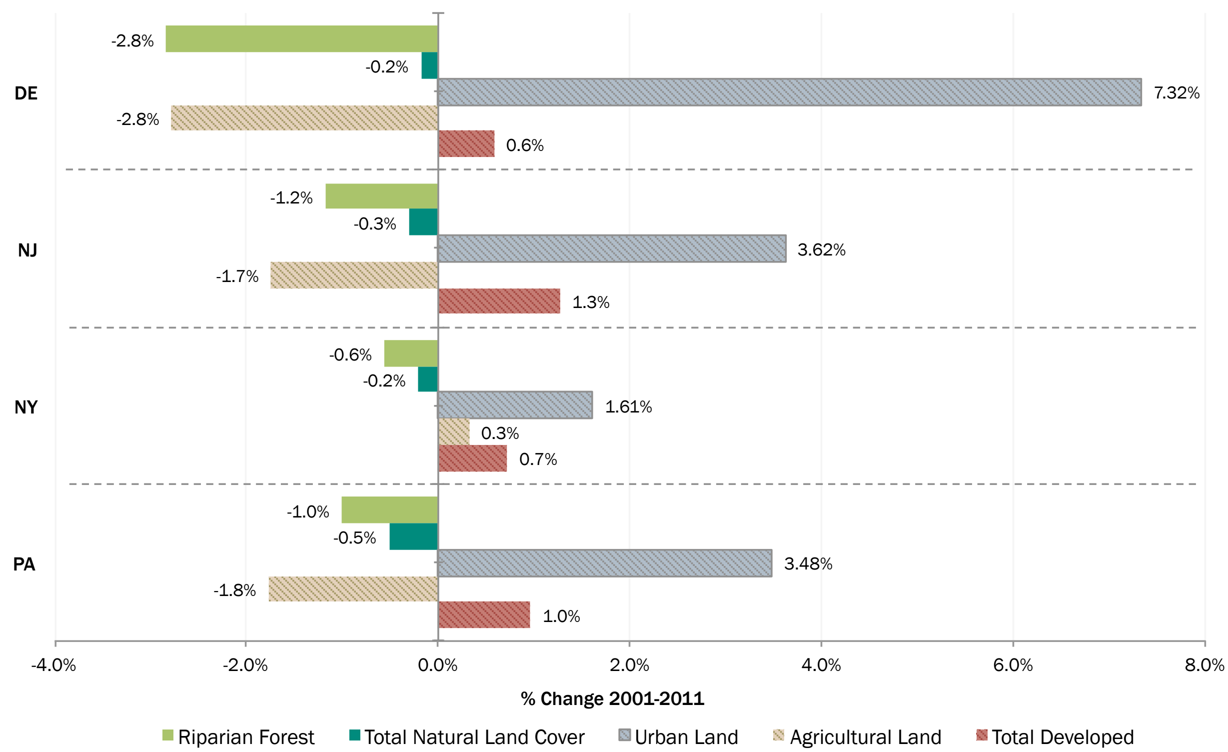
- **Shrub/Scrub -** *areas dominated by shrubs; less than 5 meters tall with shrub canopy typically greater than 20% of total vegetation. This class includes true shrubs, young trees in an early successional stage or trees stunted from environmental conditions.*
- **Grassland/Herbaceous -** *areas dominated by graminoid or herbaceous vegetation, generally greater than 80% of total vegetation. These areas are not subject to intensive management such as tilling (in which case they would classified as agricultural land), but can be used for grazing. The grassland/herbaceous category also does not include residential yards and lawns – these are included in either the 'low intensity urban development' or the 'developed open space' categories.*

Non-forest categories of natural land cover – shrub/scrub and grasslands – increased on the whole during between 2001 and 2011.

Trends in land cover change can be understood in absolute (i.e., total acres of forest lost) and relative to total stock (i.e., acres of forest lost compared to total acres of forest). For example, Pennsylvania lost over four times as many acres of riparian forest as Delaware (Figure 9), but Delaware lost a larger share of its total riparian forest than Pennsylvania (2.8% loss in DE vs. 0.6% in PA; Figure 10).

Figure 10. Percent Land Cover Change in the Riparian Zone (350-foot Buffer) by State, 2001-2011, Delaware River Basin

Source: ECONorthwest with data from the US EPA's Watershed Index Online



These change estimates include the effects of existing protection policies, such as buffer protection ordinances in Pennsylvania and New Jersey and protection through public ownership generally. For reference, 18 percent of the Delaware River Basin is protected by federal, state, and local governments or as private conservation easements through land trusts accessible to the public.[8]

Implications for Buffer Protection

Information about development trends in the riparian zone allows us to estimate the amount of undeveloped riparian land that could be preserved with policy changes and community protection. As described in the next section ('Buffer Widths and Vegetation Cover'), studies suggest 100 feet is the minimum functional buffer width for most objectives, while 350 feet of width are needed for habitat benefits.

Based on the net change in natural land cover within 100 feet of streams between 2001 and 2011, buffer ordinances adopted throughout the Basin would protect nearly 1,700 acres over ten years, or 167 acres a year. For a 350-foot buffer, over 6,000 acres of natural land cover would be protected over 10 years (Table 4).[9] This assumes constant development rates in the future matching those of the period 2001 to 2011 and does not account for potential variances or development exceptions, which would decrease the number of acres on which development is prevented. We also chose to use the net loss of natural land cover as the basis for policy modeling instead of lost forestland.[10] Forested buffers provide the greatest diversity and amount of ecosystem services, so transition to a grass or shrub dominated state will still result in a net loss of services. Our estimates of ecosystem services lost to development are likely underestimates to the extent they omit loss of conversion from forested buffers to other natural land cover.

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[8] Kauffman, G., Belden, A. and Homsey, A., 2009. Technical Summary: State of the Delaware Basin Report.

[9] See earlier discussion for buffer width basis.

[10] Some of the decline in riparian forest observed between 2001 and 2011 was due to natural disturbances and processes (e.g., flooding, windthrow), and some could be due to prior misclassification of forest land cover. An unknown portion of the transition from forest to shrub/scrub and grassland could also conceivably be due to human clearing (for grazing, for example), but might not be detected and/or categorized as one of the urban uses defined above. Only transition to land covers classified as 'urban' can be reliably linked to human development.

Table 4. Development of Natural Riparian Areas and Net Loss of Riparian Cover in the Delaware River Basin by State and Buffer Width (Acres), 2001-2011

Source: ECONorthwest with data from the US EPA's Watershed Index Online

	350-ft Buffer Zone		100-ft Buffer Zone	
State	Net Loss of Riparian Forest	Net Loss of Natural Land Cover	Net Loss of Riparian Forest	Net Loss of Natural Land Cover
2001 - 2011				
DE	-1,079	-334	-300	-93
NJ	-2,423	-1,912	-673	-531
NY	-1,040	-454	-289	-126
PA	-4,766	-3,328	-1,324	-924
DRB	-9,308	-6,028	-2,585	-1,674
Annual Average				
DE	-108	-33	-30	-9
NJ	-242	-191	-67	-53
NY	-104	-45	-29	-13
PA	-477	-333	-132	-92
DRB	-931	-603	-259	-167

Riparian Ecosystem Services in the Delaware River Basin

The Chesapeake Bay Program identifies riparian forest buffers as being perhaps the single best practice to maintain and improve the quality of downstream waters and habitats:

> *"Riparian forest buffers provide critical barriers between polluting landscapes and receiving waterways using relatively little land. Forest buffers reduce the adverse effect of excessive nitrogen, phosphorus, and suspended sediment inputs. Per acre, they likely provide more benefits and are more cost-effective than any other* [management practice], *especially when considering the added high value habitat at the critical juncture of land and water."*[11]

Categories of Benefit

We focus our analysis on these identified functions and benefits of riparian areas in the Delaware River Basin:

- **Water Quality Protection** (specifically, treatment and prevention of nutrient and sediment pollution, interception of urban stormwater runoff, and drinking water provision)
- **Carbon Sequestration**
- **Mitigation of Air Pollution**
- **Provision of Habitat and Movement Corridors for Fish and Wildlife**
- **Flood Prevention**
- **Improvements in Property Values**
- **Outdoor Recreation Opportunities**

Buffer Widths and Vegetation Cover

The size (width and area) and vegetative cover type determine a buffer's capacity to provide ecosystem services and benefits. Generally speaking, wider buffers provide greater benefits. Each of the ecosystem services above also requires a certain minimum area or size of land area surrounding water bodies to be fully realized. Many reviews suggest that 100 feet is the minimum width at which all of the relevant services are provided.[12] Some services are realized relatively quickly (e.g., bank stabilization), while other services require much larger widths to

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[11] Chesapeake Bay Program. 2014. Buffering the Bay: A Report on the Progress and Challenges of Restoring Riparian Forest Buffers in the Chesapeake Bay Watershed.

[12] Sweeney, B.W. and Newbold, J.D., 2014. Streamside forest buffer width needed to protect stream water quality, habitat, and organisms: a literature review. *JAWRA Journal of the American Water Resources Association*, *50*(3), pp.560-584.

provide efficient services (e.g., 300 feet for wildlife habitat). Depending on a water body's position in the watershed, the type of vegetation present, adjacent land uses and slope, some buffers may require thousands of feet to provide ecological functions and benefits.[13] Forested riparian buffers, as opposed to grass or shrub dominated buffers, deliver the greatest range of environmental benefits (Table 5).[14]

Table 5. Buffer Vegetation and Effectiveness

Source: NRCS. 1999. Managing Streamside Areas with Buffers.

Benefit	Grass	Shrub	Tree
Stabilize Bank Erosion	Low	High	High
Filter Sediment	High	Low	Low
Filter Nutrients, Pesticides, Bacteria			
Sediment-bound Particle Removal	High	Low	Low
Soluble Particle Removal	Medium	Low	Medium
Aquatic Habitat	Low	Medium	High
Wildlife Habitat			
Range/Pasture/Prairie Wildlife	High	Medium	Low
Forest Wildlife	Low	Medium	High
Flood Protection	Low	Medium	High
Water Temperature	Low	Low	High

Multiple vs. Single Service Provision

Some of the environmental services provided by forested riparian areas might be partially provided by human-built structures and technologies, such as reservoirs for flood control and wastewater treatment plants for pollutant removal. However, these substitutions are directed at single functions rather than the multiple functions that riparian areas carry out simultaneously, including functions not easily replicated. Unlike built alternatives, riparian buffers support multiple habitat benefits while also improving water quality, aesthetics, etc.[15]

This also highlights the importance of recognizing the complementary benefits of riparian buffers for other natural and built assets in a watershed. Buffers can make other resources, such as downstream water bodies and adjacent forests, more functional and valuable. They are also complementary within their own system, in that upstream buffers can make downstream buffers more beneficial and vice versa.

[13] Schueler, T., Site Planning for Urban Stream Protection, Metropolitan Washington Council of Governments 111 (1995), at 3.

[14] Lowrance, R. R. 1997. Water quality functions of riparian forest buffer systems in the Chesapeake Bay watershed. Environmental Management 21(5): 687-712.

[15] Sweeney, B.W. and Newbold, J.D., 2010. Removal of Nonpoint Source Pollutants by Riparian Buffers: A Short Summary of the Scientific Literature.

A. Values of Specific Ecosystem Services

We provide ranges in service values to account for the fact that marginal benefits will not be constant across the Basin. Ecosystems and individual parcels of land vary considerably in quality and capacity to provide specific services, and the value of these services can also depend on the regional context.[16] For example, buffers adjacent to agriculture provide a different mix and magnitude of benefits than those adjacent to forests or residential properties.

The demand curve for most ecosystem services is presumed to be downward sloping, suggesting diminishing returns. The marginal value of benefits provided by riparian buffers should decrease as the portion of a given area constituted by buffers increases.[17] With some ecosystem services, such as carbon sequestration, extrapolating values across large acreages could be relatively accurate because marginal benefits are likely to be nearly constant. Other services, such as habitat provision, may be even more valuable on large acreages.

All values are in 2017 dollars unless noted otherwise. Literature values were updated to current year dollars using the Consumer Price Index.

1. Water Quality

Riparian areas act as natural filtration systems that improve water quality by absorbing excess amounts of sediment, nutrients, and other contaminants from urban and agricultural runoff.[18] Streamside vegetation also supports a large number and diversity of aquatic insects that process pollutants and further improve water quality.[19]

Figure 11 shows stream segments in the Basin that do not meet minimum standards for certain uses (such as fishing and swimming). Beyond their ability to address specific pollutants, forested riparian buffers are also linked to stream health and quality generally (see Table 20, pg. 42).

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[16] Kauffman, G.J., 2016. Economic Value of Nature and Ecosystems in the Delaware River Basin. *Journal of Contemporary Water Research & Education*, *158*(1), pp.98-119.

[17] Ballard, J., J. Pezda and D. Spencer. 2016. An Economic Valuation of Southern California Wetlands. University of California – Santa Barbara.

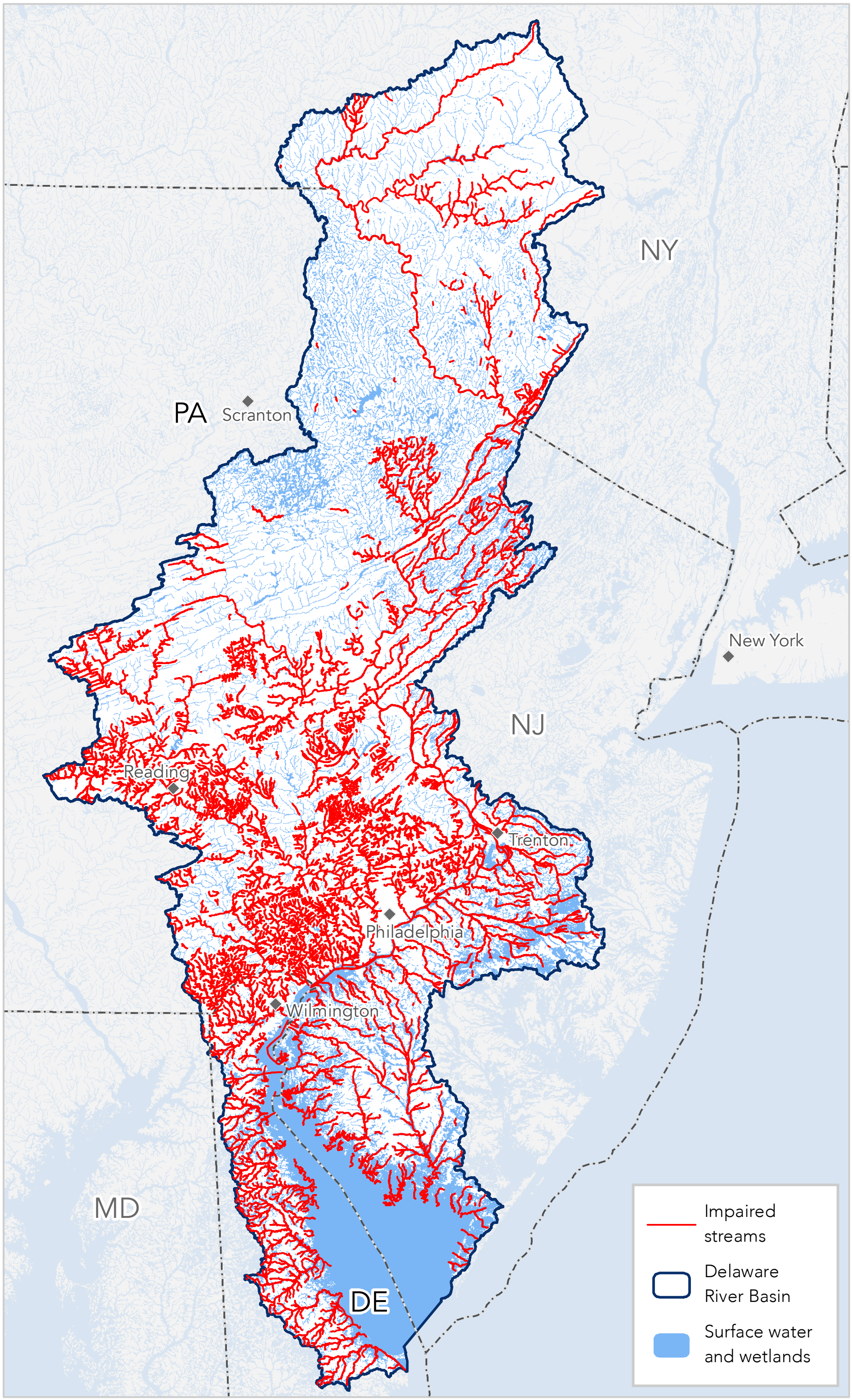
[18] Sweeney, B.W. and Newbold, J.D., 2014. Streamside forest buffer width needed to protect stream water quality, habitat, and organisms: a literature review. *JAWRA Journal of the American Water Resources Association*, *50*(3), pp.560-584.

[19] Sweeney, B.W., Bott, T.L., Jackson, J.K., Kaplan, L.A., Newbold, J.D., Standley, L.J., Hession, W.C. and Horwitz, R.J., 2004. Riparian deforestation, stream narrowing, and loss of stream ecosystem services. *Proceedings of the National Academy of Sciences of the United States of America*, *101*(39), pp.14132-14137.

Figure 11. Stream Segments Listed as Impaired by the EPA

Sources: ECONorthwest with data from the US EPA Water Quality Assessment and TMDL Tracking (ATTAINS) database, EPA 2002 Impaired Waters Baseline National Geospatial Dataset, and the Pennsylvania Department of Environmental Protection 2016 Integrated Water Quality Report.

Note: Stream impairments only include categories 4 (polluted streams that do not require a TMDL) and 5 (polluted waters that require a TMDL).



Nitrogen and Phosphorus Reductions

High concentrations of nutrients such as nitrogen and phosphorus can fuel excessive plant growth (e.g., nuisance algae) and lower dissolved oxygen levels in streams and lakes. Nutrient concentrations are a commonly used indicator of water quality.

We begin by estimating the amount of nitrogen and phosphorus discharged to the environment with and without riparian buffers. We use a database of nutrient loadings for various land uses and land covers in the Chesapeake Bay in the absence of similar information for the Delaware River Basin.[20] Our nutrient accounting methodology is based on that of the Chesapeake Bay Program, the North Carolina Buffer Mitigation Program, and the USDA Conservation Reserve Enhancement Program (CREP).

The value provided by buffer policies is not only for the water filtration services that buffers provide, but also the problems that are avoided when other land uses are excluded (Table 6). The nutrient reduction benefit of riparian buffers includes both the nutrient retention associated with keeping an acre of forest from turning into urban or agricultural uses - measured as the difference in nutrient loadings between forest and developed land uses (Table 6) – and the buffer's treatment of runoff from upland acres.

Table 6. Increase in Nutrient Delivery with Land Use Change

Source: ECONorthwest with data from University of Maryland Center for Environmental Science and Maryland Department of Natural Resources (http://dnr2.maryland.gov/ccs/Documents/trustfund/AgricultureandForestCalculator.xls)

1: The composite value is an average of the developed, crop and pasture land covers.

Values may not sum due to rounding

Land Use/Land Cover	Nitrogen (lb/acre/yr)		Phosphorus (lb/acre/yr)	
	Average	Range	Average	Range
Developed	7.5	0 - 21.7	0.5	0 - 1.1
Crop	15.5	0 - 44.7	1.1	0 - 3.7
Pasture	5.1	0 - 17.1	0.6	0 - 1.2
Composite Urban/Agricultural[1]	9.4	-	0.7	-
Forest	1.9	0 - 5.8	0.1	0 - 0.1
Increase in nutrient delivery with loss of streamside forest	**7.5**	**-**	**0.7**	**-**

The values shown in Table 6 are consistent with previously reported estimates.[21] Based on guidance from the Chesapeake Bay Commission, we assume that an acre of riparian buffer

[20] Data are available online at http://dnr2.maryland.gov/ccs/Documents/trustfund/AgricultureandForestCalculator.xls

[21] Stephenson, K., Aultman, S., Metcalfe, T. and Miller, A., 2010. An evaluation of nutrient nonpoint offset trading in Virginia: A role for agricultural nonpoint sources? *Water Resources Research*, *46*(4).

treats four upland acres with respect to total nitrogen loads and two upland acres with respect to phosphorus and sediment (see next section for sediment calculations).[22]

To account for varying effectiveness of individual buffer units as well as the range of buffer widths used in the source literature, we use a range of 48 to 95 percent for nitrogen capture/treatment, 36 to 79 percent for phosphorus (Table 7), and 70 to 96 percent for sediment (Table 12, next section).[23]

Table 7. Nutrient Loads and Estimates of Buffer Treatment Capacity

Sources: ECONorthwest with data from sources cited in text.

Nutrient Factors		Land Use/Land Cover					
		Pasture		Developed		Crops	
Total Nitrogen	Loading rate (lb/ac/yr)	5.1		7.5		15.5	
	Discharge to buffer w/ 4:1 upland/buffer ratio	20.5		29.9		62.2	
	Removal efficiency	48%	95%	48%	95%	48%	95%
	Nitrogen yield (lb/ac/yr)	**9.8**	**19.4**	**14.4**	**28.4**	**29.8**	**59.0**
Total Phosphorus	Loading rate (lb/ac/yr)	0.6		0.5		1.1	
	Discharge to buffer w/ 2:1 upland/buffer ratio	1.2		1.0		2.1	
	Removal efficiency	36%	79%	36%	79%	36%	79%
	Phosphorus yield (lb/ac/yr)	**0.4**	**1.0**	**0.3**	**0.8**	**0.8**	**1.7**

For comparison, the North Carolina mitigation program (described in the next section) assumes that each acre of riparian buffer within 50 feet of streams prevents 75.77 pounds of nitrogen and 4.88 pounds of phosphorus per year from reaching waterways. Buffers in Maryland and Georgia were found to retain 23 to 65 pounds of nitrogen (67 to 89 percent of inputs) and 1.1 to 2.6 pounds of phosphorus (24 to 81 percent of inputs) per acre of buffer per year.[24]

We value each pound of nitrogen and phosphorus with the cost of removal or prevention using various practices. Loss of riparian buffers will increase the costs of nitrogen and phosphorus removal, while buffer protection will allow society to avoid these control costs. The costs of removing nitrogen are generally between $4 and $58 per pound, while phosphorus removal costs $24 to $399 per pound (Table 8).[25] Removal costs vary based on the technology used, the

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[22] Riparian Buffer Expert Panel, 2014. Recommendations of the Expert Panel to Reassess Removal Rates for Riparian Forest and Grass Buffers Best Management Practices.

[23] Hawes and Smith. 2005. Riparian Buffer Zones: Functions and Recommended Widths. Prepared for the Eightmile River Wild and Scenic Study Committee

[24] Lowrance, R. R. 1997. Water quality functions of riparian forest buffer systems in the Chesapeake Bay watershed. Environmental Management 21(5): 687-712.

[25] Van Houtven, G., Loomis, R., Baker, J., Beach, R. and Casey, S., 2012. Nutrient credit trading for the Chesapeake Bay: An economic study. *RTI International, Research Triangle Park, NC.*

US Environmental Protection Agency. 2002. Economic Analysis of the Final Revisions to the National Pollutant Discharge Elimination System Regulation and the Effluent Guidelines for Concentrated Animal Feeding Operations - Appendix E Cost-Effectiveness Analysis. Washington, DC.: Office of Science and Technology, Pub No. EPA-821-R-03-002.

scale of treatment, and landscape setting. The cost to remove or prevent a pound of nitrogen or phosphorus from farm runoff and drainage, for example, is typically 4 or 5 (and as high as 10 or 20) times less than the cost to remove the same amount from municipal wastewater or urban stormwater.[26]

Table 8. Increase in Nutrient Delivery with Buffer Losses
Sources: ECONorthwest with data from sources cited in text.

Nitrogen		**Low**	**High**
1) Increase in TN export with land use change (lb/acre/yr)		7.5	
2) Loss of TN removal from nonpoint source runoff (lb/acre/yr)		9.8	59.0
Total increase in nitrogen delivery (lb/acre/yr)		17.3	66.6
Treatment cost per pound of nitrogen:	$4	$63	$241
	$58	$1,012	$3,885
Total Increase in N treatment costs with buffer loss ($/acre/yr)		$241	$3,885
Phosphorus		**Low**	**High**
1) Increase in TP export with land use change (lb/acre/yr)		0.7	
2) Loss of TP removal from nonpoint source runoff (lb/acre/yr)		0.3	1.7
Total increase in phosphorus delivery (lb/acre/yr)		1.0	2.3
Treatment cost per pound of phosphorus:	$24	$24	$55
	$389	$394	$905
Total increase in P treatment costs with buffer loss ($/acre/yr)		$55	$905
Combined N+P ($/ac/yr):	Low prices	**$87**	**$296**
	High prices	**$1,406**	**$4,789**

Annual service losses repeat year after year, and build cumulatively. For example, in year one we value the losses associated with 167 acres of riparian forest, and in the second year we value losses from 334 acres. In the first year there are not only 167 acres of newly developed lands discharging more nutrients than the forested riparian acreages did previously, but also 668 upland acres that have lost their nitrogen filtration barrier (based on a 1 to 4 treatment ratio), and 334 acres that have lost their phosphorus and sediment filtration barrier (based on a 1 to 2 treatment ratio).

To produce an estimate of potential losses between 2018 and 2028 (Table 9), we apply the mid-range of values (Table 8; $296 to $1,406 per acre, rather than the upper and lower extremes of $87 to $4,789 per acre).

[26] National Association of Clean Water Agencies. 2011. Controlling Nutrient Loadings to U.S. Waterways: An Urban Perspective

Table 9. Annual and Projected Nutrient Costs from Riparian Development

		DE	NJ	NY	PA	Basin Total
Net Loss of Natural Land Cover (100-ft buffer, acres/yr)		-9	-53	-13	-92	-167
Low Buffer Effectiveness, Low Avoided Treatment Costs (-$87/acre/yr)		-$806	-$4,613	-$1,095	-$8,028	-$14,543
Low Buffer Effectiveness, High Avoided Treatment Costs (-$1,406/acre/yr)		-$13,055	-$74,699	-$17,726	-$129,988	-$235,468
High Buffer Effectiveness, Low Avoided Treatment Costs (-$296/acre/yr)		-$2,750	-$15,733	-$3,733	-$27,378	-$49,595
High Buffer Effectiveness, High Avoided Treatment Costs (-$4,789/acre/yr)		-$44,459	-$254,390	-$60,365	-$442,675	-$801,889
Total NPV 2018-2028	Low Range (-$296/acre/yr)	-$126,992	-$726,636	-$172,426	-$1,264,450	-$2,290,503
(mid-range values, cumulative effect, 3% discount rate)	High Range (-$1,406/acre/yr)	-$602,932	-$3,449,930	-$818,646	-$6,003,368	-$10,874,876
2018-2028 Annualized	Low	-$12,699	-$72,664	-$17,243	-$126,445	-$229,050
	High	-$60,293	-$344,993	-$81,865	-$600,337	-$1,087,488

The Chesapeake Bay Commission and North Carolina Buffer Mitigation Program value nitrogen and phosphorus treatment costs separately and additively. However, many treatment practices will treat both nutrients simultaneously, so under some treatment scenarios and circumstances there may be double counting when avoided costs are valued separately.

North Carolina Buffer Mitigation Program

Since 1997, North Carolina has actively managed development within its riparian zones to maintain and improve water quality in the state's streams and bays. The state has designated 50-foot riparian buffers, and sets "exempt," "allowable," "allowable with mitigation," and "prohibited" uses within this regulated buffer zone.[27] Impacts that are "allowable with mitigation" must be offset by the restoration of buffers elsewhere within the same watershed.

Mitigation is based on the nutrient (nitrogen and phosphorus) loading that will result from land use changes over a 30-year period. Compliance options include providing stormwater BMPs at the development site to offset the lost nutrient treatment capacity, or paying to create a new riparian buffer elsewhere in the watershed.

This mitigation approach has effectively created a market for forested riparian buffers. The North Carolina Ecosystem Enhancement Program (NCEEP), a state agency, completes stream, wetland, and riparian buffer mitigation projects and sells credits to other agencies, private companies, or individuals that need to purchase mitigation as part of a development project. NCEEP's nutrient offset credit rates vary by watershed, but current prices range from $9 to $21 per pound of nitrogen and $167 to $382 per pound of phosphorus.[28]

NCEEP estimates that over a 30-year period, one acre of forested riparian buffer prevents 2,273 pounds of nitrogen and 146.4 pounds of phosphorus from reaching surface waters. Taking the average of the watershed nutrient prices, one acre of forested riparian buffer has a value of: $14.99/lb. X 2,273 lbs. of nitrogen over 30 years = $34,061 and $274.78/lb. X 146.4 lbs. of

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[27] Chatham Conservation Partnership. 2011. Chatham Conservation Plan Appendix G - Forest Resources: Economic Analysis for Water Quality

[28] North Caroline Department of Environmental Quality. 2016-17 Statewide Stream & Wetland & 2017 Riparian Buffer Rates. https://deq.nc.gov/about/divisions/mitigation-services/dms-customers/fee-schedules

phosphorus over 30 years = $40,227. This equates to $2,476 per acre year for both nitrogen and phosphorus reductions, which is two to eight times higher than the nutrient values we apply in our analysis.

The combined nutrient removal value for one acre of restored forested riparian buffer over a 30-year period is $74,288. The price for a riparian buffer mitigation credit through NEEP is currently $1.16/square foot, which translates to $50,530/acre. The net benefit of an acre of riparian buffer, in this case, would be about $24,000 over a 30-year period.[29] Riparian wetlands are slightly more expensive to offset and produce, at $40,297 to $71,273 per acre. These costs include land purchase (at least $19,000 an acre and often more depending on how urbanized the watershed is), long-term maintenance and monitoring, as well as relatively high transaction costs (e.g., for permitting, planning and program management).[30]

The values above are meant to illustrate and confirm the magnitude of potential benefits and costs associated with nutrient retention and treatment by buffers. These are essentially one-time payments/losses/benefits, and NCEEP's nutrient prices are specific to the region's water quality goals.

Based on mitigation applications to NCEEP between 2005 and 2010, more than half of the costs/benefits associated with the buffer mitigation rule have been incurred by the North Carolina Department of Transportation, and another third by private developers.[31]

Sediment Reductions

Roots, stems and fallen trees in a riparian buffer slow the flow of surface runoff, allowing sediment to settle out and be trapped before reaching streams and lakes. Capturing sediment before it reaches waterways creates a number of benefits for local communities and industries (Table 10).[32] For example, excessive sediment loads impose damage and control costs on multiple kinds of infrastructure (e.g., reservoirs, power plants, roads, canals), exacerbate flooding, and lower catch rates for commercial and recreational marine fisheries. The categories and values shown in the table below are based on models that the USDA Economic Research Service uses to assign monetary values to changes in soil erosion and sediment deposition.[33] These models provide information on the costs and damages associated with a ton of sediment discharged to regional waterways, with values specific to the northeastern region.

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[29] Ibid

[30] RTI International and the Center for Watershed Protection. 2007. A Study of the Costs Associated with Providing Nutrient Controls that are Adequate to Offset Point Source and Nonpoint Source Discharges of Nitrogen and Other Nutrients. Prepared for the North Carolina General Assembly's Environmental Review Commission

[31] North Carolina Department of Environmental and Natural Resources. 2015. Fiscal and Regulatory Impact Analysis - Buffer Mitigation Rules.

[32] Hansen, L. and Ribaudo, M., 2008. Economic Measures of Soil Conservation Benefits: Regional Values for Policy Assessment. USDA Technical Bulletin Number 1922

[33] Ibid

Table 10. Benefits of Sediment Capture

Source: ECONorthwest with data from Hansen and Ribaudo 2008

Note: categories without ranges are those for which have values specific to the Northeast region. All cost figures are in 2017$.

Categories	Description of Benefit	Value ($/ton)
Reservoir services	Avoided cost of dredging reservoirs	$0 to $1.86
Navigation	Avoided cost of dredging harbors and shipping channels	$0 to $6.75
Irrigation ditches and channels	Reduced cost of removing sediment and aquatic plants from irrigation channels	$0.01
Road drainage ditches	Less damage to and flooding of roads	$0.27
Municipal water treatment	Lower sediment removal costs for water-treatment plants	$0.36
Flood damages	Reduced flooding and damage from flooding	$1.04
Marine fisheries	Improved catch rates for marine commercial fisheries	$1.25
Marine recreational fishing	Increased catch rates for marine recreational fishing	$2.12
Municipal & industrial water use	Reduced damages from salts and minerals dissolved from sediment	$1.96
Steam powerplants	Reduced plant growth on heat exchangers	$0.89
	Total ($/ton)	**$8 to $17**

We use the same accounting method and data sources used for nitrogen and phosphorus to estimate the increase in sediment discharge that occurs when natural buffers are replaced by urban and agricultural development.

Table 11. Increase in Sediment Delivery with Land Use Change

ECONorthwest with data from University of Maryland Center for Environmental Science and Maryland Department of Natural Resources (http://dnr2.maryland.gov/ccs/Documents/trustfund/AgricultureandForestCalculator.xls)

Land Use/Land Cover	Sediment (TSS) (lb/acre/yr)	
	Average	Range
Developed	359	0 - 1,236
Crop	1,054	0 - 5,178
Pasture	210	0 - 1,401
Composite Urban/Agricultural[1]	541	-
Forest	52	0 - 267
Increase in nutrient delivery with loss of streamside forest	**489**	**-**

Table 12. Sediment Loads and Estimates of Buffer Treatment Capacity

Sources: ECONorthwest with data from sources cited in text.

Sediment Loading and Removal Factors	Land Use/Land Cover					
	Pasture		**Developed**		**Crops**	
Loading rate (lb/ac/yr)	210		359		1,054	
Discharge to buffer w/ 2:1 upland/buffer ratio	420		718		2,109	
Removal efficiency	70%	96%	70%	96%	70%	96%
Sediment yield (lb/ac/yr)	**294**	**403**	**502**	**689**	**1,476**	**2,025**

We estimate that every acre of riparian buffer lost to development will increase sediment discharge by approximately 800 to 2,500 pounds (0.4 to 1.3 US tons) per year (see Table 13 below). These estimates are consistent with values used in the Conservation Reserve

Enhancement Program's (CREP) project accounting, which assumes that 0.5 and 0.1 tons are generated by an acre of row crop and pasture, respectively.[34]

We use loading estimates from the Chesapeake Bay database for consistency with nitrogen and phosphorus accounting, but these estimates likely do not capture the upper range of possible sediment capture by buffers. For example, over a 100-year period (1880-1979), a riparian zone in a coastal plain agricultural watershed in Georgia accumulated an estimated 190,667 to 283,276 pounds of sediment (95 to 142 US tons) per acre per year.[35] Additionally, our accounting likely does not capture the sediment discharges associated with construction projects, which could be an important stressor given the scale of urbanization occurring in the Basin. Estimates of uncontrolled construction-site sediment loadings range from 7.2 to 1,000 tons per acre per year.[36]

Table 13. Increase in Sediment Delivery with Buffer Losses and Economic Values

Sources: ECONorthwest with data from sources cited in text.

Sediment Delivery	Low	High
1) Increase in sediment export with land use change (lb/acre/yr)	489	
2) Loss of sediment removal from nonpoint source runoff (lb/acre/yr)	294	2,025
Total increase in sediment delivery (lb/acre/yr)	783	2,513
Benefit Categories	**Low** ($/acre/yr)	**High** ($/acre/yr)
Reservoir services	$0.00	$2.34
Navigation	$0.00	$8.48
Irrigation ditches and channels	$0.01	$0.02
Road drainage ditches	$0.11	$0.34
Municipal water treatment	$0.14	$0.46
Flood damages	$0.41	$1.31
Marine fisheries	$0.49	$1.58
Marine recreational fishing	$0.83	$2.66
Municipal & industrial water use	$0.77	$2.46
Steam powerplants	$0.35	$1.12
Total Costs/Damages ($/acre/yr)	**$3.1**	**$20.8**

The value of sediment control by an acre of natural riparian buffer will generally fall between $3 and $21 per acre per year, with the largest potential benefits realized in avoided dredging costs,

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34 See, for example, the Wisconsin CREP worksheet at https://datcp.wi.gov/Documents/CREPEnvirBenefitReport.doc

35 Lowrance, R., J.K. Sharpe, and J.M. Sheridan. 1986. Long-term sediment deposition in the riparian zone of a coastal plain watershed. Journal of Soil & Water Conservation 41:266-271.

For a review of sedimentation rates, see Lowrance, R., Altier, L.S., Newbold, J.D., Schnabel, R.R., Groffman, P.M., Denver, J.M., Correll, D.L., Gilliam, J.W., Robinson, J.L., Brinsfield, R.B. and Staver, K.W., 1997. Water quality functions of riparian forest buffers in Chesapeake Bay watersheds. Environmental Management, 21(5), pp.687-712.

36 Langland, M. and Cronin, T., 2003. A summary report of sediment processes in Chesapeake Bay and watershed (No. 2003-4123).

enhanced catches for marine fishing, and reduced damage to municipal and industrial water infrastructure.

Table 14. Annual and Projected Sediment Costs Associated with Riparian Development

		DE	NJ	NY	PA	Basin Total
Annual Net Loss of Natural Land Cover (100-ft buffer, acres/yr)		-9	-53	-13	-92	-167
Low (-$3/acre)		-$29	-$164	-$39	-$286	-$518
High (-$21/acre)		-$193	-$1,103	-$262	-$1,919	-$3,475
Total NPV 2018-2028	Low	-$1,327	-$7,591	-$1,801	-$13,210	-$23,929
(cumulative effect, 3% discount rate)	High	-$8,899	-$50,918	-$12,083	-$88,605	-$160,505
2018-2028 Annualized	Low	-$133	-$759	-$180	-$1,321	-$2,393
	High	-$890	-$5,092	-$1,208	-$8,861	-$16,051

These costs mount over time, building cumulatively with annual loss of buffer capacity. Over the next ten years we project that total sediment–related costs across the basin due to buffer loss will fall somewhere between $24 and $161 thousand. These impacts are low in comparison to the other categories addressed in this report, which is due in part to the low costs of removing sediment. These values could be substantially greater than these estimates suggest given that much higher rates of sediment capture by buffers have been reported in the literature.

With the exception of damages to marine recreational fishing which are included in the recreation valuation section, we do not include sediment-related costs in the final summation of costs, shown in Table 26. At the local scale, secondary costs such as these might be of more prominent importance. Well-implemented and managed riparian buffers can effectively address site-specific needs. The total cost of sediment pollution caused by riparian habitat loss might be low across the Basin, but the localized value can still be an important factor for assessment.

Urban Stormwater Treatment

As vegetated areas are replaced, the ability of the land to absorb and filter stormwater runoff is reduced. Flooding, bank erosion, and runoff subsequently increase. Impervious surfaces also reduce groundwater recharge and infiltration for stream base-flows.

Based on municipal stormwater treatment costs in the Basin, protecting or restoring one acre of forested riparian buffer could save $540 to $1,898 per year (Table 15). Urban treatment costs are based on stormwater volume, as opposed to the concentration of specific nutrients. The full replacement costs associated with stormwater treatment (e.g., for construction of retention ponds), as opposed to the marginal treatment costs, are much higher at $2.03 per cubic foot.[37]

[37] New Jersey Department of Environmental Protection, 2007. Valuing New Jersey's Natural Capital: An Assessment of the Economic Value of the State's Natural Resources.

Streamside property owners in communities with stormwater crediting programs can lower monthly stormwater bills by decreasing impervious cover on their property.[38]

Table 15. Costs of Stormwater Treatment by Land Cover

Sources: ECONorthwest with data from the Trust for Public Land.[39]

We apply lower runoff values for all categories; forest runoff can be as high as 20 percent, suburban can be as high as 60 percent, dense urban as high as 70 percent, and city commercial as high as 80 percent.[40]

The runoff coefficient is the proportion of rainfall that is converted to storm water runoff.

Average Rainfall/ac/yr = 150,000 cu. ft./acre			Stormwater Treatment Cost ($/cu. ft.)		Annual Savings Per Acre of Riparian Forest	
			Philadelphia, PA	Wilmington, DE		
Land Cover	**Runoff Generation**	**Runoff/ac/yr (cu. ft./acre)**	$0.012	$0.023	Low	High
Forest	5%	7,500	$90	$173	-	-
Suburban Residential	35%	52,500	$630	$1,208	$540	$1,035
Dense Urban Residential	50%	75,000	$900	$1,725	$810	$1,553
City Commercial	60%	90,000	$1,080	$2,070	$990	$1,898

The Problem of Channelized Flow: Buffers can be less effective at treating water pollution in urban environments. Models concerning the effectiveness of riparian buffers typically assume that water flows evenly across the landscape and interacts with the buffer equally at all points. In nature and particularly in urban environments this is rarely the case and certain areas will receive more runoff than others, which can quickly overwhelm a buffer's filtering capacity. Because of channelization and pipes, stormwater in urban environments often goes straight from impervious areas to receiving water bodies, passing through pipes and bypassing riparian buffer treatment zones altogether. An urban buffer's ability to treat stormwater depends on how much the flow has become channelized before it enters, and how long it is detained in the buffer. However urban buffers also provide many other unique benefits in an urban setting including reduction of heat island effect, reduced concentrations of air pollutants (Section 3) and increased property values (Section 5).

Drinking Water Source Protection

The Delaware River Basin provides water for roughly five percent of the US population. Most of the drinking water entering the streams in the Basin initially passes through riparian buffers in headwater regions. Headwaters account for approximately 75 percent of the total waterway length in watersheds.[41] Riparian buffers will often be more effective along small or low-order

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[38] http://www.phillywatersheds.org/whats_in_it_for_you/reduce-your-stormwater-fees

[39] Trust for Public Land. 2008. How Much Value Does the City of Philadelphia Receive from its Park and Recreation System?

Trust for Public Land. 2009. How Much Value Does the City of Wilmington Receive from Its Park and Recreation System?

[40] Pennsylvania Department of Environmental Protection. 2012. Erosion and Sediment Pollution Control Program Manual.

Pennsylvania Department of Transportation. 2015. PennDOT Drainage Manual.

[41] Meyer, JL. 2003. Where Rivers Are Born: The Scientific Imperative for Defending Small Streams and Wetlands. Washington (DC): American Rivers, Sierra Club.

streams than larger or high-order streams since most water delivered to channels from uplands enters along low-order streams.

Forested areas (including riparian buffers) decrease costs by reducing the need to clean and filter public drinking water:

- Portland, Oregon avoided purchasing a $200 million filtration treatment system for its water supply by protecting 102 square miles of its watershed. This avoided cost constitutes an economic benefit of just under $3,000 per acre for water filtration services.
- New York City draws half of its drinking water from three reservoirs located in the Catskill Mountains in the headwaters of the Delaware River. By spending $1.5 billion on watershed protections, New York City has avoided spending at least $6 to $8 billion in capital costs for the construction of a water filtration plant, as well as the $300 million it would cost every year to operate that plant.

In both examples, building a treatment plant would not have generated the wide array of ancillary ecosystem services provided by the conservation alternative, such as carbon sequestration, wildlife habitat, and recreational opportunities.

Water quality is also reflected in elevated property prices (Section 5) and increased number and quality of recreational trips (Section 6).

2. Carbon Storage

Riparian areas contribute to climate regulation by storing carbon in biomass (e.g., vegetation and soils). When riparian areas are replaced by other land cover types, such as agriculture or residential development, the stored carbon is released into the atmosphere as greenhouse gases that contribute to climate change.

We collected information on the amount of carbon stored above ground, below ground and in the soil in various kinds of riparian forests as well as alternative land uses, and estimate the net loss in carbon storage that occurs when an acre of streamside forest is developed.[42] To quantify the economic value of carbon sequestration, we use an estimate of the social cost of carbon in the atmosphere ($31 per ton of CO_2 in $2010, or $127 per metric ton of CO_2 equivalent in $2017).[43] The social cost of carbon estimates the present value of the stream of annual costs and

[42] Based on the overall accounting method outlined in the InVEST package (Carbon Storage and Sequestration: Climate Regulation), as well as regional values reported in:

Industrial Economics. 2011. Economic Valuation Of Wetland Ecosystem Services In Delaware. Prepared for the Delaware Department Of Natural Resources And Environmental Control.

Smith, J.E., Heath, L.S. and Hoover, C.M., 2013. Carbon factors and models for forest carbon estimates for the 2005–2011 National Greenhouse Gas Inventories of the United States. *Forest Ecology and Management*, *307*, pp.7-19.

[43] Nordhaus, W.D., 2017. Revisiting the social cost of carbon. *Proceedings of the National Academy of Sciences*, p.201609244. Estimates of the social cost of carbon vary widely, and ours can be considered a conservative value.

damages (e.g., changes in agricultural production, flooding, wildfire, human health, drought etc.) expected to result from the emission of one metric ton of CO_2.

Table 16. Land Use Change and the Value of Lost Carbon Storage Capacity
Sources: ECONorthwest with data from the InVEST package, IeC 2011 and Smith et. al 2013.

Land Use/Land Cover		Carbon Storage (metric tons/acre)			
		Aboveground	Belowground	Soil	Total
Developed		-	-	16	16
Agriculture		4	2	22	28
Rangeland		1	1	30	32
Oak/Hickory		41	6	21	69
Elm/Ash/Cottonwood		31	4	45	81
Maple/Beech/Birch		48	6	28	82
Change in Carbon Storage with Land Cover Change (metric tons/acre)					
Oak/Hickory	To Developed	-41	-6	-6	-53
Elm/Ash/Cottonwood	To Developed	-31	-4	-30	-65
Maple/Beech/Birch	To Developed	-48	-6	-13	-66
Oak/Hickory	To Agriculture	-37	-4	1	-41
Elm/Ash/Cottonwood	To Agriculture	-27	-2	-23	-52
Maple/Beech/Birch	To Agriculture	-44	-4	-6	-54
Oak/Hickory	To Rangeland	-40	-5	8	-37
Elm/Ash/Cottonwood	To Rangeland	-30	-4	-16	-49
Maple/Beech/Birch	To Rangeland	-47	-5	1	-51
Value of Change in Carbon Storage ($/acre)					
Oak/Hickory	To Developed	-$5,258	-$795	-$722	-$6,775
Elm/Ash/Cottonwood	To Developed	-$3,937	-$573	-$3,766	-$8,276
Maple/Beech/Birch	To Developed	-$6,114	-$764	-$1,599	-$8,477
Oak/Hickory	To Agriculture	-$4,742	-$537	$103	-$5,175
Elm/Ash/Cottonwood	To Agriculture	-$3,421	-$315	-$2,941	-$6,676
Maple/Beech/Birch	To Agriculture	-$5,598	-$506	-$774	-$6,878
Oak/Hickory	To Rangeland	-$5,103	-$691	$1,032	-$4,762
Elm/Ash/Cottonwood	To Rangeland	-$3,782	-$470	-$2,012	-$6,264
Maple/Beech/Birch	To Rangeland	-$5,959	-$660	$155	-$6,465

Table 17. Annual and Projected Values of Lost Carbon Storage

		DE	NJ	NY	PA	Basin Total
Net Loss of Natural Land Cover (100-ft buffer, acres/yr)		-9	-53	-13	-92	-167
Low (-$4,762/acre)		-$44,210	-$252,967	-$60,028	-$440,199	-$797,405
High (-$8,477/acre)		-$78,697	-$450,299	-$106,853	-$783,584	-$1,419,432
Total NPV 2018-2028	Low	-$388,436	-$2,222,600	-$527,409	-$3,867,640	-$7,006,084
3% Discount Rate	High	-$691,441	-$3,956,372	-$938,822	-$6,884,650	-$12,471,285
2018-2028 Annualized	Low	-$38,844	-$222,260	-$52,741	-$386,764	-$700,608
	High	-$69,144	-$395,637	-$93,882	-$688,465	-$1,247,128

In contrast to the water quality and air pollution mitigation value, which repeat every year, we value losses in carbon storage as one-time events.

3. Air Quality

Streamside forests improve regional air quality. Forest Service researchers have quantified the capacity of trees to capture air particulates and how this translates into reduced healthcare costs.[44] The economic benefit of trees is highest in urban areas where human populations and the health effects of air pollution are concentrated.

Table 18. Annual and Projected Air Pollution Damages from Riparian Development
Source: ECONorthwest with data from EPA and Nowak et. al. 2004

		DE	NJ	NY	PA	Basin Total
Net Loss of Natural Land Cover (100-ft buffer, acres/yr)		-9	-53	-13	-92	-167
Low Value: Rural ($3 to $7/ac/yr)		-$51	-$276	-$42	-$652	-$1,021
High Value: Urban ($42 to $132/ac/yr)		-$584	-$2,312	-$1,722	-$11,728	-$16,346
Total NPV 2018-2028 (cumulative effect, 3% discount rate)	Low	-$1,371	-$7,843	-$1,861	-$13,648	-$24,723
Total NPV 2018-2028 (cumulative effect, 3% discount rate)	High	-$56,477	-$323,155	-$76,683	-$562,336	-$1,018,651
2018-2028 Annualized	Low	-$137	-$784	-$186	-$1,365	-$2,472
2018-2028 Annualized	High	-$5,648	-$32,316	-$7,668	-$56,234	-$101,865

Similar to water quality effects, we assume that air pollution losses from forest conversion repeat year after year, and build cumulatively. For example, in year one we value the losses associated with 167 acres of riparian forest, and in the second year we value losses from 334 acres.

4. Flood Mitigation

Riparian areas with undeveloped floodplains provide overbank storage for floodwaters and help attenuate large magnitude floods by reducing the height, velocity and destructive power of floodwaters downstream. Trees and other riparian vegetation help slow the speed and power of floodwaters.[45] For example, forest vegetation was shown to lower stream water elevations from 32 feet to 17.3 feet for a 100-year flood.[46] Buffers also ensure that structures are set back a safe distance from the water's edge. Reducing a property's proximity to waterways and floodwaters reduces the potential for flooding and damages.

The costs of floodplain protection and the benefits of avoided damages are realized by different groups. For instance, the costs of flooding are often spread among many downstream property

[44] Nowak, D.J., Hirabayashi, S., Bodine, A. and Greenfield, E., 2014. Tree and forest effects on air quality and human health in the United States. *Environmental Pollution*, *193*, pp.119-129.

[45] U.S. Environmental Protection Agency, 2006. Economic Benefits of Wetlands. EPA843-F-06-004.

[46] Castelle et al. (1994) Wetland and stream buffer size requirements - a review. Journal of Environmental Quality, 23(5): 878-882.

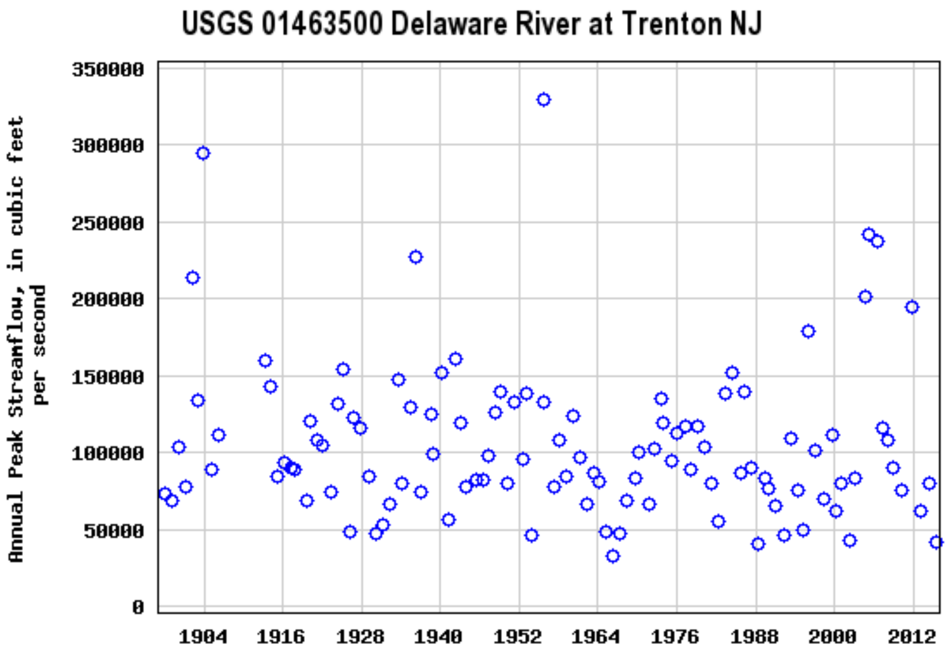
owners and insurance agencies, whereas the opportunity costs of conserving riparian areas must be borne by relatively few upstream landowners and municipalities.[47]

A riparian protection program that prohibits development in both the floodway and the flood fringe preserves natural areas for absorption of flood sized flows and protects structures from flood damage. The potential for flood damages associated with various flood stages has been characterized for many specific communities in the Basin.[48]

Figure 12. Annual flood peaks recorded on the Delaware River at Trenton, N.J., 1898-2015

Source: USGS, https://nwis.waterdata.usgs.gov/nj/nwis/peak/?site_no=01463500&agency_cd=USGS

Note: From September 2004 to June 2006, the Delaware River in New Jersey, New York, and Pennsylvania experienced three major floods that caused extensive damage.



In 2009, the DRBC Flood Advisory Committee recommended that communities *"incorporate the buffer concept as part of a comprehensive floodplain management program to protect communities from flood damage"*, and identified fixed 100-foot buffers and variable width buffers as appropriate policies. The New Jersey Flood Mitigation Task Force and the Association of State Floodplain Managers echoed these recommendations in separate reports.[49]

Flood risk and flood damages are highly site and event-specific. For example, avoided damage depends on the type, value and density of buildings in the floodplain, as well as flood heights.

[47] Watson, K.B., Ricketts, T., Galford, G., Polasky, S. and O'Niel-Dunne, J., 2016. Quantifying flood mitigation services: The economic value of Otter Creek wetlands and floodplains to Middlebury, VT. Ecological Economics, 130, pp.16-24.

[48] Delaware River Basin Commission. No Date. Flood Impacts by Location.

[49] New Jersey Flood Mitigation Task Force, 2006. Report on Delaware River Flood Mitigation.

Association of State Floodplain Managers. 2013. How-To Guide for No Adverse Impact – Infrastructure.

Few studies have addressed the topic of riparian cover and flood damages in a way that might be directly transferrable to and quantifiable in the context of the Delaware River Basin.

Suspended sediment in streams increases the frequency and severity of flooding. We estimate that every acre of riparian buffer lost to development increases flood damages by $0.4 to $1.3 due to sediment effects alone (see Section 1). Based on sediment erosion and deposition locations, under some circumstances this value might be considerably higher.

The largest flood-related benefit of a buffer policy would likely be that of preventing further development in floodplains. Not building in floodplains in the Chicago metropolitan area, for example, was estimated to save an average of $900 per acre per year in flood damages.[50]

Many regions in the Delaware River Basin face repetitive flood loss claims.[51] To help avoid flood damages, the state of Pennsylvania has voluntarily 'bought out' and demolished nearly 1,400 homes and removed 3,500 people from dangerous flood areas since 1996.[52]

Riparian buffers are creditable under the Federal Emergency Management Agency's Community Rating System (CRS).[53] Mitigation activities (like buffer ordinances and other floodplain management activities) can improve a community's rating and earn 5 percent incremental discounts on flood insurance premiums.

A number of other studies document the flood mitigation effects of, and economic justification for, protecting natural floodplains:

- In 1976 the Army Corps of Engineers used an avoided-cost approach to estimate the economic costs and benefits of wetland and floodplain preservation in the Charles River Basin, Massachusetts.[54] The Corps estimated that the loss of 8,442 acres of wetlands within the Charles River system would have resulted in annual flood damages of over $17 million, and chose to purchase and protect the floodplain parcels from development rather than constructing expensive flood control structures. This translates into roughly $2,000 per acre in avoided damages ($8,621 in $2017 dollars).
- A recent study conducted in Vermont reported an annual flood damage reduction of $459,000 from conserving 17,989 acres ($25.50/acre) of woody wetlands and floodplain forests. This is substantially lower than other values reported in the literature, and the

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[50] Johnston, D.M., Braden, J.B. and Price, T.H., 2006. Downstream economic benefits of conservation development. *Journal of water resources planning and management*, *132*(1), pp.35-43.

[51] Delaware River Basin Commission. No Date. Flood Insurance Claims In The Delaware River Basin.

[52] Pennsylvania Emergency Management Agency. *What is Hazard Mitigation*.

[53] FEMA. 2015. Fact Sheet - The Community Rating System 2015 Works to Protect Natural Floodplains.

Delaware Riverkeeper Network. 2015. Appendix A - Sample Riparian Ordinance.

[54] Thibodeau, F.R. and B.D. Ostro. 1981. An Economic Analysis of Wetland Preservation. Journal of Environmental Management, 12:19-30.

authors suggest that this is because the benefits accrue to a relatively small population of downstream beneficiaries.[55]

- A widely applied meta-analysis of wetland studies found that flood attenuation benefits provided by wetlands were between $166 and $3,256 per acre per year, with a mean value of $732 (2017$).[56]
- Allen et al. (2003) concluded that the existence of woody corridors along the Missouri River during a large flood in 1993 prevented and reduced levee damage by almost half. Areas with wider woody corridors had less levee damage, and buffer widths of 300 to 500 feet were the most protective.[57]

5. Property Values

For amenity reasons, landowners tend to prefer forested buffers to barren streambanks.[58] Forested riparian buffers were widely preferred in a photo-based survey of rural and suburban landowners, with 90 percent of suburban landowners preferring forested riparian buffers to non-vegetated corridors.[59] Additionally, in a recent study of nearly 12,000 American adults and children, seven out of 10 children surveyed said they "would rather explore woods and trees than play on neat-looking grass."[60]

A review of academic research papers on the amenity values and resulting property price effects of riparian areas concluded that the presence and quality of riparian buffers can enhance property values by less than 1 percent to upwards of 26 percent.[61] Home prices generally increase with proximity to a stream or buffer zone.

Of particular relevance to the policy context in the Delaware River Basin is a 2009 study by Bin et. al, which examined housing prices after several counties in North Carolina established a mandatory buffer rule. The authors concluded that limiting streamside development and tree removal did not have a significant impact on the value of riparian properties. They suggest that

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55 Watson, K.B., Ricketts, T., Galford, G., Polasky, S. and O'Niel-Dunne, J., 2016. Quantifying flood mitigation services: The economic value of Otter Creek wetlands and floodplains to Middlebury, VT. Ecological Economics, 130, pp.16-24.

56 Woodward, R.T. and Wui, Y.S., 2001. The economic value of wetland services: a meta-analysis. *Ecological economics*, *37*(2), pp.257-270.

57 Allen, S.B., Dwyer, J.P., Wallace, D.C. and Cook, E.A., 2003, Missouri River flood of 1993: role of woody corridor width in levee protection. Journal of the American Water Resource Association, 39(4), pp.923-933.

58 Sullivan, W.C., Anderson, O.M., Lovell, S.T., 2004. Agricultural buffers at the rural-urban fringe: an examination of approval by farmers, residents, and academics in the Midwestern United States. Landscape and Urban Planning. 69, 299–313.

59 Kenwick, R. a., Shammin, M. R., & Sullivan, W. C. 2009. Preferences for riparian buffers. Landscape and Urban Planning, 91, 88–96.

60 Kellert, S. and DJ Case and Associates. 2017. The Nature of Americans National Report: Disconnection and Recommendations for Reconnection.

61 American Rivers. 2016. The Economic Value of Riparian Buffers.

the policy may not have changed how property owners would have used or managed the land in the absence of the rule and/or that the environmental amenities protected by the buffer policy (e.g., visual aesthetics, water quality of adjacent streams, wildlife watching values) raised property values enough to offset any negative impacts.

In practice, it is difficult to isolate the effect of improved aesthetics while avoiding double-counting of benefits -- such as air quality, water quality, and flood control -- that also impact property values. For example:

- Heightened flood risk can lower property values. Qui (2006) found that homes in the FEMA floodplain were worth 4.7 to 5.6 percent less than similar homes outside of the floodplain. Other studies have shown that homes in the floodplain tend to have 4 to 12 percent lower prices.[62]
- Improvements in water quality often elevate housing prices. A study conducted by the EPA found that clean water can increase the value of single family homes within 4,000 feet of the water's edge by up to 25 percent.[63] The City of Philadelphia estimates that installation of green stormwater infrastructure in the city will raise property values two to five percent, generating $390 million over the next 40 years in increased values for homes near green spaces.[64]

6. Fish and Wildlife Habitat

Riparian corridors are some of the most diverse, dynamic and complex habitats on Earth.[65]

- As part of the Atlantic flyway, the riparian habitats of the Delaware River Basin are used by hundreds of resident and migratory bird species for feeding, nesting, and/or breeding. Bird abundances in floodplain forests can be twice as high as upland forests.
- Recreationally and commercially important fish species like trout, shad, herring, alewife, and striped bass use forested streams and rivers to spawn.[66]
- Riparian areas are especially important to amphibians and reptiles due to the fact that their lifecycle requires access to water.

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[62] Qiu, Z., Prato, T. and Boehrn, G., 2006. Economic Valuation of Riparian Buffer and Open Space in a Suburban Watershed. *JAWRA Journal of the American Water Resources Association*, *42*(6), pp.1583-1596.

[63] U.S. Environmental Protection Agency. 1973. Benefit of Water Pollution Control on Property Values. EPA-600/5-73-005.

[64] Philadelphia Water Department. 2009. Green City, Clean Waters: The City of Philadelphia's Program for Combined Sewer Overflow Control—A Long Term Control Plan Update. Summary Report.

[65] Naiman, R.J., Decamps, H. and Pollock, M., 1993. The role of riparian corridors in maintaining regional biodiversity. *Ecological applications*, *3*(2), pp.209-212.

[66] CBP (Chesapeake Bay Program), 1997. Riparian Forest Buffer Panel Report: Technical Support Document. (CBP/TRS 167/97)(EPA903-R-97-007)

Table 19 shows the preferred buffer widths for various wildlife species. Wildlife habitat needs in general greatly exceed the 100-foot area protected by buffer policies.

Table 19. Buffer Widths Required by Various Wildlife Species

Source: Ellis, J.H. 2008. Scientific Recommendations on the Size of Stream Vegetated Buffers Needed to Protect Wildlife and Wildlife Habitat, Part Three, The Need for Stream Vegetated Buffers: What Does the Science Say? Report to Montana Department of Environmental Quality, EPA/DEQ Wetland Development Grant. Montana Audubon, Helena, MT.

Species	Desired Buffer Width (feet)
Great Blue Heron nest	820–985
Cavity nesting ducks	600
Bald Eagle nests	400–1,320
Pileated Woodpecker, fisher, mink	330–600
Large mammals, bobcat, red fox, otter, muskrat, dabbling ducks	330
Wood Duck	250–600
Osprey, pine marten	200–330
Amphibians and reptiles, Belted Kingfisher, beaver	100–330
Small mammals	40–300
Hairy Woodpecker	130
Deer, Ring-necked Pheasant	75
Mourning Dove, Downy Woodpecker	50
Songbirds	50–660
American Redstart, Spotted Towhee	660
Warbling Vireo	300
Brown Creeper, Ruby-crowned Kinglet, Swainson's Thrush	200
Red-eyed Vireo, Brown Thrasher	130
Black-capped Chickadee, White-breasted Nuthatch	50
Cold water fisheries	**100-300**

Riparian Forest Cover and Aquatic Habitat Health

A stream's ability to provide ecosystem services depends on the quality and quantity of surrounding tree cover. Studies evaluating the effectiveness of forested riparian buffers suggest that where natural riparian habitats are protected, fish diversity can be maintained with up to 15 percent impervious cover in the watershed, and aquatic insect diversity can be maintained with as much as 30 percent impervious cover.[67]

In 2001, the State Legislature of Georgia reduced the minimum width of mandatory-forested riparian buffers along designated trout streams from 100 feet to 50 feet. Researchers examined the importance of forested buffers to trout populations in the Appalachian Mountains in Georgia. They concluded that streams with 50-foot wide buffers had higher temperatures than

[67] Schueler, T. R. 2003. Impacts of impervious cover on aquatic systems. Center for Watershed Protection, Ellicott, MD, Monograph No. 1 , 140p.

those with 100-foot wide buffers, with a predicted 66 to 97 percent reduction in trout reproductive success in streams with narrower buffers.[68]

Another study examining the influence of riparian buffers and impervious cover on stream health rankings found that watersheds with the best overall stream conditions had, on average, greater than 65 percent tree cover within the 100-foot riparian buffer zone and less than six percent impervious cover distributed throughout the watershed (Table 20). The other rankings ('good', 'fair', 'poor') had progressively lower levels of riparian tree cover and greater impervious cover.[69]

Table 20. Stream Health Rankings and Forested Buffers
Source: Goetz et. al. 2003

Stream Health Ranking	Forested Buffer	Impervious Cover in Local Catchment
Excellent	76.8%	3.6%
Good	71.3%	4.9%
Fair	63.2%	13.9%
Poor	56.3%	19.5%

Habitat Connectivity

Riparian vegetation along river channels functions as a primary regional migration corridor for most wildlife species. Woody vegetation must be present for many terrestrial species to find needed cover while traveling across otherwise open areas.[70]

Fragmentation results in the loss of wildlife habitat and movement corridors, which in turn results in wildlife decline and extirpation. Habitats that become isolated islands surrounded by development lose much of their ecological value even though the habitat may not be directly

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[68] Jones. K.L., G.C. Poole, J.L. Meyer, W. Bumback and E.A. Kramer. 2006. Quantifying expected ecological response to natural resource legislation: a case study of riparian buffers, aquatic habitat and trout populations. Ecology and Society 11(2):15

[69] Goetz, S.J., Wright, R.K., Smith, A.J., Zinecker, E. and Schaub, E., 2003. IKONOS imagery for resource management: Tree cover, impervious surfaces, and riparian buffer analyses in the mid-Atlantic region. *Remote sensing of environment*, *88*(1), pp.195-208.

Goetz, S.J., 2006. Remote sensing of riparian buffers: past progress and future prospects. *JAWRA Journal of the American Water Resources Association*, *42*(1), pp.133-143.

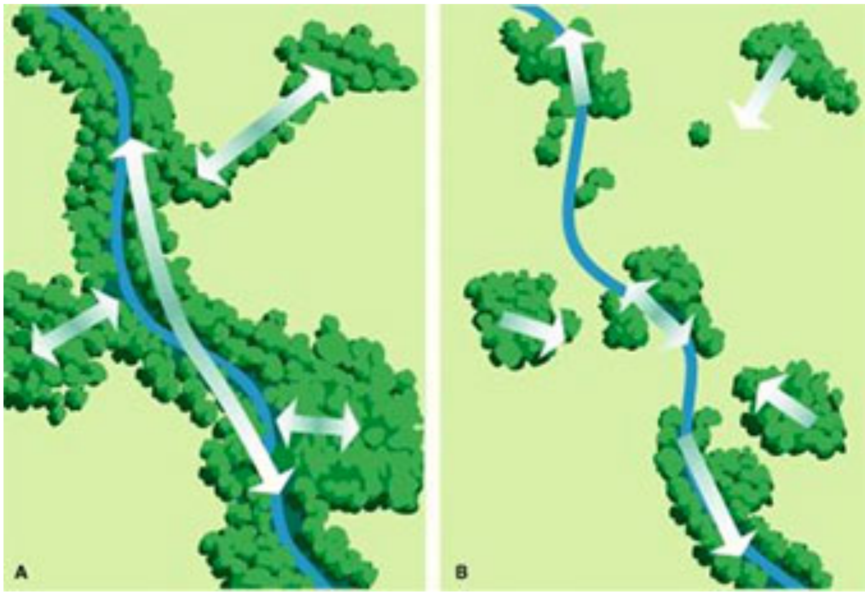
Snyder, M.N., Goetz, S.J. and Wright, R.K., 2005. Stream health rankings predicted by satellite derived land cover metrics. *JAWRA Journal of the American Water Resources Association*, *41*(3), pp.659-677.

[70] USDA NRCS. 1996. Riparian Areas Reservoirs of Diversity.

affected (Figure 13).[71] Researchers have suggested a nation-wide network of wildlife corridors along rivers to facilitate wildlife migration and enable adaptation to climate change.[72]

Figure 13. Movement Corridors and Habitat Connection

Source: http://conservationcorridor.org/wp-content/uploads/riparian_diagram.jpg



Increased riparian habitat can also benefit commercial operations by protecting wildlife populations. In addition to sediment-related benefits for marine fisheries (see Section 1), other examples include:

- **Pollination by native pollinators:** The Nature Conservancy estimates that protecting and restoring habitat for native pollinators can boost agricultural earnings on New Jersey tomatoes farms by $30 to $222 per acre.[73]
- **Pest control by forest birds:** birds control many insect pest species. The cost to replace the biological control provided by forest birds with pesticides or genetic engineering has been estimated to be at least $7.34 per acre.[74]

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[71] Newcomb et. al.. 2002. Surface Water and Riparian Areas of the Raritan River Basin - A Technical Report for the Raritan Basin Watershed Management Project.

[72] Fremier, A.K., Kiparsky, M., Gmur, S., Aycrigg, J., Craig, R.K., Svancara, L.K., Goble, D.D., Cosens, B., Davis, F.W. and Scott, J.M., 2015. A riparian conservation network for ecological resilience. *Biological Conservation*, *191*, pp.29-37.

[73] The Nature Conservancy. No Date. Analysis of Native Pollinator Benefits to New Jersey Farms.

[74] Moskowitz, K. and Talberth, J., 1998. The economic case against logging our national forests. *Santa Fe, New Mexico: Forest Guardians*.

Existence Values

About half of the animal species of concern in the Mid-Atlantic Region are dependent on wetlands, streams, rivers, and riparian areas.[75] Riparian protection and restoration efforts could improve conditions for federally-listed endangered species such as the Atlantic sturgeon, as well as more common species such as blueback herring and alewife that have experienced widespread declines from historical levels. Economic research on passive-use values suggests particularly high value for rare species.

7. Recreation

Loss of riparian forest can affect both land and water-based recreational opportunities. For example, development can reduce the total area of forest available for certain types of recreational activities, or it can reduce enjoyment by altering the visual appeal of streamside recreation areas. In a study of nearly 12,000 American adults and children, seven out of 10 children surveyed said they "would rather explore woods and trees than play on neat-looking grass."[76] The quantity and quality of riparian habitats also strongly influences the availability of wildlife populations that in turn support a variety of recreational activities. Insofar as riparian buffers provide habitat and improve wildlife populations, the quality of hunting, fishing, wildlife viewing, nature photography, and other wildlife-dependent activities will be improved. Riparian corridors can provide important opportunities for trail development along waterways, maintaining public access.

Recreational effects can be measured in a variety of ways, including number of trips taken, consumer spending on travel and equipment, as well as 'consumer surplus', which refers to a person's enjoyment of a recreation activity above and beyond what they actually pay for it. Economists at the USDA Economic Research Service have developed models to describe the recreation benefits of the U.S. Department of Agriculture's Conservation Reserve Enhancement Program (CREP).[77] This program pays private landowners to retire agricultural lands from production and convert them to forests and grasslands, with a particular emphasis on planting in riparian areas. Based on nation-wide recreation participation data and information about regional land cover, the models estimate the gain in recreational use and consumer surplus that occurs when an acre of land is converted from cropland to natural cover. This is essentially the process of buffer loss and development in reverse and therefore represents an appropriate and useful set of values to assess incremental changes in recreation due to land use change.

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[75] Brooks, R.P. and Serfass, T.L., 2013. Wetland-Riparian Wildlife of the Mid-Atlantic Region: An Overview. In *Mid-Atlantic Freshwater Wetlands: Advances in Wetlands Science, Management, Policy, and Practice* (pp. 259-268). Springer New York.

[76] Kellert, S. and DJ Case and Associates. 2017. The Nature of Americans National Report: Disconnection and Recommendations for Reconnection.

[77] Feather, P., Hellerstein, D. and Hansen, L., 1999. Economic valuation of environmental benefits and the targeting of conservation programs: the case of the CRP. USDA Economic Research Service. Agricultural Economic Report No. 778.

Table 21 shows per-acre consumer surplus values for various recreational activities in the Northeastern region. Every acre of natural riparian land converted to alternative uses results in a loss of $62.8 in recreational use and enjoyment, on average. This loss in use and enjoyment could be due to a number of factors including lower recreation participation, less access, or reduced wildlife populations that reduce the quality of hunting and viewing.

Table 21. Value of Private Lands for Recreation

Source: ECONorthwest with data from Feather and Hansen 1999 and Hansen and Ribaudo 2008

Note: the per-acre estimate for marine recreational fishing is transferred from sediment related impacts described in Section 1.

Recreation Type	Value (consumer surplus/ac/yr)
Wildlife viewing	$49.0
Pheasant hunting	$8.6
Freshwater recreation	$3.4
Marine recreational fishing	$1.7
Total	**$62.8**

Cumulative losses amount to approximately $48.5 thousand per year, summing to a projected $485 thousand over the course of the next ten years (Table 22).

Table 22. Annual and Projected Recreation Losses Associated with Riparian Development

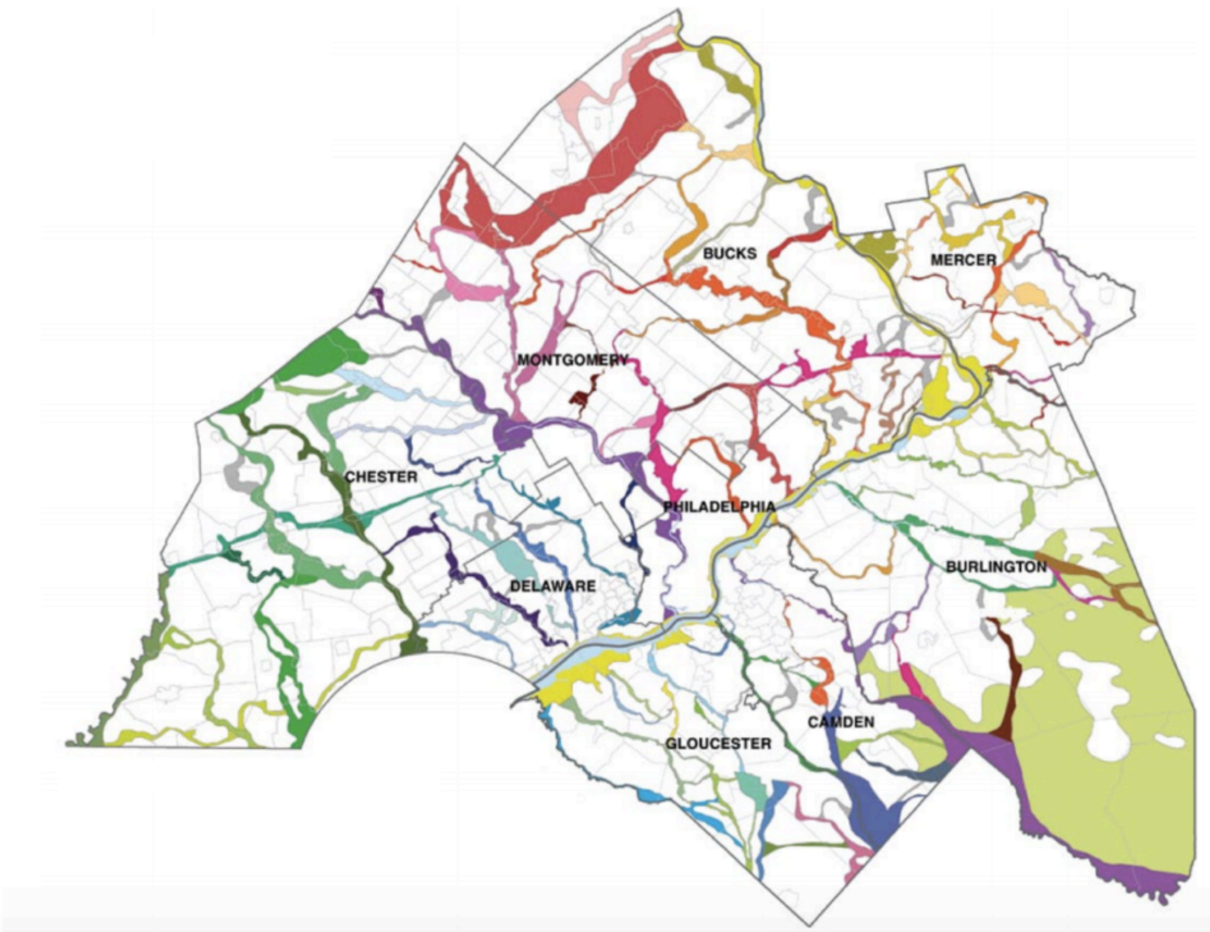
	DE	NJ	NY	PA	Basin Total
Annual Net Loss of Natural Land Cover (100-ft buffer, acres/yr)	-9	-53	-13	-92	-167
Annual Loss in Consumer Surplus ($63/acre)	-$583	-$3,334	-$791	-$5,802	-$10,509
Total NPV 2018-2028	-$26,910	-$153,975	-$36,537	-$267,938	-$485,359
2018-2028 Annualized	-$2,691	-$15,397	-$3,654	-$26,794	-$48,536

A study in Philadelphia estimated that restoring riparian vegetation and developing streamside parks would increase recreational trips by almost 350 million over 40 years, translating to roughly $950/ac/year in additional consumer surplus (2009$).[78] Riparian corridors are an important part of Philadelphia's GreenPlan, regional riverfront access initiatives, and other planning efforts.[79] For example, in 2009 the Delaware Valley Regional Planning Commission (DVRPC) developed an open space plan which links the region's watersheds and parks to a two-state, nine-county network of streams, trails, and greenways (Figure 14).

[78] The Conservation Fund. 2014. Ecosystem Services Literature Review. Prepared for the Chicago Metropolitan Agency for Planning.

[79] Wallace Roberts & Todd. 2010. GreenPlan Philadelphia.

Figure 14. Planned Network of Streams, Trails, and Greenway Connections in the Delaware Valley
Source: Delaware Valley Regional Planning Commission and GreenPlan Philadelphia



Other studies demonstrate the close link between water quality, habitat restoration, and spending on outdoor recreation. For example:

- In the central Appalachian region, restoring streams to support fish could generate an additional $239 million in freshwater fishing expenditures across the region.[80]
- Research has demonstrated that, for every extra meter of visibility in a lake, recreationists are willing to travel 56 minutes farther (equivalent to US$22 in travel costs).[81]

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[80] Jackson, L.E., Rashleigh, B. and McDonald, M.E., 2012. Economic value of stream degradation across the central Appalachians. *Journal of Regional Analysis & Policy*, *42*(3), p.188.

[81] Keeler, B.L., Wood, S.A., Polasky, S., Kling, C., Filstrup, C.T. and Downing, J.A., 2015. Recreational demand for clean water: evidence from geotagged photographs by visitors to lakes. *Frontiers in Ecology and the Environment*, *13*(2), pp.76-81.

- The improvements in water quality achieved in the Chesapeake Bay by 1996 alone increased the value of recreational use (beach use, boating, and striped bass sport fishing) by $357.9 million to $1.8 billion (1996$).[82]

Collectively, riparian buffers improve conditions for outdoor recreation on-site and elsewhere in the watershed. Outdoor recreation importance to quality of life, public health, and general regional attractiveness to businesses and skilled workers make it an important contributor to regional economy stability and growth.

B. Aggregate Value of Riparian Buffer Services

People appreciate and value riparian buffers directly and with recognition of the collective suite of amenity and ecological services they provide. Johnston et al. (2015) published a valuation study estimating Maine residents' Willingness to Pay (WTP) for protecting and restoring riparian habitat (Table 23).[83] Based on a general population survey of three towns in south coastal Maine, the authors estimated that households in the study watershed were willing to pay an average of $0.140/year/additional foot of riparian development setbacks (the survey question specifically asked about WTP to increase the currently protected buffer area of 100 feet to 200 feet).

[82] Morgan, C. and Owens, N., 2001. Benefits of water quality policies: the Chesapeake Bay. Ecological Economics, 39(2), pp.271-284.

[83] Johnston, R.J., C. Feurt and B. Holland. 2015. Ecosystem Services and Riparian Land Management in the Merriland, Branch Brook and Little River Watershed: Quantifying Values and Tradeoffs. George Perkins Marsh Institute, Clark University, Worcester, MA and the Wells National Estuarine Research Reserve, Wells, ME.

These annual household values are supported by a previous study that examined New York residents' willingness to pay for different types of coastal habitat restoration in the Peconic Estuary system: Johnston, R.J., Grigalunas, T.A., Opaluch, J.J., Mazzotta, M. and Diamantedes, J., 2002. Valuing estuarine resource services using economic and ecological models: the Peconic Estuary System study. Coastal Management, 30(1), pp.47-65.

Table 23. Representative Household WTP (Willingness to Pay) for Riparian Protection Measures and Benefits
Source: Johnston et al. 2015

Outcome	Description of Outcome *(All effects are within the MBLR Watershed)*	Value per Household, per Year *(Additional taxes/fees that each household would be willing to pay, per year)*
Riparian Land Condition	The number of riparian acres with natural vegetation.	**$0.044** per additional acre with natural vegetation.
River Condition	The average ecological condition of area rivers, measured using a 100-point aquatic biotic index.	**$1.280** per point increase in the biotic index
Recreational Fish	The average number of brook trout per 1000 square feet of river.	**$3.833** per additional fish, per 1000 square feet of river
Swim Safety	The percentage of days during which government tests show that area beaches (Laudholm, Drakes Island, Crescent Surf and Parson) are safe for swimming.	**$2.020** per percentage point increase in safe swimming days
Setbacks	The minimum width of the riparian area where development is restricted, in feet.	**$0.140** per foot of **increased** development setbacks.
Enforcement	Whether enforcement is increased to prevent illegal development or clearing on riparian land.	**$17.310** for increased enforcement and inspections, compared to the status quo

Table 24. Estimated Household Values for Increased Riparian Protection
Source: U.S. Census 2010; Johnston et. al. 2015

State	Number of Households in Basin (2010)	Total Annual WTP for 100-foot Development Setback
Delaware	330,944	$4,633,215
New Jersey	1,070,859	$14,992,027
New York	48,585	$680,184
Pennsylvania	2,188,921	$30,644,894
Delaware River Basin	**3,639,309**	**$50,950,320**

We can apply these values to the Delaware River Basin in multiple ways. Using 2010 Census data on the number of people living in the Basin, we estimate the number of households by dividing the population by average family size (2.5). A 100-foot development setback program (or an increase to 200 feet in states that already have 100 foot buffers, for example) would be worth $14 to households every year, summing to nearly $51 million every year across the Basin.

These per household values align well with those reported elsewhere in the literature. For example, Holmes et al. (2004) report that annual household WTP for a riparian restoration program in North Carolina ranged from $0.95 – $74, depending on the spatial scale of restoration.[84] Similarly, a meta-analysis examining household willingness to pay to protect farmland from development found that mean annual household WTP per acre ranges from

[84] Holmes, T.P., Bergstrom, J.C., Huszar, E., Kask, S.B. and Orr, F., 2004. Contingent valuation, net marginal benefits, and the scale of riparian ecosystem restoration. *Ecological Economics*, *49*(1), pp.19-30.

$0.0001 in Colorado and Wyoming to $21.90 in Massachusetts, with an average across all studies of $1.80.[85]

Summary of Riparian Ecosystem Services in the Delaware River Basin

In summary, riparian buffers in the Delaware River Basin provide tens of thousands of dollars in benefits per acre annually, with evidence that additional non-monetized benefits would substantially increase these totals (Table 25). Furthermore, households and homeowners benefit from riparian buffers in multiple ways, including aesthetics, recreation access and quality, and appreciation for habitat and wildlife. With greater population density, more potential beneficiaries also increase the total economic value provided per segment of riparian buffer.

Table 25. Summary of Ecosystem Services Values by Riparian Buffers in the Delaware River Basin
Source: ECONorthwest with data from a number of sources (see report)

Ecosystem Service Provided	Per-unit Value for Services
Nutrient Retention	$87 to $4,789 per acre per year
Carbon Storage	$4,762 to $8,477 per acre per year
Air Quality	$3 to $132 per acre per year
Aesthetic Values	+1% to +26% Property Price Premium
Flood Mitigation	Qualitative Description
Recreation	$63 per acre per year (lower bound)
Wildlife Habitat	Qualitative Description
Combined Buffer Services	$14/Household/Year

Extrapolating the rate of riparian land development observed in the Delaware River Basin between 2001 and 2011, and applying ecosystem service values monetized at a per acre scale, the net present value of future losses will be in the tens of millions of dollars (Table 26). Looking at only the narrower of the two buffer widths considered (100 foot width) the discounted benefit over the next ten years of avoiding additional loss of riparian buffer would likely be worth greater than $25 million.

[85] Bergstrom, J.C. and Ready, R.C., 2009. What have we learned from over 20 years of farmland amenity valuation research in North America?. *Applied Economic Perspectives and Policy*, *31*(1), pp.21-49.

Table 26. Summary of Projected Ecosystem Service Losses, by State, 2018-2028

Source: ECONorthwest with data from a number of sources (see report)

Note: Net Present Value calculations apply a 3 percent discount rate.

Water pollution refers only to nitrogen and phosphorus effects, and does not include sediment benefits; see Table 9, Section 1.

Carbon storage effects are detailed in Table 17, Section 2

Air pollution effects are detailed in Table 18, Section 3

Recreation effects are detailed in Table 22, Section 7.

State		Delaware	New Jersey	New York	Pennsylvania	Basin Total
Net Loss of Natural Land Cover	Annual	-9	-53	-13	-92	-167
(100-ft buffer, acres)	Decadal	-93	-531	-126	-924	-1,674
NPV 2018-2028						
Water Pollution Removal	Low	-$388,436	-$2,222,600	-$527,409	-$3,867,640	-$7,006,084
	High	-$691,441	-$3,956,372	-$938,822	-$6,884,650	-$12,471,285
Carbon Storage	Low	-$126,992	-$726,636	-$172,426	-$1,264,450	-$2,290,503
	High	-$602,932	-$3,449,930	-$818,646	-$6,003,368	-$10,874,876
Air Pollutant Removal	Low	-$1,371	-$7,843	-$1,861	-$13,648	-$24,723
	High	-$56,477	-$323,155	-$76,683	-$562,336	-$1,018,651
Outdoor Recreation	-	-$26,910	-$153,975	-$36,537	-$267,938	-$485,359
Total Quantified Services	**Low**	**-$543,708**	**-$3,111,053**	**-$738,233**	**-$5,413,675**	**-$9,806,669**
	High	**-$1,377,759**	**-$7,883,432**	**-$1,870,688**	**-$13,718,293**	**-$24,850,172**
Annualized Value						
Water Pollution Removal	Low	-$38,844	-$222,260	-$52,741	-$386,764	-$700,608
	High	-$69,144	-$395,637	-$93,882	-$688,465	-$1,247,128
Carbon Storage	Low	-$12,699	-$72,664	-$17,243	-$126,445	-$229,050
	High	-$60,293	-$344,993	-$81,865	-$600,337	-$1,087,488
Air Pollutant Removal	Low	-$137	-$784	-$186	-$1,365	-$2,472
	High	-$5,648	-$32,316	-$7,668	-$56,234	-$101,865
Outdoor Recreation	-	-$2,691	-$15,397	-$3,654	-$26,794	-$48,536
Total Quantified Services	**Low**	**-$54,371**	**-$311,105**	**-$73,823**	**-$541,368**	**-$980,667**
	High	**-$137,776**	**-$788,343**	**-$187,069**	**-$1,371,829**	**-$2,485,017**

Implementing Protection and Restoration of Riparian Areas

Providing these economic benefits of riparian buffers is not a particularly costly endeavor. Per-acre, agricultural land costs $8,400 in Delaware, $12,800 in New Jersey, $2,980 in New York, and $5,500 in Pennsylvania.[86] The price of an easement is generally 60 to 80 percent of the land price.[87] These prices suggest that the one-time burden of riparian buffer costs in areas not yet urbanized would generally be less than the annual benefit. Prices in urban and suburban areas are much higher. For example, in 2016 urban land in Philadelphia cost $52,187 per acre.[88] Retrofitting riparian buffers back into urbanized areas can be particularly costly. These figures establish a clear urgency for protecting the Basin's remaining riparian forests. See the Appendix Maps for more information on this issue.

Protection vs. Restoration

Buffer rules offer the opportunity to keep existing riparian forests in place. Protecting forests will protect water bodies from further declines and could avert much larger costs to fix the Basin's impaired habitats and waters in the future. Restoration is much more expensive than protection. In work we have completed in the Puget Sound Basin reviewing habitat restoration and conservation projects, restoration projects tended to cost at least ten times more than equivalent conservation projects.[89]

Furthermore, restoration can be challenging, and success rates are well below 100 percent. A review of wetland mitigation projects in Washington State found less than a 50 percent success rate.[90] Programs based on restoration have often had a difficult time meeting restoration goals.[91] For example, the Chesapeake Bay program has consistently failed to meet planting objectives: *"A goal of 900 miles/year was a goal first set by the states in 2007. Since that time, this goal has never been reached. … Average annual mileage [*between 2012 and 2014*] was 220 miles. In a 10-year period, from 2001-2010, average annual mileage was 650 miles."*[92] The report cites a variety of barriers that have slowed progress.

[86] USDA National Agricultural Statistics Service. 2016. Land Values 2016 Summary.

[87] New Jersey Transfer of Development Rights Program. 1999. Appraisal Guidelines For Determining Development Potential.

[88] Lincoln Institute of Land Policy. 2016. Land and Property Values in the U.S. - Land Prices for 46 Metro Areas.

[89] See, for example ECONorthwest. 2008. Puget Sound Partnership Action Agenda: Financing Strategy Task 1: Cost Analysis.

[90] Washington State Department of Ecology. 2000. Washington State Wetland Mitigation Evaluation Study.

[91] Chesapeake Bay Program. Track the Progress – Planting Forest Buffers. Online at: http://www.chesapeakebay.net/indicators/indicator/planting_forest_buffers

[92] Chesapeake Bay Program. 2015. Riparian Forest Buffer Outcome Management Strategy 2015–2025, v.1

Restoration not only costs more than protection, but also provides lower service levels during recovery. For example, when planted, a riparian forest buffer composed of saplings will not be very effective in reducing nutrient runoff, but its effectiveness will increase as the trees mature. A recent study of riparian buffer age and its effects on stream aquatic function supports the idea that restoration may require significantly longer time periods to display restored ecological functions and values. Orzetti et. al. (2010):

> "*…collected data on water quality, habitat, and macroinvertebrates from 30 Piedmont streams with buffers ranging from zero to greater than 50 years of age in the Chesapeake Bay watershed. Overall, buffer age was positively related to improved stream habitat, water quality, and a suite of macroinvertebrate metrics. The data collected showed marked improvements occurring within 5–10 years postrestoration, with conditions approaching those of streams with long established buffers within 10–15 years postrestoration*".[93]

Urbanization

Riparian buffers are "*uniquely capable of producing high levels of multiple ecosystem services in otherwise nonforested landscapes*".[94] For example, in a model assessing the impacts of urbanization on Chesapeake Bay water quality between 2000 and 2030, researchers demonstrated that, if implemented throughout the Basin, riparian buffers could reduce overall nitrogen and phosphorus loads even as urban point sources increase.[95]

Federal and state policies have traditionally prioritized agricultural properties for technical and financial support and participation in incentivized riparian buffer programs, such as the U.S. Department of Agriculture's Conservation Reserve Enhancement Program (CREP). In contrast, part-time farmers (and/or amenity owners) and residential landowners have received much less programmatic attention (information and incentives) for buffer implementation. Based on the increase in urban cover in the riparian zone and the decline in forest and agricultural cover throughout the Basin, federal and state policy might shift from its present agricultural emphasis to better address residential riparian conditions and loss. Urbanization is projected to increase throughout the Basin in the coming decades (Figure 15).

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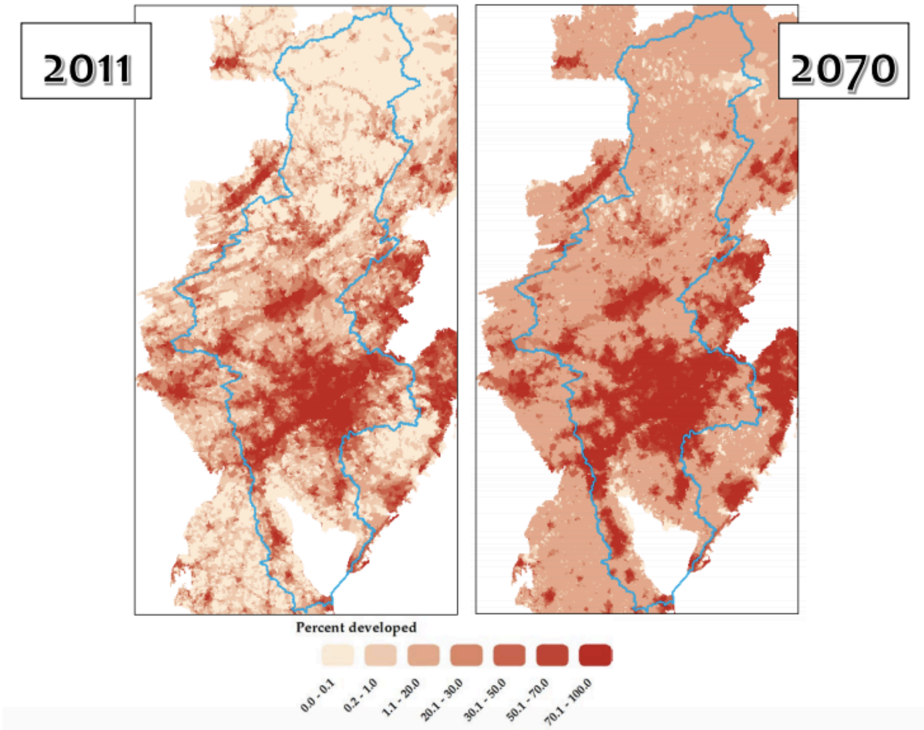
[93] Orzetti LL, Jones RC, Murphy RF (2010) Stream condition in Piedmont streams with restored riparian buffers in the Chesapeake Bay watershed. J Am Water Resour Assoc 46:473–485

[94] Stanturf, J., Lamb, D. and Madsen, P. eds., 2012. *Forest landscape restoration: Integrating natural and social sciences* (Vol. 15). Springer Science & Business Media.

[95] Roberts, A.D., and S.D. Prince. (2010). Effects of urban and non-urban land cover on nitrogen and phosphorus runoff to Chesapeake Bay. Ecological Indicators 10: 459-474

Figure 15. Urban Development Projections, 2011-2070
Source: The Delaware River Basin Project, Presentation by Dr. Jantz, Shippensburg University



Researchers studying riparian buffer implementation in urban environments observed "that residential landowners without buffers often were not familiar with riparian functions or conservation organizations; nor did they find the practices promoted by buffer programs applicable for their backyards".[96] They concluded that:

> *"Residential riparian landowners are dramatically less willing to implement buffers on their property than agricultural landowners … In the eyes of residential riparian landowners, the current size and demands of buffers are not acceptable; however, neighborhood cohesion may play an encouraging or discouraging role depending on the prevailing normative standards. As buffers become more common on residential properties, potentially through experimentation and education that emphasizes local outcomes, backyard buffers may more effectively adhere to aesthetic and property management norms"*[97]

Social Barriers and Constituencies

The Technical Advisory Committee for Pennsylvania's Riparian Buffer Initiative Implementation Plan issued a comprehensive report based on the input of more than 100

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[96] Armstrong, A. and Stedman, R.C., 2012. Landowner willingness to implement riparian buffers in a transitioning watershed. *Landscape and Urban Planning*, *105*(3), pp.211-220.

[97] Armstrong, A. and Stedman, R.C., 2012. Riparian landowner efficacy in an urbanizing watershed. *Society & Natural Resources*, *25*(11), pp.1193-1203.

individuals and representatives of Pennsylvania groups that represented a range of interests in the Chesapeake Bay watershed.[98] The report identified six categories of barriers to riparian forest buffers in Pennsylvania:[99]

- **Economic barriers** include the need for farmers to maximize production, the fact that smaller farms may suffer more than larger farms from loss of riparian land from production, and the costs of planting and maintenance.
- **Education and awareness**: fear of government control, failure to consider buffers in site designs, and failure to understand the need for or function of buffers.
- **Marketing**: landowners may not know where to go for help.
- **Policy, planning and legislative** barriers: engineered flood control projects do not take buffers into account; transportation, utility, and other corridors are often located along streams; landowners lack incentives, and; Pennsylvania has no driving legislation.
- **Physical, chemical, or biological barriers**: Lack of space in urban areas and the use of streamside lands for active recreation.
- **Attitudes**: landowners think that buffers harbor invasive plants or undesirable wildlife; a desire for access to streams; the value of tidiness; the importance of traditional appearances and habits; lack time to establish or manage riparian forests; interference with viewsheds; and landowner-rights issues.

Based on landowner surveys, Dutcher et. al. (2004) report that these barriers must be addressed in order for successful policy implementation:

> *"An effective approach to conserving and maintaining riparian forests needs to emphasize the role of riparian forests, respect concerns and dignity of individual landowners, and use credible advisors who understand landowner needs. Initially, it might be more effective for planners and policy makers to encourage riparian landowners to develop and execute personal management plans that incorporate landowner interests than to expect landowners to buy into abstract, arbitrary goals for buffer widths and stream reaches. … To be successful, any effort to create and maintain riparian forests on private lands should address landowner concerns about flooding, the reluctance of many landowners to abandon the ordered landscapes to which they are accustomed, and the economic interests of farmers. Centrally administered, coercive regulations will not be well received, although a broad, flexible regulatory framework that accounts for the interests of individual landowners may be acceptable once*

[98] Dutcher, D.D., Finley, J.C., Luloff, A.E. and Johnson, J., 2004. Landowner perceptions of protecting and establishing riparian forests: a qualitative analysis. *Society and Natural Resources*, *17*(4), pp.319-332.

[99] Pennsylvania Department of Environmental Protection. 1998. *Pennsylvania Riparian Buffer Initiative Implementation Plan, Report of the Technical Advisory Committees, Final Draft.*

more democratic approaches have been tried and landowners have learned more about the importance of streamside reforestation".[100]

Residential and commercial landowners are more likely to approve of riparian buffers when their ecosystem services are recognized.[101] Similarly, agricultural landowners are more likely to support riparian conservation if they believe that these areas are important for the community.[102]

Constituencies that will benefit from protecting riparian areas include angling and boating groups, hunters, outdoor recreationists, commercial fishermen, public water utilities, dam operators, tourism bureaus, businesses needing clean water, and local landowners. Buffer management policies must be designed to address the concerns of groups who may perceive losses, including agriculture, industry, residential owners, utilities, realtors, homebuilders, and landowner associations.

In a paper reviewing the implications of climate change and other large-scale trends in the Basin, researchers at the Pinchot Institute highlighted the importance of buffers and the role of local governments:

> *"In considering the findings of the risk assessments, analysis and prioritization, it is clear that risks to the region could be reduced significantly through implementing land use policies that maintain existing forest cover, reduce forest fragmentation, maintain impervious cover at reasonable levels (e.g., < 10 percent), and take full advantage of the ecosystem services provided by floodplains and riparian corridors. Local governments have primary responsibility for the land use decisions that can ultimately make communities less vulnerable and more economically resilient to environmental changes. Although it is a challenge to coordinate land use policy in a region that includes three states, seven counties and hundreds of municipalities, it has great potential for far-reaching climate resiliency benefits"*[103]

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[100] Dutcher, D.D., Finley, J.C., Luloff, A.E. and Johnson, J., 2004. Landowner perceptions of protecting and establishing riparian forests: a qualitative analysis. *Society and Natural Resources*, *17*(4), pp.319-332.

[101] Wagner, M.M., 2008. Acceptance by knowing? The social context of urban riparian buffers as a stormwater best management practice. *Society and Natural Resources*, *21*(10), pp.908-920.

[102] Schrader C (1995) Rural greenway planning: the role of streamland perception in landowner acceptance of land management strategies. Landsc Urban Plan 33:375–390

[103] Price, W. and Beecher, S., 2014. Climate change effects on forests, water resources, and communities of the Delaware River Basin.

Table 27. Distribution of Benefits and Costs from Buffer Policies

Source: Huron River Watershed Council[104]

Entity	Costs	Benefits
Local Governments	Staff time Staff Training Technical Assistance to Developers and landowners Public education efforts	Increased property values Reduced water treatment costs Stormwater management Reductions in flood damage Habitat preservation and increased wildlife populations
Developers and Property Owners	Technical surveys and reports Buffer delineation Loss of developable land Buffer restoration Buffer protection during construction	Increased property values Stormwater management Bank stabilization and erosion control Increased diversity of wildlife Recreation opportunites Potential economic uses of buffer (e.g., logging)

Programs must be designed carefully to avoid unintended consequences that work against the objectives of riparian buffer protection efforts. For example, farmers and other landowners might preemptively reduce riparian areas in natural vegetation on their property with potential limits under consideration. The North Carolina Environmental Management Commission introduced North Carolina's buffer rule as an immediate rule in July 1997 to minimize such activity.

In conclusion, efforts to protect existing riparian buffers can provide benefits well in excess of the costs associated with protecting such remaining areas. And policy should be designed and implemented with expediency as a primary objective.

Policy Implications

The key findings relevant to policy from this study are:

1. Benefits of well-functioning riparian buffers in the Delaware River Basin are high in economic value, particularly in comparison to typical costs.
2. Investments should prioritize protection of existing buffers. Preservation is generally much more cost-effective than restoration.
3. Beneficiaries of riparian buffers are numerous, widespread and geographically diffuse.

The widespread distribution of benefits suggests that individual private investment alone will generally lead to underinvestment in riparian buffers. Benefits to others will typically play a negligible role in individual private investment decisions. Even when riparian landowners recognize their benefits from riparian buffers, it will be most advantageous, all else equal, to free-ride on buffers provided by others upstream and downstream. The free-riding approach leads to little private investment overall, with a heavy reliance on public contributions where feasible.

The benefits of riparian buffers in the Basin compared to the costs are particularly favorable, to an extent rarely observed in the scope of potential public investments. Opportunities to invest

[104] Huron River Watershed Council. 2008. Riparian Corridor Protection in the Huron River Watershed.

thousands of dollars per acre to see that return or more every subsequent year are uncommon. The challenge is that the costs are not well-aligned with a narrow set of beneficiaries, but rather a diverse set of upstream and downstream beneficiaries, and society at large.

Collectively these results dictate that government involvement is needed to coordinate and maintain investment in riparian buffers for the Delaware River Basin. By requiring protection and in some cases restoration of riparian buffers, those who benefit also contribute, while the society as a whole experiences the broader benefits. There is a fairness to this approach as well, in that riparian landowners have disproportionately benefitted from society-wide investments to improve water quality and aquatic habitat conditions in the Basin.

Appendix Maps

Maps in Figure A-16 and Figure A-17 show land coverage and changes in land coverage by type from 2001 to 2011. Of particular note are the declines in agricultural lands and corresponding increases in urban lands. Urban land generally has higher prices than agricultural land, suggesting that the sooner riparian buffer protections can be established, the less costly they will be. Furthermore, urban areas have more people to benefit from the presence of riparian buffers, so the value of riparian buffers will increase over time as well.

Figure A-16. Percent Cover in Riparian Zone, 2011

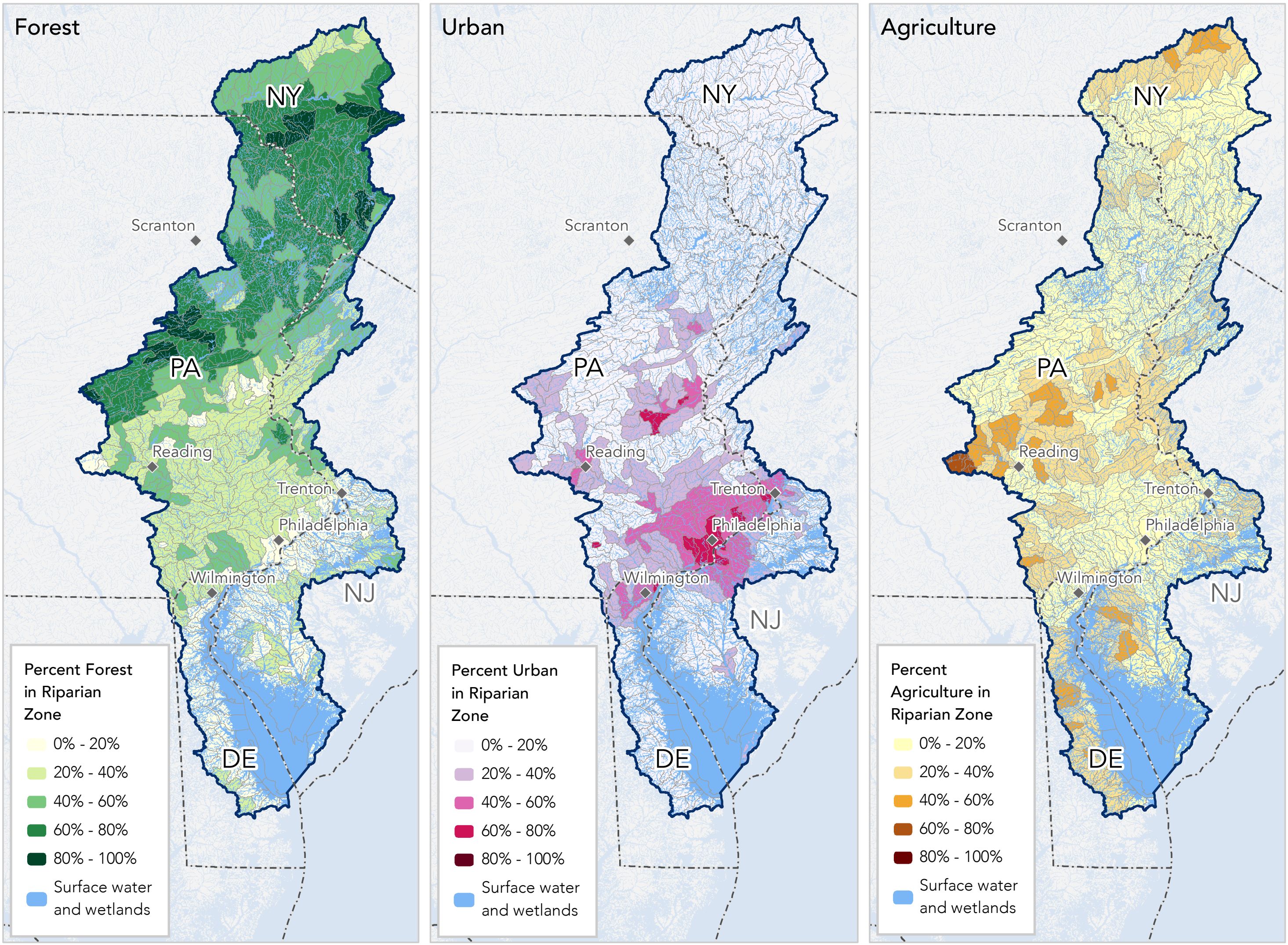

Figure A-17. Percent Change in Land Cover, 2001-2011