Protecting Forests for Clean Water:

Findings from a 10-year initiative to promote best practices across the land conservation field

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OPEN SPACE INSTITUTE

Contents

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Founded in 1974, the Open Space Institute (OSI) has grown to become a national conservation leader, partnering in the protection of more than 2.4 million acres across the Eastern US and Canada. OSI protects land for clean drinking water, public recreation, healthy communities, wildlife habitat, and climate protection, since the intact forests and floodplains we protect capture carbon and protect against extreme weather events.

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Executive Summary

This report synthesizes findings from a four-part, multi-year assessment of the 10-year Delaware River Watershed Protection Fund. The fund was administered by the Open Space Institute as part of the Delaware River Watershed Initiative. The study analyzes the water quality benefits of 21,000 forested acres across New Jersey, New York, and Pennsylvania that were permanently conserved by the Protection Fund grantees.

The report quantifies the benefits of permanent land protection to water quality, develops new ways to measure those benefits, and offers strategies to increase collaboration between clean water programs and conservation organizations.

Key findings:

- Forests keep water clean. Stream sampling studies found nitrogen levels spiked when forest cover levels fell below 66 percent. When forest cover is maintained at 70 to 90 percent or greater, streams and rivers stay healthier and cleaner, and wildlife thrives.
- Protecting forests along streams filters pollutants from the surrounding landscape. The land protected by DRWI grantees filters and reduces about 1,680 pounds of total nitrogen annually, with rates increasing if development occurs nearby.
- Allowing protected land to return to forested conditions results in quantifiable reductions in pollutants. More than 600 acres of the land protected by the fund were returned to forested conditions, which resulted in 4,070 pounds of total nitrogen exported annually from these areas.
- In largely forested headwaters, loss of forest cover was most strongly correlated with reductions in water quality, rather than increases in upstream farmland or development. Water condition was gauged by the presence of macroinvertebrates such as insect larvae, snails, or worms, which are good indicators of water health.
- Across the 21,000 acres protected, land protection resulted in the avoidance of an estimated $57 million in total stormwater capital costs and $6 million in annual maintenance costs for projected development—more than three times the cost of the land protection itself.

Additional recommendations and findings to advance the role of forests as a clean water strategy:

Develop a set of agreed-upon best practices for assessing the water quality benefits of land protection.

The ability of land trusts, watershed associations, and private philanthropy to leverage the funding and resources available through federal and state clean water programs is limited by the lack of shared goals and measures.

Set goals and target priorities with consideration of both water resources and pollutant loads.

The gap between clean water programs and conservation organizations extends beyond the use of terminology to differences in methodology, goals, and measures of success. One major distinction is that conservation organizations use general indicators of ecological and watershed health to set goals and assess impact, while clean water programs seek strict water quality metrics, such as in-stream pollutant loads. These differences limit the use of land protection as a clean water strategy.

Identify land cover thresholds that define good water quality.

In largely forested headwaters, water quality was most closely correlated with loss of forest cover as opposed to increases in farmland or development. The study of macroinvertebrate communities in these watersheds revealed that sites with greater than 80 percent forest cover would generally be classified as "Good" quality. In contrast, sites with approximately 70 percent forest cover would generally be classified as "Fair." This finding illustrates how impacts to water quality can be detected well above the thresholds where regulatory actions would be triggered. Importantly, the findings suggest that tracking forest cover can offer a simple way for non-specialists to set targets for water quality levels.

Diversify the modeling approaches used to quantify pollutant impacts.

Avoided pollutant models are the most common approach used to estimate pollutant loads, but these models offer a limited window into land protection's contribution to clean water. This project developed novel modeling approaches to assess 1) the pollutants filtered by the protected forested stream buffers; 2) the pollutants reduced due to changes in management that occurred at the time of protection; and 3) the downstream distance at which avoided pollutants would be detected. These approaches develop new methods for assessing the range of ways land protection contributes to measurable water quality impacts.

Related Resources

Technical reports developed as part of the study:

- Literature Review: Forest Cover & Water Quality – Implications for Land Conservation
- Water Quality Protection Programs: Insights from Six Eastern United States Cases
- Estimating the Influence of Land Protection on Water Quality
- Measuring the Impact of Protecting Forests on Water Quality and Stream Health

Additional guidance and resources developed as part of OSI's work on the Delaware Initiative:

- Overview of OSI approach to evaluating land protection projects through the Delaware River Watershed Protection Fund
- OSI's Delaware River Watershed Protection Fund Request for Proposals
- Delaware River Watershed Protection Fund capital grant project dashboard
- Research brief summarizing findings from literature review and water program interviews

Introduction

Purpose and Intended Audiences

Protecting Forests for Clean Water is designed to clarify and advance the role of forest protection as a clean water strategy. The approaches, findings, and recommendations draw on insight from the Open Space Institute's (OSI) 10 years of experience administering a forestland protection program for water quality as part of the Delaware River Watershed Initiative and four research reports studying the impacts of this work.

The document is also intended to recognize and celebrate the efforts of the more than 50 organizations that worked together over these 10 years to advance water quality in the Delaware Watershed.

This paper summarizes novel approaches and replicable strategies to quantify the benefits to water quality from land protection. It offers recommendations and best practices to bridge the gap between the broad ecosystem benefits often measured by land trusts and the pollutant load measures that serve as the primary "currency"of clean water programs. It also outlines specific approaches for incorporating land protection into the range of activities needed to achieve clean water outcomes, including setting goals, targeting priorities, modeling impacts, and monitoring in-stream indicators.

The paper is written for the spectrum of organizations working on water quality programs, including land trusts, watershed associations, other NGOs, water utilities, government agencies, and foundations.

OSI intends for this paper to advance the establishment of best practices. An iterative feedback process among practitioners, funders, and government agencies will ultimately be needed to establish effective approaches. To that end, we welcome you to contact us with feedback and thoughts.

Bridging the Gap between Clean Water Programs and Land Protection

Forestland protection is widely recognized as a strategy to maintain clean water by preventing the passage of pollutants to waterways. However, land protection is underutilized as a tool for protecting clean water in many programs in favor of restoring streams that are already degraded. Ultimately, where possible, pairing the two strategies is the most effective way to ensure restoration is permanent and intact areas are not further degraded.

State and federal clean water programs charged with implementing the Clean Water Act typically require quantitative improvements in water quality to justify spending. Unlike with restoration programs, where changes in water quality before and after a practice, such as manure containment, can be easily modeled and measured in the stream, the benefits of protection are more difficult to quantify.

Forestland protection prevents potential future pollutants from entering the waterway. This avoided impact can be modeled through "what if" scenarios, but the results are inherently uncertain. Apart from documenting no change, the impact of land protection can never be directly measured through in-stream sampling. Instead, the land protection community has generally communicated progress toward water quality goals in terms of indirect measures, reporting miles of streams protected, acres of wetlands, or other broad watershed health metrics.

There are additional issues related to the capacity of land trusts (see text box) to address the complex criteria and pollutant load modeling required of many clean water programs. Clean water programs across the United States do not consistently incorporate land protection as a component of their efforts to protect and restore waters and where they do, they rarely offer suitable pathways for land protection to qualify for funding. This limits opportunities for land trusts and other conservation organizations to engage with these programs.

Land Trusts 101

Land trusts are nonprofit organizations that use a variety of tools and strategies to protect and steward land in perpetuity. Some land trusts conserve land through direct purchase, while others partner with willing landowners to place permanent protections on a property using a legal tool called a conservation easement. According to the Land Trust Alliance, there are approximately 1,300 land trusts across the United States. Staffing capacity varies widely, with an average of 10.5 full-time equivalent (FTE) employees for accredited land trusts, compared with 2.6 FTE for land trusts that are eligible but not accredited,[*] as well as many volunteer-led organizations. Land trust staff tend to have expertise in real estate transactions. Larger land trusts may have additional staff focused on ecology or conservation science, and specialized knowledge of watershed science or hydrology is less commonly represented within land trust organizations.

* P. Szabo, (2018) Land Trust Accreditation Impact Evaluation, Appendix E. Analysis of Land Trust Census Data. https ://www.landtrustaccreditation.org/storage/downloads/impactevaluation/appendix_e_analysis_land_trust_census_data.pdf.

Delaware River Watershed Initiative

The Delaware River Watershed Initiative was launched by the William Penn Foundation in 2013 and implemented by over 50 conservation organizations. The now 10-year-old Initiative included a $20 million Delaware River Watershed Protection Fund administered by OSI[*] in addition to funding for strategies on restoration[**], science, and collaboration. To date, OSI's Protection Fund has distributed 57 grants totaling $10.6 million to 13 partner organizations for the protection of over 21,000 acres. At the time of publication, OSI has approved an additional 11 grants that would protect approximately 5,900 acres, with additional projects expected through the end of the Initiative in February 2025. An up-to-date snapshot of the Protection Fund can be found in the conservation dashboard here.

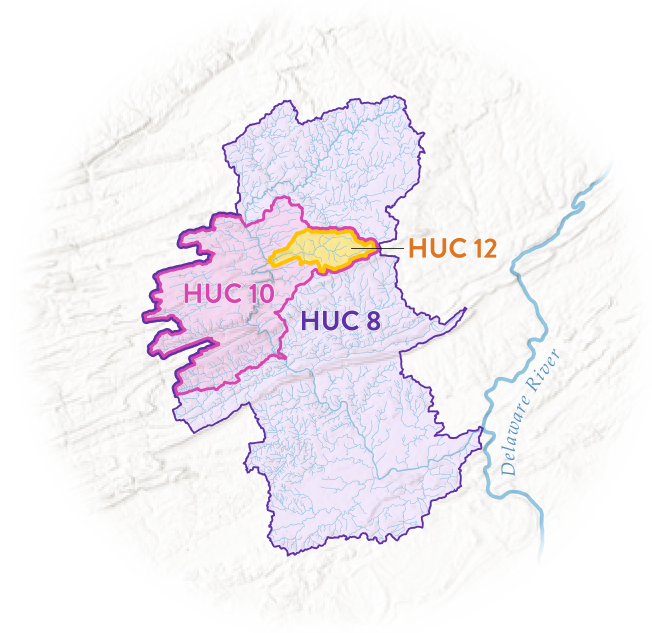
Because of the large investment in land protection, extensive support provided by watershed science-based organizations, and a major investment in the capacity of groups on the ground, the Initiative offered an unprecedented opportunity to advance our understanding of land protection as a tool to achieve water quality goals.

Initiative partners undertook extensive planning at two points during the Initiative to target land protection and restoration to focus on areas in eight "watershed clusters." The watershed clusters were often based on a Hydrologic Unit Code (HUC) 10 scale (see image on page 5), covering about 25 percent of the Delaware River Basin in total. Within these areas, partners identified 21 focus areas ranging from 400 to 68,000 acres (generally one or more HUC 12). OSI's Protection Fund criteria were designed to support progress toward three-year water resource protection targets set by the conservation partners working in each focus area (see map on page 7).

* In addition to OSI's capital grant fund, OSI offered "catalyst" grants of up to $35,000 to support organizations in integrating watershed science into town or county open space plans and other conservation efforts. This complementary effort sought to build alignment between funding and prioritization of land protection.

** In parallel, the National Fish and Wildlife Foundation (NFWF) oversaw administration of the $7 million Delaware River Restoration Fund, which provided capital grants for restoration, stewardship, and green stormwater infrastructure. The impact of this work is the subject of a companion report expected in early 2024.

The stated outcome of the Delaware River Watershed Initiative was "watersheds that provide high quality and sufficient water quantity for healthy ecosystems and human communities." The William Penn Foundation set up the Initiative with the intention of measuring quantitative water quality indicators to track progress. However, this proved challenging due to the broad watershed health-related goal of the Initiative and the diverse set of priorities held by the participating organizations.



Impact Assessment

This synthesis summarizes the high-level findings from a three-year, four-part project to measure the impact of OSI's Protection Fund on water quality. A literature review and an assessment of watershed protection programs were led by University of Vermont PhD candidate Joshua Morse. Modeling and sampling work was led by Stroud Water Resource Center and Academy of Natural Sciences, Drexel University, with support from Shippensburg University.

The full reports and findings for each of the formal components of the study are available via the embedded links below. The project included the following components:

- Literature Review: Forest Cover & Water Quality – Implications for Land Conservation
- Water Quality Protection Programs: Insights from Six Eastern United States Cases
- Estimating the Influence of Land Protection on Water Quality
- Measuring the Impact of Protecting Forests on Water Quality and Stream Health

In the following sections, we present top-level findings from the above reports, as well as lessons from the 10-year Initiative, to facilitate broad, field-wide conversation about best practices for evaluating the water quality benefits of land protection. The document is organized into findings and lessons from three major aspects of clean water programs: 1) setting goals and targeting priorities; 2) sampling for landcover thresholds; and 3) modeling pollutant load impacts.

The final section of this report offers recommendations to advance best practices. The methods and technical details associated with the findings can be found in the full reports.

Findings and Lessons

This section summarizes findings and lessons from OSI's 10 years of experience administering the Protection Fund. We compare our experience with the approaches used by the six watershed protection programs interviewed in the early stages of our study.

Set Goals and Target Priorities with Consideration of Both Water Resources & Pollutant Loads

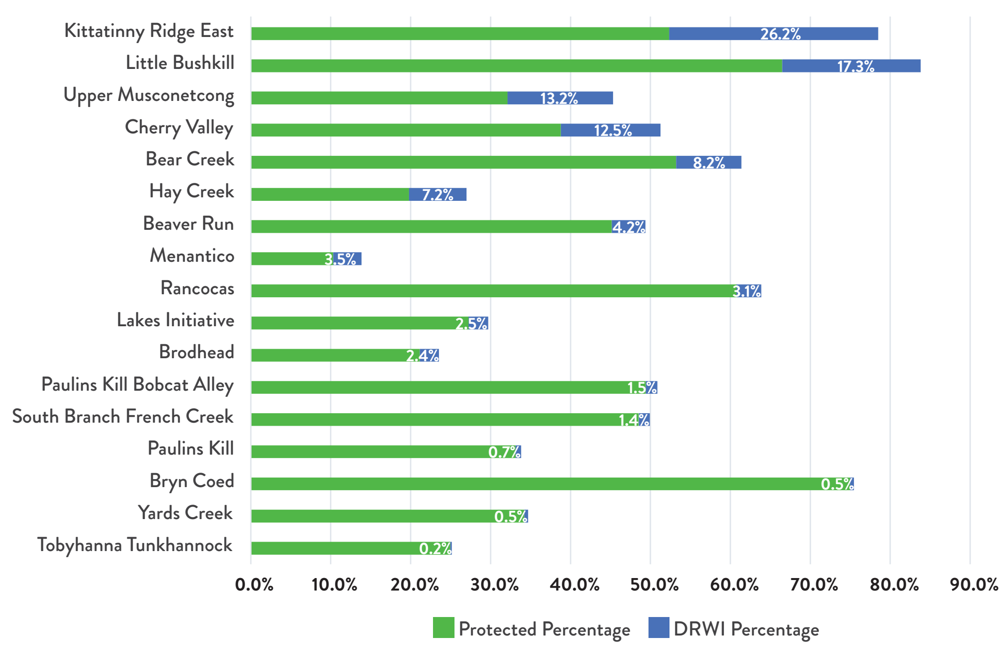
FINDINGS

As of 2023, OSI's Protection Fund has protected more than 21,000 acres, ensuring conservation of forests along 110 miles of stream, a distance equivalent to 35 percent of the length of the Delaware mainstem. The Protection Fund successfully targeted projects to the protection of streams in intact headwaters with over 50 percent of protected acres concentrated in 5 of the 21 focus areas. (See figure 1 below and the map in figure 2 on next page.)

Through an evolving set of online tools, datasets that prioritize watersheds for protection, [guidance documents](), and technical assistance, the partners working on land protection and restoration across the watershed clusters successfully coordinated priorities by watersheds and developed quantitative targets for protection and restoration of stream miles, active river area,* wetlands, and headwaters within each focus area.

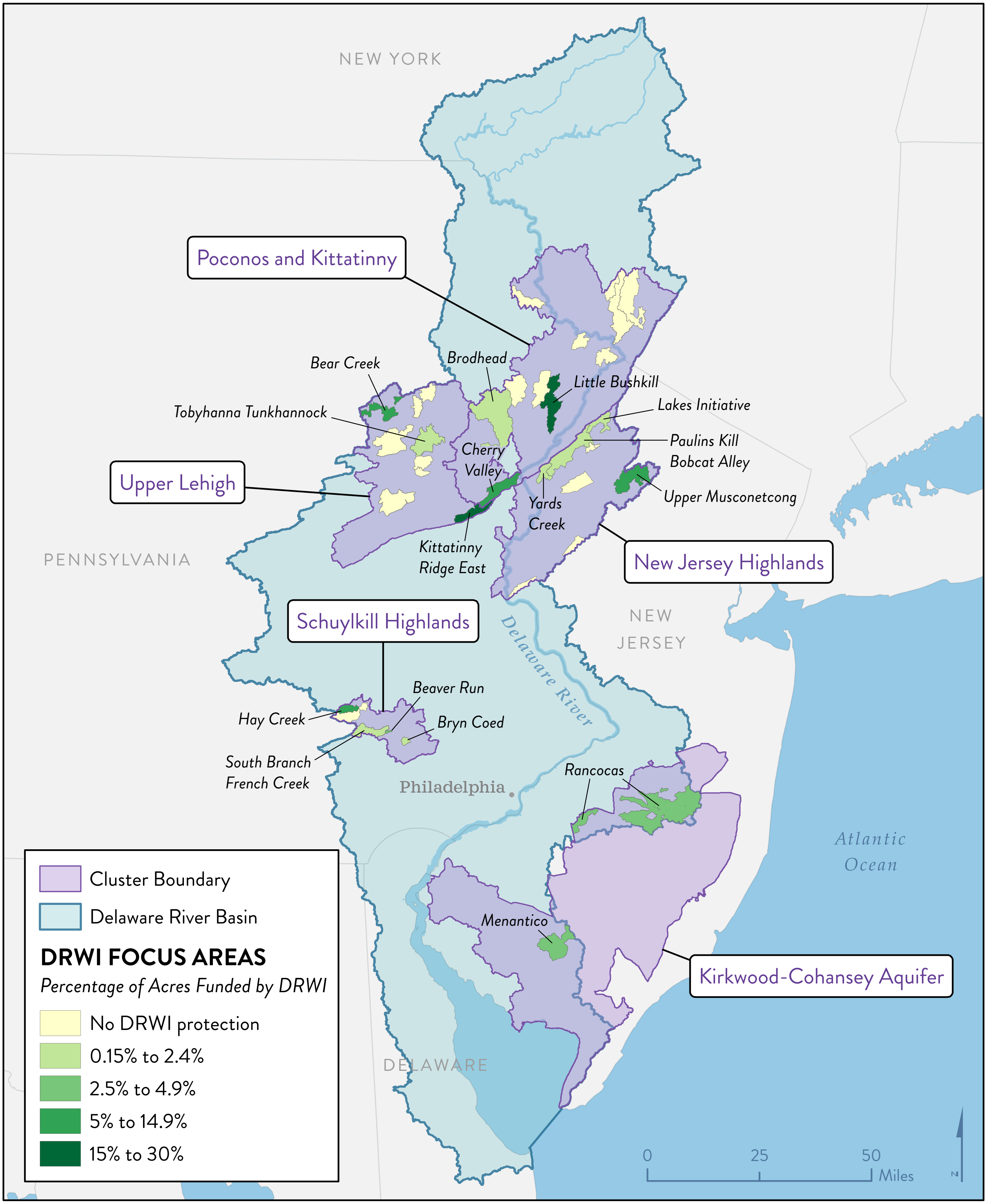
These watershed health metrics represented significant and meaningful progress, especially at local focus area scales, yet did not achieve the types of direct water quality outcomes sought by the Foundation and required by clean water programs.

Figure 1: Percentage of focus areas protected at the start of the Initiative (green) and additional forestland protection contributed by the Delaware River Watershed Protection Fund (blue)



* "Active river area" is a framework developed by The Nature Conservancy to capture the full spatial extent of the channels and riparian lands needed to accommodate the dynamic physical and ecological processes of rivers. It includes components such as riparian wetlands, floodplains, and meander belts. See The Nature Conservancy (2008), The Active River Area: A Conservation Framework for Protecting Rivers and Streams. http://www.conservationgateway.org/Documents/ASFPM_TNC_Active_River_%20Area.pdf

Figure 2: DRWI clusters eligible for protection and percentage of focus areas protected with DRWI funding



As a result of this targeting, more than 80 percent of stream miles protected were first- or second-order streams,** and 79 percent of protected acres protect active river area, headwaters, and/or wetlands. Much of this success was achieved by 14 projects in 4 of the 21 focus areas that accounted for 69 percent of acres protected and 81 percent of priority water resources protected. The focus areas in which this progress was made included the Rancocas, Upper Musconetcong, Cherry Valley, and Little Bushkill Focus Areas.

Projects protected by the Protection Fund also had as much as 89 percent greater drainage density (see figure 3) than the average for the broader surrounding HUC 10 watershed landscape within which the focus area is located (see table 1). The exception was the Upper Lehigh, where drainage density was 36 percent lower on projects funded by the Protection Fund than the surrounding landscape. These projects tended to be headwaters with intermittent streams that weren't well captured in the National Hydrography Dataset (NHD) used to calculate drainage density.

Figure 3: Drainage density

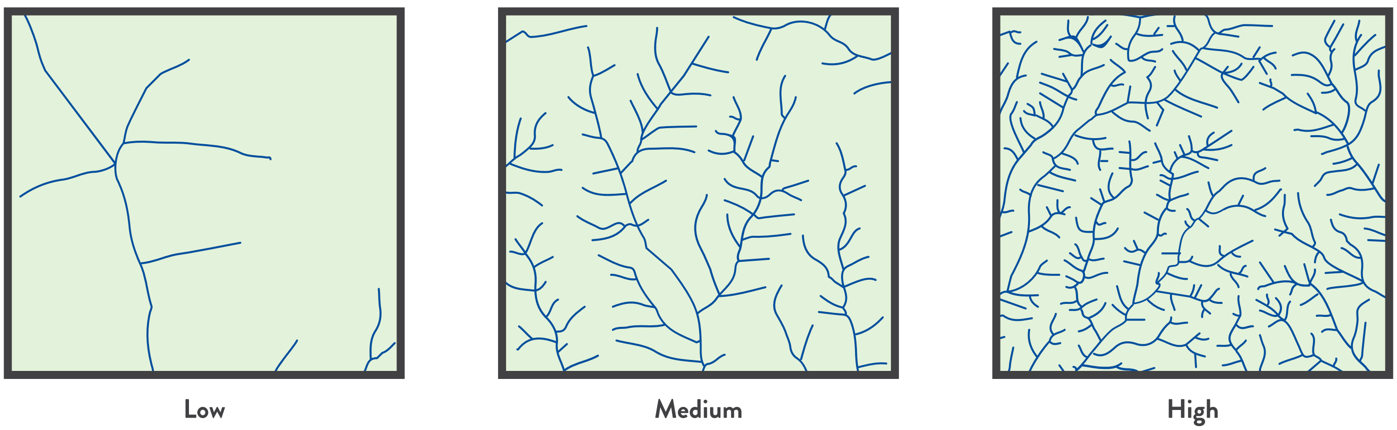


Table 1: Drainage Density by Watershed Cluster *(feet of stream bank per acre)*

	Average drainage density for the cluster	Average drainage density for the Protection Fund projects in the cluster	Ratio of drainage density in Protection Fund projects to their associated watershed-wide averages
All clusters	24	28	17%
All without Upper Lehigh	25	31	24%
Kirkwood-Cohansey	28	53	89%
New Jersey Highlands	21	28	33%
Poconos-Kittatinny	21	22	5%
Schuylkill Highlands	22	27	23%
Upper Lehigh	22	16	-36%

** Note that throughout, we measure "miles of stream bank" to account for each side of the stream separately because ownerships often split the stream down the middle.

The Initiative's use of indirect measures of water quality — that is, measures that track the acres of forest or other resource-based metrics — mirrors the approaches used by six eastern U.S. watershed protection programs reviewed by OSI early in the study. Science-based methods for evaluating program impacts on water quality remain uncommon. Project evaluation still largely relies on metrics of success like dollars, acres, and miles of stream frontage. These approaches emphasize land protection milestones but fall short of quantifying the direct impacts on water quality.

The few land protection programs that have sought to demonstrate direct water quality outcomes frequently use development risk and avoided pollutant models to identify projects for funding. However, methodologies vary widely, and there is no clear consensus on best practices. Further, using development risk as a driver of land protection priorities tends to concentrate work in areas with significant existing development where it is expensive and difficult to conduct land protection.

The organizations and programs OSI reviewed had limited knowledge of how their peers function, which further emphasizes the need for best practices and field guidance. Lack of funding, limited research capacity, and varying comfort and fluency in science all limit the types of strategies adopted by practitioners.

LESSONS

Resource-based, indirect measures of water quality like acres of headwaters or miles of stream bank do not *directly* measure the quality of the water but are strongly *correlated* with water quality. Furthermore, these metrics are relatively simple to track and represent important information that is missing from estimates of avoided pollutant loads. For example, pollutant load models do not account for the proximity of the projected development to the stream or consider whether the stream is protected.

Resource-based measures could serve as an effective proxy for water quality goals. An initiative might, for example, aim to protect 75 percent of stream bank miles and 50 percent of headwaters within a watershed. While achieving that goal does not necessarily ensure high water quality, in the absence of any major point source pollutants, it could be considered an effective measure of success. This approach could be further strengthened by considering water quality and forest conversion models that provide insight into the sources of current pollutant loads and support protection or planning to avoid expected increases in forest conversion.

As well, initiatives that use metrics that are easily understood and simple to measure are more likely to be successful in part because all partners understand and communicate about the goals and targets.

Drainage density offers an effective single metric to express how well individual projects targeted multiple watershed values. The metric incorporates successful targeting to streams, active river area, and headwaters since headwaters have a higher density of streams.

Throughout the Initiative, OSI's Protection Fund grantees were incentivized to concentrate protection within targeted focus areas through a reduction in the required match to the grant award. While concentrating land protection projects is necessary for achieving progress towards resource-based goals, such as protecting 75 percent of stream bank miles within a given sub-watershed, this method does not necessarily result in a greater pollutant load avoided. This illustrates another important difference between these measures. However, narrowly targeting land protection likely slowed the pace of conservation and as well as the rapid deployment of the Fund's capital.

For initiatives that span multiple large watersheds, we recommend balancing targeting with allowance for large projects to occur outside of focus areas if they protect water resources at a significant scale and help avoid significant development. For more focused watershed protection plans, targeting is inherently built into the system.

Sample for Land Cover Thresholds That Define Good Water Quality

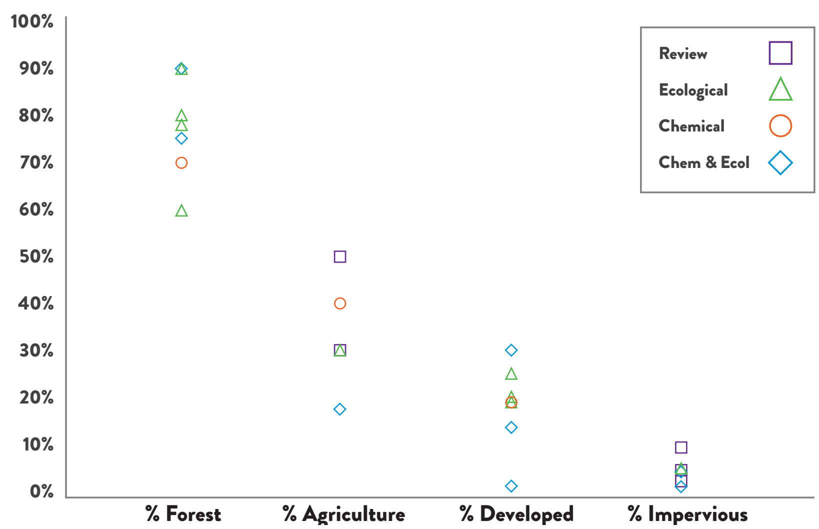
This portion of the report summarizes findings from the literature review and stream sampling-studies. Both studies sought to identify the levels of water quality associated with declines in easily measured resource-based values, such as forest cover or other land uses. We measured the levels of forest cover loss that triggered detectable and ecologically meaningful declines in a variety of water quality indicators, including chemistry, macroinvertebrates, and fish. The full methods and findings are available in the reports linked on page 2 of this document.

FINDINGS

The literature review found that watersheds with 60-90 percent forest cover reliably yielded high water quality. The range of thresholds found is summarized in figure 4.

We followed this literature review with a sampling study that sought to use in-stream sampling to refine these findings for the Delaware Basin.

Figure 4: Literature values for thresholds to ensure good water quality for each major land cover type in our review. Values represent either individual thresholds or the high and low ranges of transition bands reported by papers that favored a range over an individual threshold. Values are organized by response variable: ecological (invertebrates, fish), chemical (nutrient concentrations, major ion concentrations, sedimentation, pH, dissolved oxygen, etc); combined response variable studies; and review studies that did undertake original empirical tests of water quality.



While the Initiative included significant stream monitoring from its outset in 2013, we found the sampling conducted between 2013 and 2019 largely occurred in watersheds with less than 75 percent forest cover, and only 20 of the 141 sampling sites in watersheds had more than 75 percent forest cover. This reveals a bias in the initial sampling to monitor changes in stream pollutant concentrations from restoration over protection activities and mirrors a broader, field-wide bias.

Stroud Water Research Center and the Academy of Natural Sciences designed a sampling study that sought to refine our knowledge of where water quality declines as land cover changes. They identified 51 additional headwater sites for sampling that focused on watersheds with forest cover largely between 50 and 100 percent. Watersheds with identified point sources or wetland cover of 2 percent were removed from the study to simplify the variables.

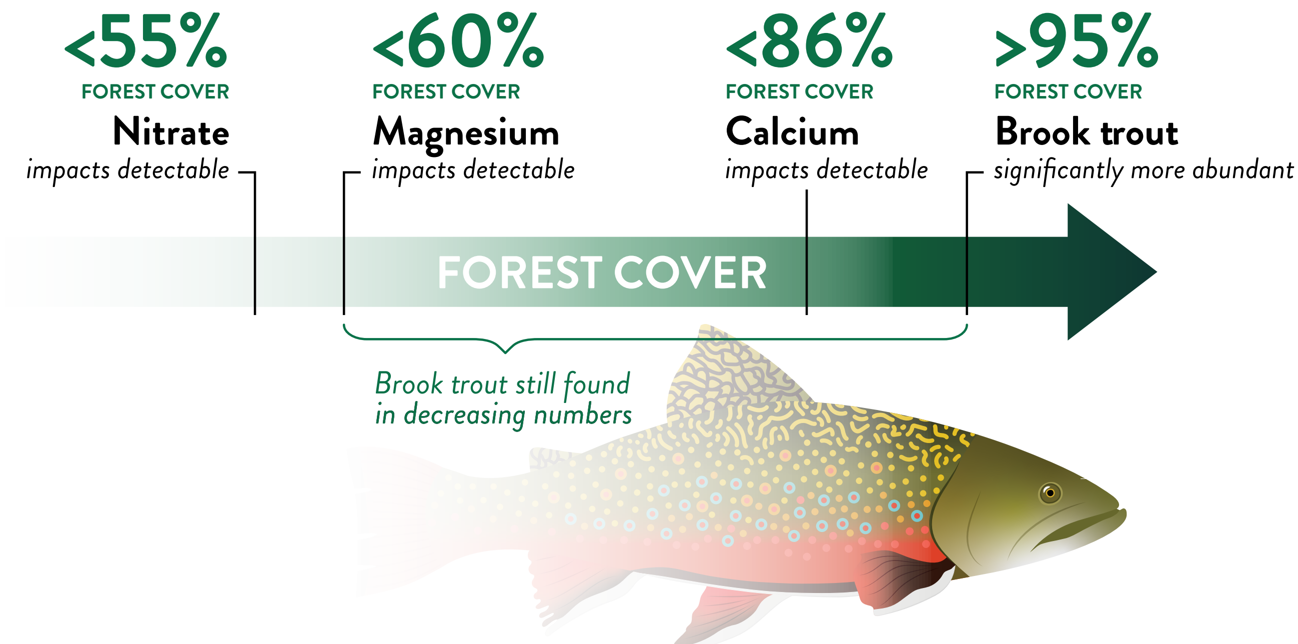
Forest cover generally explained more variation in the macro invertebrate sampling among sites than other land covers, including the amount of development and agriculture.

While 50 percent forest cover is often considered a “well-forested” watershed, there are statistically significant changes in chemistry, macroinvertebrates, and fish between 50 and 80 percent forest cover. Notably, these ecological and chemical changes were detected well above regulatory or conventional thresholds (e.g. the 10 percent impervious surface rule).

The study measured significant increases in sodium, magnesium, calcium, chloride, nitrate, total nitrogen, and conductivity as forest cover in these watersheds decreased. Chemical changes had a stronger correlation to increases in developed land than to loss of forest cover.

The study found relevant breakpoints in the relationship between increasing forest cover and water quality indicators. Brook trout were significantly more abundant at sites with >95 percent forest cover, though they could still be found at sites with more than 60 percent forest cover, but they were replaced by brown trout (a more thermally tolerant species) as forest cover decreased (see figure 5).

Figure 5: Breakpoints in the relationship between increasing forest cover and various water quality indicators

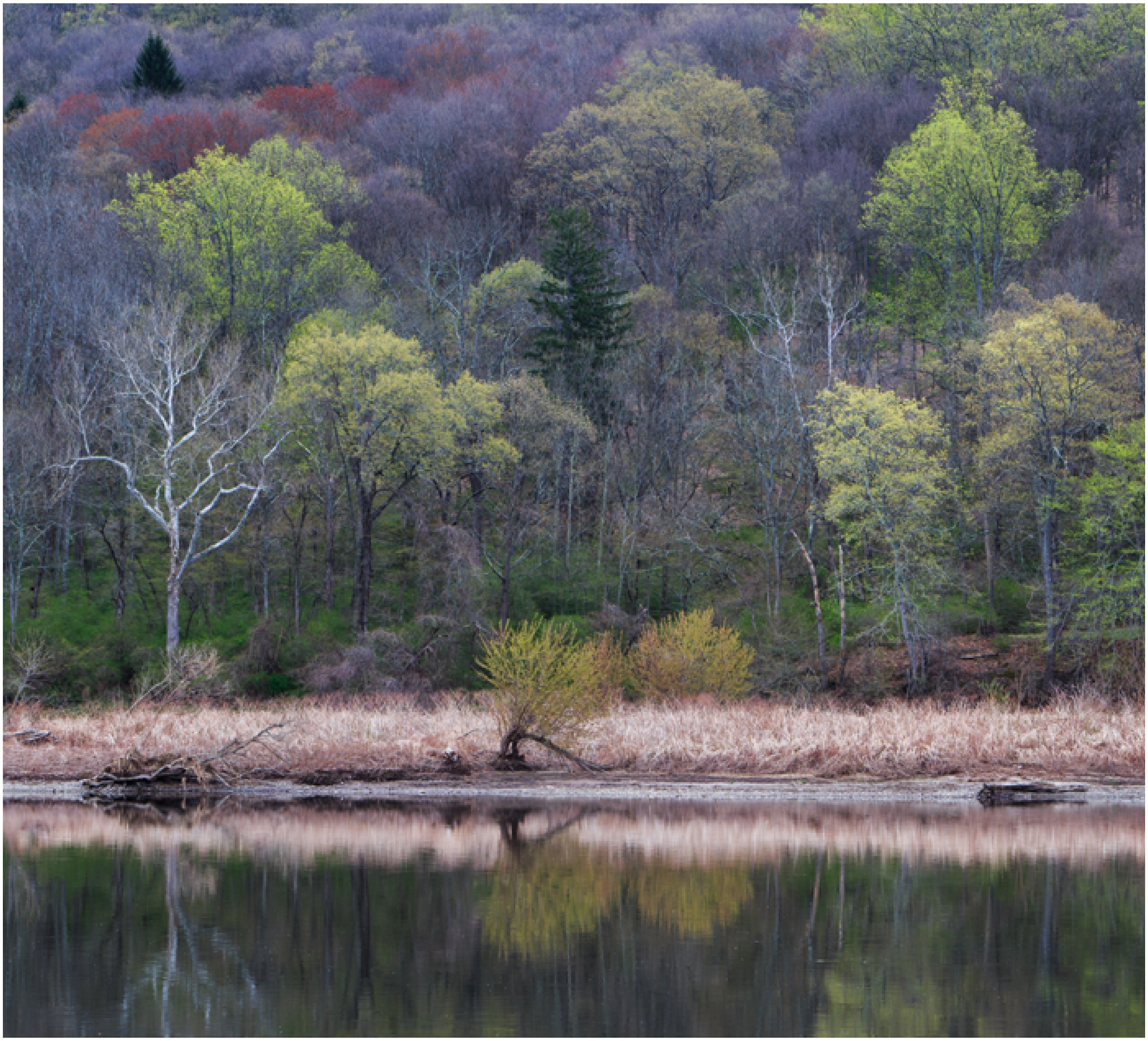


Overall, the macroinvertebrate study found that sites with greater than 80 percent forest cover would generally be classified as "Good" quality. In contrast, sites with 70 percent forest cover would generally be classified as "Fair." While the most rigorous definitions of an "intact" watershed might require 80 percent or more forest cover, there was evidence from the sampling study that many watersheds with 50 to 80 percent forest cover can still produce relatively clean water, justifying land preservation investments that may be best paired with restoration practices.

LESSONS

The analysis demonstrates measurable ecological and chemical degradation among well-forested watersheds that should be addressed prior to the need for regulatory enforcement.

The strong correlation between loss of forest cover and declines in water quality suggests that the percentage of forest cover is a reliable proxy for understanding water quality in more "intact" watersheds. The breakpoints listed above offer a useful approach to communicate the relevant forest cover thresholds for various water quality indicators. This rubric applies only to headwater watersheds where all upstream influences are accounted for and there are no known point sources.



The identification of thresholds for water quality on protected lands within the area of study provides broadly applicable and easily measurable thresholds to guide progress. The approach directly links resource protection goals to in-stream water quality. When using forest cover thresholds to set goals, it is important to consider that land protection is not the only tool to achieve desired outcomes. Other strategies to keep forests intact – including current use taxation programs, local zoning and regulation, and incentives for good land management – also play important roles in maintaining forest cover.

Diversify the Modeling Approaches Used to Quantify Pollutant Impacts

This component of the project sought to broaden the set of tools available to quantify the pollutant load benefits of land protection for water quality. Modeling the pollutant loads that would have occurred if the land were not protected is the most common way to assess the water quality impacts of land protection. While pollutant load models provide a window into only one aspect of water quality, they function as the primary "currency" for understanding regulatory measures, and therefore warrant attention.

The modeling study sought to expand the approaches for estimating the impacts of land protection on pollutant loading to better express the multiple ways land protection benefits water quality. The list below summarizes the approaches:

1. **Improve and augment avoided development models.**
2. **Estimate the pollutant loads reduced due to the change in land management that occurs at the time of land protection.**
3. **Estimate pollutant loads filtered from the local watershed feeding into forested buffers along protected streams.**
4. **Calculate the distance downstream at which the pollutant load created in a development scenario would no longer be detectable (~5 percent of the in-stream pollutant concentration).**

Details on methods and findings for approaches 1, 3, and 4 are available in the full modeling report. Below, we summarize the findings and lessons from each of the approaches, which were applied across a subset of projects conserved through the Protection Fund.

1. Improve and augment avoided development models.

FINDINGS

In addition to using traditional development models to predict likely forest loss, OSI created near-term development predictions based on the "local knowledge" of applicants to the Protection Fund. These predictions included the intentions of the seller, purchase offers, and zoning, which are all considerations missing from development models.

These "local knowledge"-based predictions estimate that land protection projects avoided the modification of 6,143 acres (30 percent of project acres) of land from forest cover. This would have resulted in 1,602 acres of new impervious surface when accounting for the density of predicted development. The development avoided through these projects prevents an annual load of 5.4 million pounds of sediment, 4,535 pounds of total nitrogen (TN), and 1,725 pounds of total phosphorus (TP), saving an estimated $57 million in stormwater capital costs and $6 million in annual maintenance costs.

Modelers compared the local knowledge estimates of development with future land cover scenarios drawn from an existing model of predicted development in the Delaware River Basin produced by Shippensburg University, called the DRB2100*.

The DRB2100 model offered a more conservative alternative prediction, suggesting that 2,297 acres (9.1 percent) might have been converted out of forest cover had these protection projects not occurred.

LESSONS

Overall, the Protection Fund projects avoided development that would have otherwise pushed select focus areas over impervious acre thresholds for "impairment" (typically 10 percent of a given watershed), and that would have cost more than six times the land protection investment in stormwater capital costs.

The DRB2100 model estimated 40 percent less development than the local knowledge approach, suggesting that either the local knowledge approach inflates future forest loss or development models underestimate forest loss. Given the proximity of the Delaware Basin to major metropolitan centers and recent trends toward remote work, which allows for people to settle away from job centers, local knowledge may be picking up important trends that the model is unable to detect.

The greatest contribution of avoided development under both models occurred in the Poconos-Kittatinny watershed cluster focus areas. Poconos-Kittatinny is the northernmost focal region of the Initiative and has the least existing development and most forest cover. The cluster contributed more than 50 percent of avoided impervious surface based on the local knowledge approach and one-third of avoided developed acres predicted in the DRB2100 model. The high contribution of avoided development from this region is likely a result of the large parcels and larger percentage of protected land contributed by the cluster. The Poconos-Kittatinny watershed cluster contributed 53 percent of all protected acres by the Protection Fund.

2. Estimate the pollutant loads reduced due to the change in land management that occurs at the time of land protection.

FINDINGS

Land protection often spurs changes in landownership and alignment of management priorities with conservation, which may result in reforestation of agricultural or developed lands. OSI estimated the contribution of passive or active restoration that occurred on Protection Fund land using average pollutant loading rates for the restored land use.

Projects resulted in restoration of at least 660 acres, or 3 percent, of protected land at no cost to the Protection Fund. Once restored, annual reductions in pollutant loads will include 139,676 pounds of sediment, 4,071 pounds of TN, and 213 pounds of TP annually. The high amount of nitrogen reduced is due to restoration of 128 acres of cornfields in the Schuylkill Highlands. The most restoration occurred in the Kirkwood-Cohansey cluster, followed by the Poconos-Kittatinny; however, the pollutant load reduced per acre was by far the greatest in the Schuylkill Highlands.

Restoration benefits seen in the clusters were primarily driven by one or two large restoration projects. In the Kirkwood-Cohansey, benefits were due to restoration of cranberry farms back to natural wetlands. In the Poconos-Kittatinny, the restoration will result from conversion of a golf course to forestland.

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* Shippensburg University's Future Land Cover Scenarios (DRB2100) forecast urban land cover in the Delaware River Basin out to 2100. The model provides estimates based on a "Corridors" scenario, which emphasizes high-growth "urban sprawl" along major transportation corridors, and a "Centers" scenario, where growth is focused near urban centers. See Future Land Cover Scenarios (DRB2100 Version 3.1), Delaware River Basin Land Use Dynamics, Shippensburg University, **https://drbproject.org/products/**.

LESSONS

While the Protection Fund requires restoration of any non-forest lands that exceed 10 percent of the project area, it does not actively solicit restoration projects, and preference is given to projects with high amounts of existing forest cover. If pollutant load reductions are a primary measure of impact, it may be more logical to favor projects that include restoration.

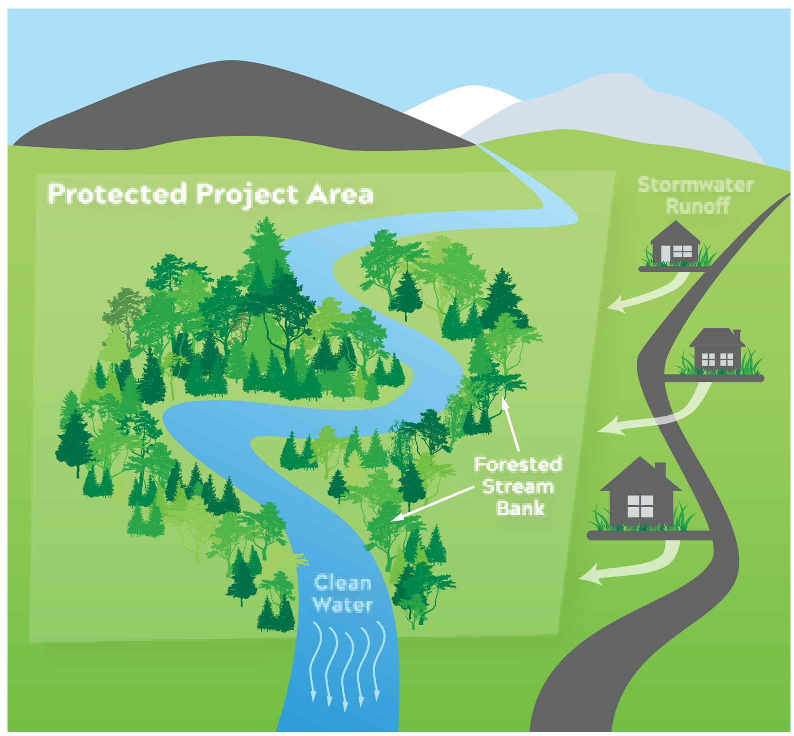
The estimate of pollution reduced from restoration is a concrete and permanent benefit of the land protection and could be reported along with any estimated avoided pollutant loads. Further, the benefits of the restoration practices will be achieved permanently even though they are measured in annual loads reduced.

3. Estimate pollutant loads filtered from the local watershed feeding into forested buffers along protected streams.

FINDINGS

Forested buffers along streams capture and filter pollutants that flow from outside of the protected parcel. OSI used digital elevation models to identify the watersheds flowing into protected streams and found 11,600 acres outside of project boundaries that filter directly into protected streams. Stream buffers on protected land support filtration of 133,700 pounds of sediment, 1,680 pounds TN, and 185 pounds TP, with rates increasing if further development occurs in the future.

The Cherry Valley and Little Bushkill focus areas in the Poconos-Kittatinny cluster contributed 53 percent of acres draining into the protected streams. However, most phosphorus is filtered by projects in the Kirkwood-Cohansey cluster (33 percent of TP loads) and the Schuylkill Highlands cluster. The Schuylkill Highlands cluster contributed 30 percent of TP loads filtered, even though it accounted for only 2 percent of total project acres.



LESSONS

This approach quantifies the broader ecosystem service provided by protecting streamside forests. The approach favors projects with more adjacent development within the watershed of the protected stream. While OSI does not recommend prioritizing projects for this purpose, this method helps to expand the set of measures available to communicate the multiple values of land protection.

4. Calculate the distance downstream at which the pollutant load created in a development scenario would no longer be detectable (~5 percent of the in-stream pollutant concentration).

FINDINGS

This modeling approach employed a thought experiment: if medium-density development were applied uniformly across all protected projects, how far downstream could the pollutants from this development be detected within the waterway? We measured the distance downstream at which the pollution from the project parcel would contribute more than 5 percent of total in-stream pollutant loads. For each project, we calculated the distance downstream or "tail of impact" as a measure of the effectiveness of the project at protecting intact headwaters and maintaining clean water downstream (see figure 6).

In our analysis, if all project acres were developed as a standard medium-density development (uniform single-family housing lots), the cumulative distance the pollutant loads would be detected was 283 miles downstream – nearly the length of the Delaware River mainstem.

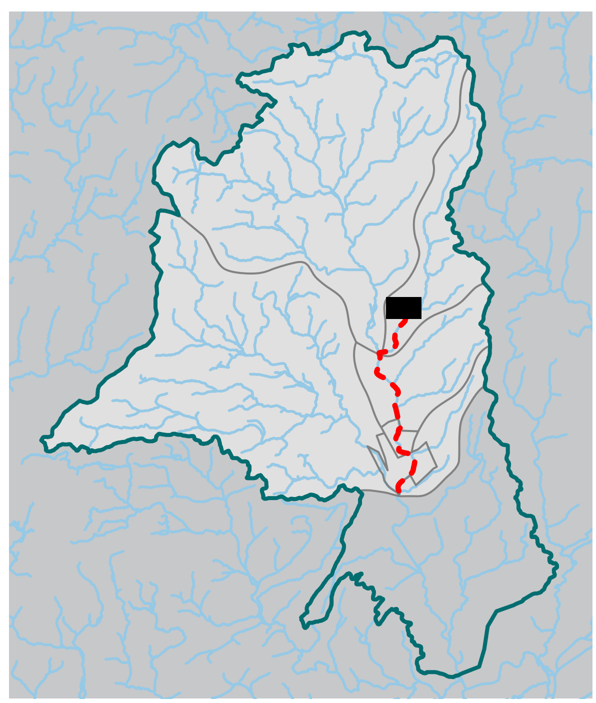
The distance downstream from the project area at which pollution from development would be detected is an indicator of which projects protected land in the most intact headwaters. Most of the length was contributed by the Kirkwood-Cohansey cluster (34 percent), Poconos-Kittatinny cluster (26 percent), and Upper Lehigh cluster (20 percent, despite contributing only 7 percent of the project acres).

LESSONS

The results of this analysis express three factors about the project: 1) where the project lies in the stream network (headwaters vs. downstream); 2) the amount of development and resulting instream pollution above and immediately below the project area; and 3) the size of the project, which determines the total pollutants flowing from the project into the stream. A greater benefit will be measured from larger projects in intact headwaters. Protection in headwaters has an outsized impact since the same load is being delivered to a smaller stream with less water volume, and therefore lower dilution potential.

More than providing a realistic scenario, this modeling approach conveys several complex factors in a simple and meaningful visual: the stream length along which pollutant loads from development of the project would be detected.

Figure 6: Calculation of the distance at the point downstream at which the pollutant load contributed by a "converted" forest parcel is equal to 5% or less of the total load of the drainage area



Making the Model Real

An example of a project that scored high in terms of avoiding future water quality impacts is the Bear Creek Properties LLC project. In this instance, converting the relatively large project area (about 375 acres) to developed land would have an immediate effect on water quality in the forested headwater drainage in which it is located. In this case, the current sediment loading rate of 121 pounds/acre could potentially increase to 1,102 pounds/acre if this parcel were developed with medium-intensity development, resulting in almost a 10-fold increase. As well, the sediment load produced by this potential development would not become relatively "insignificant" (less than 5 percent of the total load) until a point almost two miles downstream of this location.

On the other hand, the Warwick Furnace project is an example that does not appear to exhibit a significant impact on downstream water quality. This project, which comprises about 95 acres, has a fairly large upstream drainage area (about 6,178 acres) within which it is located. This drainage area already has a fairly high sediment loading rate due to the extensive amount of developed and agricultural land present, and the conversion of forest land to developed land increases the loading rate for the drainage area by only about 2 percent (from 578 to 587 pounds/acre). Similarly, because the sediment load that could potentially be produced if the parcel were converted to developed land is far less than the load produced by other existing sources, the downstream impact becomes negligible after about 0.13 miles.

Recommendations for Advancing Best Practices

The ability of land trusts, watershed associations, and private philanthropy to leverage the funding available through water utilities and federal and state clean water programs is limited by the lack of shared goals and measures among these groups.

Land trusts and other organizations that protect land need tools to better measure and advocate for the water quality benefits of land protection. At the same time, clean water programs need to ensure measures and approaches are meaningful and within the capacity of the organizations doing land protection.

It will be important to support land trusts in understanding the tools and resources available to quantify the contributions of land protection to the most common water quality parameters, such as total phosphorus, nitrogen, and sediment, to comply with clean water programs.

At the same time, clean water programs need improved measures for land protection. As a starting place, OSI recommends incorporating local knowledge into avoided development estimates. Land protection project leaders often have realistic knowledge of likely development threats that are missing from development models, which typically fail to consider zoning or other local regulatory frameworks, COVID-influenced patterns of rural development, and other relevant factors.

OSI recommends vetting these approaches with clean water programs and land conservation practitioners to identify the most useful additions to traditional measures.

Regardless of which modeling approaches are used, the high costs and long-term benefits of land protection are best expressed by multiple indicators, rather than a single pollutant load number. Standard pollutant load models offer limited insight into how land protection can advance broader watershed health objectives.

Tracking and communicating about all three of the following measures can express progress toward the full range of values relevant to various stakeholders:

1. Pollutant loads avoided, reduced, and/or filtered based on water quality models.
2. A set of simple watershed health metrics, including stream density, miles of stream bank protected, acres of headwaters, wetlands, and active river area.
3. A summary of the additional ecosystem service benefits, especially focused on flood resilience, drinking water and other water-related values.

The following additional recommendations would further ensure effective integration of clean water programs and land protection:

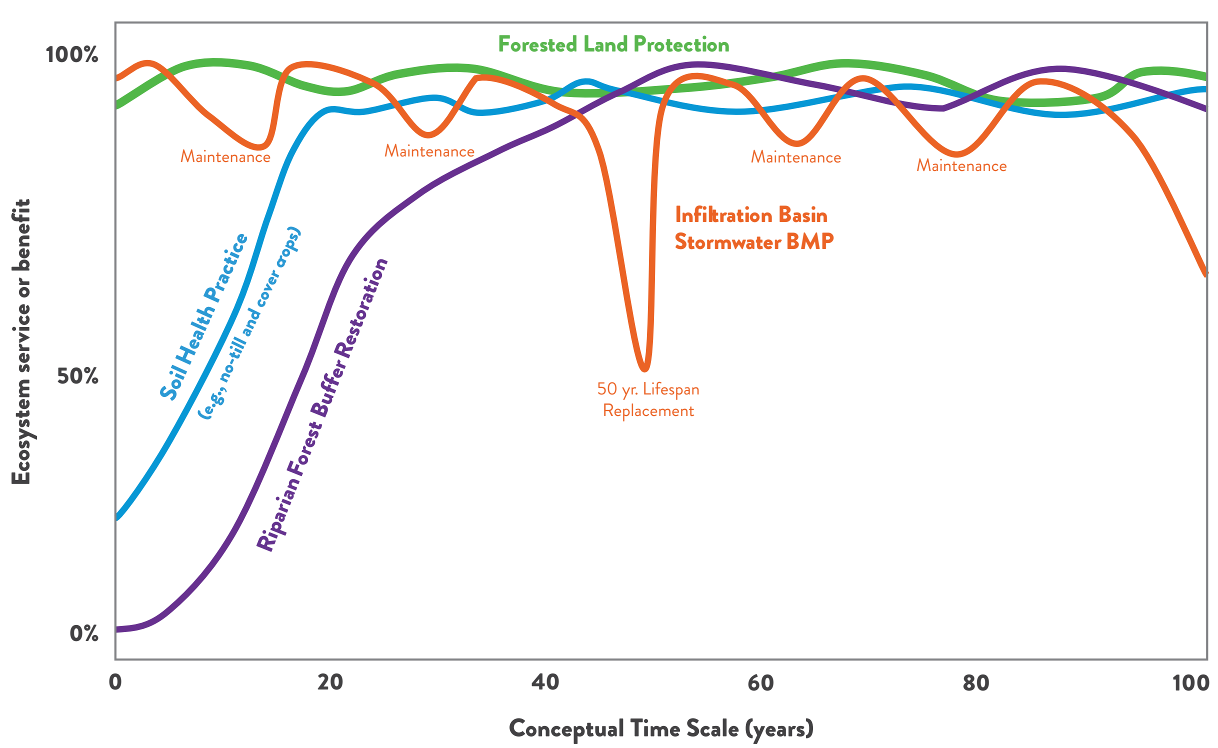
- Vet best practices with practitioners and field experts to identify practical solutions that meet water quality program goals and are practical for land conservation organizations.
- Provide guidance for estimating near-term development risk based on zoning, landowner intent, and recent offers.
- Identify the most suitable models for assessing long-term development trends and incorporate land cost and parcel size to avoid directing protection to areas that may be more appropriate for infill development.

- Develop easy-to-use estimates of avoided pollutant loads per acre of expected impervious surface to create a ready-made approach to translating development risk to pollutant load avoided.
- Provide training on the use of free data and tools that estimate watershed pollutants, such as [Model My Watershed.]
- Consider development of new tools that include necessary data and automate analyses relevant to land protection that incorporate water quality models, watershed health indicators, and related co-benefits.
- Engage watershed associations to play a valuable bridge role between clean water programs and land protection, in recognition of their awareness of the U.S. Environmental Protection Agency clean water program plans (total maximum daily loads [TMDLs], 319 plans, etc.) and connections to land trusts operating in their geography.
- Share tools and resources that can help land trusts identify watershed plans that overlap with their service areas.
- Develop clear and appropriate measures to integrate land protection into watershed planning.
- Provide one-on-one technical assistance to land trusts and encourage evolution of programs addressing obstacles.

Comparing Impacts from Restoration & Protection

The studies did not include a formal comparison of land protection and restoration impacts across the Initiative, but OSI was able to informally compare the cost per ton of pollutants avoided by land protection with the cost per ton of pollutants reduced by restoration. Overall, the cost per ton of pollutant load reduced by restoration was much less than the cost per ton of pollutant load avoided by land protection. However, the models account for only one year of activity and assume the restoration practice is functioning at its peak performance. Therefore, it is important that we better understand the time value of land protection relative to restoration, which may have diminishing returns without annual or periodic maintenance. Figure 7 offers a visual to communicate this issue and suggests additional considerations.

Figure 7: Land protection relative to restoration



Consider the provision of benefits over time as well as ongoing maintenance costs associated with different restoration strategies and practices. Additional considerations should include the following:

- Restoration practices are modeled at their peak performance (for example, the peak performance of a riparian buffer might be 10 years out from planting of the buffer).
- Cover crops and no-till agriculture are annual practices but are often sustained by landowners once they realize the associated cost savings. The value of these practices increases if they are sustained.
- Other practices last for multiple years but have limited lifespans. For example, the utility of manure storage degrades over its 30-year lifespan.
- Urban and suburban stormwater infrastructure is challenging to compare with land protection because of the high costs of installation and regular maintenance that is required to maintain performance. In addition, most engineered stormwater best management practices (BMPs) have diminishing benefits after 30 to 50 years, after which replacement would be required to maintain the ecosystem benefit.
- Forest restoration and forested stream buffers will have a similar benefit to forest protection once well established. However, forest establishment takes decades and can be derailed by invasive species, fires, windstorms, and drought. Even with successful establishment, the benefit from reforestation of riparian buffers takes time and typically occurs gradually over 30 to 50 years. Plantings with one- to two-year-old seedlings typically require 7 to 10 years for canopy closure, which is necessary to provide shade and nutrients for aquatic organisms and an additional 20 years or more for tree limbs to begin to enter the water and slow stream flow, providing additional water quality benefits.
- Forest protection prevents annual pollutant loads from future development in perpetuity. Land conservation often leads to improved management, resulting in ongoing improvements in water quality. Nevertheless, there are also risks to forests, such as invasive species outbreaks, high-wind blowdowns, flooding, fire, or climate change induced species decline, which may hinder the forest's ability to provide its maximum ecosystem benefit.

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