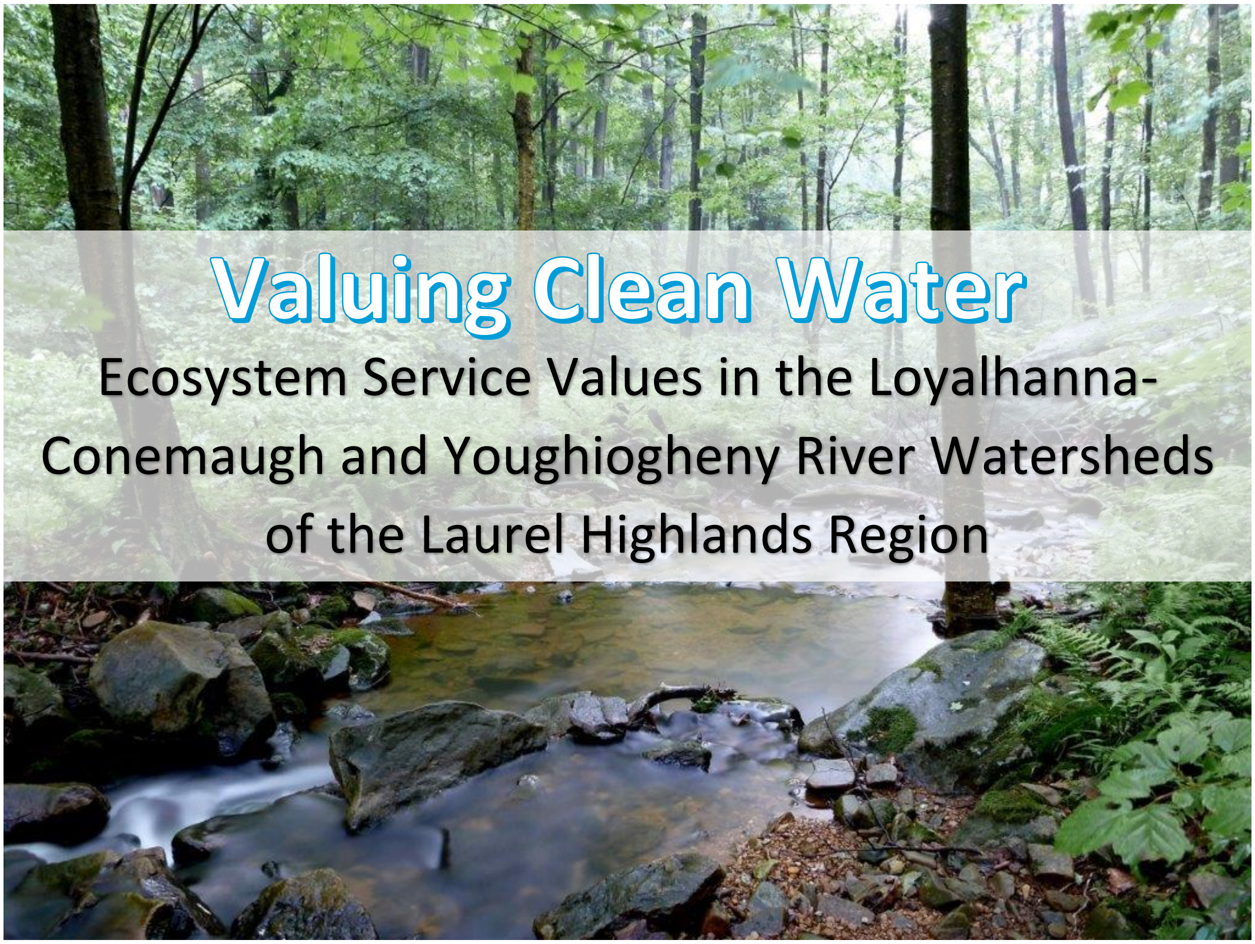

Valuing Clean Water

Ecosystem Service Values in the Loyalhanna-Conemaugh and Youghiogheny River Watersheds of the Laurel Highlands Region

October 15, 2019

Prepared for:

Mountain Watershed Association and the Laurel Highlands Conservation Landscape

Anna Perry

Sonia Wang

Spencer Phillips, PhD

Carolyn Alkire, PhD

KEY-LOG ECONOMICS

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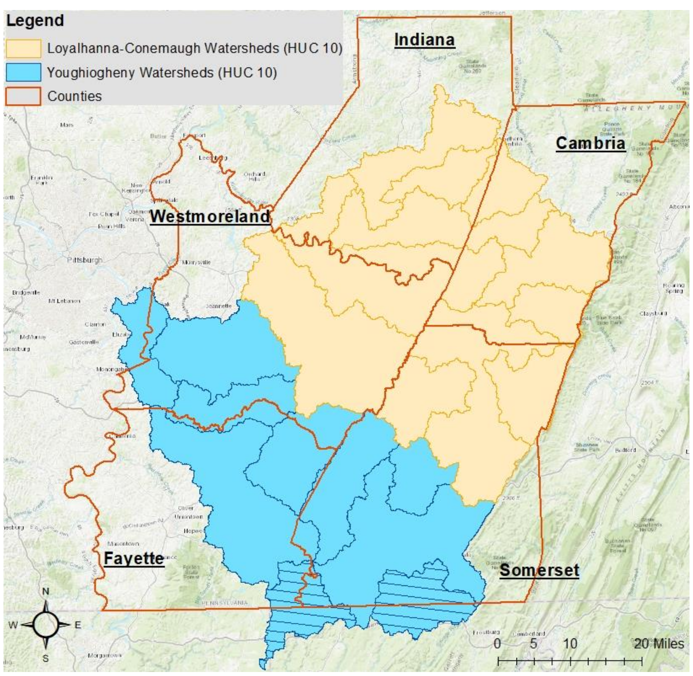
Title page photo credit: Leo Vensel

Executive Summary

Youghiogheny River at Ohiopyle State Park
Credit: Carla Ruddock

The 21 watersheds of the Youghiogheny and Loyalhanna-Conemaugh River Basins contain 6,000 stream miles and generate $3.7 billion annually in ecosystem service benefits, or benefits provided by nature. This $3.7 billion comes from services like recreation, aesthetics & scenery, water quality, and flood protection, and can continue to grow if the region invests in watershed restoration and conservation.[1,2] An economy built around enhancing ecosystem services and benefits like clean water produces a high-quality of life, tourism revenue, and higher property values, all of which attract new residents and visitors.



Project Study Region

The portion of the Laurel Highlands (left) covers 1.9 million acres and is home to 550,000 people. While teeming with abundant natural beauty and recreational opportunity, the watersheds are still recovering from a legacy of coal mining that has left hundreds of miles of streams impaired by abandoned mines. Meanwhile, a resurgence in active coal mining and destructive quarrying practices, extreme weather events, pollution from agricultural and urban runoff, natural gas drilling, water withdrawal and inter-basin transfers, and inadequate sewage management are degrading water quality and

[1] Estimates are provided in 2017 $ unless otherwise noted.
[2] Full citations can be found in the technical report, available for download at keylogeconomics.com/laurel-highlands

threatening the resilience of regional watersheds.

This study highlights the economic benefits of clean water in these watersheds and illustrates the value in improving ecosystem services through restoration and conservation projects. Incorporating these benefits into policy and funding decisions will help create an environment in which both the economy and the watersheds can thrive.

Ecosystem Service Values in the Laurel Highlands: Baseline Assessment

"Ecosystem services" are benefits that people receive from nature, such as clean air and water, scenic views, experiences in nature, and fertile soil to grow food. People often receive these benefits for free; ecosystems filter air and water, absorb harmful toxins, and provide a natural buffer to extreme weather events, all at no cost.

Ecosystem services are benefits people receive from nature for free. These services –clean air, clean water, scenic views, fertile soil – produce value in the economy, and can results in economic costs if damaged.

Stressors in watersheds, such as development and pollution, can reduce or disrupt the flow of these services. This disruption results in an economic cost to society. These costs can take the form of spending on man-made means of providing the same services (for example, by installing more expensive water treatment systems), or in the form of spending on health care to treat illnesses resulting from pollution.

Putting these effects in monetary terms helps convey the level in benefit of clean water and intact ecosystems. The existing annual value of ecosystem services in the 21-watershed region is estimated at $3.7 billion. Additional funding and resources devoted to restoring and maintaining the health of these watersheds can not only prevent loss of this value but stimulate and enhance the provisioning of services as well.

Regional watersheds produce $3.7 billion per year in benefit:
$897 million in flood/extreme event protection
$592 million in recreational value
$587 million in aesthetic value

The study examines several scenarios (AMD remediation, continued development of unconventional natural gas, promoting higher water quality for recreation, improving sewage management, and increasing natural riparian buffers), in which future ecosystem service flows could increase or decrease. In each scenario, the models developed estimate the magnitude of those changes in monetary terms using the best available data.

Abandoned Mine Drainage Remediation: Investing in Restoring Impaired Streams

There are 878 miles of streams in the Loyalhanna, Conemaugh, and Youghiogheny watersheds of the Laurel Highlands that have been damaged by heavy metals and/or acidity from abandoned mine drainage (AMD) (PA DEP, 2018d). AMD-impaired streams affect local communities and watersheds through degraded water quality, forgone recreation or recreational opportunity, and lost natural beauty. These environmental changes have economic costs attached to them including higher water treatment costs, lower recreational economic activity, and lost property values.

Kalp Discharge Remediation at Indian Creek
Credit: Anna Perry

Passive treatment systems[3] throughout the region are beginning to restore streams, improving water quality and allowing fisheries to thrive in waters once too toxic to support aquatic life. An average passive treatment system in these watersheds costs $415,000 to construct and requires $16,600 of annual maintenance to ensure water quality improvements are sustained (Stream Restoration Inc., 2018; PA DEP, 2016b). Capital costs for active treatment systems, less common in the region, can range from $50,000 to $12 million depending on the treatment type (Beam, 2019). [4] In the Stonycreek River watershed, proposed lime doser treatment sites were projected to cost $98,334 on average to construct, and $3,829 annually to maintain (Null, Deal, & Lichvar, 2009).

Continued AMD remediation captures lost economic benefits; restoring streams damaged by AMD in the study region could bring an additional benefit of $16.8 million in recreational fishing and raise nearby property values by 5.0-12.8% (Hansen et al., 2008; Thurston et al., 2009).[5] This translates to an average one-time economic benefit of $41,133 per stream mile restored, with an annual recreational benefit of $19,131 per average stream mile restored.

*AMD remediation in the region can produce an additional **$16.8 million** a year in recreational fishing and **$36-$765 million** in increased property values*

Surveys in the region reveal residents value AMD remediation of damaged streams and would be willing to pay for AMD remediation, reflecting a one-time benefit of $20 to $32 per household once streams are restored (Hansen et al., 2008). Applied to the 257,000 households in the region, residents may value AMD-stream restoration at $5.67 million.

[3] Passive treatment systems, generally expensive to install, are designed to treat AMD water passively for 10-15 years with low maintenance by removing metals and stabilizing pH levels (Eastern Pennsylvania Coalition for Abandoned Mine Reclamation).

[4] Active treatment systems, which use chemicals to treat water, require frequent maintenance and higher upfront costs for mechanical equipment to treat AMD in areas where passive treatment may be insufficient (Penn State Extension, 2017). The range in active treatment costs regionally may vary from average statewide estimates.

[5] The range in property values estimated reflect different levels of impact and zones of influence in the two studies. Because of heterogeneity in property values and AMD-impairment across the 21-watershed study region, no conclusions are drawn about which study may be more applicable to the entire region. Rather, the range in potential impacts are presented.

Ongoing and Projected Natural Gas Well Pad Construction in Regional Watersheds

Natural gas hydraulic fracturing ("fracking") in the region is expected to increase drastically in the next ten years. By 2030, another 8,796 unconventional wells may be drilled on 1,466 well pads in the Loyalhanna, Conemaugh, and Youghiogheny watersheds, resulting in the loss of more than 30,000 acres of forest and agricultural land (Johnson, 2010). More than 13,000 of the acres at risk are in important recreation and habitat areas including state parks and lands, native trout watersheds, and within a half-mile of exceptional value (EV) or high-quality (HQ) waters. Construction of these wells could result in an additional 192 million gallons of water demanded a day from surface waters in the region.

The loss of forest acreage and the fragmentation of overall forest coverage means less land and lower-quality habitat for native species and for recreation. Ecosystem service value losses from well pad construction includes damages to the services of recreation, habitat & biodiversity, water filtration, and carbon storage. Annual ecosystem service value losses from this well pad construction could total more than $57.4 million by 2030 in the high development scenario. Costs associated with lost agricultural production and carbon storage on agricultural land could reach $2.7 million per year and $3.8 million per year by 2030 in the middle scenario. Table ES-1 summarizes ecosystem service losses from forest loss in three development scenarios in the region.

Table ES-1. Ecosystem Service Losses from Forest Conversion to Natural Gas Well Pads

Natural Gas Well Pad Development Scenarios	Low	Medium	High
Potential Number of Well Pads in Forests*	604	982	1,490
Estimated Wells per Pad	10	6	4
Annual Ecosystem Service Loss**	$23,290,031	$37,865,581	$57,453,885

*We present estimates under the assumption all well pads will be constructed. Although certain well pads have less likelihood of being constructed, this scenario provides a more complete picture of potential losses.
**Approximately the same number of wells are drilled in each development scenario. The low, medium, and high scenarios pertain to the amount of land converted for new well pads, depending on the density of wells per pad.

Source: Johnson, 2010; Jerrilyn.

Water-Based Recreation & Economic Benefits from Water Quality Improvements

Watersheds in the region offer a wealth of recreational opportunities that support local economies but require clean water in order to be sustained. Popular water-based recreational activities include fishing, kayaking, white-water rafting, paddling, boating, and swimming. Anglers participate in more than 844,000 recreational fishing days a year in regional watersheds, which produces $31.7 million in regional spending, and an additional $41.9 million in net economic benefit[6] to anglers.

[6] Net economic benefit represents the amount recreational fishing participants value the experience above and beyond what they paid for it.

Unsafe water, or the perception of unsafe water, negatively affects the demand for recreation and the value of recreation. That is, poorer water quality will mean fewer people will spend less time — and less money — pursuing recreational experiences in the region. Each recreational experience returns less value to the recreational user, whether visitors or residents. By the same token, higher water quality can lead to increased visitation and spending in the region, supporting more local jobs and businesses and even attracting new residents, as well as greater satisfaction with each recreational experience.

Native Brook Trout Caught in Laurel Hill Creek
Credit: Forbes Trail TU

Researchers have found that outdoor recreators and non-recreators alike are willing to pay more for improved water quality. Farber and Griner (2000) studied the value of water quality improvements around the Loyalhanna Creek and Conemaugh River, both considered polluted, and found that residents were willing to pay between $57 and $82 per household per year over a five-year period for stream quality improvement from moderately polluted to unpolluted. To improve water quality from severely polluted to unpolluted, households were willing to pay between $140 and $180 per year for five years. Applying these survey results to the study region, water quality improvements across streams currently classified as impaired yields a benefit of at least $1.1 million for people who participate in water-related recreation activities (2018 $).

44 million potential visitors live within 200 miles of the study region. The watersheds draw in more than 844,000 annual recreational fishing days, producing $32 million in regional spending and an additional $42 million in net economic benefit.

Natural Riparian Buffers: Value from Controlling Runoff

Increasing natural land cover along waterways can be one of the most cost-effective management tools for reducing runoff and sedimentation. Natural buffers reduce sedimentation and improve water clarity, which can have a positive benefit on the services of aesthetics, recreation, and overall water quality (Evans & Corradini, n.d.). An estimated 654 miles of streams in the region are impaired by excessive siltation — or high concentrations of suspended particles in the water — largely due to stormwater runoff from agricultural sources, residential areas, roads, and other developed land uses.

The riparian buffer scenario converts 1,463 agricultural acres to forested acres within 100 feet (30 meters) of 176 impaired stream miles. This scenario provides an annual net benefit of $2.9 million once established. Table ES-2 provides the estimated benefit by ecosystem service, including nutrient retention and aesthetics.

Table ES-2. Summary of Ecosystem Service Benefits and Establishment, Opportunity Costs for Forested Buffers

Increased Riparian Forest Buffer: Annual Benefits and Costs	
Ecosystem Service	**Estimated Annual Benefit/Cost**
Benefit: Nutrient Retention	$1,262,424
Benefit: Recreation	$86,619
Benefit: Carbon Storage	$2,210,467
Opportunity Cost: Forgone Agricultural Production	$650,998
Annual Net Benefit	**$2,908,51**2
Increased Riparian Forest Buffer: One-Time Benefits and Costs	
Ecosystem Service	**Estimated Annual Benefit/Cost**
Benefit: Aesthetics	$4,650,531
Establishment Cost	$2,545,475
One-Time Net Benefit	**$2,105,056**

Sewage Management: Problems with On-Lot Septic Systems and Public Treatment Facilities

Water quality degradation from failing septic systems and antiquated public water treatment plants is another prominent concern within the study region. There are 124,000 homes in the region that use on on-lot septic systems to treat their sewage and 27,000 homes that rely on "wildcat" sewers which discharge human waste directly into streets, gullies, or streams (Regional Water Management Task Force, 2008). Roughly 20% of on-lot sewage systems in Pennsylvania are failing, and with estimated failure rates even higher for rural communities.

Many on-lot systems are improperly maintained and over half a century year old. Failing septic tanks contribute to nutrient enrichments in streams which causes excessive algal growth, are a source of suspended particles, and contribute to increases in water temperature and levels of fecal coliform bacteria in water. The Pennsylvania Department of Environmental Protection and most local municipalities do not currently have data on the number of failing septic tanks, their spatial distribution, reasons for failures, or associated costs. Compounding these problems is the fact that the dominant soil types in the region are not suitable for the disposal of septic tank effluent or on-lot systems (Western Pennsylvania Conservancy, 2003). Thus, the region has many poorly maintained and/or failing on-lot sewage systems that perhaps should not be there in the first place.

The problems are different for households attached to municipal sewerage systems. Throughout Pennsylvania, and especially in rural communities, antiquated public sewage treatment facilities are failing and older systems are frequently overwhelmed during heavy rainfall events (Western Pennsylvania Conservancy, 2003). Many municipalities have multiple water and sanitary authorities, with each authority differing in what they handle and how many people are served, making regional collaboration difficult.

Recommendations

Stream Restoration Preserving Property Value of 1798 Compass Inn in Laughlintown
Credit: Monty Murty

These results present an economic case for fruitful work that communities, agencies, and individuals can begin now. This includes funding for continued, more extensive, and more effective watershed protection measures such as AMD remediation, expanded riparian buffers, and measures to mitigate damage from gas, coal, and gravel mining. Along with such on-the-ground improvements, organizations, local governments, and state agencies can continue research, collecting new information to inform the next round of strategies and actions to protect habitat and improve water quality in the 21-watershed study region. Specifically, the following are likely to be cost-effective actions supported by the information now at hand regarding the economic value of clean water and other ecosystem services in the region.

Prioritize Funding for AMD Treatment Systems

- **Compare the costs of continued operation and maintenance for passive treatment systems with recurring ecosystem service benefits.** Agencies and organizations must consider the ecosystem services that will provide recurring benefit so long as treatment and restoration are maintained. Restored stream miles on average provide $19,131 per year per mile in recreational fishing benefit alone.
- **Site-specific characteristics can lead to higher-than-average ecosystem service benefits.** Remediation projects in areas with higher population densities, in waterways with native trout populations, and in waterways with stocked trout will experience higher-than-average property value benefits and recreation benefits. Based on property value impacts measured in the Cheat River watershed in West Virginia, remediation of some stream miles could provide a one-time property value gain of $908,398.

Consider Ecosystem Service Values in Energy Permitting

- **Require an ecosystem services impact assessment for each new natural gas well and any surface disturbance associated with coal and gravel mining.** The results from this analysis show potential ecosystem service value losses of up to $57 million per year from the loss of forests just in the study region. Impact assessments conducted during the permitting process must consider additional disturbances beyond the direct footprint of construction.

- **Set impact fees for industry use to compensate for watersheds' incurred costs.** These assessments can be used to evaluate the net benefits of mining and/or to set impact fees for such industrial uses. Realistically, energy development will continue in the region, but communities should be compensated for damages in the areas where drilling and mining occur.
- **Determine potential sources of the additional water demand required for unconventional natural gas drilling in regional watersheds by 2030.** Unconventional natural gas wells in the region used an average of 11.4 million gallons in 2017 with 70% of the water coming from surface water intakes. Many watersheds are already facing low water flows from strains on water supply. Watershed groups and public water suppliers could partner to determine whether the watersheds in the region do not have excess supply to support additional water demand for unconventional natural gas production.

Focus on Water Quality when Promoting Outdoor Recreation

- **Management actions should be initiated to improve degraded water quality that is threatening the resilience of regional watersheds, and to ensure the continued protection of those that are healthy and resilient.** Improving watersheds that are currently impaired would provide opportunities for more recreation and spending in the region, supporting more local jobs and businesses and improving visitor experiences.

Require Cost-Benefit Analyses for Riparian Buffer Projects

- **State-wide, regional, and local programs should incorporate ecosystem service benefits into consideration of compensation levels for conserved riparian acres.** Incentivizing the establishment of forested riparian buffers along streams impaired by sedimentation or nutrient enrichment can provide the greatest return in ecosystem service value.
- **Explore compensation schemes between downstream municipalities and upstream landowners**. In stream segments with high nutrient concentrations and sedimentation levels upstream of municipalities and boroughs, both landowners and townships could benefit from establishing a payment-for-ecosystem-services (PES) scheme. In this arrangement, townships compensate landowners for lower raw water treatment costs at public water intakes.

Foster Regional Collaboration on Sewage Data and Water Quality Monitoring

- **Commission research to fill data gaps on the number, location, and degree of failure of on-lot septic systems in the region near existing impaired streams.** Use the resulting information to target accelerated connection to municipal systems and/or incentives for upgraded or alternative on-lot systems appropriate to soil types and other conditions in the region.

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Key Terms

Stream Designations and Classifications

Class A Wild Trout Waters: A Pennsylvania Fish and Boat Commission (PFBC) surface water designation indicating which waterways support naturally producing populations of trout of enough size and abundance to maintain a long-term sport fishery.

Cold Water Fishes (CWF): Special designation for waterways that have maintenance and/or propagation of fish and aquatic species indigenous to a cold-water habitat.

Designated Use: Water body uses (aquatic life habitat, recreation, water supply) specified in Pennsylvania's Chapter 93 indicating the fixed use of a water segment and whether they are currently attained.

Exceptional Value Waters (EV): Highest classification of high-quality surface waters, relating to anti-degradation.

Existing Use: Water body uses, as specified in Pennsylvania's Chapter 93, attained by the water body.

High-Quality Waters (HQ): Surface waters with water quality exceeding levels necessary to support propagation of fish, shellfish, wildlife, and recreation.

High-Quality Cold-Water Fishes (HQ-CWF): Surface waters designated as both high-quality and cold-water fishes.

Hydrological Units and Hydrological Unit Codes (HUCs): Hierarchal codes used by the United States Geological Survey to describe drainage areas including, in ascending order of size, subwatersheds (HUC12), watersheds (HUC10), sub-basins (HUC08 or HUC8), and basins (HUC06/HUC6). Vernacular writing and speech may misclassify the technical hierarchy nomenclature, for example, characterizing what is technically a basin as a watershed. In this report, we identify the technically established geographical definitions in figures and tables but defer to regional nomenclature in the report. The 21 HUC10-level watersheds in the study region are contained in either the Youghiogheny Basin or the Kiski-Conemaugh Basin. In this report, the study region is often referred to as the "Youghiogheny watersheds and Loyalhanna-Conemaugh watersheds", identifying the major river systems that the study focuses on, which excludes most watersheds in the Kiskiminetas River of the Kiski-Conemaugh Basin, except for the Loyalhanna watershed.

Natural Heritage Areas (NHAs): An area containing one or more plant or animal species of concern at the state or federal level, including exemplary natural communities or native biological diversity.

Pennsylvania Department of Environmental Protection (PA DEP): Pennsylvania's state agency responsible for the protection and restoration of Pennsylvania's air, water, and land resource quality.

Pennsylvania Fish and Boat Commission (PFBC): A state agency responsible for protecting, conserving, and enhancing Pennsylvania's aquatic resources as well as providing fishing and boating opportunities.

Trout Stocking-Trout Stocked Fisheries (TSF): The maintenance of stocked trout from February 15 to July 31 in addition to maintenance of fish and aquatic species indigenous to warm water habitats.

Warm Water Fishes (WWF): The maintenance and propagation of fish and aquatic species indigenous to warm water habitats.

Wilderness Trout Streams (WT): A Pennsylvania Fish and Boat Commission (PFBC) surface water designation indicating protection and promotion of native trout fisheries, designated to maintain and enhance wilderness aesthetics and ecological requirements necessary for the natural reproduction of trout.

Environmental

Abandoned Mine Drainage (AMD): Refers to water polluted by mining activity, most commonly coal mining. Types of abandoned mine drainage that affect water quality are acid mine drainage, alkaline mine drainage, and metal mine drainage.

Best Management Practices (BMPs): Practices implemented to protect water quality and support soil conservation around waterways.

Ecosystem Services (ES): In the terms chosen by the U.S. Forest Service, "the benefits people obtain from ecosystems" (USDA Forest Service, 2012). We prefer a definition with a little more power to guide analyses of ecosystem services:

"Ecosystem services are the effects on human well-being of the flow of benefits from *ecosystems to people* over given extents of space and time" (Johnson, Bagstad, Snapp, & Villa, 2010).

The italics are to emphasize that ecosystem services are about human welfare, not nature for its own sake. They are about flows of benefits (as opposed to states of nature). Ecosystem services also flow from one place to another at one time or another (they are not static). This definition is an important component of the lens through which we have viewed and evaluated the existing literature.

For descriptions of the ecosystem services included in this report, please see Appendix B.

Economic

Avoided Cost: A value of a service determined by the costs or damage that would occur in the absence of that service. For example, natural riparian buffers can prevent higher water treatment costs downstream.

Benefit Transfer Method (BTM): A means of establishing the value of ecosystem service flows in one setting by transferring values derived through primary research in another setting. For example, if a study of the ecosystem service values of a wetland forest in one area determined that each acre generates $1,000 per acre per year in recreational value (because it is good songbird habitat and therefore supports birdwatching, say), that value may be transferred to an acre of wetland forest in another location. This is an example of the sub-genre of BTM known as "unit value transfer", in which a single number or set of numbers is transferred from the earlier study.

Consumer Surplus: The value of a good or service to the consumer, over and above what the consumer pays for that good or service.

Contingent Valuation: A method for estimating the value a person places on a good or service; determining willingness-to-pay or accept compensation for a certain change in provision of a good or service.

Ecosystem Service Value (ESV): The translation of a flow of benefits into dollar terms. For example, we can say that a flow of a million gallons of water per day in a watershed is an ecosystem service. And if each gallon is worth a penny, we could say that the ecosystem service value of that daily flow would be $10,000.

Opportunity Cost: the value of a next-best alternative, which is forgone when another option is chosen.

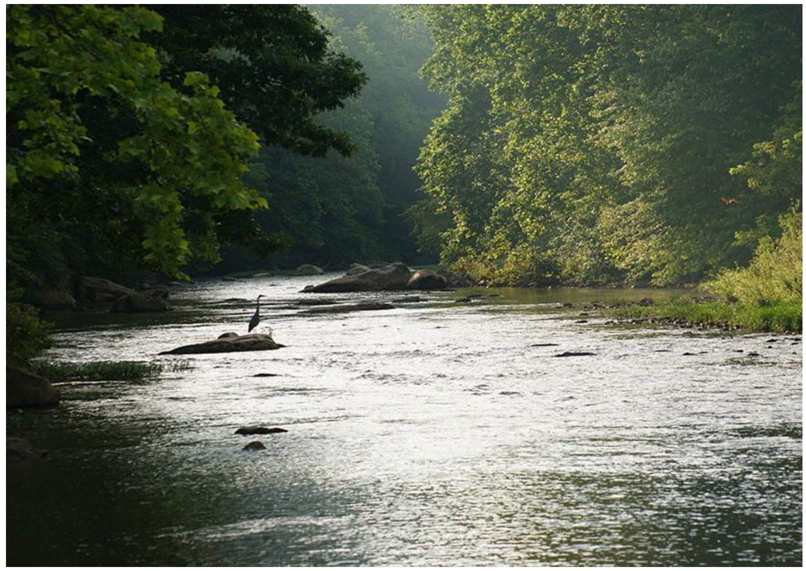
Production Function or ***Ecological*** **Production Function Methods**: Relative to BTM, a more detailed or precise means of estimating ecosystem service value. In these methods one begins by estimating the *biophysical flow* of an ecosystem service (water for recreation, for hydro power, or for drinking, for example), and then applies unit value estimates of the various effects on human well-being of that flow to get to estimates of the dollar value of the flow. (This method can include an intermediate step of estimating non-dollar-valued effects, such as a greater physical or mental health leading to fewer lost days of work or years of life, and then applying dollar-valued estimates of those effects.)

In short, where BTM leapfrogs from landscape conditions (cover, stocking, etc.) to economic value supported by a landscape, the (ecological) production function methods fill in some of the steps along the value chain from land to people to welfare to monetary estimates.

Net Economic Benefit: The benefit received from paying less for a good or service than the maximum amount that an individual or group is willing to pay for it.

Willingness to Pay (WTP): The maximum price a consumer is willing to pay for a good or service.

Purpose & Background: The Value of Clean Water



Loyalhanna Creek
Credit: Loyalhanna Watershed Association

Southwestern Pennsylvania's legacy of coal mining, logging, steel making, and gas production have left the region's watersheds severely impaired and the future of water resources unclear. Many rivers in the region are unable to support aquatic life and classified as unsafe for recreation.[7] Thousands of miles of rivers are still damaged from abandoned mine drainage (AMD) and many residents still lack access to potable and safe water. In addition, the surge of natural gas drilling from the Marcellus Shale boom and the resurgence of coal mining poses a new threat to the region's watersheds. The watersheds in the Laurel Highlands region exhibit both the legacy of coal mining and conventional natural gas drilling, and the success of restoration efforts that have brought streams back to life and attracted visitors and new residents to the region.

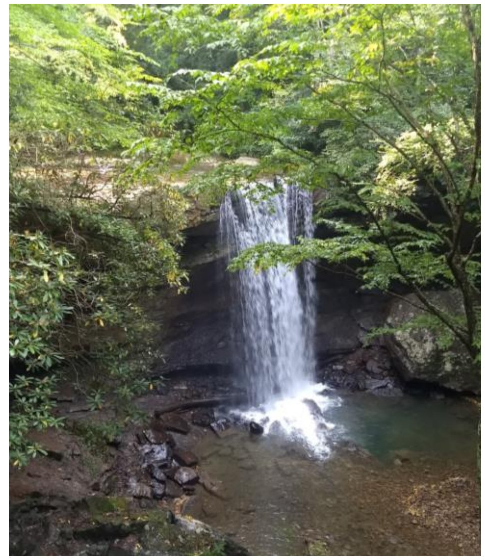
The region is comprised of rural counties with local economies still largely tied to extractive industries. Many residents are led to believe that the consequences of their presence are just trade-offs to maintaining their livelihood. For decades, the prevailing narrative has pitted economics and the environment against one another, suggesting that a choice must be made between jobs and income or investment in the natural landscape. This could not be further from the truth; protecting and restoring watersheds goes hand in hand with developing and maintaining a strong, vibrant economy for generations to come.

This study highlights **the value of clean water** in the Laurel Highlands region and illustrates the economic benefits provided by the watersheds' ecosystem services, enhanced by communities' restoration and conservation. By cleaning up damaged streams and attracting residents and visitors alike to the rivers, both the economy and the watersheds can thrive.

[7] According to PA DEP data on impaired streams. Jacks Run and Sewickley Creek are examples of streams impaired for recreational use by pathogens.

Natural Assets & Attractions

The region includes five national parks, nine state parks, the state's highest peak and deepest river gorge, and 245,000 acres of protected lands including agricultural and conservation easements, recreation areas, and state lands (Pennsylvania DCNR, 2018).



Cucumber Falls
Credit: Anna Perry

There are 44 million potential visitors that live within 200 miles of the region, which offers an abundance of recreational activities such as whitewater rafting in Ohiopyle State Park, biking the Great Allegheny Passage, and boating on Yellow Creek Lake.[8] Recreational anglers have access to 587 miles of stocked trout streams, wild native trout fisheries in Baldwin Creek and Powdermill Run, and Class A Wild Trout streams like Rasler Run on Chestnut Ridge and Higgins Run above the Quemahoning Reservoir.

The region also has 191 Natural Heritage Areas (NHA) sites, designated as important habitat for species or populations critical to Pennsylvania's native biodiversity and are at particular risk. Important NHA sites include Somerset Lake, which provides habitat for thousands of migratory waterfowl, and the wetlands in Upper Indian Creek, home to a red maple-black ash palustrine forest (Pennsylvania DCNR, 2018).

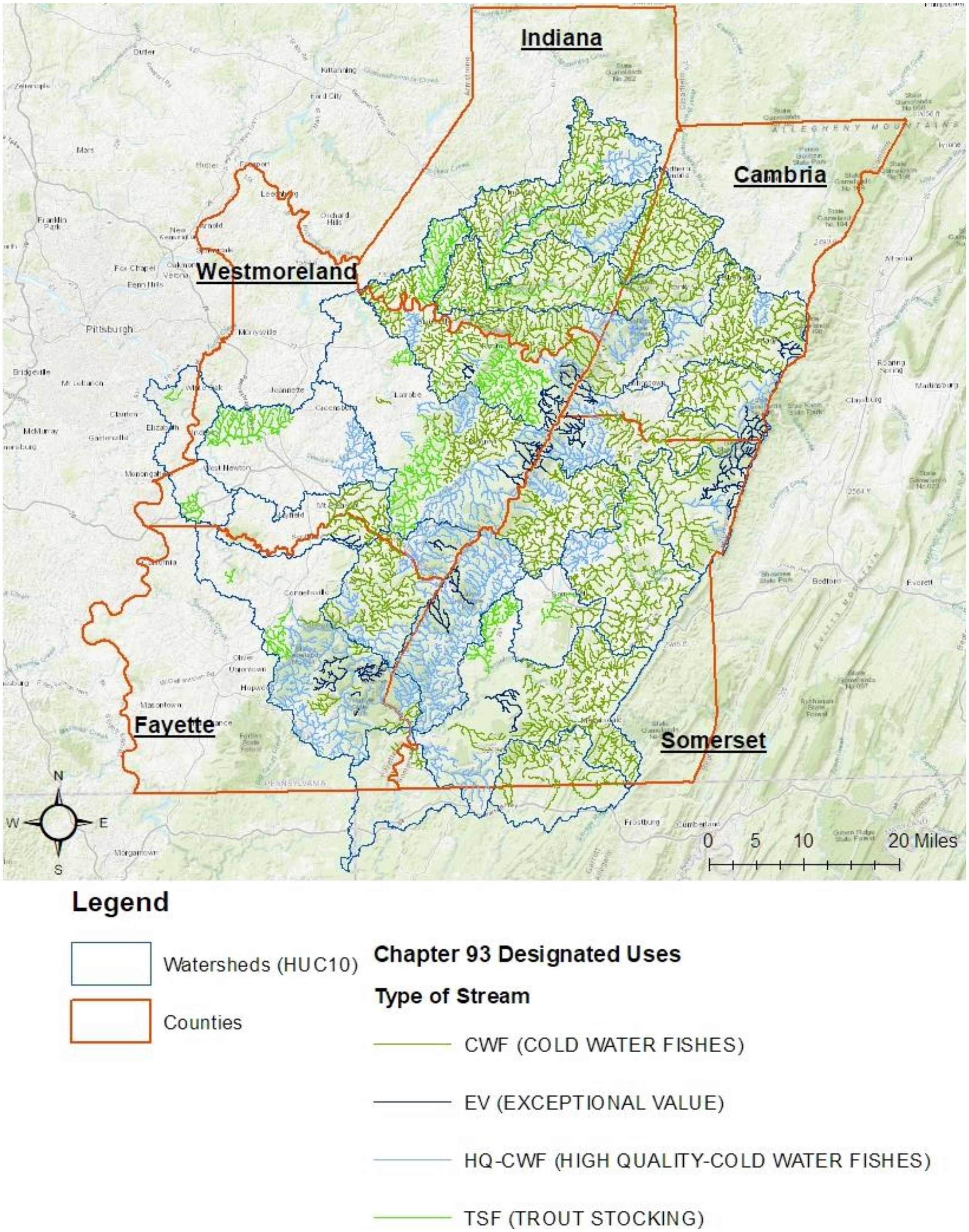
The Pennsylvania Department of Environmental Protection (PA DEP) also develops water quality standards for all the state's surface waters, which defines use designations and the benchmarks necessary to protect uses (PA DEP, 2019). All surface waters in the state are supposed to be protected for designated aquatic life uses, such as warm water fishes, trout stocking, cold-water fishes, and migratory fish, as well as several water supply and recreational uses (PA DEP, 2019). Streams that are found to have excellent water quality may further be designated exceptional value or high-quality waters.

Roughly 6,000 miles of streams and rivers flow through the region, with 300 of those stream miles designated as exceptional value streams,[9] including 30 miles of wilderness trout streams (PA DEP, 2019). More than 3,700 miles of streams are designated for cold-water fishing, with 1,200 of those miles designated as high-quality (Figure 1). While thousands of stream miles are not attaining their designation, Figure 1 provides a snapshot into the rich recreation and resource potential of the watersheds in the region.

[8] Major cities within 200 miles of the study region include Washington D.C., Baltimore, MD, Pittsburgh, PA and Cleveland, OH (Laurel Highlands Visitor Bureau).

[9] The stream designation "exceptional value" by Pennsylvania's Chapter 93 water quality standards includes streams in protected areas, of exceptional recreational value, exceptional water quality, and/or designated as wilderness trout streams by the Pennsylvania Fish and Boat Commission (PFBC) (Commonwealth of Pennsylvania, 2013).

Figure 1. Designated Stream Uses in the Laurel Highlands
Source: PA DEP, 2019

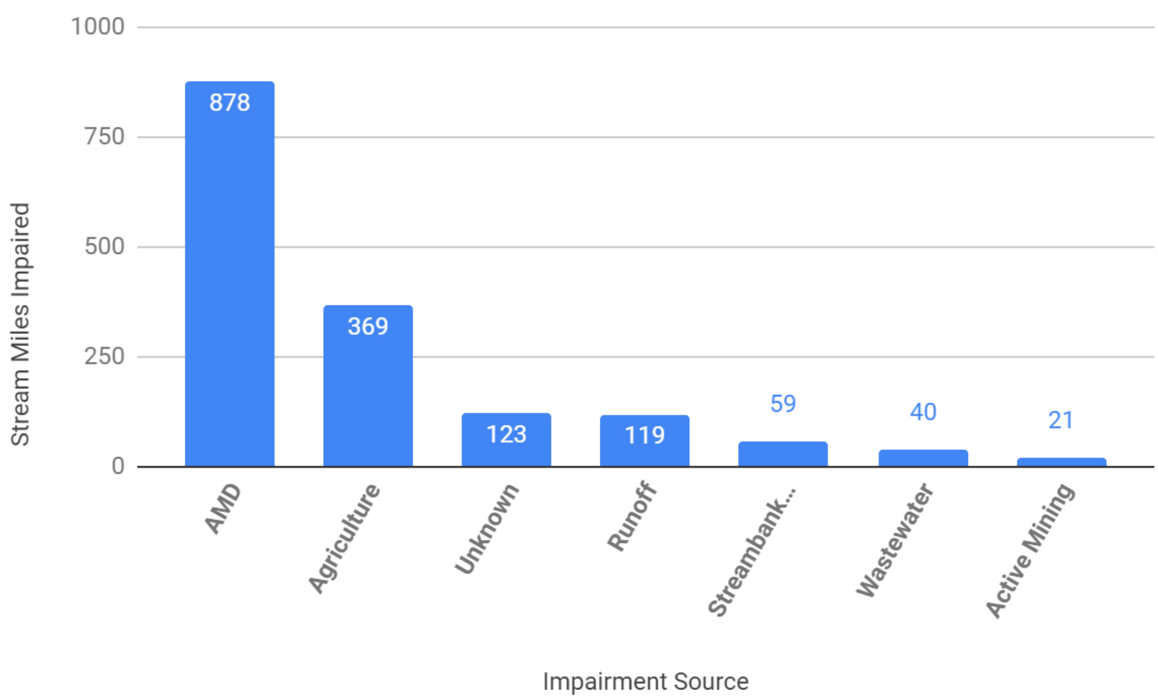


Issues & Opportunities

Of the nearly 6,000 miles of streams in the Laurel Highlands region, 1,675 miles are considered impaired by the Pennsylvania Department of Environmental Protection (PA DEP, 2018d). PA DEP compiles data on the relative quality of the state's surface waters, including whether the water is impaired and the reason for impairment (The Pennsylvania Geospatial Data Clearinghouse, 2019). The data also includes why the water is non-attaining, either because there have been impairments to aquatic life use attainment, fish consumption use attainment, recreational use attainment, and potable water supply use attainment.

More than half of impaired streams in the Laurel Highlands are damaged by abandoned mine drainage, leaving water contaminated with heavy metals, suspended solids, and sometimes pH levels so acidic, fish and other aquatic life cannot survive. Other sources of impairment include agriculture, urban runoff and poor stormwater management, sewage discharge from public treatment plant overflows or failing on-lot septic systems, and erosion and sedimentation from development. In the region, there are at least 350+ industrial discharge sites, 77 sewage treatment discharge sites, at least 38 active underground mining permits, 2,000 conventional oil and gas wells, and another 331 unconventional natural gas wells across the landscape (PA DEP, 2018a; 2018b; 2018c). Figure 2 shows stream miles damaged by major pollution sources, a number which will only increase if the existing systems treating impaired streams cease to maintain current operations.

Figure 2. Sources of Stream Impairment in the Laurel Highlands
Source: PA DEP, 2018d



Of the nearly 300 designated exceptional value (EV) streams[10], only 38 miles currently meet the water quality standard of their designation (Pennsylvania DCNR, 2018). Only 20 miles of high-quality cold-water fishery (HQ-CWF) streams, or less than 2% of total miles designated, meet current standards.

While hundreds of miles of streams still need to be restored, opportunity and value exist in their restoration. At least 67 passive treatment systems are restoring AMD-impaired streams across 14 of the 21 watersheds in the region. Stories of success include five passive treatment systems along the Stonycreek River that led to the recovery of fish populations across the watershed, including a year-round trout fishery between Shanksville and Benson (Null, Deal & Lichvar, 2009).

The value and potential in outdoor recreation and tourism in the region continues to grow as well. From 1998-2016, travel and tourism jobs in the Laurel Highlands increased by 7.8% while employment in all other industries fell by 0.3% (Headwaters Economics, 2015). Restoring and preserving water quality and water resources across the region will continue to attract new businesses, visitors, and residents.

Economic Profile of the Laurel Highlands Region

There are 550,000 people living in the 21 watersheds of the study region. The geographic extent of the study watersheds covers five counties—Cambria, Fayette, Indiana, Somerset, and Westmoreland Counties. Traditional measures of economic performance suggest that the region is generally resilient, though there are variations between the counties. From 2000 through 2016 in the five-county study region:[11]

- Population decreased by 0.07% compared to a 0.03% decrease in all rural (non-metro) Pennsylvania counties[12]
- Employment grew by 0.01 %, the same as the average for rural Pennsylvania
- Personal income increased by 0.15%, compared to a 0.17% decrease for rural Pennsylvania
- Average earnings per job were higher by $96/year than that of rural Pennsylvania
- Per capita income was higher by about $1,000/year than the average for rural Pennsylvania
- The average unemployment fell by 3.2%, compared to 3.8% for rural Pennsylvania

This region has the potential for what regional economists McGranahan and Wojan have called the “Rural Growth Trifecta” of outdoor amenities, a creative class of workers, and a strong “entrepreneurial context” (innovation-friendliness) (2010). Individual workers, retirees, and visitors are attracted to the natural beauty of the region and the quality of life it supports. Evidence in the study region supports this dynamic:

- From 2000-2017, net migration was 246 people.
- Since 2010, the proportion of the population 65 years and older has increased from 18.2% to 20.4%.
- In 2016, proprietors’ employment comprised 21.9% of total employment compared to only 18.9% in 2000.

[10] Includes wilderness trout (WT) streams, which are designated as exceptional value (EV) streams.
[11] U.S. Census data as reported in the Headwaters Economics Economic Profile System (2018)
[12] “Non-metro Pennsylvania” comprises those counties that are not a part of a federally defined metropolitan statistical area (MSA).

- Since 2000, non-labor income (primarily investment returns and age-related transfer payments like Social Security) increased 26.4%.
- From 1998 to 2016, employment in travel and tourism industries grew by 7.8%, compared to a decline of 0.3% for other industries.

Baseline Ecosystem Service Assessment in the Laurel Highlands

The baseline ecosystem service assessment sets the stage for how management scenarios and conservation strategies can result in changes in the supply of ecosystem services. By incorporating ecosystem service values into funding prioritization, policymaking, and resource management planning, decisionmakers get a more complete picture of the costs and benefits of any one restoration effort and can make better-informed decisions (see Appendix A for methods).

What are Ecosystem Services?

Ecosystem services are the benefits that people receive from nature over space and time. Examples of ecosystem services are clean air, clean water, scenic views, experiences in nature, and fertile soil to grow food. These benefits are often received for free; local ecosystems filter the air and water people breathe, absorbing harmful toxins, and providing a natural buffer to extreme weather events, all at no cost.

Youghiogheny Gorge Overlook
Credit: Anna Perry

Aesthetic Value: Benefits people receive from an attractive landscape

Eastern Hellbender Salamander in Loyalhanna Creek
Credit: Loyalhanna Watershed Association

Biodiversity & Habitat: Benefits of increasing and sustaining genetic diversity across and within a species

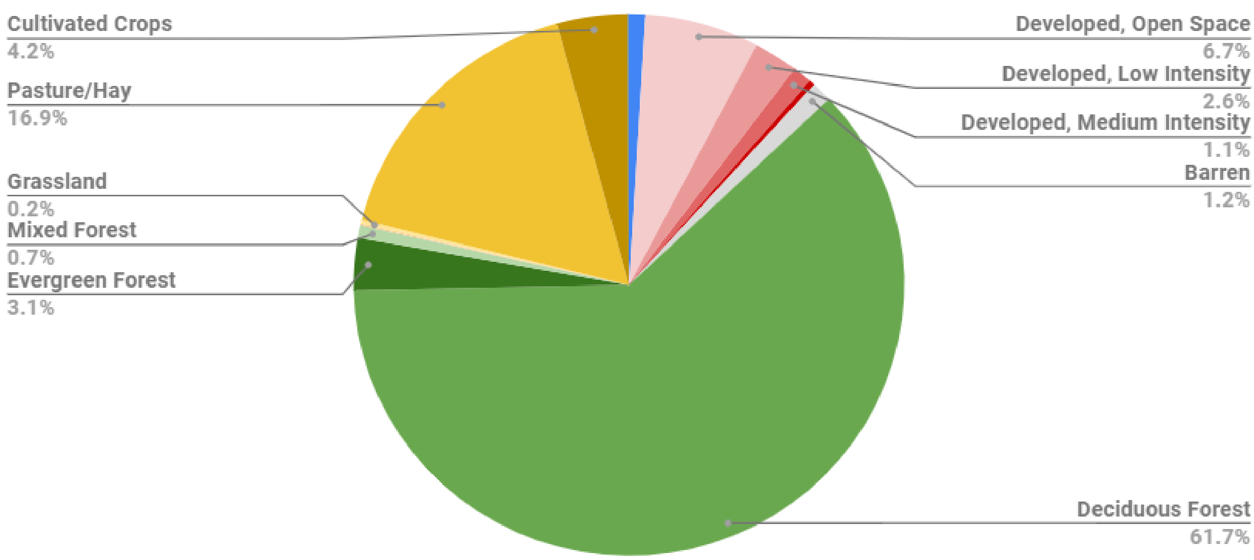
Stressors on the ecosystem, such as urban development and pollution, can reduce or disrupt the supply of these services. This disruption results in an economic cost to society. In some cases, these services must be replaced through man-made means, which have a material cost, and in some cases, human health suffers as well.

For example, when clean water is polluted, communities pay more in water treatment costs and residents can suffer from sickness and lost recreational experiences. These losses can be quantified in dollar terms, which helps underscore the benefit of clean water. For definitions of the ecosystem services assessed, see Appendix B: NLCD Land Cover and Ecosystem Service Descriptions.

Land Cover in the Region

The study watersheds cover 1.9 million acres, of which most is deciduous forest. The breakdown by land cover type is shown in Figure 3. Deciduous forest and pasture or hay land comprise nearly 80% of the study region, followed by developed, open space (6.7%) and cultivated crops (3.9%).

Figure 3. Study Region Land Cover Distribution



Forested land has significant value for services such as recreation and air quality, while wetlands are valued for their natural protection from extreme events and water regulation in a land area. Agricultural lands provide high food and raw material values, much of which is reflected as market values because the benefit is directly consumed by people. As shown in the following section, the Laurel Highlands has more than $1 billion in annual value for the service food and nutrition, followed by nearly a billion dollars in value from protection from extreme events, and $500 million for aesthetic and recreational value (Table 1).

Baseline Ecosystem Service Values in the Region

The baseline estimate for total annual ecosystem service value provided in the region is $3.7 billion (Table 1). Services with the highest values include food and nutrition, protection from extreme events (such as flood protection), recreation, aesthetic or scenic value, and air quality (see Appendix B for definitions of each ecosystem service).

Table 1. Baseline Ecosystem Service Values in the Laurel Highlands

Ecosystem Service	Baseline Estimate (2017$/year)
Aesthetic	$587,090,772
Air Quality	$374,130,045
Biodiversity	$6,312,648
Climate Regulation	$90,459,688
Cultural, Other	$1,356,191
Erosion Control	$3,160,768
Food/Nutrition	$1,019,106,557
Medicinal	$6,455,425
Pollination	$954,120
Protection from extreme events	$897,295,964
Raw Materials	$2,248,729
Recreation	$591,935,690
Renewable Energy	$721,578
Soil Formation	$929,132
Waste Assimilation	$11,449,856
Water Supply	$87,125,968
Grand Total	**$3,680,733,131**

Ecosystem Service Values by Watershed

The table below shows the breakdown of annual ecosystem service value provided by the lands in the 21 focal watersheds. Differences in baseline values for each watershed are mostly a reflection of watershed size; larger watersheds have a higher ecosystem service value. Watersheds with more developed land will generally have a lower ecosystem service value than less developed watersheds with a higher percentage of forest cover or wetlands.

Table 2. Regional Results by Watershed (HUC 10)

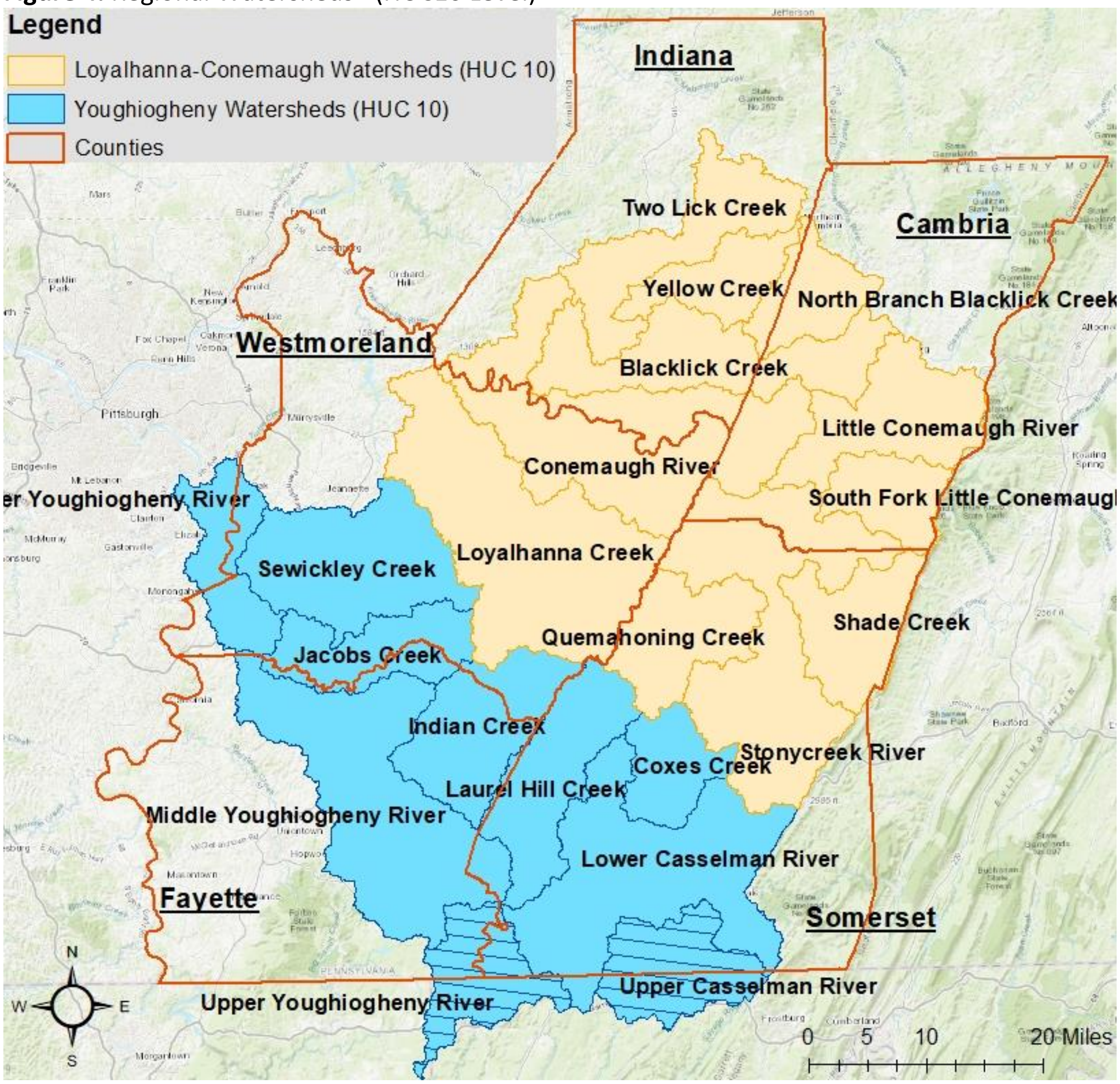
Basin	Watershed (HUC 10)	Baseline Estimate (2017 $/yr)	Total Acres
Youghiogheny	Indian Creek	$120,499,069	79,864
	Jacobs Creek	$99,878,314	60,598
	Sewickley Creek	$159,286,985	107,212
	Laurel Hill Creek	$129,980,765	79,799
	Coxes Creek	$96,921,966	41,636
	Upper Youghiogheny	$100,280,149	56,228
	Middle Youghiogheny	$248,732,620	169,765
	Lower Youghiogheny	$76,184,286	52,357
	Upper Casselman	$118,829,413	92,574
	Lower Casselman	$377,538,735	165,499
Kiski-Conemaugh*	Blacklick Creek	$189,010,092	100,635
	North Branch Blacklick Creek	$76,700,465	44,098
	Yellow Creek	$91,218,656	42,480
	Two Lick Creek	$166,176,302	80,458
	Conemaugh River	$314,219,083	188,829
	Little Conemaugh River	$158,744,660	80,670
	South Fork Little Conemaugh	$101,585,257	40,950
	Stonycreek River	$496,012,881	173,972
	Quemahoning Creek	$126,653,755	63,634
	Shade Creek	$152,257,904	62,562
	Loyalhanna Creek	$279,532,710	191,240
Total Study Region		**$3,680,733,131**	**1,975,060**

*Specifically, Conemaugh River watersheds and Loyalhanna Creek watershed.

Watersheds in the Laurel Highlands Region

There are two basins (HUC 6) with 21 watersheds (HUC 10) containing 89 subwatersheds (HUC 12) in the study region. Figure 4 and Table 3 give an overview the watersheds of the Youghiogheny, Loyalhanna, and Conemaugh, and the following section provides background on each.

Figure 4. Regional Watersheds* (HUC10 Level)[13]



*Note: Only subwatersheds partially or entirely in Pennsylvania in the Upper Youghiogheny River and Upper Casselman River are included in the study.

[13] Unless otherwise noted, all watershed boundaries used in this report are from U.S. Geological Survey, 2018, all county boundaries are from U.S. Census Bureau, 2017, and the base map used in all other figures is from Esri, HERE, DeLorme, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, MapmyIndia, © OpenStreetMap contributors, and the GIS User Community

Table 3. Study Region Watersheds

Basin (HUC 6)	Watersheds (Regional Nomenclature)	Watershed (HUC 10)	Total Acres
Youghiogheny Basin	Indian Creek Watershed	Indian Creek	79,864
	Jacobs Creek Watershed	Jacobs Creek	60,598
	Sewickley Creek Watershed	Sewickley Creek	107,212
	Laurel Hill Creek Watershed	Laurel Hill Creek	79,799
	Coxes Creek	Coxes Creek	41,636
	Youghiogheny River Watershed	Upper Youghiogheny	56,228
		Middle Youghiogheny	169,765
		Lower Youghiogheny	52,357
	Casselman River Watershed	Upper Casselman	92,574
		Lower Casselman	165,499
Kiski-Conemaugh Basin	Blacklick Creek Watershed	Blacklick Creek	100,635
		North Branch Blacklick Creek	44,098
		Yellow Creek	42,480
		Two Lick Creek	80,458
	Conemaugh River Watershed	Conemaugh River	188,829
		Little Conemaugh River	80,670
		South Fork Little Conemaugh	40,950
	Stonycreek River Watershed	Stonycreek River	173,972
		Quemahoning Creek	63,634
		Shade Creek	62,562
	Loyalhanna Creek Watershed	Loyalhanna Creek	191,240
Total Study Region			**1,975,060**

Youghiogheny River Watersheds

Indian Creek Watershed

Indian Creek, a tributary of the Youghiogheny River, originates in the Forbes State Forest and flows south and west for 28.1 miles through Westmoreland and Fayette Counties (Mountain Watershed Association, 2001). The 125-square mile Indian Creek watershed is predominantly forested, with low-density residential development in and around the towns of Indian Head and Donegal. There are an estimated 276 stream miles in the watershed (Mountain Watershed Association, 2001).

Indian Creek Watershed

Baseline Ecosystem Service Value
$120.5 million

Protected Lands
14,000 Acres

Natural Heritage Areas
18

Exceptional Value Streams
21 miles

Class A Streams
35 miles

Total Impaired Streams
15 miles

Natural and Recreational Assets

The annual baseline ecosystem service value estimated for Indian Creek watershed is $120.5 million. The watershed is home to an abundance of recreational trails: the five-trail Mountain Streams Trail system, eight trails within the Roaring Run Natural Area, and Indian Creek Valley Trail, which runs 24 miles from Route 31 to the Youghiogheny River (Ruddock, 2019). Once completed, the trail will connect with a network of trails that stretch from Corapolis, PA to Washington, DC. Water-based activities like kayaking are popular along the lower reaches of Indian Creek, which is also a significant public water supply source for Indian Creek Valley Water Authority.

The Youghiogheny River is designated as a high-quality cold-water fishery (HQ-CWF) at its confluence with Indian Creek. The basin of Indian Creek to the confluence with Champion Creek, as well as Trout Run, Neals Run and Mills Run are all classified as HQ-CWF, and Camp Run is designated an exceptional value (EV) CWF. All tributaries entering Indian Creek below Champion Creek are classified as CWF or HQ-CWF. In 2017, the Pennsylvania Fish and Boat Commission (PFBC) added the upper portion of Indian Creek to its list of Class A wild trout streams. Class A wild trout populations represent the best of Pennsylvania's naturally reproducing trout fisheries and such streams are managed solely for the perpetuation of the wild trout fishery (PFBC, 2017). Roaring Run is designated as a Wilderness Trout stream located within the Roaring Run Natural Area.

Issues & Opportunities

Currently, 10 of the 15 stream miles impaired in Indian Creek are impaired by AMD (PA DCNR, 2018). For 150 years, water quality in the Indian Creek watershed has been significantly impacted by AMD from deep mine portals, surface mines, and coal refuse piles. The Kalp and Gallentine mine discharges are the largest sources of AMD effluent draining into Indian Creek.

In 1998, the Mountain Watershed Association published a comprehensive plan to remediate AMD and rehabilitate the Indian Creek watershed. Shortly thereafter, the Natural Resources Conservation Service's (NRCS) Watershed Plan and Environmental Assessment identified 10 AMD treatment sites that would improve water quality in the watershed. The NRCS estimated that the 10 treatment sites would restore 17.4 miles of impaired streams translating to an annual economic value of $1,291,788 (2018$). Furthermore, these 10 sites would treat 94% of the acid load, 90% of the iron load, and 93% of the aluminum load entering Indian Creek and its impacted tributaries (USDA NRCS, 2000). The Kalp remediation site, completed in 2007, cleans 8 miles of Indian Creek (Mountain Watershed Association). Five passive treatment systems and one land-liming project are currently operating in the watershed, with two more AMD remediation projects in planning and construction phase.

Erosion, land development, and sewage also significantly affect water quality in the watershed (Mountain Watershed Association, 2001). As of 2019, there are three ongoing streambank restoration projects in Indian Creek watershed, with several other projects in planning.

Jacobs Creek Watershed

Jacobs Creek watershed covers 98-square miles within Westmoreland County and a portion of Fayette County and includes two subwatersheds, Headwaters Jacobs Creek and Jacobs Creek. (A.D. Marble & Company, 2009). The 91-mile Jacobs Creek begins along Chestnut Ridge, flows westward through Mount Pleasant and Scottdale where it drains into the Youghiogheny River. Approximately 177 stream miles lie within the watershed. The watershed is primarily forested, with some urban and agricultural land in the middle portion of the watershed.

Jacobs Creek Watershed

Baseline Ecosystem Service Value
$99,600,136

Natural Heritage Areas
7

Protected Lands
4,300 acres

Exceptional Value Streams
7.5 miles

Total Impaired Streams
40 miles

Natural and Recreational Assets

The annual baseline ecosystem service value estimated for Jacobs Creek watershed is $99.6 million. Recreation opportunities in the watershed include fishing and boating at Greenlick Dam, Bridgeport Dam, and Chestnut Ridge Park, and hiking and biking along the Coal and Coke Trail, which connects Mt. Pleasant and Scottdale (A.D. Marble & Company, 2009). The headwaters of Jacobs Creek are designated as exceptional value (EV) waters and a cold-water fishery (CWF), becoming warm water fisheries downstream. There are 2,400 acres of state game lands that support hunting, trapping, and fishing, while seven natural heritage areas in the watershed provided habitat for species of concern such as the Allegheny woodrat and the mountain saxifrage (Pennsylvania DCNR, 2018).

Issues and Opportunities

The major stressors impacting the Jacobs Creek watershed that collectively contribute to water pollution in Jacobs Creek and its tributaries identified in the 2009 Jacob's Creek Watershed Implementation and Restoration Plan are (A.D. Marble & Company, 2009):

1. Ongoing agricultural land use, including nutrient loading and sedimentation
2. Pollution from urban runoff, particularly uncontrolled stormwater discharge and urban sprawl
3. Abandoned mine drainage from past deep and surface coal mining practices

Around 70% of the Jacobs Creek watershed has been mined, mostly underground but with the presence of some surface mining as well. Quarries are expanding along ridges in Jacobs Creek watershed. Stauffer Run, Shupe Run, and Sherrick Run are the streams most heavily impaired by AMD, evidenced by low pH and dissolved oxygen as well as high levels of iron, sulfur, and aluminum that reduce the opportunity for biological functions.

Current management practices aimed to improve water quality in Jacobs Creek Watershed include completed streambank stabilization projects in Shupe Run and Greenlick Run and stormwater management around paved areas in boroughs like Mt. Pleasant. As of 2009, no AMD remediation projects have been completed in Jacobs Creek, although Trout Unlimited sponsored a report on discharge sites at Sherrick Run and Shupe Run. The Jacobs Creek Watershed Implementation and Restoration Plan details phases and sources of funding for potential remediation projects at identified discharge sites within the watershed (A.D. Marble & Company, 2009).

Sewickley Creek Watershed

Sewickley Creek Watershed encompasses 168-square miles in the southwestern portion of Westmoreland County. Sewickley Creek's main stem runs almost 30 miles before draining into the Youghiogheny River (Western Pennsylvania Conservancy, 2003). The four subwatersheds in the Sewickley Creek Watershed are Jacks Run, Little Sewickley Creek, Upper Sewickley Creek and Lower Sewickley Creek. Jacks Run enters Sewickley Creek at Cowansburg, while Little Sewickley Creek enters Sewickley Creek at Youngwood.

Sewickley Creek Watershed

Baseline Ecosystem Service Value
$159,047,529

Protected Lands
2,023 Acres

Natural Heritage Areas
9

AMD-Impaired Streams
71 miles

Total Impaired Streams
129 miles

Natural and Recreational Assets

The annual estimated baseline ecosystem service value of Sewickley Creek watershed is $159 million. Upper Sewickley Creek contains HQ-CWF designated streams, though none are currently attaining their designated use. The PFBC stocks trout in the mainstem of Sewickley Creek and the Mammoth Dam, but no Class A wild trout streams or wilderness trout waters currently exist in the Sewickley Creek watershed (Pennslyvania DCNR, 2018). Guffy Hollow and Wetley Run are two of the Natural Heritage Areas in Sewickley Creek supporting plant species of concern, including Harbinger-of-spring (PA DCNR, 2018).

Issues and Opportunities

Sewickley Creek Watershed's water quality suffers from many mine drainage points and excess sewage discharges. Resource extraction through the mining of Pittsburgh and Redstone Coal seams has significantly impacted surface water quality and community development around mined areas without integrated planning for sewage treatment systems further contribute to the issue (Western Pennsylvania Conservancy, 2003). The Brinkerton Mine discharge is the most prominent AMD discharge site in the watershed, severely degrading water quality downstream for decades (WPC, 2003). Passive treatment and natural wetlands around the site have been in development, and the discharge area, located close to historic areas and the potential Mammoth to Youngwood trail, offers a unique opportunity to become a multi-use trail and educational recreation site. Other notable discharges exist at Boyer Run, Wilson Run, and the Marchand abandoned deep mine site (WPC, 2003).

Other sources of water quality degradation and pollution in Sewickley Creek include agricultural runoff, erosion and sedimentation, fracking activity, and lack of stormwater management. Horizontal directional drilling spills from natural gas lines around Tenaska and fracking waste leaks contribute to water quality damage in Sewickley Creek. The construction of another natural gas pipeline, Mariner East 2, could increase the frequency of these events. Residentially, a considerably high portion of the population in Sewickley Creek utilizes private well systems for their water supply, which may also be at risk (WPC, 2003). Ecologically, the aggressive invasive Japanese knotweed exists in riparian zones of much of Sewickley Creek and its tributaries, crowding out native plant species.

Laurel Hill Creek Watershed

The Laurel Hill Creek watershed covers 124-square miles in Somerset, Westmoreland, and Fayette counties, and contains three subwatersheds: Laurel Hill Lake Dam, Fall Creek, and Sandy Run. Laurel Hill Creek originates on the eastern flank of Laurel Ridge, west of Lavansville, and flows 38 miles until it meets the Casselman River in the Borough of Confluence, where it then flows into the Youghiogheny River (Somerset Conservation District, 2011).

Natural and Recreational Assets

The annual baseline ecosystem service value of Laurel Hill Creek watershed is $129 million. The watershed is a major recreational area, with three state parks, two major resorts, and one of the most heavily stocked and fished creeks in the region, including brown, brook, and rainbow trout. People come from all over the world to catch its elusive brown, brook, and rainbow trout. Streams are not only popular for fishing; a water trail established from Laurel Hill State Park to the Kings Covered Bridge provides scenic recreation experiences for kayakers and canoers. Paddling clubs from Pittsburgh also run from the Whipkey Dam area through the Laurel Hill Creek Gorge to the Lower Humbert covered bridge. The 70-mile Laurel Highlands Hiking Trail, which welcomes 70,000 annual visitors, traverses the ridgetop of the watershed (Suppes, 2017). All the tributaries of Laurel Hill Creek, along with the main stem, are designated high-quality cold-water fisheries, and four tributaries are exceptional value (EV) streams: Jones Mill Run, Cole Run, Blue Hole Run, and Garys Run (PA DCNR, 2018). The lower lying portions of Laurel Hill Creek, including Sandy Run, provide quality nesting habitat for the American Woodcock (PA DCNR, 2018).

Laurel Hill Creek Watershed

Baseline Ecosystem Service Value
$129,438,343

Natural Heritage Areas
16

Protected Lands
25,236 acres

Exceptional Value Streams
22 miles

Class A Streams
3 miles

Total Impaired Streams
40 miles

Issues and Opportunities

Laurel Hill Creek is one of two watersheds in the Commonwealth of Pennsylvania to be designated a Critical Water Planning Area under ACT 220 due to the intense pressure of water withdrawal from both surface waters and aquifers in the watershed. Somerset Borough, at least two nearby resorts, three golf courses, and a limestone-quarry pump water from groundwater and surface water sources creating a strain on the local water supply and native trout fisheries (Galeone et al., 2017).

While Laurel Hill Creek is considered one of the most pristine waterways in the region, the upper reaches of the watershed suffer from water quality impairments from high nutrient concentrations, bank erosion and sedimentation around steep agricultural buffer areas, and dissolved chloride and sodium concentrations downstream of Interstate 76 (Somerset County District, 2011; USGS, 2016).

A 2010-2011 study on nitrogen and sedimentation in Laurel Hill Creek watershed identified that agricultural lands and streambanks are the major contributors of sedimentation during storm events (Sloto et al., 2012). Restoration projects in the 2005 Laurel Hill Creek Conservation plan included increasing riparian buffer zones, updating residential sewage systems, improving stream access points to reduce soil and bank erosion, and diversifying water supplies for Somerset Borough to reduce strain on cold-water habitats in Laurel Hill Creek (Southern Alleghenies Conservancy). Currently, a Critical Water Resource Plan is being updated with public meetings held to discuss future strategies. Continued collaboration among the Chestnut Ridge Chapter of Trout Unlimited, PennDot, Laurel Hill State Park, and the Somerset Conservation District may aid in furthering bank stabilization projects in the upper reaches of Laurel Hill Creek (Somerset Conservation District, 2011).

Coxes Creek

Coxes Creek is the smallest watershed in the study region, spanning 65-square miles in Somerset County. The watershed includes portions of Berlin, Somerset, Bakersville, and Stoystown. The headwaters for Coxes Creek are located around the town of Somerset, flowing toward Rockwood where it joins the Casselman River (PA DCNR, 2018).

Natural and Recreational Assets

Coxes Creek has an annual baseline ecosystem service value of $96.5 million. Four Natural Heritage Areas are located within the watershed, and approximately 4,230 acres of land are protected, including State Game land 50 and Somerset County easements (PA DCNR, 2018). The NHA's include Kimberly Run Natural Area, which contains rich riparian forest home to three at-risk species, and Somerset Lake, a popular warm water fishing destination that supports habitat for thousands of migratory birds.

Coxes Creek Watershed

Baseline Ecosystem Service Value
$96,525,638

Natural Heritage Areas
4

Protected Lands
4,230 acres

Trout-Stocked Streams
15 miles

Total Impaired Streams
89 miles

Issues and Opportunities

Siltation and abandoned mine drainage are two major stream impairments in Coxes Creek; siltation is largely due to runoff from historic mining, active mining operations, and cropland in the watershed (PA DEP, 2018d). In Coxes Creek, only 55.8% of agricultural land is buffered, the lowest watershed buffer rate in the study region (EnviroAtlas). An estimated 66 miles of streams in the watershed are impaired by siltation.

Upper and Lower Casselman River Watershed

The Casselman River Watershed encompasses 475-square miles largely in Somerset County. The Casselman River originates in the Savage River State Forest in Maryland, flowing northward into Pennsylvania for 47 miles until it empties into the Youghiogheny in Confluence. The Upper Casselman River watershed stretches into Maryland and West Virginia and includes five subwatersheds within the study region: Headwaters Casselman River, Red Run-Piney Creek, Flag Run, Little Piney Creek, Tub Mill Run, and Miller Run. The Lower Casselman River includes nine subwatersheds in the study region: Whites Creek, Flaugherty Creek, Town Line Run, High Point Lake, Elklick Creek, Buffalo Creek, Blue Lick Creek, Middle Creek, and South Glade Creek.

Natural and Recreational Assets

The annual baseline ecosystem service value of the Upper and Lower Casselman watershed is $494 million. The Casselman River is stocked with rainbow trout and other cold-water species, providing recreational fishing opportunities that generate economic benefits for nearby communities (Bryant, n.d.). In the Upper and Lower Casselman watersheds, 11 of the 15 subwatersheds contain designated cold-water fisheries. In the Lower Casselman River, High Point Lake and Whites Creek have streams with high-quality cold-water fisheries (HQ-CWF), and Town Line Run contains exceptional value (EV) streams. Isers Run is a high-quality designated stream, and Whites Creek, Blue Lick Creek, Elklick Creek, Flaugherty Creek, and Piney Creek all have Longnose Sucker populations, one of the rarest fish species in Pennsylvania (Somerset Conservation District, 2013).

Tub Mill Run, Sand Spring Ridge, and High Point Lake are a few of the NHAs in the Upper and Lower Casselman providing exceptional habitat to species of concern (PA DCNR, 2018). There are also three Important Bird Areas (IBAs)[14] in the Casselman River watersheds: Allegheny Front, Youghiogheny Valley, and Winding Ridge Forest Block (PA DCNR, 2018).

Upper & Lower Casselman River Watershed

Baseline Ecosystem Service Value
$494,383,897

Natural Heritage Areas
28

Protected Lands
9,062 acres

Exceptional Value Streams
18 miles

Class A Streams
7 miles

Wild Trout Streams
6 miles

AMD-Impaired Streams
76 miles

Total Impaired Streams
103 miles

Issues and Opportunities

The Casselman River was drastically altered by a major acid mine discharge in 1993, which left much of the river lifeless from Boyton to the confluence of the Youghiogheny River (Somerset Conservation District, 2011). Today, the river faces a resurgence of mining in the area of the 1993 Shaw Mine blowout.

Although threatened by a potential resurgence of mining, the Casselman River watershed harbors a great diversity of fish and insects that support wild trout populations and endangered sucker species. Remediation efforts after the 1993 event succeeded in restoring water quality from Boyton to Meyersdale (Somerset Conservation District, 2011). The once uninhabitable portions of the river now support a stocked trout fishery and a smallmouth bass fishery.

Restoration efforts for water quality improvements in the Casselman River watershed, as laid out in the Casselman River Conservation Plan, include the development of formal sewage treatment plans, targeted programs for abating acid mine drainage, and further developing fish stocking that focuses on both trout and warmwater gamefish species such as smallmouth bass and walleye (Bryant, n.d.).

Upper, Middle, and Lower Youghiogheny River Watersheds

The Youghiogheny River flows through Somerset County, Fayette County, and Westmoreland County. The Upper, Middle, and Lower Youghiogheny River comprise three of the 21 regional watersheds, with 12 subwatersheds in total. The Upper Youghiogheny extends well into Maryland and West Virginia, but only subwatersheds fully or partially in Pennsylvania are included in the study region. The subwatersheds included are the Youghiogheny River Lake, Mill Run, and Buffalo Run. The six

[14] An Important Bird Area is an area recognized as being globally important for the conservation of bird populations (PA DCNR, 2018).

subwatersheds in the Middle Youghiogheny are Meadow Run, Drake Run, Dunbar Creek, Opossum Run, Mounts Creek, and Dickerson Run. In the Lower Youghiogheny, the subwatersheds are Cedar Creek, Long Run, and Pollack Run

Upper, Middle, and Lower Youghiogheny River

Baseline Ecosystem Service Value
$417,181,880

Natural Heritage Areas
36

Protected Lands
52,580 acres

Exceptional Value Streams
62 miles

Class A Streams
5 miles

AMD-Impaired Streams
44.5 miles

Total Impaired Streams
99 miles

Natural and Recreational Assets

The annual baseline ecosystem service value of the Upper, Middle, and Lower Youghiogheny watersheds is $417 million. The Youghiogheny River Lake subwatershed is designated as HQ-CWF and serves as flood control for downstream communities. The area is also a popular boating, camping, fishing, and hiking destination in southwestern Pennsylvania. The middle portion of the Youghiogheny, which runs downstream from the Pennsylvania state line to the dam at South Connellsville, Pennsylvania, includes the descent from the Laurel Mountains into Ohiopyle State Park, known for its rapids and whitewater rafting (Rizzo, 2013). People commonly travel from out of state to visit attractions in and around Ohiopyle State Park, like the Youghiogheny Gorge and the Youghiogheny River Water Trail.

The Middle Youghiogheny watershed contains designated EV waters in Drake Run and Opossum Run and HQ-CWF designations in Drake Run, Dunbar Creek, Meadow Run, and Opossum Run. Designated HQ trout stocking occurs in Dickerson Run, Dunbar Creek, and Opossum Run. In the Lower Youghiogheny River watershed, streams in Long Run are designated as HQ trout stocking, and routine trout stocking occurs in Pollack Run and Cedar Creek as well.

Issues and Opportunities

The Middle Youghiogheny faces a lack of stormwater runoff and sewage treatment management coupled with a growing demand for public access along waterways, which can lead to increases in erosion and bank destabilization if not addressed and cited properly (Rizzo, 2013). Historically, the Dunbar Creek subwatershed in Fayette County experienced widespread forest removal and other land-use changes from development and farming, leading to weaker flood control, eroding riparian buffers, lower water quality, and a dwindling cold-water fishery (Skelly and Loy Consultants, 2009).

The Youghiogheny River is not only impacted by past resource extraction, but current energy development as well, including a natural gas power plant, Tenaska, under construction in Westmoreland County that will withdraw at least 7.5 million gallons a day from the Youghiogheny River at Connellsville (Westmoreland County Conservation District, 2018). Invenergy submitted a proposal for a second power plant just five miles upstream of Tenaska in June of 2018, which would permit wastewater discharges into the Youghiogheny River, contributing significantly to thermal pollution (Mountain Watershed Association, 2018).

In the Middle Youghiogheny watershed 4/5 of the land cover is forest, which provides a substantial natural buffer against runoff. However, pollution from AMD continues to pose the greatest threat to the watershed (Rizzo, 2013). A two-pronged effort of watershed stabilization and water quality improvements will help reduce the impacts of nonpoint pollution runoff in the Youghiogheny River, with attention required for the lower Dunbar Creek corridor which has experienced the worst stream degradation (Skelly and Loy Consultants, 2009). There are also 16 projects identified in Dunbar Creek for priority stream corridor rehabilitation, most of which focus on bank stabilization, instream habitat enhancement, fish passage restoration, and amenity improvements in recreational areas (Skelly and Loy Consultants, 2009).

Loyalhanna & Conemaugh River Watersheds

Blacklick Creek Watershed

The 540-square mile Blacklick Creek Watershed includes the tributaries of Two-Lick Creek and Yellow Creek and spans both Indiana and Cambria Counties (Kimball & Associates, 2005). Blacklick Creek, a major tributary to the Conemaugh River, is formed by the confluence of the north and south branches of Blacklick Creek and flows into the Conemaugh River near Blairsville, PA. The watershed includes the following nine subwatersheds: Main Stem, North Branch Blacklick Creek, South Branch Blacklick Creek, Lower Blacklick Creek, Upper Two Lick Creek, Lower Two Lick Creek, Tearing Run, Upper Yellow Creek, and Lower Yellow Creek.

Blacklick Creek Watershed

Baseline Ecosystem Service Value
$519,782,477

Natural Heritage Areas
24

Protected Lands
22,245 acres

AMD-Impaired Streams
218 miles

Total Impaired Streams
408 miles

Natural and Recreational Assets

The annual baseline ecosystem service value of Blacklick Creek, Two-Lick Creek, and Yellow Creek watersheds is $520 million. Nearly all the watershed's streams are designated Cold-water Fisheries (CWF). Three of these – Stewart Run, South Branch Two Lick Creek, and Little Yellow Creek – are also designated HQ streams. Stewart Run, Brush Creek, Pompey Run and Repine Run, as well as several smaller tributaries, support wild brook trout populations (Kimball & Associates, 2005). The PFBC currently stocks trout in the three streams not designated as CWF.

Indiana County Parks Commission and the Cambria County Conservation Recreation Authority maintain several year-round recreational trails; the Ghost Town Trail currently extends 16 miles from Blacklick to Ebensburg along the Blacklick Creek, the Hoodlebug Trail extends 10 miles from Indiana to Red Barn along Route 119, and the Blacklick Natural Area supports 6 miles of trails. The 3,000-acre Yellow Creek

State Park has five miles of trails and a 720-acre lake for recreationists to swim, boat and fish (Kimball & Associates, 2005). Warm-water game is also stocked in the 60-acre lake at Duman Lake County Park.

Issues and Opportunities

Blacklick Creek watershed has housed coal mining since the late 1800's and drainage from hundreds of abandoned surface and underground mines and coal refuse piles has left the water quality within the watershed severely impacted. Discharges from natural gas wells, production, and storage, as well as the disposal of brines from fracking, further degrade surface and groundwater across the watershed (Kimball & Associates, 2005).

The Blacklick Creek Watershed Assessment/Restoration Plan documents more than 490 mine discharge points with varying flow rates and chemical compositions. These discharge points contribute to the impairment of 40 miles of streams in the watershed (Kimball & Associates, 2005). In total, Blacklick Creek watersheds hold a quarter of the study region's AMD-impaired streams and a quarter of the total regional impaired stream miles (PA DEP, 2018d). In addition to AMD, pollutants including from sewer overflows, agricultural and animal waste, and discharges of untreated sanitary wastes from municipalities and neighborhoods contribute to water quality degradation within the watershed (Kimball & Associates, 2005).

The Black Creek Watershed Association has completed 13 mine drainage treatment and reclamation projects in the watershed. The Army Corp of Engineers constructed a large passive treatment system and the PA DEP Bureau of Abandoned Mine Reclamation (BAMR) has proposed a large active treatment plant that would treat large mine pools, the source water for multiple discharges. The quality of the Blacklick Creek watershed is expected to improve as more passive treatment systems are installed (Blacklick Creek Watershed Association, n.d.).

Conemaugh River, Little Conemaugh, and South Fork Little Conemaugh Watersheds

The Conemaugh, Little Conemaugh, and South Fork Little Conemaugh watersheds contain 13 subwatersheds: Beaverdam Run, South Fork Little Conemaugh, Bens Creek, Clapboard Run, North Branch Little Conemaugh River, Tubmill Creek, Stony Run, Richards Run, McGee Run, Hinckston Run, Hendricks Creek, Baldwin Creek, and Aultman's Run. The Little Conemaugh River begins high on the Allegheny Ridge, with a steep decline 30 stream miles before meeting the Stonycreek River in Johnstown to form the Conemaugh River.

Natural and Recreational Assets

The annual baseline ecosystem service value of the Conemaugh River watersheds is $569 million. Upstream portions of the South Fork of the Little Conemaugh are used as a public water supply and contain Class A native brook trout fisheries. Beaverdam Run is designated as both an EV stream and a HQ-CWF. In the Little Conemaugh, both Bens Creek and Clapboard Run are designated HQ-CWFs and Bens Creek is also designated as an EV stream. Of the eight subwatersheds in the Conemaugh River watershed, five streams are designated as HQ-CWF, and six are designated for trout stocking. Baldwin Creek, McGee Run, and Tubmill Creek are all designated EV streams. Tubmill Creek contains exceptional wild rainbow and native brook trout populations, with water quality high enough to support the Eastern Hellbender, a key indicator species for healthy ecosystems (Kiski-Conemaugh Stream Team, 2009).

Issues and Opportunities

Nearly all the streams within the Little Conemaugh River and the South Fork Little Conemaugh watersheds are impacted or severely degraded by AMD, with very few springs or water supply wells in the two watersheds unaffected by coal mining (PA DEP, 2003). In the Little Conemaugh River Basin, the Hughes borehole, Miller Shaft, and Sulfur Creek borehole all contribute daily to pollution in the Little Conemaugh River (PA DEP, 2003). The South Fork of Little Conemaugh is afflicted by coal refuse piles and AMD discharges below Beaverdale, evident in high concentrations of iron and aluminum around Beaverdale, Allendale, Dunlo, St. Michael, and South Fork (PA DEP, 2003). There are also at least 11 passive treatment systems operating in the Conemaugh River watersheds (Stream Restoration Inc., 2018)

Conemaugh River Watershed

Baseline Ecosystem Service Value
$569,429,582

Natural Heritage Areas
25

Protected Lands
48,790 acres

Exceptional Value Streams
65 miles

Class A Streams
17 miles

Wild Trout Streams
11 miles

AMD-Impaired Streams
158 miles

Total Impaired Streams
305 miles

Stonycreek River, Quemahoning Creek, and Shade Creek Watersheds

The Stonycreek River watershed crosses Somerset County and Cambria County covering 467-square miles and containing 538 stream miles (Deal et al., 2008). The Stonycreek River is a tributary of the Conemaugh River and begins in Pius Springs in Berlin, Somerset County. From there it flows north before meeting the Little Conemaugh River in Johnstown, then joining to form the Conemaugh River.

Quemahoning Creek and Shade Creek are often included as part of the Stonycreek River watershed, although they are separated into three same-order watersheds (HUC10) in the USGS hydrological unit system. There are 16 total subwatersheds within the Stonycreek River watershed, including Quemahoning Creek and Shade Creek's subwatersheds. The ten subwatersheds within the Stonycreek River watershed are Headwaters, Upper, Middle, and Lower Stonycreek River, Beaverdam Creek, Lower Stonycreek River, North and South Fork Bens Creek, Paint Creek, and Wells Creek.

Natural and Recreational Assets

The annual baseline ecosystem service value of Stonycreek River watershed is $493.5 million. Stonycreek River, Quemahoning Creek, and Shade Creek watersheds all contain EV and HQ-CWF streams. Clear Shade Creek and the North and South Fork of Bens Creek are also notable EV streams. In fact, Clear Shade Creek has one of the state's oldest and most popular fly fishing only special trout regulation areas. Piney Run and Roaring Run are the two wild trout streams in the Stonycreek River Watershed and Class A trout streams include Higgins Run, Pickings Run, and Allwine Creek (PA DCNR, 2018).

There are seasonal water releases in the Quemahoning Reservoir that create additional boating, floating, and whitewater recreational opportunities in the region. An 11 million gallon a day cold water conservation release creates a tail water trout fishery in the last 1.3 miles of Quemahoning Creek below the reservoir and restores water quantity to the Stonycreek River. Large swaths of protected and state lands cross the Stonycreek River watershed, including Forbes State Forest, Laurel Mountain State Park, Laurel Ridge State Park, and Gallitzin State Forest (PA DCNR, 2018). Important NHAs include Furnace Run, Jennerstown Bottom, and Crumb Bog (PA DCNR, 2018).

Stonycreek River Watershed

Baseline Ecosystem Service Value
$493,590,936

Natural Heritage Areas
37

Protected Lands
35,148 acres

Exceptional Value Streams
65 miles

Class A Streams
21 miles

Wild Trout Streams
3 miles

AMD-Impaired Streams
174 miles

Total Impaired Streams
318 miles

Issues and Opportunities

Historically, the coal-rich deposits in the watershed have led to extensive mining in the region. In 1994, the USGS identified 270 abandoned mine discharges in the Stonycreek River watershed (Reckner & Null, 2017). The Quecreek Mine Disaster in 2002 spilled millions of gallons of mine drainage into the Quemahoning Creek, reinforcing the urgency of water quality protections and remediation efforts throughout the watershed (Lichvar & Gorden, 2012).

The Stonycreek River has made significant strides toward recovery, in part due to $10 million of funding to address AMD discharges in the watershed since 1997. Passive treatment systems along the Stonycreek River, including the Lamberts Run system, Onstead and Adams systems, and Reitz and Boswell systems in Shade and Quehamoning helped restore decades of AMD damage (Lichvar & Gorden, 2012). Water quality improvements in the Stonycreek River watershed are heralded as one of the best conservation success stories in the state. Mitigation of AMD impairment has led to a net alkaline chemistry in the middle portion of the river, which now supports a year-round trout and warmwater fish population (Somerset Conservation District, 2011).

AMD is still largely unabated in the Dark Shade and Shade Creek watersheds, encompassing 18 stream miles that are impaired by several AMD discharges including the Reitz #4- the largest AMD discharge in the Stonycreek River watershed. Similar discharges remain untreated in the Paint Creek watershed that combine to create a dead zone on the lower Stonycreek River.

Loyalhanna Creek Watershed

Loyalhanna Creek Watershed

Baseline Ecosystem Service Value
$278,278,759

Natural Heritage Areas
21

Protected Lands
29,609 acres

Exceptional Value Streams
24 miles

Class A Streams
17 miles

Wild Trout Streams
6 miles

AMD-Impaired Streams
83.5 miles

Total Impaired Streams
128 miles

The Loyalhanna Creek watershed covers nearly 300-square miles in eastern Westmoreland County, with 2,500 miles of streams flowing through largely rural, forested, and agricultural landscape. The Loyalhanna Creek starts on the Laurel Ridge and flows west through the communities of Ligonier, the City of Latrobe, and New Alexandria, where it then joins the Conemaugh River in Saltsburg to form the Kiskiminetas River (Wright, 2006). The eight subwatersheds within the Loyalhanna Creek watershed include the Headwaters, Upper, Middle, and Lower Loyalhanna Creek, Crabtree Creek, Fourmile Run, Mill Creek, and Ninemile Run.

Natural and Recreational Assets

The Loyalhanna Creek watershed's annual baseline ecosystem service value is $278 million. Serviceberry Run, which flows into Loyalhanna Lake in the Lower Loyalhanna Creek, contains a HQ-WWF (Wright, 2006). Significant portions of the Loyalhanna Creek Headwaters and Upper Loyalhanna Creek are designated HQ-CWF.

While the watershed contains significant deposits of bituminous coal, it has been historically protected from coal mining, with many streams surrounded by state forestlands, game lands, and private lands. Recreation abounds in the pristine streams sourced from springs along the Laurel Ridge, which is the headwaters of the Loyalhanna Creek and one of the most western high points in Pennsylvania (Wright, 2006).

Keystone Lake and Loyalhanna Lake are two popular recreation areas in the middle and lower portion of the watershed and serve as designated areas for fishing, boating, and swimming. Loyalhanna Lake is also a flood control area (Wright, 2006). In the upper portions of the Loyalhanna Creek watershed, Mill Creek, a tributary to the Loyalhanna Creek, provides one of the last remaining HQ recreational areas in Ligonier Valley, and supports a reproducing native brook trout population (Forbes Trail Trout Unlimited).

Issues and Opportunities

The watershed is the least degraded in the Kiski-Conemaugh River Basin, largely due to the lack of resource extraction in its headwaters (Reckner & Null, 2017). Fieldwork from the Loyalhanna Creek

Watershed Implementation and Restoration Plan identified priority impairments in the region based on known impacts in the watershed and potential for restoration (Wright, 2006):

1. AMD and its effects
2. Agricultural non-point source pollution
3. Riparian zone degradation
4. Erosion and channel alteration

The largest source of untreated mine water in the Loyalhanna Creek Watershed is from Crabtree Discharge, stemming from abandoned underground coal mines near the village of Crabtree (Loyalhanna Watershed Association, 2017). Crabtree Discharge pollutes Loyalhanna Creek, which experiences iron loading for several miles below the inflow from Crabtree Creek.

The identified restoration projects within the Loyalhanna Creek Watershed include targeted riparian enhancements along eroded stream segments, working with landowners and farmers to implement further agricultural BMPs, additional AMD remediation, and septic sewage management development for select townships and boroughs (Wright, 2006).

Ecosystem Service Valuation of Regional Action

This study examines five resource management and action scenarios focused on water quality and changes to ecosystem service values associated with water resources. The process of developing these scenarios and results involved concept mapping, specifically using a method called "means-ends" diagramming (Bear, 2014). "Means-ends" diagramming helps convey the idea that land management and policy decisions work their way through ecosystem processes and ultimately affect the well-being of people. Because the technique is endorsed and in use by several federal and nonfederal agencies, the work of this project will have immediate resonance with a range of policy makers, resource managers, and potential funding sources in positions to help implement restoration strategies in the region.

The results of these actions produce changes in ecosystem services that are estimated, as noted above, in biophysical and/or monetary terms. The five major focus areas identified for ecosystem service valuation in the study area watersheds are:

1. AMD-impaired streams and remediation
2. Gains in recreational value from improved water quality
3. Natural gas well pad construction and resource conservation
4. Agricultural and stormwater runoff and Best Management Practices (BMPs)
5. Sewage treatment and potable water

ACTIVE TREATMENT VS. PASSIVE TREATMENT

AMD treatment requires systems that can treat acidity and heavy metals from mine discharges into streams. There are a handful of ways to treat the AMD and treatment selection depends on the type of impairment, the amount of funding available, surrounding landscape, and access to the site.

Passive treatment systems, most common in the study region, use chemical and biological processes to treat acidity and remove metals and require ongoing maintenance and monitoring (Penn State Extension, 2017). Examples of passive treatment include aerobic and vertical-flow wetlands which are common in smaller stream restoration projects and often utilized by watershed and community organizations (Penn State Extension, 2017). Operation and maintenance costs can include regular monitoring, flushing, and pipe cleaning.

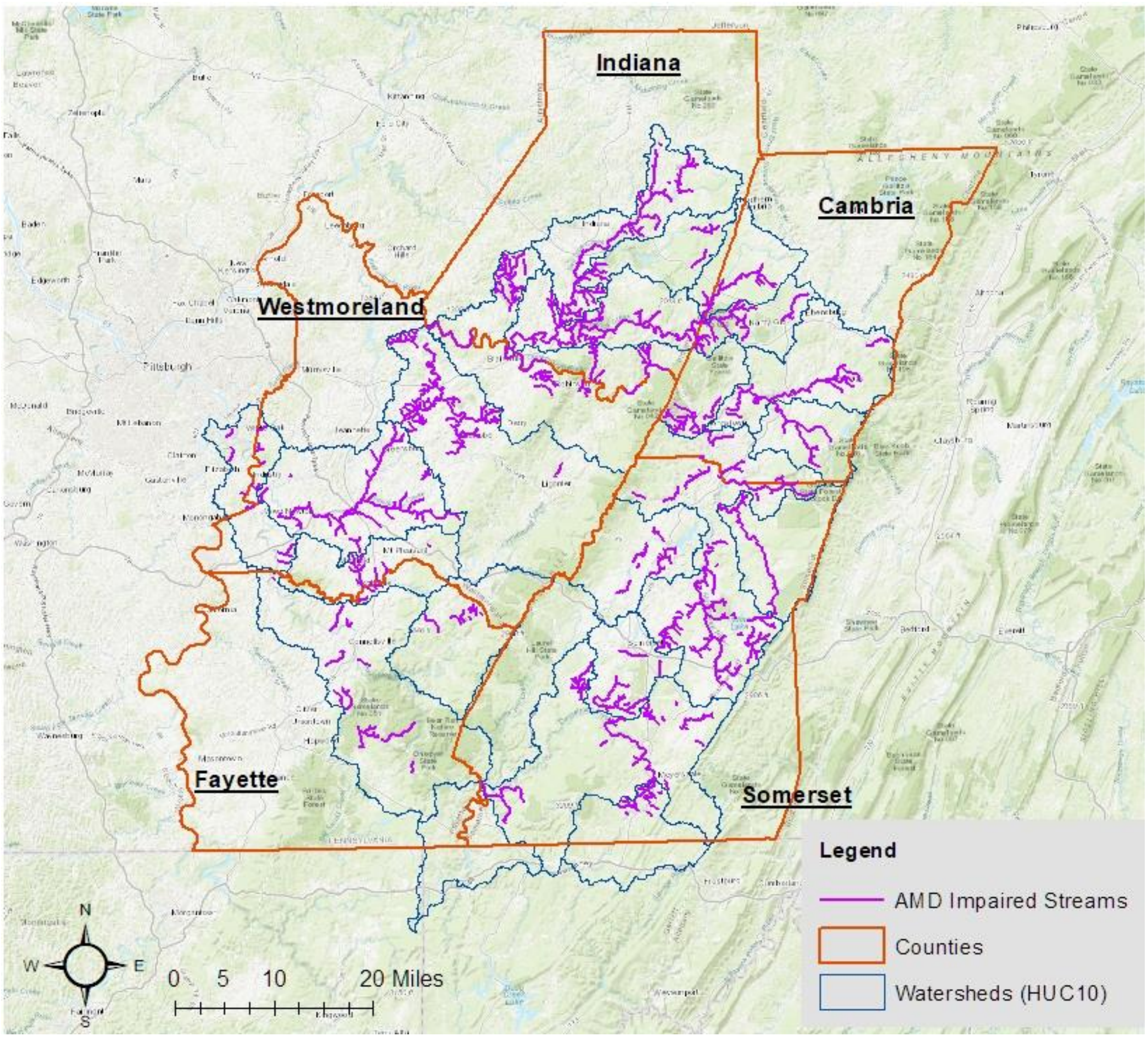
Active treatment systems require frequent maintenance and higher upfront costs for mechanical equipment to treat AMD in areas where passive treatment may not be feasible or sufficient (Penn State Extension, 2017). Lime dosers, an example of active treatment, require continued input of alkaline materials to receiving streams using waterwheel or bucket systems (Hansen et al., 2010). Active treatment is less common in the study region, although a few are operating in the Little Conemaugh River and Blacklick Creek watersheds (Lichvar, 2019). Despite high costs, utilizing these systems could yield a net economic benefit if prioritized in areas with high recreational potential value. For example, in the West Branch of the Susquehanna, an active treatment plant has restored 25 miles of the Susquehanna River to a wild trout fishery (Lichvar, 2019). In the Little Conemaugh watershed, Rosebud Mining funded the construction and operation of the St. Michael Treatment Plant, which treats the largest AMD discharge in the Little Conemaugh River and has restored 10 miles along Topper Run, from St. Michael to Mineral Point (4WARD Planning, 2018).

Still in the planning phase, an active treatment system near Central City on Dark Shade Creek could address four large discharges that passive treatment systems would not be able to treat. If completed, the Dark Shade Creek project could restore 13 miles of Dark Shade Creek and Shade Creek to a recreational fishery and improve water quality for an additional 14 miles of the Stonycreek River (PA DEP, 2017).

Economic Benefits from Treating AMD-Impaired Streams

Restoring water quality for the 878 miles of AMD-impaired streams in the Laurel Highlands (Figure 5) can provide economic value in the form of higher property values, new recreational angling opportunities, and lower water treatment costs. The ecosystem services associated with these economic benefits are aesthetic value, recreation, and water quality.

Figure 5. AMD-Impaired Streams in the Laurel Highlands Watersheds
Source: The Pennsylvania Geospatial Data Clearinghouse, 2019



There are at least 67 passive treatment systems in the Laurel Highlands that collectively treat 8.9 billion gallons of AMD a year. These passive treatment systems are helping to restore a portion of the nearly 900 miles of AMD-impaired streams in the region, with dozens more under construction or being planned. Appendix E provides data on the reported passive treatment systems in the region and costs of reclamation for the average influent and effluent associated with passive treatment systems in the region[15].

Each of these treatment systems has a price tag, both for construction as well as for operation and maintenance (O&M). The average reported construction cost for a passive treatment system in the Laurel Highlands is $415,263 (Stream Restoration Inc. & 241 Computer Services, 2018). While operation and maintenance costs are not reported on the regional level, annual O&M costs for passive treatment systems are estimated at 4% of capital costs on average (PA DEP, 2016b). This translates to an average O&M cost of $16,610 for an average passive treatment system in Pennsylvania (PA DEP, 2016b). This recurring cost is critical to sustaining improvements in water quality and includes labor needs, chemical and power consumption, sludge management, and other wear and tear maintenance for the systems (PA DEP, 2016).

The Rogue Discharge at Sagamore Treatment Site
Credit: Carla Ruddock

With enough O&M funding, these systems provide a stream of economic benefits, including increased property value premiums and recreation expenditures. By incorporating the benefits of AMD remediation into funding decisions, funders and organizations can better assess the true value of each dollar spent on AMD treatment. The Somerset Conservation District incorporated economic values into its evaluation of restoration projects in the Stonycreek River. In 2009, Null, Deal, and Lichvar estimated the total cost of AMD abatement in the Shade Creek watershed to be $6.27 million for two active treatment sites and eight passive treatment sites, with a yearly total maintenance cost of $429,818. They estimated that the economic return from AMD treatment included $1.85 million a year in recreational fishing activity from the restoration of 25 miles of trout stocked fisheries and an additional $1.2 million a year after restoring five miles of intermediate whitewater rafting (Null, Deal & Lichvar, 2009).

Values Gained from AMD Stream Restoration

Regional studies on AMD remediation show that restored streams increase property values, spending by recreational anglers, consumer surplus, and can help lower public water suppliers' water treatment costs (Hansen et al., 2008). These benefits reflect higher ecosystem service values from water quality, recreation, and aesthetic value.

[15] Averages are calculated from the self-reported data on Datashed.org; not all treatment sites provide data for each field, and the number of reported sites is likely lower than the number of operating sites in the region.

Studies on the economic value of AMD remediation from the Cheat River watershed in West Virginia and the West Branch Susquehanna River watershed in Pennsylvania demonstrate increases in residential property values near AMD-impaired streams by 5% to 13% after successful restoration (Thurston et al., 2009; Hansen et al., 2008). In the West Branch Susquehanna watershed, lost recreational fishing values from AMD-impaired streams are estimated at $22 million annually (Hansen et al., 2008).

Key Ecosystem Services

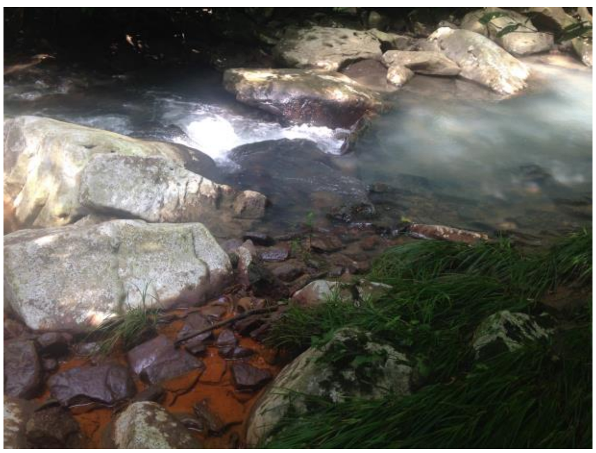
Water Quality

Recreation

Aesthetics

Higher Property Values

Assessments of property value losses in Pennsylvania and West Virginia show that households within 200 feet to a quarter mile of AMD-impaired streams have 5% to 12.8% lower property values, respectively (Thusrton et al.,2009; Hansen et al., 2008). By cleaning streams impaired by AMD, tens of thousands of households in the study region could experience increases in property value.



Heavy metals, including iron and aluminum, in the Fulton Discharge
Credit: Carla Ruddock

In the 21 watersheds of the study region, there are an estimated 4,800+ households within 200 feet of a stream impaired by AMD and nearly 52,000 households within a quarter mile (see Appendix D). If remediation efforts restore AMD-impaired streams to their full attaining use, one-time property value gains in the study region range from $36 million to nearly $765 million, depending on how far the zone of influence around AMD streams extends. This gain in property value translates into an additional $358,000 to $10 million in annual property tax revenue for Fayette, Somerset, Cambria, Westmoreland, and Indiana Counties.[16]

Recreational Fishing Benefits

Pennsylvania Fish and Boat Commission calculates average use and harvest rates for trout stocked fishery streams, warm water fishery streams, and wilderness trout streams (Hansen et al., 2008, see Appendix D). There are 126 miles of potential trout stocked fisheries and nearly 300 miles of warm water fisheries impaired by AMD in the region (PA DEP, 2018d). Restoration of these 400+ stream miles could yield $16.8 million in annual economic benefit to the region, based on average use and spending rates per mile in the state (Hansen et al., 2008). Another 500 stream miles of designated cold-water fishery streams, including 45 miles of high-quality cold-water fishery (HQ-CWF) streams, are currently AMD-impaired. If restored, these cold-water fisheries would bring additional economic benefit to the region.

[16] The average property tax rate in the region is 1.3% (Tax-Rates.org, 2019).

Regional Willingness-to-Pay: Consumer Surplus

Willingness-to-pay (WTP) studies for AMD remediation and water quality improvements in the West Branch Susquehanna watershed in Pennsylvania, Deckers Creek watershed in West Virginia, and the Loyalhanna and Conemaugh watersheds provide information on how much value residents or communities place on remediation efforts. These values range from $30-$157 per household per year and reflect WTP values for AMD remediation and general water quality improvements (Hansen et al., 2008; Collins et al., 2005). The amount a household is willing to pay for these water quality improvements illustrates the perceived benefit people derive from the environmental change without any money exchanging hands, also known as consumer surplus.

There are 277,063 households in the Laurel Highlands study region and about 56,000 of those households are located within a quarter mile of an AMD-impaired stream.[17] Naturally, residents in the watershed region value AMD remediation efforts differently. Those living closest to AMD impaired streams may be expected to value remediation the most. Residents that live in watersheds less affected by AMD may not be as aware of the issue and do not necessarily stand to benefit directly as much from restoration efforts. At the same time, a resident from Philadelphia may highly value AMD remediation, even if they are not there to experience the direct benefits; the valuation may come from knowing that future opportunities exist for trout fishing in clean water, or simply a value for the *existence* of clean water. This concept is referred to by economists as existence value and WTP for the existence of a resource or place can reflect satisfaction knowing that it is not degraded. Applying values from WTP surveys conducted in the region, the one-time benefit gained from AMD remediation within the study watersheds is $5.67 million (see Appendix D).

Lower Drinking Water Treatment Costs

When public water supply authorities withdraw surface water from AMD-impaired streams, they may pay more in water treatment costs to remove heavy metals and reduce acidity in the water (Hansen et al., 2008). The cost-differential for public water suppliers to treat AMD-impaired water has not been extensively studied. In a survey sent to water suppliers in the West Branch Susquehanna Basin, many suppliers were unsure of how much treating AMD sourced water costs, although some were worried that they would soon need to start drawing water from AMD-impaired streams. One supplier estimated that they would soon need to intake from a severely impaired AMD stream due to drought conditions, which would cost an additional $1 per 1,000 treated gallons to remove heavy metals (Hansen et al., 2008).

Natural Gas Landscape in 2030: Watershed Value Lost from Projected Energy Development

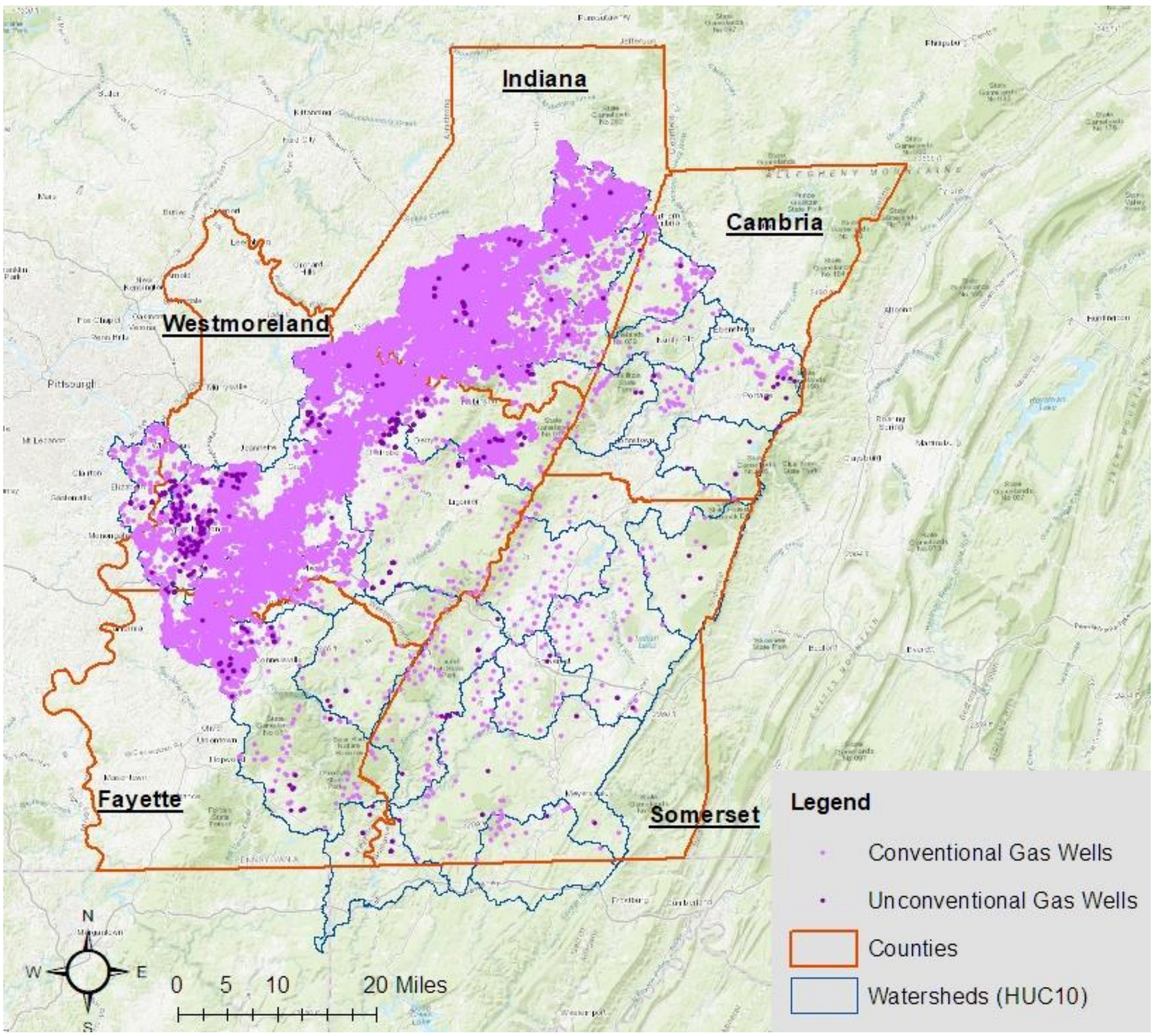
Whether it be coal mining, oil rigs, and now fracking from natural gas, Pennsylvania's history is tied to the rich resources its lands offer. These energy industries have offered jobs and income for

[17]This range represents the estimated number of houses within a quarter mile of AMD streams using block group census data.

Pennsylvanians, but their presence comes with a cost: abandoned mines and impaired waterways, health risks to workers, and communities struggling to attract new visitors, residents, and business.

Natural gas development in the five-county study region is some of the densest in the state. As of 2017, there are 331 active unconventional natural gas wells and at least 8,358 active conventional natural gas wells in the region (Figure 6) (PA DEP, 2018c). Unconventional wells, used to retrieve Marcellus Shale gas, require much more intensive resource use than conventional wells; wells reach up to 5,000 feet outwards from the well pad and use 11.4 million gallons of water, as opposed to 100,000 gallons for a conventional well (Miller et al., 2015; Kelso, 2018). The infrastructure surrounding unconventional well pads— roads, pipelines, stream crossings, water impoundments— takes up an additional 5.7 acres on average, for roughly a 9-acre disturbance per well pad (Johnson, 2010).

Figure 6. Active Natural Gas Development in the Laurel Highlands



Projected Land Use Change from New Natural Gas Well Pads

The Nature Conservancy developed projections for natural gas infrastructure development from 2010 out to 2030, including low, medium, and high development scenarios (Johnson, 2010). The scenarios were developed using 1,500 existing drilled or permitted well pads in the Marcellus Shale Region to build a predictive model and a handful of counties in Southwestern Pennsylvania are recognized as 'hotspots' for future development (Jerrilyn; Johnson, 2010). The scenarios account for the number of wells per pad and the spatial distribution of well pads.

In the medium development scenario, 1,466 unconventional well pads may be constructed in the Laurel Highlands region by 2030; for the low and high development scenarios, the number of potential well pads are 902 and 2,048, respectively (Johnson, 2010). The medium development scenario assumes there are on average six wells per pad with pads spaced out approximately 4,000 feet apart (Johnson, 2010). This scenario is used to evaluate ongoing and expected impacts to ecosystem services from unconventional natural gas well pad development.

Critical Habitat and Protected Lands at Risk

The spatial disturbance of natural gas development spans beyond the direct construction of well pads. Especially in forested areas, construction of well pads leads to an additional 21 acres of habitat disturbance and degradation per pad (Johnson, 2010). The loss of this forest habitat puts vulnerable aquatic and terrestrial species at risk, degrades the water quality in adjacent streams and rivers, and reduces recreation quality in the region (Miller et al., 2015). These losses all have economic impacts in the form of increased water treatment costs, lost existence value for rare and threatened species, and forgone recreation activity, either from direct changes to the landscape or changes in resident and visitor perspectives on the quality of the recreation in the region (see ecosystem service concept model in Appendix C).

Key Ecosystem Services

Habitat & Biodiversity

Recreation

Water Quality & Supply

Carbon Storage

By 2030, a total of 348 well pads could be constructed within a half-mile of designated EV and HQ-CWF waterways, and 237 within watersheds containing populations of brook, brown, or rainbow trout. Figure 7 depicts well pad development within a half-mile of designated EV and HQ cold-water fishery streams and well pads within Eastern Brook Trout Joint Venture-identified trout watersheds.

Figure 7. Brook Trout Habitat and EV, HQ Streams Impacted by Natural Gas Development
Sources: Eastern Brook Trout Joint Venture, PA DEP 2017, Jerrilyn

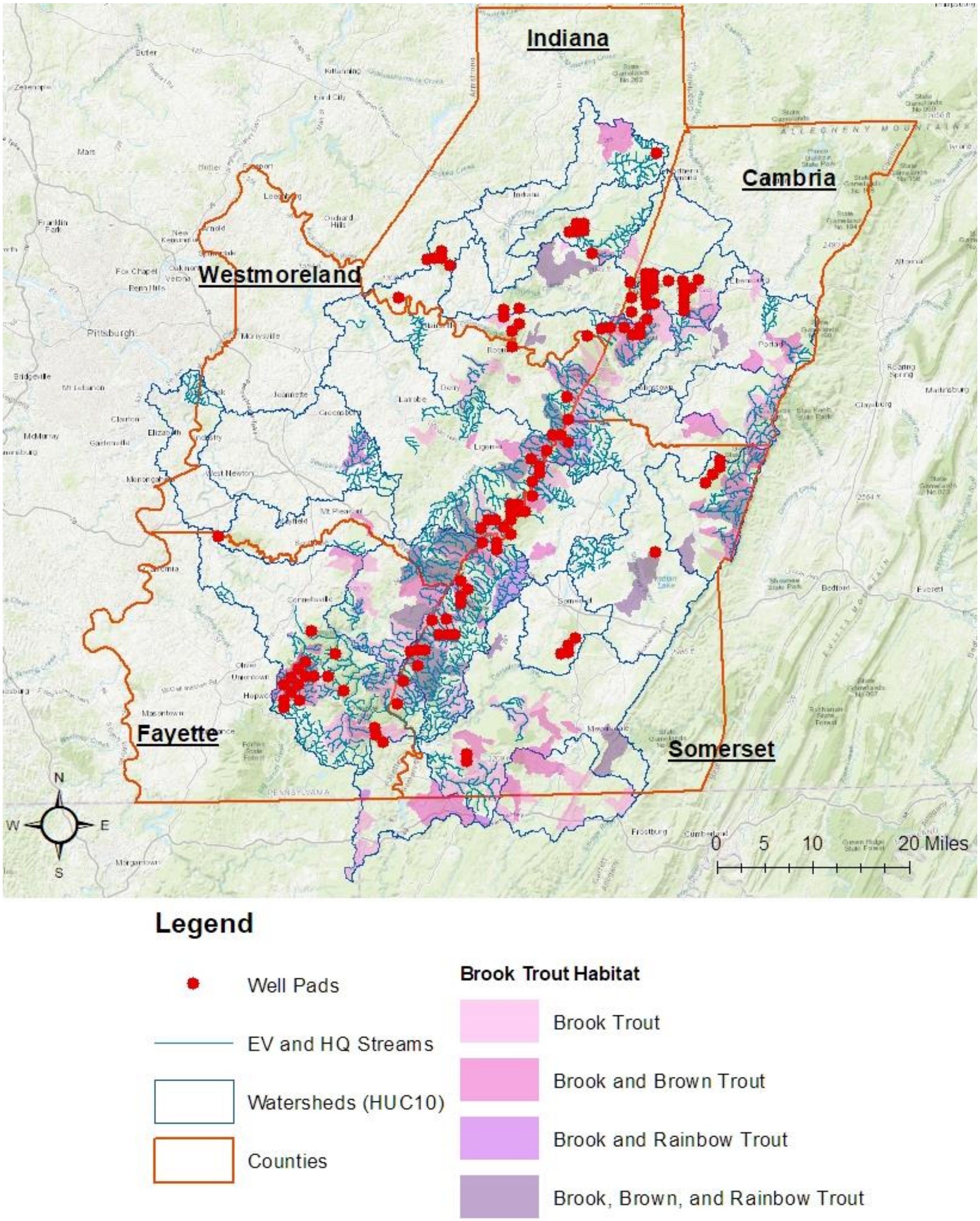
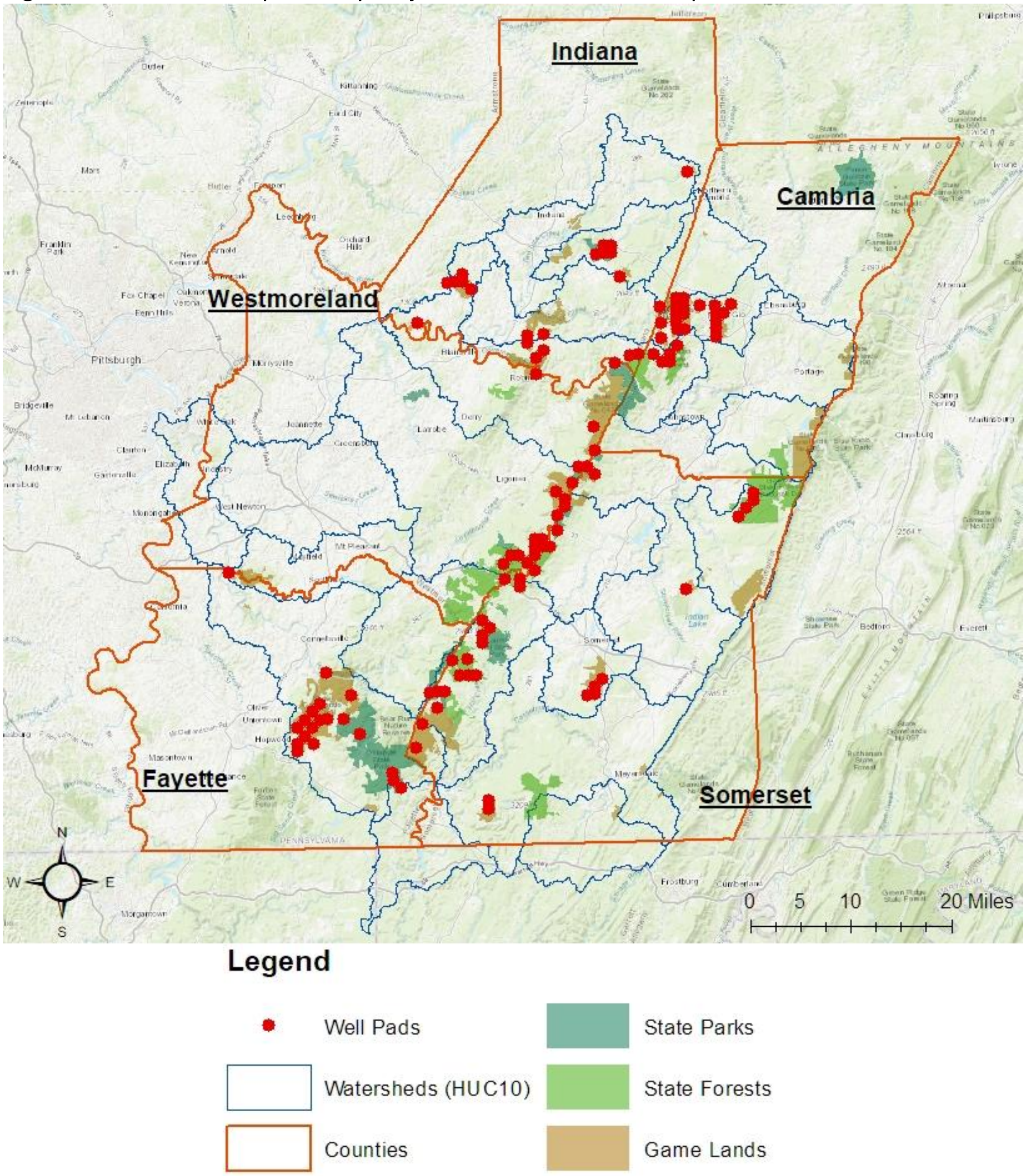


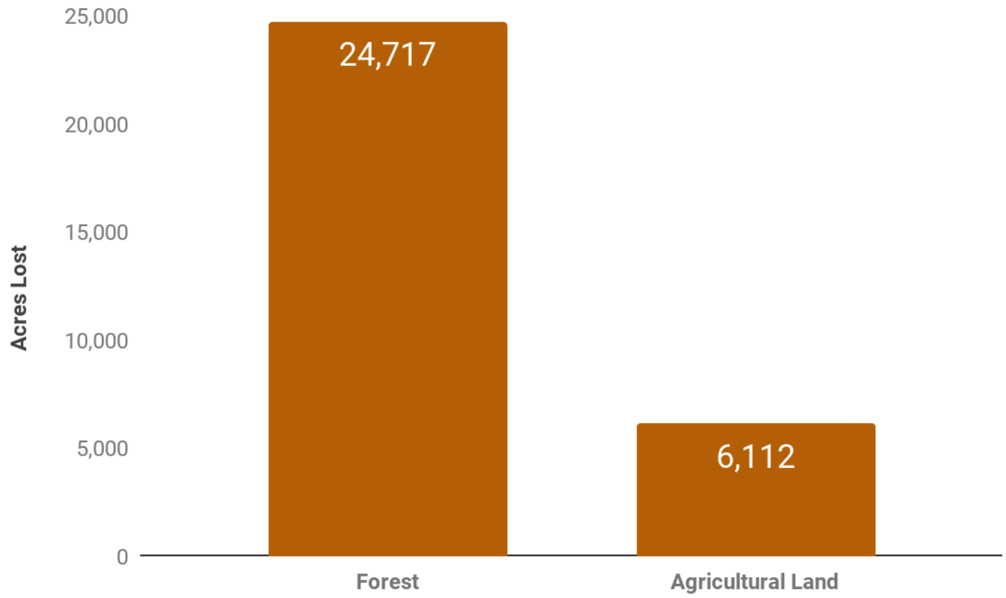
Figure 8 shows the overlap between projected natural gas development and protected lands in the region. In the medium development scenario, 982 well pads will fall in forested areas, 22 pads within state parks, 32 within state forests, and 64 within state game lands.

Figure 8. State Lands Impacted by Projected Natural Gas Development



The intersection among these critical areas amounts to more than 1,000 acres disturbed within state lands and nearly 4,000 acres disturbed within trout watersheds and near designated EV and HQ waterways. Figure 9 captures the total forest and agricultural land converted for natural gas development in the watersheds.

Figure 9. Projected Forest and Agricultural Land Lost from Natural Gas Development in the Laurel Highlands by 2030



Ecosystem Service Value Loss from Forests

Recreation

Forests provide recreational value for wildlife viewing, hunting, hiking, camping, and more. There are nearly 25,000 acres of forested land in the region that could be impacted, directly or indirectly, from natural gas well pads, not including from additional natural gas infrastructure. More than 13,000 of these acres are on state parks, state lands, state forests, near exceptional value streams, high-quality cold-water fisheries, and/or in a watershed with brook trout.

Based on primary studies of forests' recreational value in the Appalachian region, annual losses in recreational value in forests from wells are estimated to be $6.8 million a year. On average, approximately $275 in recreational value per acre of forest could be lost annually (see Appendix D for methods).

Habitat and Biodiversity

Pennsylvania's globally rare and threatened species are at risk from Marcellus Shale development as well; around 40% of these species are found in areas with high potential for development—including in Southwestern Pennsylvania (Johnson, 2010). Three examples of species in danger are snow trillium, the green salamander, and the black-throated blue warbler. About three-quarters of the snow trillium habitat and the entire green salamander population are in high potential development areas, while the black-throated blue warblers' breeding habitat is particularly vulnerable (Johnson, 2010).

Of the nearly 1,500 well pads that may be constructed, two-thirds would be in forested areas, meaning the indirect impacts from natural gas infrastructure are greater to potential habitat and biodiversity losses. Western Pennsylvania Conservancy performed a two-year assessment of high ecological value areas at risk from natural gas development and identified 35 sites with particularly high-quality land and water resources (Miller et al., 2015). Out of the 35 sites, six fall within the study region: Yellow Creek, Tubmill Creek, McGee Run, Mill Creek, Shafer Run, and Dunbar Creek (Miller et al., 2015). Yellow Creek has suitable habitat for eastern hellbenders, while Dunbar Creek has one of the few locations with populations of green salamander (Miller et al., 2015).

Estimated losses associated with forest habitat and biodiversity range from $6.7 million to $12 million annually, or $272-448/acre annually (see Appendix D). This cost estimates the value placed on the existence of rare species, the habitat that supports them, and the role these species serve in supporting other ecosystem services, such as water quality, natural pest management, and genetic resources.

Water Quality

The health of watersheds related to natural gas development depends on many factors, including pollution, erosion, and water extraction. Forest cover is positively related to the quality of a watershed; larger forested areas are linked to a higher quality of untreated water and lower drinking water prices (Boettner et al., 2014). Likewise, loss of forest cover in a watershed leads to lower water quality and higher treatment costs. The projected lost value to water quality from forested lands by 2030 is $1.4 million annually in the region (see Appendix D).[18]

Carbon Storage

Forests can store between 69 and 82 metric tons of carbon per acre, developed land stores 16 metric tons of carbon, and barren land stores none. The value of this storage, in dollar terms, is equivalent to the cost to society that the release of stored carbon would impose. Assuming forest is converted to barren land or industrial development, the amount of carbon stored in currently forested acres will be released into the atmosphere, contributing to global warming and other climate change effects.

The carbon storage lost from converting forests to barren and developed lands for natural gas infrastructure averages to $2,147 an acre (Rempel & Buckley, 2018). This amounts to $18,554,374 a year lost in carbon storage value under the middle development scenario.

Natural Gas Well Pad Construction: Large-Scale Costs from Lost Forests

If 1,466 well pads are constructed by 2030 in regional watersheds, 25,000 acres of forestland and 6,000+ acres of agricultural land would be disturbed or lost. Each new well pad and associated infrastructure covers roughly nine acres, with indirect impacts to the ecosystem in forested areas spanning an additional 21 acres. While unconventional wells bring a valued commodity to market, they damage the societal benefits ecosystems provide, such as water quality and supply, recreation, and species' habitat. Table 4 shows the scale of annual lost ecosystem services in regional forests based on potential development scenarios.

[18] This value captures only the damage to water quality and filtration from lost forest and does not capture the water quality degradation of wastewater discharges.

Table 4. Forest Ecosystem Service Losses in Low, Medium, and High Development Scenarios in the Region

Natural Gas Well Pad Scenarios	Low	Medium	High
Number of Potential Well Pads in Forests	604	982	1,490
Estimated Wells per Pad	10	6	4
Annual Ecosystem Service Loss*	$23,290,031	$37,865,581	$57,453,885

*We present estimates under the assumption all well pads will be constructed. Although certain well pads have less likelihood of being constructed, this scenario provides a more complete picture of potential losses.
**Approximately the same number of wells are drilled in each development scenario. The low, medium, and high scenarios pertain to the amount of land converted for new well pads, depending on the density of wells per pad.

Source: Johnson, 2010; Jerrilyn.

Agricultural Productivity Loss

Additional natural gas well pads may convert 6,000 acres currently used for agriculture to barren or developed land. Cropland and pastures do not provide the same benefit of water quality, habitat for native species, recreation, or level of carbon storage that forests do, but the production of crops and livestock provide value in raw materials and food. The conversion of over 6,000 acres of agricultural land for unconventional natural gas production would yield an annual agricultural loss of $2.7 million (USDA, 2017) (See Appendix D). The associated carbon storage loss from converting 6,112 agricultural acres to well pads is more than $3.8 million a year.

Unaccounted Costs from Unconventional Drilling

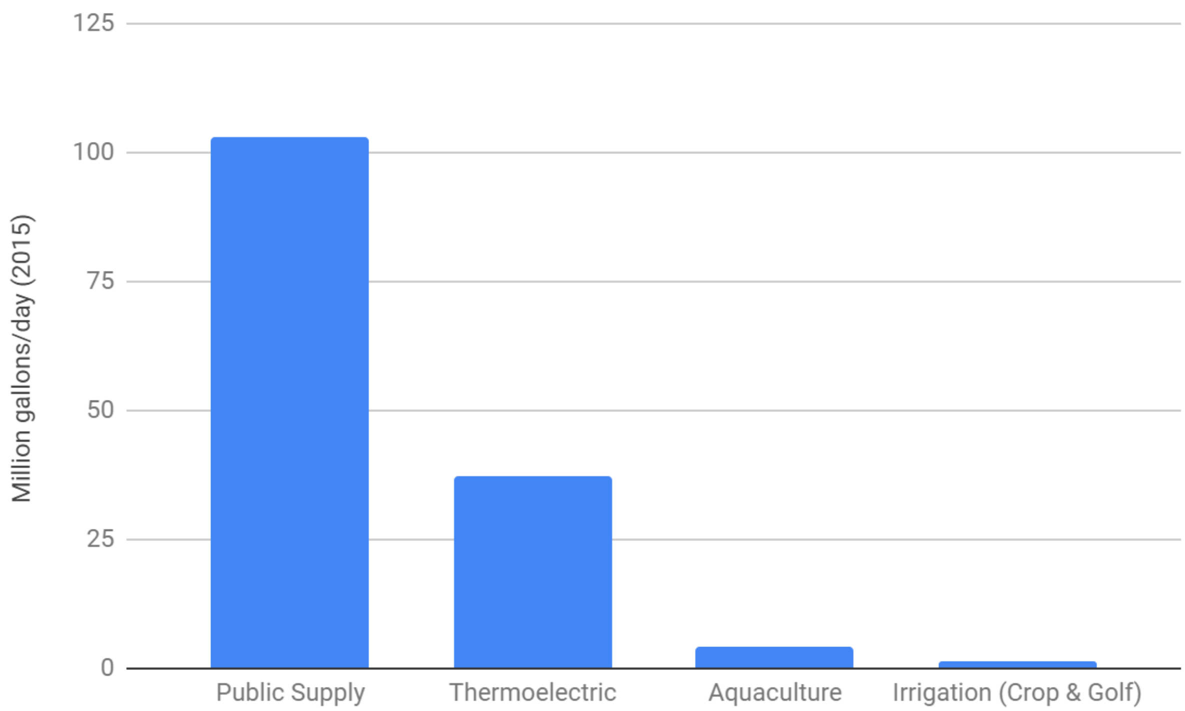
The estimated ecosystem service losses accompanying additional natural gas well pad construction in the region only identify losses within the footprint of the natural gas well pad, given consideration whether the land is interior habitat, close to important waterways, and managed by public agencies. The costs do not take into account damages that extend beyond disturbed acres, including release of wastewater and toxins into surface waters and groundwater, indirect impacts to invasive species management, and impacts on the regional economic resilience of the five-county region, whether it be the appeal to new residents and businesses, or the ability to retain vibrancy and character in existing communities. Costs unaccounted for in this analysis are explored in more detail below.

Water Supply

In the Marcellus Shale region, the average annual water use and discharge per well has been steadily increasing, with the average well intake at 11.4 million gallons in 2017 (Kelso, 2018). Under the medium development scenario, 1,466 well pads may be constructed by 2030, averaging six wells per pad (Johnson et al., 2010). With 8,796 unconventional wells assumed operating by 2030, an additional 5.4 billion gallons of wastewater could be released in the study region's watersheds and another 100 billion gallons of water demanded annually, 70 billion gallons of which would likely be drawn from surface waters (ECONorthwest, 2019). This amounts to an additional 192 million gallons a day that could be demanded from the 21 watershed's surface waters by 2030.

The current landscape of water demand in the region indicates that the projected increase in water use from unconventional drilling could drastically alter water resources in the region. Figure 10 shows the breakdown of the top four surface water withdrawal sources in the five-county region in 2015, which averaged 146.4 million gallons/day (Dieter et al., 2018). Public water supply accounts for 70% of total surface water withdrawals and includes raw water for both drinking and wastewater (Dieter et al ., 2018). This indicates that there will be a significant opportunity cost for the surface water withdrawn for new unconventional natural gas drills if water withdrawn would otherwise be used for public water supply.

Figure 10. 2015 Water Demand & Use in the Five-County Study Region
Source: USGS, 2015



Current rates provided by public water suppliers reflect a wide range in costs that customers pay for water in the region. Data from municipalities, boroughs, and counties in the study region reveal water rates range from $2 to $12.28 per 1,000 gallons (PA DEP, 2018e). Should water demand from natural gas drilling cut into current water use by public suppliers, the opportunity cost of forgone water supply use could reach hundreds of millions per year.

Wastewater

Wastewater from well pads, or the fluid that returns to the surface after fracking ("flowback"), can contain heavy metals, radioactive material, endocrine disruptors, volatile organic compounds, and carcinogens (Physicians for Social Responsibility & Concerned Health Professionals of New York, 2019). One recent analysis found that shale gas wastewater contained median barium concentrations more than 200 times the EPA's limit for barium in drinking water and 40 times the Pennsylvania limit for wastewater effluent (Kuwayama et al., 2013). While wastewater and flowback are meant to be stored and treated before being released into surface waters, storage facilities are often unlined or weak, leading to leaks and spills (Kuwayama et al., 2013). Wastewater spills are common, 1,923 spills were documented in Pennsylvania between 2005 and 2014, translating to 4.3% of wells spilling a year (Patterson et al., 2017). Compounding reported spills, roughly 5% of all wastewater is lost to spills, usually during transport (Physicians for Social Responsibility & Concerned Health Professionals of New York, 2019).

Despite industry claims of risk-free fracking, Physicians for Social Responsibility & Concerned Health Professionals of New York (2019) finds irrefutable evidence that fracking contaminates groundwater, with the likelihood of contamination increasing closer to well pads. In Pennsylvania, 343 private drinking wells were contaminated as a result of drilling and fracking operations over eight years (Physicians for Social Responsibility & Concerned Health Professionals of New York, 2019).

In surface waters, spills and discharges are associated with the altering of stream chemistry and ecology throughout entire watersheds. Contaminants levels in polluted streams often exceed federal drinking water standards and can pose human health risks (Physicians for Social Responsibility & Concerned Health Professionals of New York, 2019).

Human Health Damages from Infrastructure, Potential Wastewater Leaks or Groundwater Contamination

ECONorthwest released a study in May 2019 that monetizes human health damages from unconventional natural gas production, particularly fracking, in Pennsylvania. This includes health costs associated with low birth weights, asthma & respiratory issues, sleep disruption, depression, and avoidance costs, which totals $135 million per year for the state (ECONorthwest, 2019). Undoubtedly, the five-county study region will bear a higher proportion of these state-wide costs, as some of the densest natural gas production is expected to occur in Southwest Pennsylvania.

Westmoreland County and Fayette County rank 3rd and 4th in the state respectively for highest annual health costs of fracking from the number of people living within two miles of an active or inactive well (ECONorthwest, 2019). Westmoreland County has 80,337 people living within 2 miles of a well, which results in an estimated annual cost of $12.3 million (ECONorthwest, 2019). Fayette County has 61,473 people living within 2 miles of a well experiencing an annual cost of $7.9 million (ECONorthwest, 2019). With an expected 9,000 wells added to the study region by 2030, the number of people living within 2 miles of wells will increase drastically, resulting in higher human health costs.

Value of Water Recreation and Higher Water Quality

The 21 watersheds in the study region offer a wealth of recreational opportunity. Shoreline and fly-fishing, white-water rafting, kayaking, boating, and swimming are major recreational activities that support local economies and depend on clean water. Higher water quality can lead to an increase in visitation and spending in the region, supporting local jobs and businesses and even attracting new residents.

Outdoor Recreation Economy in Pennsylvania & Laurel Highlands Region

Great Allegheny Passage at Ohiopyle State Park
Source: Carla Ruddock

Outdoor recreation in the state supports 251,000 direct jobs, $8.6 billion in personal income, and generates $29.1 billion in consumer spending — $2.2 billion more than the construction industry (Outdoor Industry Association, 2017). The nine state parks[19] in the study region hosted 1.1 million visitors that spent more than $65 million in the region in 2010 (Table 5). The Great Allegheny Passage, a 150-mile trail running from Pittsburgh to Cumberland, MD, passes through Westmoreland, Somerset, and Fayette Counties and attracted more than one million visitors in 2016, generating more than $40 million in annual revenue for nearby businesses (Perry; Ford, n.d.).

A 2019 analysis of counties across the country shows that recreation-focused counties[20], especially in rural areas, have higher net migration rates[21] than other counties, higher income among newcomers, and faster income growth (Lawson, 2019). In the five-county study region, Somerset County is classified as a recreation county and experienced 1.8% growth in average job earnings from 2010 to 2016 (Lawson, 2019). All five counties in the study region had population loss from 2010-2016, underscoring the urgency and opportunity for the region to attract new residents and visitors through continued water quality improvements in its watersheds (Lawson, 2019).

> *Outdoor recreation supports more than **3 times** as many jobs as the natural gas industry in Pennsylvania.*

[19] Laurel Hill State Park, Linn Run State Park, Yellow Creek State Park, Keystone State Park, Kooser State Park, Laurel Ridge State Park, Laurel Summit State Park, Ohiopyle State Park, Laurel Mountain State Park.

[20] A recreation county is defined by the percentage of employment in entertainment, recreation, and accommodation sectors, percentage of total income reported in those counties, and percentage of vacant housing units intended for seasonal use (USDA ERS, 2017).

[21] In other words, more people are moving into the county than leaving relative to other rural counties. Many rural counties are experiencing negative net migration, meaning more people leave each year than move in.

Table 5. Recreation Profile of State Parks in the Laurel Highlands in 2010

River Basin	Park	Total Visitor Days	Total Spending	Job Contribution
Kiski-Conemaugh	Keystone	161,811	$9,056,000	135
Kiski-Conemaugh	Yellow Creek	94,904	$5,071,000	76
Kiski-Conemaugh	Linn Runn	74,898	$3,244,000	49
Kiski-Conemaugh	Laurel Mountain	38,235	$2,043,000	31
Kiski-Conemaugh	Kooser	36,043	$1,597,000	24
Kiski-Conemaugh	Laurel Summit	10,036	$402,000	6
Youghiogheny	Ohiopyle	513,395	$34,880,000	604
Youghiogheny	Laurel Hill	124,133	$6,958,000	104
Kiski-Conemaugh/ Youghiogheny	Laurel Ridge	51,731	$2,073,000	29
Total		**1,105,186**	**$65,324,000**	**1,058**
Source: Pennsylvania State University, 2012				

Water-Based Recreation in the Region

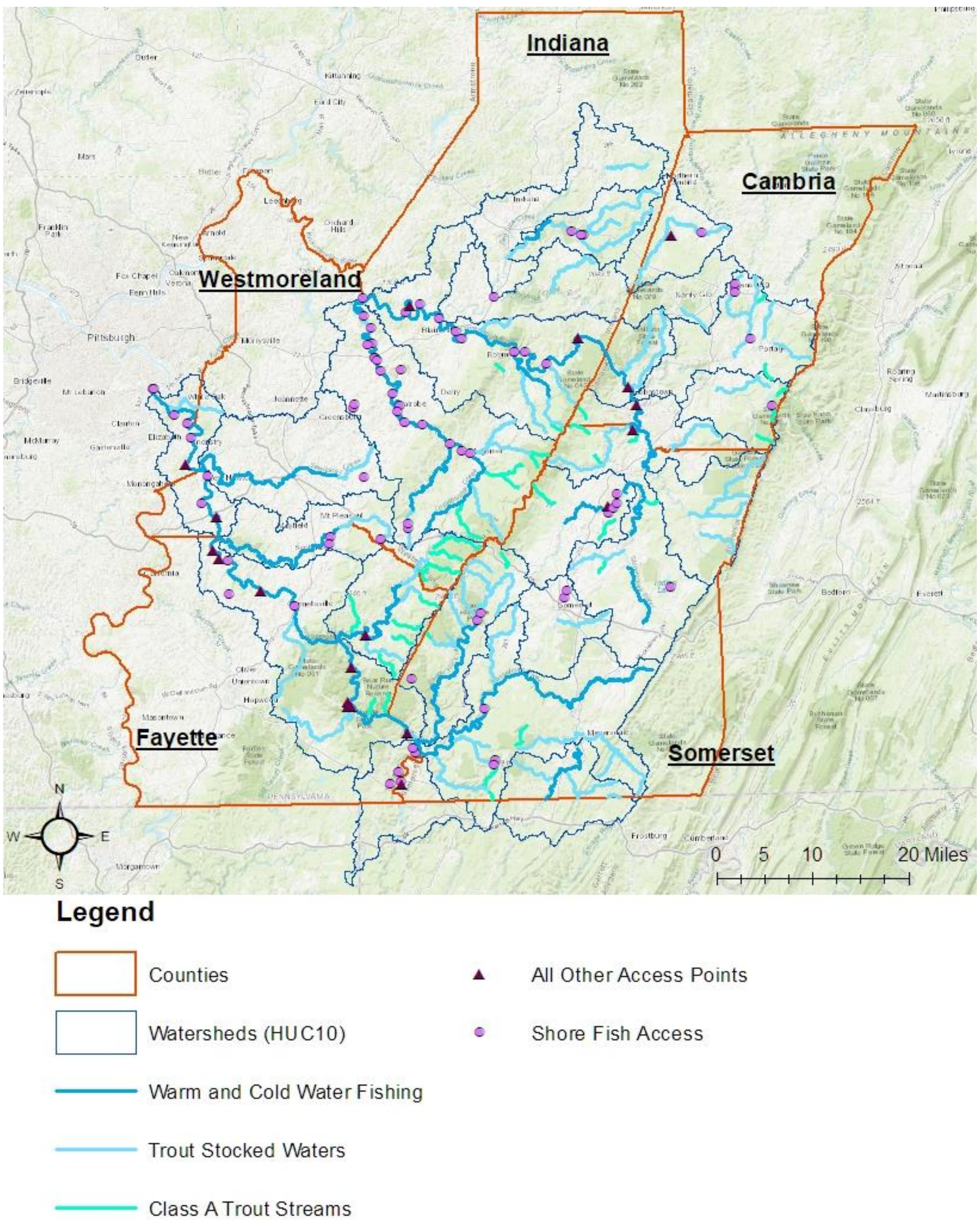
Water-based recreation includes recreational fishing, kayaking, white-water rafting, paddling, boating, and swimming. Economic benefits from these activities rely on high water quality. Unsafe water, or the perception of unsafe water, negatively affects the demand for days of recreation and how people value those experiences. Table 6 provides estimates of water-based recreation participation in state parks in the region based on surveys conducted by Penn State and in Keystone, Laurel Hill, and Ohiopyle State Parks (Penn State, 2012; Mowen et al., 2015).

Table 6. Water Recreation Participation in State Parks of LH Region

Water Recreation Activity	Days with Visitor Participation*	Visitor Days- Primary Activity*
Fishing	299,797	132,604
Boating (Non-Motorized)	198,318	88,073
Swimming	343,600	55,327
Beach Use	388,319	11,590
Total	**1,241,087**	**287,594**
Estimated using: Penn State, 2012; Mowen et al., 2015.		
*Days with visitor participation include all estimated visitor days with some participation in each activity. Visitor Days-Primary Activity includes only estimates of visitor days in which the activity is the primary activity and main reason for visiting.		

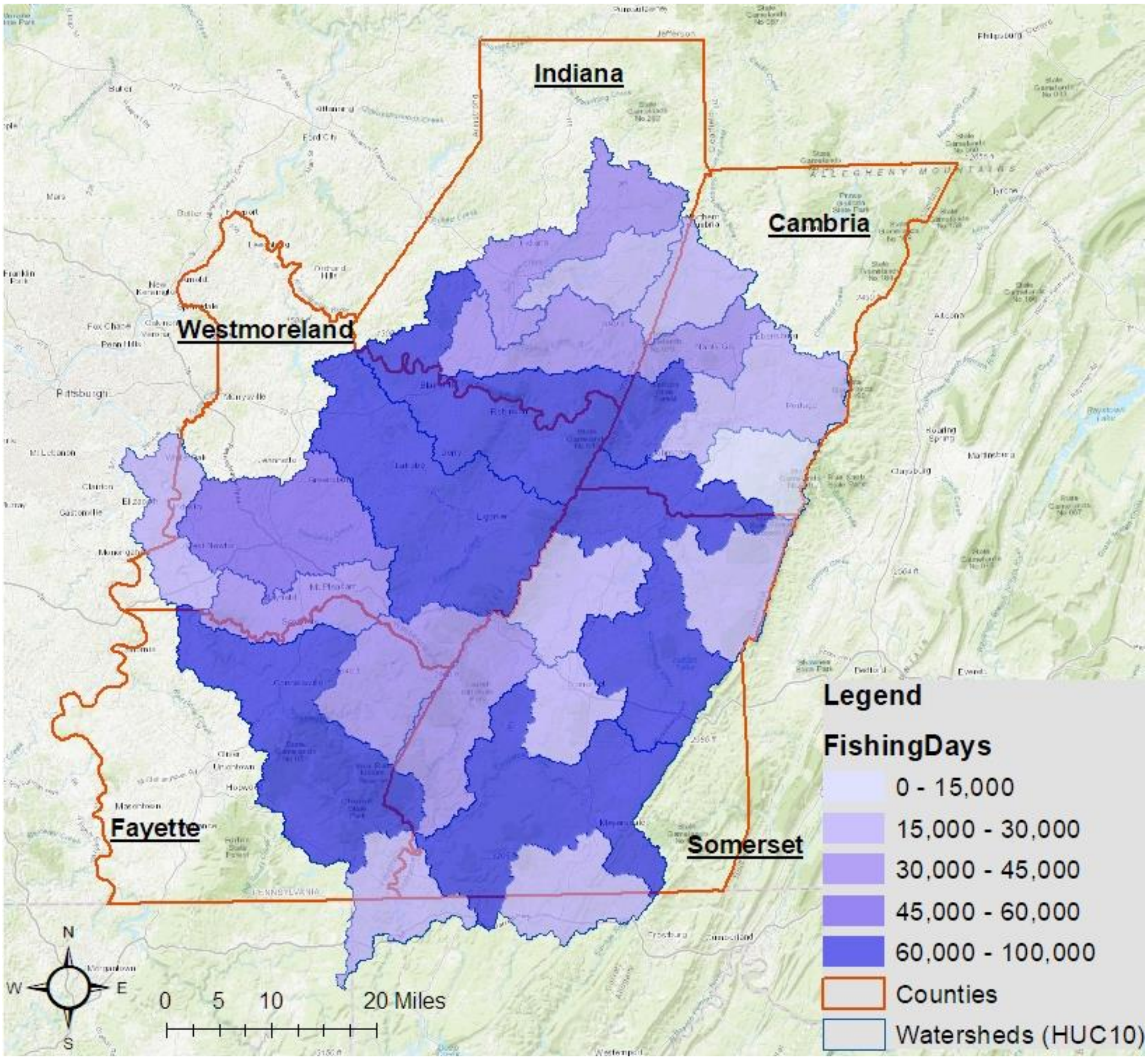
Water-based activities account for an estimated 26% of visitation to the state parks, or $17 million of the annual spending at the nine state parks in the region (Penn State, 2012; Mowen et al., 2015). Opportunities for water-related recreation are not limited to park boundaries; The Pennsylvania Fish and Boat Commission tracks fishing and boating access points throughout the state, and the study region has 91 access points, 72 of which provide shoreline fishing (PFBC, 2019). There are 578 miles of trout-stocked streams in the region, and 377 stream miles provide warm and cold-water fishing (Figure 11) (PFBC, 2019).

Figure 11. Water Recreation Opportunities
Source: Pennsylvania Fish and Boat Commission, 2019



Regional anglers participated in an estimated 844,310 recreational fishing days in 2010, with the highest demand in the Middle Youghiogheny, Loyalhanna Creek, and the Conemaugh River watersheds (Figure 12) (U.S. Environmental Protection Agency). Recreational fishing in the region generates an estimated $31.7 million a year in regional spending and an additional $41.9 million in net economic benefit to participants.

Figure 12. Recreational Fishing Days in Youghiogheny, Conemaugh, and Loyalhanna Watersheds



This nearly $42 million in net economic benefit represents how much anglers value their fishing trip above and beyond what they have paid for it; with improved water quality, this value will increase and begin to attract new visitors as well.

Water trails throughout the region provide points of access for kayakers, paddlers, and fishers alike, cultivating outdoor recreation businesses along the rivers. The 75-mile Youghiogheny River Water Trail,

A wild native brook trout in Laurel Highlands' headwaters
Source: Len Lichvar

managed by the Mountain Watershed Association, is a major recreation attraction to white-water rafters. Popular water trails in the region, like the Loyalhanna Creek Water Trail and Kiski-Conemaugh Water trails, could not be enjoyed by so many today without major restoration efforts throughout the 1990s (Reckner & Null, 2017). A 2012 economic impact study on water trails in Pennsylvania reported that 40% of water trail visitors were concerned about water quality when they visit (ICF Macro, Inc., 2012). Water quality impacts on recreation are not limited to rivers; the Quemahoning Reservoir in Somerset County, whose water quality is sustained by two AMD passive treatment systems upstream, experienced a 40% increase in seasonal passes and 10% increase in day-use passes from 2017 to 2018 (Biery and Dranzik, 2019).

Recreation & Value of Water Quality Improvements

Researchers have found that people are willing to pay (WTP) for improvements in water quality, whether they participate in outdoor recreation or not. A survey of recreational users of lakes, rivers, and coastlines in six New England states found that the annual average per person willingness to pay for improving water quality (from medium to high[22]) ranged from $14 for boating and fishing uses, $53.29 for viewing,[23] and $119.40 for swimming use (reported in 1994 dollars as $8.25 for boating, $8.26 for fishing, $31.45 for viewing, and $70.47 for swimming uses; adjusted to 2018 dollars using CPI) (Parsons, Helm, and Bondelid, 2003). These average values include both participants and nonparticipants.

A study of the value of water quality improvements surveyed residents living within 90 miles of the Loyalhanna Creek and Conemaugh River, which were both considered polluted (moderately and severely, respectively) at the time (Farber & Griner, 2000). In the mail survey, residents were presented with stream quality improvement scenarios for two river segments and a hypothetical price to achieve a perceived level of improvement: from moderately polluted to unpolluted, severely polluted to

[22] Water quality is defined in terms of biological oxygen demand, total suspended solids, dissolved oxygen, and fecal coliform levels. "Sites with medium water quality have some game fishing and usually few visible signs of pollution. Sites with high water quality are suitable for extensive human contact, have the highest natural aesthetic, and support high quality sport fisheries."

[23] The survey defined viewing as trips where the primary purpose was to visit a beach or waterside for picnics, nature study, or other purposes.

moderately polluted, or severely polluted to unpolluted. Severely polluted streams were considered incapable of supporting aquatic life, moderately polluted streams were defined as those that support only some fish and other organisms (with fishing catch limited), and unpolluted streams were those in which fish and other organisms can thrive.

Keeping those pollution levels in mind, survey results suggest that nearby households (stream users and non-users) are willing to pay between $57 and $82 per year (2018 $) for a five-year period to have stream quality improved from moderately polluted to unpolluted. To improve water quality from a severely polluted to unpolluted condition, households expressed willingness to pay between $140 and $180 per year (2018 $) for five years.

These values, when applied to households near stretches of severely and moderately polluted streams in the region, provide a study region-wide estimate of households' value of improving impaired streams to an unpolluted state. The potential benefit of improving the water quality of streams currently classified as impaired to people who participate in water-related recreation activities is $1.1 million.

Natural Stream Buffers & Cost-Savings from Reducing Runoff

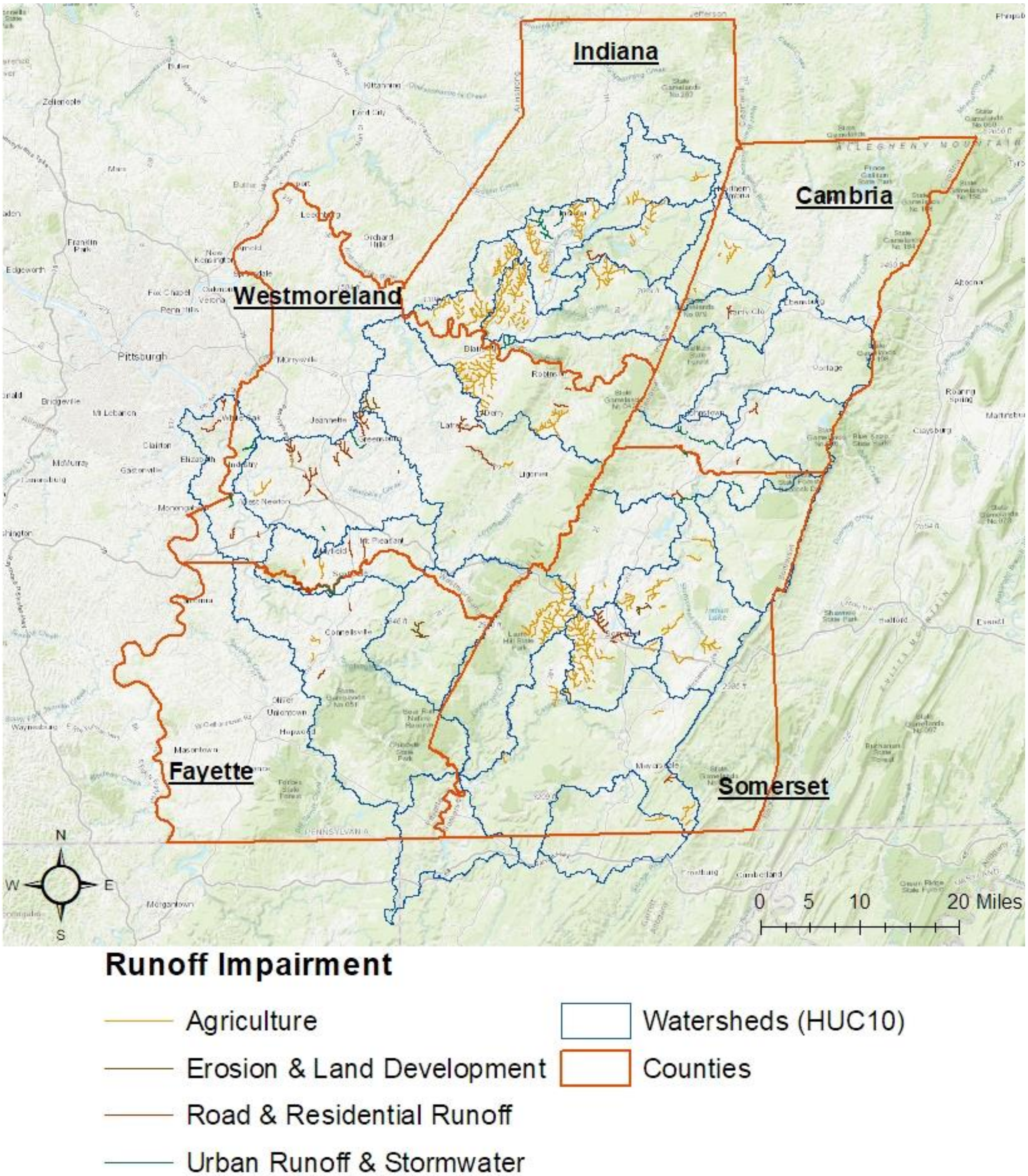
Soil erosion and runoff pollutants from agricultural land and from other development damage hundreds of miles of streams in study watersheds. Table 7 and Figure 13 show the extent of impairment from nonpoint source pollution throughout the watersheds. Those nonpoint sources include runoff from agricultural land uses, runoff from roads and other urban land uses, and stormwater discharges (PA DEP, 2018d).

Table 7. Runoff Impairment in the Study Region

Impairment Source	Total Stream Miles	Watersheds Most Impacted
Agriculture (General)	242	Coxes Creek, Stonycreek River, Conemaugh River, Laurel Hill Creek
Crop-Related Agriculture	111	Blacklick Creek, Two Lick Creek, Conemaugh River
Grazing-Related Agriculture	16	Laurel Hill Creek
Road & Residential Runoff	81	Jacobs Creek, Sewickley Creek, Laurel Hill Creek
Urban Runoff & Stormwater	39	Two Lick Creek
Erosion & Land Development	20	Loyalhanna Creek, Indian Creek

Most agricultural runoff-based impairment is concentrated in Indiana County, around the upper portion of the Conemaugh River, Blacklick Creek, and Two Lick Creek, and in Somerset County, around Coxes Creek, Laurel Hill Creek, and Stonycreek River.

Figure 13. Runoff & Erosion Stream Impairment in the Laurel Highlands' watersheds
Source: PA DEP, 2018d



Siltation, the suspension of dirt in water, is the most common type of damage in these stream miles. Erosion and runoff can also deliver excess nutrients (nitrogen and phosphorous), pathogens (fecal coliform bacteria) and other pollutants (e.g. toxins) into surface water. While organisms in streams need nutrients to survive, excess nutrients entering streams can damage water quality and suffocate aquatic life. Excess nutrients can come from chemical fertilizer applied to agricultural and urban land, from human waste and livestock and poultry manure, and/or from the normal breakdown of vegetation into small particles containing those nutrients. Under these conditions, implementing Best Management Practices (BMPs) is often the most cost-effective way to restore and retain higher water quality throughout watersheds.

What are Best Management Practices (BMPs)?

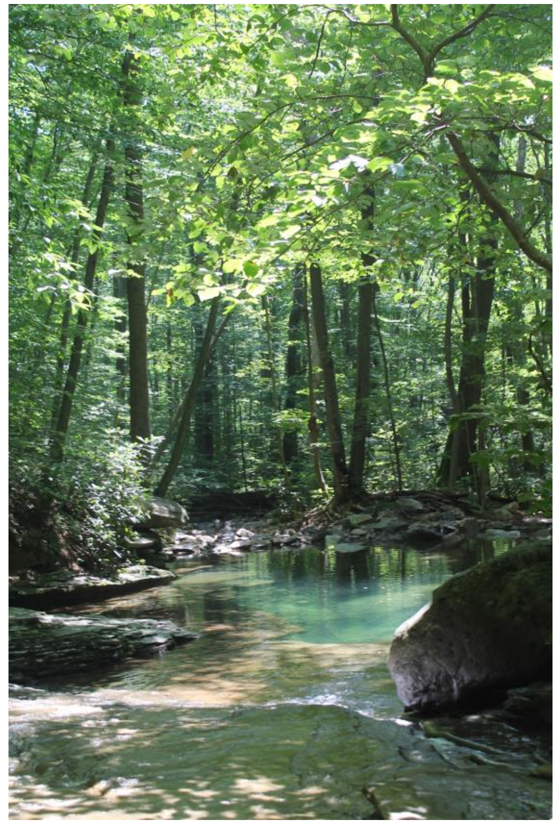
BMPs are practices implemented to protect water quality and support soil conservation around waterways (NC Forest Service, 2017). BMPs can be both physical structures and actions and processes, both around the area of runoff and downstream, that help to prevent and mitigate pollution (NC Forest Service, 2017). Examples of structural BMPs include fencing and vegetation plantings, and preventive strategies and processes include stormwater management and reduced fertilizer application.

In the five-county study region, Westmoreland County, Indiana County, and Fayette County have county-wide stormwater management plans, while Cambria County and Somerset County have plans broken out by municipality and watershed (i.e. Stonycreek River). Westmoreland County recently released an Integrated Water Resources Plan, highlighting the use of residential and urban BMPs such as rain gardens, pervious and permeable paved surfaces, bioretention facilities, and riparian buffer plantings around parking lots, community centers, and other developed areas as effective practices for stormwater management (Westmoreland Conservation District, 2018).

The Southwestern Pennsylvania Commission provides resources on BMPs for a variety of land-uses, including residential development, urban areas, agricultural land, and highways. In addition to the residential and urban BMPs highlighted in Westmoreland County, common agricultural BMPs in the region include fencing, use of cover crops, no-till seeding, fertilizer application management, and maintaining riparian buffers around cropland and pastureland (Southwestern Pennsylvania Commission, 2017).

Natural Buffers: Current Regional Landscape and Existing Incentive Programs

Riparian buffers are one of the most common and effective ways to manage nonpoint pollution runoff. In a healthy, well-functioning watershed, vegetation — trees, grasses, and other plants — is essential for water purification and nutrient retention. Many riparian zones in the region lack enough vegetation to handle water purification and nutrient retention needs, evident in the number of stream miles damaged by siltation, high nutrient levels, and low levels of dissolved oxygen (PA DEP, 2018d).



Blue Hole Creek, Casselman River
Credit: Carla Ruddock

According to data available in the EnviroAtlas (U.S. Environmental Protection Agency, 2019), almost 75% of the land within 100 feet of any stream or waterbody in the study region is comprised of natural land cover (forest, shrub, grassland, wetland, etc.). The remaining 24% is in agricultural, urban, or other development uses.

This distribution changes for land cover within 100 feet of siltation-damaged streams (see Figure 13 above); the portion of natural land cover falls to 62%. This is not surprising: less natural land cover should translate into less of the water purification process described above and, therefore, lower water quality.

Pennsylvania's Conservation Reserve Enhancement Program (CREP) aims at addressing this issue by rewarding landowners for conserving or converting land in the riparian zone to natural coverage. An acre of natural buffer next to cropland can retain 2.5 tons of soil (which could otherwise become sediment and silt downstream), 6.4 pounds of nitrogen, and 1.1 pounds of phosphorus (USDA FSA, n.d.). Landowners receive 10-15 years of guaranteed annual rental payments, payments that cover up to 90% of the costs to establish the buffer, as well as a maintenance rate incentive.

Buffer Strip Benefits: Changes in Ecosystem Service Value

A word about "benefits": Economists are typically very careful about using the word "benefit". Benefits are thought of as the excess of the value of a good or service, like clean drinking water or a recreational experience, over the cost of obtaining the good or service. That contrasts with the total value of the goods or services.

For example, the total value of a day's guided fly fishing to an angler is the monetary equivalent of the satisfaction the angler would expect to receive expected from experience. Some of that value could be the value of the food a fish caught, killed, and eaten represents. Some would be the value to the angler's physical or psychological wellbeing from being out in nature, and some could be the satisfaction from carrying on a tradition or sharing an experience with other anglers.

The angler has a "willingness-to-pay" (WTP) for the bundle of values he associated with the experience, and he would be willing to pay up to that full amount to have the experience. If, however, the angler finds a guide service that can provide the experience for less than the angler's full WTP, the difference (WTP minus the guide's fee) is some number of dollars that stay in the angler's pocket rather than being paid to the guide. Those dollars are called "consumer surplus" and represent part of the benefit of one day of guided fly fishing.

The guide service, for its part, receives the angler's fee as its revenue, and after paying its expenses (for wages, gear, fuel, insurance, etc.), the guide service gets to keep the difference in its pocket. That difference is "producer surplus" and it is closely related to the guide service's profit.

The total benefit of the day's fly fishing is the sum of the angler's consumer surplus and the guide service's producer surplus. This avoids double counting portions of the guide's fee because that is a wash — a transfer of dollars from the angler to the guide service, and from the guide service to its employees and vendors.

This matters because just going out to compute the total of every dollar associated with the day's fishing adventure ends up over-estimating something. Guide service employee's wages, plus guide service revenue, plus angler's WTP would, for example, TRIPLE count the wages.

Economic Benefits of Increased Natural Buffers Along Impaired Streams

Key Ecosystem Services

Nutrient Retention

Recreation

Aesthetics

Water Quality

Carbon Storage

Given the relationship between natural buffers and stream quality, it could be more efficient, or cost-effective, to target mitigation or restoration efforts on the region's most impaired streams. For that reason, the analysis focuses on ecosystem service value gains resulting from expanded buffer strips around siltation-impaired streams.

In the modeled scenario, the conversion to 1,463 additional natural acres along siltation-damaged streams results in estimates of potential economic benefits from improvements to the ecosystem services of aesthetic value and flood mitigation, nutrient retention, carbon storage, and recreation. A summary of projected economic benefits is provided in Table 8, and details on calculations and methods can be found in Appendix D.

Table 8. Annual and One-Time Costs and Benefits of Establishing Forested Riparian Buffer in Siltation-Damaged Streams

Increased Riparian Forest Buffer: Annual Benefits and Costs	
Ecosystem Service	**Estimated Annual Benefit/Cost**
Benefit: Nutrient Retention	$1,262,424
Benefit: Recreation	$86,619
Benefit: Carbon Storage	$2,210,467
Opportunity Cost: Forgone Agricultural Production	$650,998
Annual Net Economic Benefit	**$2,908,51**2
Increased Riparian Forest Buffer: One-Time Benefits and Costs	
Ecosystem Service	**Estimated Annual Benefit/Cost**
Benefit: Aesthetics	$4,650,531
Establishment Cost	$2,545,475
One-Time Net Economic Benefit	**$2,105,056**

Aesthetics, Flood Protection & Property Values

Certain dimensions of water quality are more likely to be capitalized in property values, including flood protection, capacity and habitat for wildlife, and recreation potential (Nicholls & Crompton, 2018). While many factors contribute to the degradation of water quality, turbidity, or how murky the water is, has been shown to reduce property values. Many studies examining the relationship between water clarity and property values focus on the depth of clarity in lakes and lakeside properties; a study on dozens of lakes in Northern Minnesota found that a one-meter change in water clarity corresponds with millions of dollars in shoreline property value (Krysel et al., 2008). Water clarity is also a motivating factor for prospective residents, and homebuyers are willing to pay more to live near clearer water (Krysel et al., 2008).

Fewer studies have examined the relationship between property values and turbidity in rivers, or the value of a riparian buffer along rivers and streams. American Rivers released a study on the economic impact of riparian buffers, citing that proximity to a riparian buffer can generate a price premium (increase) for residential properties between 1% and 26%, depending on the quality of the buffer, the baseline property value, and whether the property is surrounded by other valuable natural assets and amenities (Young, 2016). In the Neuse River Basin of North Carolina, land with riparian buffers have a 26% higher property value compared to non-buffered land (Bin et al., 2009).

If 1,463 agricultural acres in the study region near streams with excessive siltation are converted to natural (forested) buffer, an estimated 1,175 homes worth $34.5 million could experience $4.65 million in enhanced property value from protective buffer around the waterways (U.S. Census Bureau, 2010; U.S. Census Bureau, 2017; Young, 2016). The design of vegetated buffer strips (whether it enhances or damages aesthetic value), the location of the property in a floodplain zone, and the distance of the property from the stream can all factor into the net impact on property values.

Nutrient Retention

Economic benefits from nutrient retention include lower loads of phosphorous, nitrogen, and sediment in rivers, which lead to cost-savings for water treatment plants and reduced human health damages downstream. The Riparian Buffer Expert Panel estimates that an acre of natural riparian buffer can retain four upstream acres of nitrogen loads and two upstream acres of phosphorus and sediment loads (Rempel & Buckley, 2018). The improvement in this ecosystem service in watersheds provides an estimated $1.3 million in annual economic benefit.

Carbon Storage

The social cost of carbon is a comprehensive estimate of the economic cost of harm associated with the emission of carbon. Previous studies have identified the amount of carbon stored above and below ground in various riparian forests, which can then be valued in dollar terms using the estimated social cost of carbon. An acre of developed land stores 16 metric tons of carbon per acre while an acre of agricultural land stores 28 metric tons of carbon per acre. Depending on forest type, forests can store between 69 and 82 metric tons of carbon per acre (Rempel & Buckley, 2018).

Applying those carbon storage differences among land cover types in the scenario, converting 1,463 acres of agricultural land to natural buffer could yield an additional 69,493 metric tons of carbon stored each year, worth $2.2 million a year.

Recreation

Siltation is one of the most visible indicators of poor water quality, which is why it can be one of the greatest deterrents for potential or existing recreation. A study of licensed boaters in Central Iowa found that excessive siltation influences recreation behavior; 45% of surveyed boaters in eight counties were less likely to recreate in waters with sediment loading and excessive siltation (Robertson & Colletti, 1994). For Maine fishers and boaters, loss in water clarity of half a meter, one meter, and one and a half meter are associated with net economic benefit declines of 3%, 6%, and 10%, respectively (Schuetz et al., 2001).

The USDA studied the economic benefits from wildlife viewing and recreational freshwater fishing associated with the Conservation Reserve Program (CREP in Pennsylvania) and estimate a conserved acre of riparian buffer provides a recreational benefit of $59.21 a year (Hansen et al., 1999). Wildlife viewing accounts for most of this per-acre value, as natural riparian buffers are critical habitat for waterfowl. Converting 1,463 agricultural acres to natural riparian buffers around impaired streams can produce $86,619 a year in added recreational benefit to watersheds in the study region.

This benefit may be increased substantially if conserved acres are focused around public access points. In the region, nine recreational access points lie on streams impaired by excessive siltation (Table 9). Almost all these access points have shoreline fishing opportunity and could significantly benefit from the addition of natural buffers either upstream or near the access point (PFBC, 2019). Increase in water clarity around these public access points could not only attract new fishers and boaters but increase the value of the recreation visit as well (Schuetz et al., 2001; Robertson & Colletti, 1994).

Table 9. Recreational Fishing Opportunities Near Streams Impaired by Siltation

Access Point	County
Yellow Creek State Park	Indiana
Cedar Creek Park Access	Westmoreland
Duman Dam	Cambria
Keystone State Park Lake	Westmoreland
Aultmans Run Access	Indiana
Mission Rd. Bridge	Westmoreland
Kingston	Westmoreland
Idlewild Hill Road	Westmoreland
Power St. River Wall	Cambria

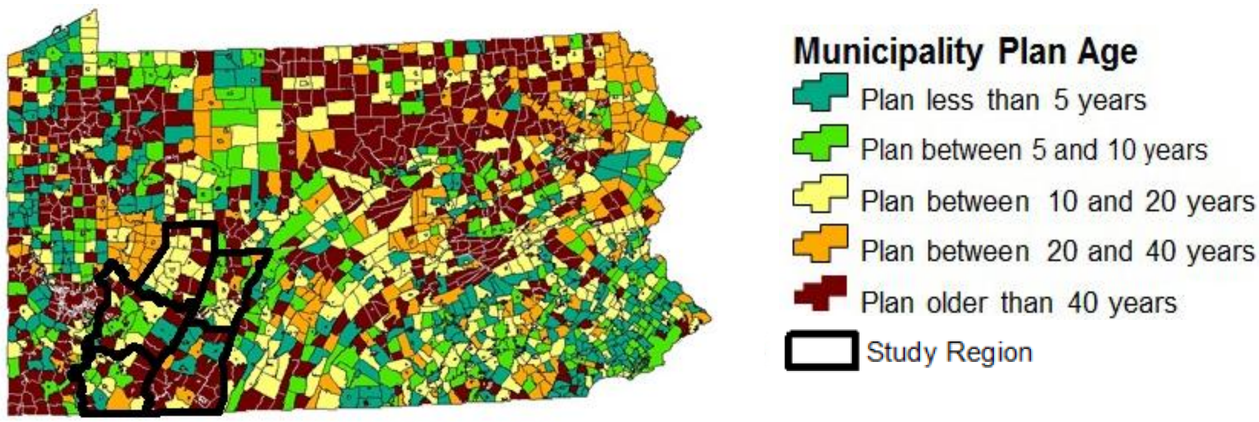
Buffer Strip Costs

Establishing and maintaining buffers entails both costs and benefits. The initial cost of establishing an acre of natural buffer is estimated at $1,740, or a total of $2.5 million for a quarter of all siltation-damaged streams in the region (PA DEP, 2010). Programs like Pennsylvania's Conservation Reserve Enhancement Program are already in place to compensate landowners for upfront costs of converting and maintaining natural riparian buffers. Considering the acres converted in this scenario are agricultural acres, annual costs incurred reflect the forgone revenue or agricultural production from these 1,463 acres. Based on the market value per acre of agricultural production in the five-county region, the estimated annual opportunity cost is $445 per acre, or $650,998 total per year (USDA, 2017).

On-lot Sewage Issues in the Laurel Highlands

Within watersheds In the Laurel Highlands, water quality degradation from failing septic systems and antiquated public water treatment plants is a prominent concern. In 1965, the Pennsylvania passed The Sewage Facilities Act (Act 537), which requires that all municipalities develop and implement plans to provide solutions for existing sewage disposal problems, for future sewage disposal needs, and specifically develop plans to ensure long-term use of on-site sewage and disposal systems (septic tanks) (Day, Zhu, Bruce, & Franklin, 2008). Each municipality's Act 537 plan must be approved by the Pennsylvania Department of Environmental Protection (PA DEP). While legally each municipality has a plan, 47% of municipalities in the state have a plan that is more than 20 years old and only 17% of municipalities have a plan that is less than 5 years old (Day, Zhu, Bruce, & Franklin, 2008). Figure 14 shows the age of Act 537 plans across the state with the study region outlined in black.

Figure 14. Act 537 Official Plan Status Map
Source: Department of Environmental Protection, 2015



On-lot sewage currently impairs 40 miles of streams in the study region and the Regional Water Management Taskforce estimates that in Fayette, Indiana, Somerset, and Westmoreland counties[24] more than 124,000 homes rely on on-lot septic systems to treat their sewage[25] (Regional Water Management Task Force, 2008). For these same counties, a combined 103 authorities serve an estimated 23,500 people and across southwestern Pennsylvania, an estimated 27,000 homes rely on

[24] No estimates were provided for Cambria county.
[25] Estimates for the state suggest that 1.6 million homes, or 30% of homes, are served by on-lot systems (Pennsylvania State Council of the American Society of Civil Engineers, 2018).

wildcat sewers that discharge sewage directly into streets, gullies, or streams (Regional Water Management Task Force, 2008).

There is no official documentation by PA DEP or by local municipalities detailing what percentage of homes with septic tanks are failing[26], the spatial distribution of failing systems, reasons for failure, or associated costs of failures (Day, Zhu, Bruce, & Franklin, 2008). PA DEP asks municipalities to voluntarily provide information on on-site sewage permit issuance, but only roughly two-thirds of municipalities report any data. The data provided by municipalities does not include any documentation on the nature of septic tank failures, the age of the system, costs, and other critical information that could be used to analyze septic tank failures. Malfunctioning septic systems can present a public health risk, degrade the environment, reduce property values, contaminate drinking water supplies, and make streams unsafe for water-based recreation (PA DEP, 2016).

Exacerbating water quality degradation issues, throughout Pennsylvania and especially in rural communities like the Laurel Highlands, antiquated public sewage treatment facilities are failing, with older systems frequently overwhelmed during heavy rainfalls (National Research Council of the National Academies, 2005). Many municipalities have multiple water and sanitary authorities, with each authority differing in what they handle and how many people are served, making regional collaboration on sewage management

Septic Tank Issues in the Laurel Highlands

The dominant soil types in the Laurel Highlands region are also not suitable for the disposal of septic tank effluent or on-lot systems, forcing homeowners in the region to use alternative systems that disperse sewage in gravel, sand, or peat (Western Pennsylvania Conservancy, 2003 & University of Pittsburgh Institute of Politics, 2006). These alternative systems are often extremely costly, require meticulous maintenance, and frequently fail (University of Pittsburgh Institute of Politics, 2006). In the Sewickley Creek Watershed Conservation Plan (2003), the authors note that "many of the homes built in the watershed in the past two centuries that did not incorporate on-lot septic systems have developed leaks and cracks, issuing raw sewage into waterways." The plan also notes that municipal treatment systems exist in some areas in the watershed, but due to their age, these systems have the potential to overflow during storm and flooding events (Western Pennsylvania Conservancy, 2003). Other watershed conservation plans in the region echo similar concerns, citing examples of raw sewage discharges from failing septic tanks contributing to nutrient enrichments in streams causing algal growth, increased water temperature, and increased levels of fecal coliform bacteria (Western Pennsylvania Conservancy, 2003 & East Central Iowa Council of Governments & Indian Creek Watershed Management Authority, 2015 & Wright, 2006).

[26] Estimates suggest that failure rates in Pennsylvania range upwards of 20% (Pennsylvania State Council of the American Society of Civil Engineers, 2018).

issues difficult. A survey sent out by a regional water management task force to 11 counties' water and sewer authorities in Southwestern Pennsylvania (including study region counties Fayette, Somerset, and Westmoreland), found that 55% of authorities handle sewage only, 25% deal with only drinking water, and 20% manage both drinking and wastewater (Regional Water Management Task Force, 2006).

On-Lot Sewage Actions for Future Analysis

While sewage problems are frequently discussed in regional watershed plans, plans generally highlight specific communities or waterways in need of remediation rather than proactive strategies or actions that can be applied to the entire watershed to prevent future degradation. They also do not offer any additional insights as to why systems fail, or which households have failing systems.

Water quality degradation from failing on-lot systems negatively impacts many ecosystem services related to water, including raw material goods (water for non-drinking purposes), nutritional goods (drinking water), recreation, and human health. Water quality improvements could improve the provisioning of services and contribute to additional consumer surplus gains for recreationists, increases in property value, and health cost savings. However, due to the lack of centralized municipal level data on the percentage of homes with failing on-lot systems, why they fail, their age, spatial distribution, and associated costs, quantifying specific economic benefits is not currently possible. This analysis instead provides recommendations and areas for future study for two actions related to on-lot septic systems that could improve water quality and create downstream economic benefits in the region:

1) Connecting homes with failing on-lot septic systems near impaired streams to public sewage systems in potential low cost/high feasibility areas
    - This action would target areas near impaired streams with a high density of households with failing on-lot systems that also fall under existing public sewage service areas. These "low cost/high feasibility" households are conceivably cheaper and more feasible to extend service to, as opposed to households near impaired streams in less populated areas that do not fall under existing service areas.
    - Data Needed: The number of households near impaired streams with failing on-lot systems, existing service areas of sewage treatment facilities, survey data on whether targeted sewage facilities could handle any additional capacity, average cost to treatment facilities to add a new household, and what water quality improvements could be expected by the connection.
    - Issues: Due to a lack of spatial data on service areas, it could not be determined which authorities serve households near impaired streams or collect targeted survey data on whether they could handle additional capacity. After performing an extensive literature review, it appears there is no regional monitoring data available to quantify water quality improvements directly attributable to connecting failing on-lot systems to public systems.

2) Repairing failing on-lot septic tank systems near impaired streams
    - The second action would also target areas near impaired streams with a high density of failings systems and examine economic and water quality benefits associated with repairing failing systems.

- Data Needed: The number of households near impaired streams with failing-on lot systems, the average cost of repairing a failing system, and what water quality improvements could be expected by repairing failing systems.
- Issues: No regional water quality monitoring data exists determining what incremental water quality improvements could be expected by repairs. Cost estimates for repairs should be improved as more accurate information on how many systems are failing and their reason for failure are better understood.

Appendix D: Methods provides a blueprint for conducting future analysis with more details on existing information and literature on the topic as well as data gaps for each action.

Recommendations

The ecosystem service values that stand to be enhanced by the resource management scenarios discussed in the body of this analysis make an economic case for fruitful work that communities, agencies, and individuals should invest in now. This includes funding for continued, more extensive, and more effective watershed protection measures such as AMD remediation, expanding riparian buffers, and measures to mitigate damage from gas, coal, and gravel mining. Along with on-the-ground improvements, organizations, local governments, and state agencies should continue research to develop new information and tools for informing the next round of strategies and actions that protect habitat and improve water quality in the region.

Specifically, the following are likely to be cost-effective actions — that is, they will produce positive regional economic benefits—supported by the information revealed in this analysis regarding the economic value of clean water and other ecosystem services in the region.

Prioritizing Funding for AMD Treatment Systems

The estimated economic benefits from AMD remediation in Laurel Highlands watersheds can provide guidance for prioritizing future passive and active treatment systems in the region by:

1. **Comparing the costs of continued operation and maintenance for passive treatment systems to recurring ecosystem service benefits.** Agencies and organizations must consider ecosystem services that will provide recurring annual benefits so long as treatment and restoration are maintained. Restored stream miles on average provide $19,131 per mile per year in recreational fishing benefit.

2. **Considering that site-specific characteristics can indicate higher-than-average ecosystem service benefits.** Remediation projects in areas with higher population densities, in waterways with native trout populations, and in waterways with stocked trout will experience higher-than-average property value benefits and recreation benefits. Based on property value impacts measured in the Cheat River watershed in West Virginia, remediation of some stream segments could provide a one-time property value gain of $908,398 per mile.

Data and literature gaps persist making precise estimation of economic benefits difficult. Conducting more primary data collection and analysis within the study region's watersheds will help fill in data gaps for evaluating the economic benefits of remediation. Recommendations for further study on the economic benefits of AMD treatment systems in the study region include:

1. Examining property values on parcels of land adjacent to AMD-impaired streams to determine more specific potential increases in property tax revenue and property values for residents. In counties where passive treatment systems are in the planning stages, assessing and comparing property values before and after restoration will help determine incremental benefits associated with passive treatment systems.
2. Creating a survey to determine the number of operating AMD treatment systems (both passive and active) in the region and the number of stream miles restored to date. Datashed.org provides a wealth of data on the performance of operating treatment systems throughout Pennsylvania through volunteered reporting. However, data on the cost to operate and maintain treatment systems is not reported for all treatment systems in the region. Because operation and maintenance of treatment systems require secure and ongoing funding, this information will be valuable in providing a more complete picture of the funding required to continue the treatment of damaged streams and abandoned mine discharges.
3. Further research on water treatment costs for AMD-impaired streams should be conducted in the Laurel Highlands region. With the increase in natural gas drilling in the region, more water is required for resource extraction, which could place a larger strain on public water suppliers and force them to start withdrawing from new backup sources that could include AMD-impaired streams as shown in the West Branch Susquehanna study. Forecasting or modelling water extraction scenarios coupled with surveys to public water authorities could help decision makers in the region better understand where water extraction might take place, if additional backup sources exist, and which streams public water authorities would then need to use as backup sources. Estimates can then be obtained on the additional water treatment costs associated with modeled water extraction scenarios, if water is increasingly being drawn from AMD-impaired streams.

Ecosystem Service Values Considered in Energy Permitting

Unconventional natural gas drilling is already changing the landscape in the region. A more accurate account of external costs incurred by communities should include an assessment of ecosystem services damaged by new energy development, how water demand will increase, and what water quality measures will be degraded. Specifically, proper cost accounting should:

1. **Require an ecosystem services impact assessment for each new natural gas well and any surface disturbance associated with coal and gravel mining.** The results from this analysis show potential ecosystem service value losses of up to $57 million per year from the loss of forests just in the study region. Impact assessments conducted during the permitting process must consider additional disturbances beyond the direct footprint of construction.

2. Set impact fees for industry use to compensate for watersheds' incurred costs. These assessments can be used to evaluate the net benefits of mining and/or to set impact fees for such industrial uses. Realistically, energy development will continue in the region, but communities should be compensated for damages in the areas where drilling and mining occur.

3. Determine potential sources of the additional water demand required for unconventional natural gas drilling in regional watersheds by 2030. Unconventional natural gas wells in the region used an average of 11.4 million gallons in 2017, and 70% of the water comes from surface water intakes. Many watersheds in the region already face low water flows from strains on water supply. Watershed groups and public water suppliers could partner to determine whether the watersheds in the region have excess supply to support increasing water demand for unconventional natural gas production in the next decade.

Promoting Outdoor Recreation with Higher Water Quality

The Laurel Highlands region is known for the many water-based recreation activities it provides and residents and nonresidents alike benefit from maintaining and improving these opportunities. Clean waters and the surrounding natural beauty and wildlife attract new residents and visitors to the region and in turn promote increased recreational experiences and satisfaction. Spending on canoe trips, kayaking, fishing tackle, and other recreational equipment; restaurants and groceries; and benefits from overnight lodging for local companies and individuals that provide these services, create economic benefits not only in terms of revenue but also by supporting their employees and generating economic growth within the region.

1**. Management actions should be initiated to improve degraded water quality in streams that threaten the resilience of regional watersheds and ensure the continued protection of those streams that are healthy and resilient**. Improving water quality in impaired streams would provide opportunities for more recreation and spending in the region, support more local jobs and businesses, and improve visitor experiences.

Cost-Benefit Analyses on Riparian Buffer Projects

The USDA Natural Resource Conservation Service recognizes the benefits of establishing and maintaining natural riparian buffers and provides funding and support to landowners who are willing to establish buffers on their property. While many of the benefits of riparian buffers are felt downstream, programs like Pennsylvania's Conservation Reserve Enhancement Program help to offset the costs of riparian buffers for landowners supporting region-wide water quality improvements. Based on the net benefits estimated from the riparian buffer scenario in the region's watersheds, we recommend:

1**. State-wide, regional, and local programs incorporate ecosystem service benefits into considerations of compensation levels for conserved riparian acres.** Incentivizing the establishment of forested riparian buffers along streams impaired by sedimentation or nutrient enrichment can provide the greatest return in ecosystem service value.

2. Explore compensation schemes between downstream municipalities and upstream landowners. In stream segments with high nutrient concentrations and sedimentation levels upstream of municipalities and boroughs, both landowners and townships could benefit from establishing a payment-for-ecosystem-services (PES) scheme. In this arrangement, townships compensate landowners for lower raw water treatment costs at public water intakes.

Regional Collaboration on Sewage Data and Water Quality Monitoring

In order to improve impairments in streams caused by on-lot systems, many data gaps need to be addressed. These data gaps include, but are not limited to, spatial information on households that have on-lot systems, comprehensive assessments on system failures and the reasons for failures, and regionally focused watershed monitoring and collaboration on on-lot septic system issues.

1. **Commission research to fill data gaps on the number, location, and degree of failure of on-lot septic systems in the region near existing impaired streams.** Use the resulting information to determine potential economic benefits from connecting failing systems to municipal systems and/or repairing or replacing failing systems in high priority areas near impaired streams.

A case study approach would allow for a comparison of water quality indicators, such as fecal coliform counts or E. Coli levels, to determine incremental water quality improvements from the baseline scenario to a post-connection scenario. Furthermore, because many of the municipality level sewage authorities in the region are aging and frequently overflow during storm events, it is also important to compare baseline monitoring data to the treatment authority's output to see if the authority is successfully treating the new capacity or if water quality degradation is being passed on to another stream.[27]

Repairing failing systems near impaired streams, requires regional monitoring efforts be implemented that demonstrate "before" and "after" water quality improvements scenarios. A potential case study approach for future analysis could identify a community near a stream impaired by on-lot septic systems that is set to receive grant money for septic repairs. Monitoring efforts would provide baseline data for water quality indicators before and after the septic repairs occur, which would then show any incremental improvements in water quality. The improvements in water quality can then be applied to the estimates of households across region with failing septic systems to show how water quality will improve creating economic benefits throughout the Laurel Highlands region if failing systems are repaired.

It is important to note that there are water quality monitoring efforts in the Laurel Highlands region. The Mountain Watershed Association has been conducting the Swimmable Water Program, which provides recreational users with weekly water quality updates (pH, conductivity, total dissolved solids, total coliform, and E. Coli) for popular swimming locations within the Youghiogheny River watershed throughout the Pennsylvania swim season May 1 through September 30. Johnstown is also working on water quality monitoring efforts. Similar monitoring efforts are recommended for streams impaired by on-lot septic systems. Once incremental water quality improvements are identified, the results of monitoring efforts can be applied to estimate economic benefits.

[27] For example, if one stream's water quality improves because a community is now connected to a public treatment plant, but if the sewage authority does not successfully treat the water and their outflows further degrade a different stream, then there is no real net benefit in water quality improvement, rather just a geographical shift in where the degradation occurs.

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Appendix A: Baseline Ecosystem Service Value Methods & Estimates

By estimating the total value of ecosystem services currently provided in the Laurel Highlands, we develop a picture of the potential revenue that could be obtained if these services were monetized. At a minimum, we gain a more complete accounting of the values provided by the land in the region.

Methods

Economists have developed widely used methods to estimate the monetary value of ecosystem services and/or natural capital. The most commonly known example is from a study by Costanza et al. (1997) that valued the natural capital of the entire world. That paper and many others employ the Benefit Transfer Method (BTM) to establish a value for the ecosystem services produced in a certain region. According to the Organization for Economic Cooperation and Development, BTM is "the bedrock of practical policy analysis," particularly when collecting new primary data is not feasible (OECD, 2006).

BTM takes a rate of ecosystem benefit delivery calculated for one or more "source areas" and applies that rate to conditions in the "study area." Typically, the rates are drawn from previous studies that estimate the value of various ecosystem services from similar land cover/biome types. Benefits (in dollars per unit area) from the source areas are transferred and applied to the study-area land with the same land cover. For example, data from the source area may include the value of recreation in forestland. In that case, the per-acre value of recreation from the source area can be applied to the number of acres of forestland in the study area. Multiplying that value by the number of acres of forestland in the study area produces an estimate of the recreational value of the study area's forests. Furthermore, it is important to use source studies that are from regions with similar underlying economic, social, and other conditions to the study area. This ensures that the estimated values are accurate given the study area's specific demographics.

Estimation of ecosystem service value requires two general steps:

1. Identify the total hectares of each land cover type within the Laurel Highlands, particularly the HUC10 watersheds within the broader basins: Youghiogheny and Kiski-Conemaugh.
    a. This was performed in ArcGIS by overlaying land cover data from the National Land Cover Database and spatial watershed boundaries (HUC 10) in the study region (USGS, 2018).
2. Multiply total hectares in each land cover classification by the ecosystem service value per acre per year for each individual ecosystem service, where applicable, to arrive at a final value of ecosystem service value in dollars per year for each land cover classification in each watershed.
    a. Some land cover, such as shrub/scrub or deciduous forests, only have one ecosystem service with quantified value(s) that were appropriate for benefit-transfer valuation. Others, particularly wetlands, have a handful of measured ecosystem service values, ranging from air quality to recreation. For land cover types with multiple studies (service values) for a specific ecosystem service, we use the average ecosystem service value.

b. The variety in ecosystem services measures and number of studies for each land cover is a result of both the existence of any primary studies in each type of land and service and by the suitability of those values in application to the Laurel Highlands.

The result is a three-dimensional dataset with dollar-value estimates of ecosystem services in each hectare of the study region based on land-cover type. This provides a preliminary baseline assessment of the region's ecosystem service value which is the foundation for creating land-use change scenarios and measuring the impact of potential management actions or policies.

HUC12 Watershed Baseline Estimates

Baseline ecosystem service values differentiate based on the size of the watershed and sub watershed and the distribution of land cover within each watershed and sub watershed. The "Watershed" column corresponds to the 21 HUC10-level watersheds and the "Sub watershed" column corresponds to the 89 HUC12-level watersheds.

Table A-1. Baseline Ecosystem Service Values in the Study Region by Watershed and Subwatershed

Kiski-Conemaugh Basin (HUC 06)		
Watershed (HUC10)	**Sub Watershed (HUC12)**	**Baseline Estimate (2017 $/year)**
Blacklick Creek		
	Brush Creek	$23,783,269
	Mardis Run	$38,974,374
	Muddy Run	$68,006,255
	South Branch Blacklick Creek	$19,903,623
Blacklick Creek Total		$150,667,520
Conemaugh River		
	Aultmans Run	$33,742,185
	Baldwin Creek-Conemaugh River	$48,486,877
	Hendricks Creek	$23,433,015
	Hinckston Run-Conemaugh River	$45,933,989
	McGee Run	$36,083,466
	Richards Run-Conemaugh River	$35,355,694
	Stony Run-Conemaugh River	$69,550,375
	Tubmill Creek	$17,823,601
Conemaugh River Total		$310,409,201

Table A-1, Continued.

Watershed (HUC10)	Sub Watershed (HUC12)	Baseline Estimate (2017 $/year)
Little Conemaugh River		
	Bens Creek-Little Conemaugh River	$58,697,799
	Clapboard Run-Little Conemaugh River	$61,120,038
	North Branch Little Conemaugh River	$37,749,350
Little Conemaugh River Total		**$157,567,187**
Loyalhanna Creek		
	Crabtree Creek	$23,521,320
	Fourmile Run	$34,948,679
	Headwaters Loyalhanna Creek	$35,053,046
	Lower Loyalhanna Creek	$45,861,191
	Middle Loyalhanna Creek	$53,393,204
	Mill Creek	$24,825,559
	Ninemile Run	$19,123,386
	Upper Loyalhanna Creek	$41,169,747
Loyalhanna Creek Total		**$277,896,133**
North Branch Blacklick Creek		
	Elk Creek	$29,049,127
	North Branch Blacklick Creek	$47,429,341
North Branch Blacklick Creek Total		**$76,478,468**
Quemahoning Creek		
	Beaverdam Creek-Quemahoning Creek	$42,325,504
	North Branch Quemahoning Creek	$32,436,685
	Roaring Run-Quemahoning Creek	$50,408,970
Quemahoning Creek Total		**$125,171,158**
Shade Creek		
	Clear Shade Creek	$27,054,868
	Dark Shade Creek	$78,960,680
	Shade Creek	$45,897,863
Shade Creek Total		**$151,913,411**
South Fork Little Conemaugh		

Table A-1, Continued.

Watershed (HUC10)	Sub Watershed (HUC12)	Baseline Estimate (2017 $/year)
	Beaverdam Run-South Fork Little Conemaugh	$42,844,625
	South Fork Little Conemaugh River	$57,986,275
South Fork Little Conemaugh Total		**$100,830,899**
Stonycreek River		
	Beaverdam Creek	$18,608,852
	Headwaters Stonycreek River	$91,383,234
	Lake Stonycreek-Rhoads Creek	$69,491,274
	Lower Stonycreek River	$53,314,632
	Middle Stonycreek River	$50,908,171
	North Fork Bens Creek	$22,048,977
	Paint Creek	$95,432,786
	South Fork Bens Creek	$15,656,876
	Upper Stonycreek River	$47,363,720
	Wells Creek	$29,447,322
Stonycreek River Total		**$493,655,844**
Two Lick Creek		
	Stoney Run	$77,418,513
	North Branch Two Lick Creek	$38,808,037
	South Branch Two Lick Creek	$19,903,623
	Cherry Run	$29,594,583
Two Lick Creek Total		**$165,724,756**
Yellow Creek		
	Little Yellow Creek	$19,021,738
	Yellow Creek Lake	$71,079,381
Yellow Creek Total		**$90,101,119**

Table A-1, Continued.

Youghiogheny Basin (HUC 06)		
Watershed (HUC10)	**Sub Watershed (HUC12)**	**Estimate (2017 $/year)**
Coxes Creek		
	Somerset Lake-East Branch Coxes Creek	$48,707,780
	West Branch Coxes Creek-Coxes Creek	$47,945,464
Coxes Creek Total		**$96,653,243**
Indian Creek		
	Champion Creek-Indian Creek	$62,380,488
	Headwaters Indian Creek	$27,133,393
	Mill Run Reservoir-Indian Creek	$30,763,878
Indian Creek Total		**$120,277,760**
Jacobs Creek		
	Headwaters Jacobs Creek	$59,841,071
	Jacobs Creek	$39,781,557
Jacobs Creek Total		**$99,622,628**
Laurel Hill Creek		
	Fall Creek-Laurel Hill Creek	$47,483,101
	Laurel Hill Lake Dam-Laurel Hill Creek	$48,320,695
	Sandy Run-Laurel Hill Creek	$33,661,488
Laurel Hill Creek Total		**$129,465,284**
Lower Casselman River		
	Blue Lick Creek-Casselman River	$114,697,472
	Buffalo Creek	$71,358,243
	Elklick Creek	$25,625,726
	Flaugherty Creek	$23,162,914
	High Point Lake-Casselman River	$35,720,504
	Middle Creek	$21,759,847
	South Glade Creek-Casselman River	$37,338,470
	Town Line Run	$14,824,211
	Whites Creek	$31,176,176
Lower Casselman River Total		**$375,663,563**

Table A-1, Continued.

Watershed (HUC10)	Sub Watershed (HUC12)	Estimate (2017 $/year)
Lower Youghiogheny River		
	Cedar Creek-Youghiogheny River	$25,996,982
	Long Run	$9,691,473
	Pollack Run-Youghiogheny River	$38,802,418
Lower Youghiogheny River Total		**$74,490,874**
Middle Youghiogheny River		
	Dickerson Run-Youghiogheny River	$49,647,522
	Drake Run-Youghiogheny River	$39,070,715
	Dunbar Creek	$31,438,614
	Meadow Run	$35,423,994
	Mounts Creek	$41,371,093
	Opossum Run-Youghiogheny River	$49,400,378
Middle Youghiogheny River Total		**$246,352,317**
Sewickley Creek		
	Jacks Run	$21,693,158
	Little Sewickley Creek	$28,481,939
	Lower Sewickley Creek	$65,617,604
	Upper Sewickley Creek	$43,371,230
Sewickley Creek Total		**$159,163,932**
Upper Casselman River*		
	Flag Run-Casselman River	$29,250,219
	Little Piney Creek-Piney Creek	$7,572,939
	Miller Run-Casselman River	$26,266,567
	Red Run-Piney Creek	$25,060,343
	Tub Mill Run-Casselman River	$30,679,344
Upper Casselman River Total		**$118,829,413**
Upper Youghiogheny River*		
	Buffalo Run	$21,330,754
	Mill Run	$17,157,745
	Youghiogheny River Lake-Youghiogheny River	$57,572,995
Upper Youghiogheny River Total		**$96,061,493**
Total		**$3,654,681,132**

Appendix B: National Land Cover Database Land Cover and Ecosystem Service Descriptions

Table B-1 provides descriptions of each land cover type in the study region by National Land Cover Database classification (Homer et al., 2015).

Table B-1. National Land Cover Database (NLCD) Classifications and Descriptions

NLCD Classification	NLCD Description
Open Water	Areas of open water, generally with less than 25% cover of vegetation or soil.
Perennial Ice/Snow	Areas characterized by a perennial cover of ice and/or snow, generally greater than 25% of total cover
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% of total cover. These areas most commonly include single-family housing units.
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.
Barren Land	Areas of bedrock, desert pavement, scarps, talus, slides, volcanic material, glacial debris, sand dunes, strip mines, gravel pits and other accumulations of earthen material. Generally, vegetation accounts for less than 15% of total cover
Deciduous Forest	Areas dominated by trees generally greater than 5 meters tall, and greater than 20% of total vegetation cover. More than 75% of the tree species shed foliage simultaneously in response to seasonal change.
Evergreen Forest	Areas dominated by trees generally greater than 5 meters tall, and greater than 20% of total vegetation cover. More than 75% of the tree species maintain their leaves all year. Canopy is never without green foliage
Mixed Forest	Areas dominated by trees generally greater than 5 meters tall, and greater than 20% of total vegetation cover. Neither deciduous nor evergreen species are greater than 75% of total tree cover.
Dwarf Scrub	Alaska only areas dominated by shrubs less than 20 centimeters tall with shrub canopy typically greater than 20% of total vegetation. This type is often co-associated with grasses, sedges, herbs, and non-vascular vegetation.

Table B-1, Continued.

NLCD Classification	NLCD Description
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 but can be utilized for grazing.
Sedge/Herbaceous	Alaska only areas dominated by sedges and forbs, generally greater than 80% of total vegetation. This type can occur with significant other grasses or other grass like plants, and includes sedge tundra, and sedge tussock tundra.
Lichens	Alaska only areas dominated by fruticose or foliose lichens generally greater than 80% of total vegetation.
Moss	Alaska only areas dominated by mosses, generally greater than 80% of total vegetation.
Pasture/Hay	Areas of grasses, legumes, or grass-legume mixtures planted for livestock grazing or the production of seed or hay crops, typically on a perennial cycle. Pasture/hay vegetation accounts for greater than 20% of total vegetation.
Cultivated Crops	Areas used for the production of annual crops, such as corn, soybeans, vegetables, tobacco, and cotton, and also perennial woody crops such as orchards and vineyards. Crop vegetation accounts for greater than 20% of total vegetation. This class also includes all land being actively tilled.
Woody Wetlands	Areas where forest or shrubland vegetation accounts for greater than 20% of vegetative cover and the soil or substrate is periodically saturated with or covered with water.
Emergent Herbaceous Wetlands	Areas where perennial herbaceous vegetation accounts for greater than 80% of vegetative cover and the soil or substrate is periodically saturated with or covered with water.
Source: Homer et al., 2015	

Table B-2 provides definitions of the key ecosystem services quantified in the baseline ecosystem service assessment.

Table B-2. Ecosystem Services and Description

Ecosystem Service	Description
Aesthetics	Formation of landscapes that are attractive to people
Air Quality	Removal of contaminants from the air flowing through an ecosystem, including through filtration or decomposition
Biodiversity	The process of increasing genetic diversity across and within species

Table B-2, Continued.

Ecosystem Service	Description
Climate Regulation	Modulation of regional/local climate
Cultural, Other	Non-material benefits people obtain from ecosystems through spiritual enrichment, cognitive development, reflection, and more, excluding recreation and aesthetics
Erosion Control	Control of the processes leading to erosion, for example, by controlling the effects of water flow, wind, or gravity
Food/Nutrition	Ecosystems provide the conditions for growing food, principally from managed agro-ecosystems but marine and freshwater systems or forests may provide food for human consumption
Medicine	Ecosystems and biodiversity provide many plants used as traditional medicines as well as providing the raw materials for the pharmaceutical industry
Pollination	Contribution of insects, birds, bats, and other organisms to pollen transport resulting in the production of fruits and seeds. May also include seed and fruit dispersal
Protection from Extreme Events	Extreme weather events or natural hazards include floods, storms, tsunamis, avalanches, and landslides. Ecosystems and living organisms create buffers against natural disasters, thereby preventing possible damage
Raw Materials	Materials for construction and fuel including wood, biofuels, and plant oils that are directly derived from wild and cultivated plant species
Recreation	Leisure and activity derived from ecosystems
Renewable Energy	Resource utilization to produce renewable energy, specifically hydropower from open water
Soil Formation	Process by which soil is created, including changes in soil depth, structure, and fertility
Waste Assimilation	Improving soil and water quality through the breakdown and/or immobilization of pollution.
Water Supply	Filtering, retention, storage, and delivery of fresh water—both quality and quantity—for drinking, watering livestock, irrigation, industrial processes, hydroelectric generation, and other uses.
Descriptions follow Balmford (2010, 2013), Costanza et al. (1997), Reid et al. (2005), and Van der Ploeg, et al. (2010).	

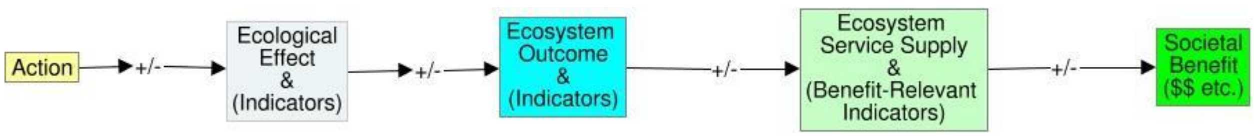
Appendix C: Ecosystem Service Concept Models

Ecosystem Service Conceptual Models: Why should we use them?

As funders, developers, and other decision-makers involved in the management of natural resources become more interested in the value of benefits we receive from nature, a model for assessing how decisions or policies impact these benefits becomes increasingly important. The use of ecosystem service conceptual models can help simplify complex relationships between humans and their environment while providing a common and credible framework for any place or any intervention.

This framework allows us to connect biophysical processes to economic outcomes in the study region, which helps create a more complete picture of environmental interventions that will result in the greatest change in benefits to communities and the general public over space and time.

Framework



Actions: These are interventions, policy scenarios, etc., and can be both positive and negative in their cascade of effects on the ecosystem. For example, we could choose a restorative or preventative intervention (i.e. widening riparian buffers) that leads to improvements throughout the ecosystem or an ecologically disruptive intervention (i.e. construction of a natural gas well) that negatively impacts measures of ecosystem health.

Ecological effect (& Indicators): These boxes represent the direct impacts to the ecosystem we might expect from the intervention. If the intervention is a new natural gas well, direct impacts could include water withdrawal from a nearby river, discharge of wastewater into waterways, and sediment runoff from the removal of natural forest cover.

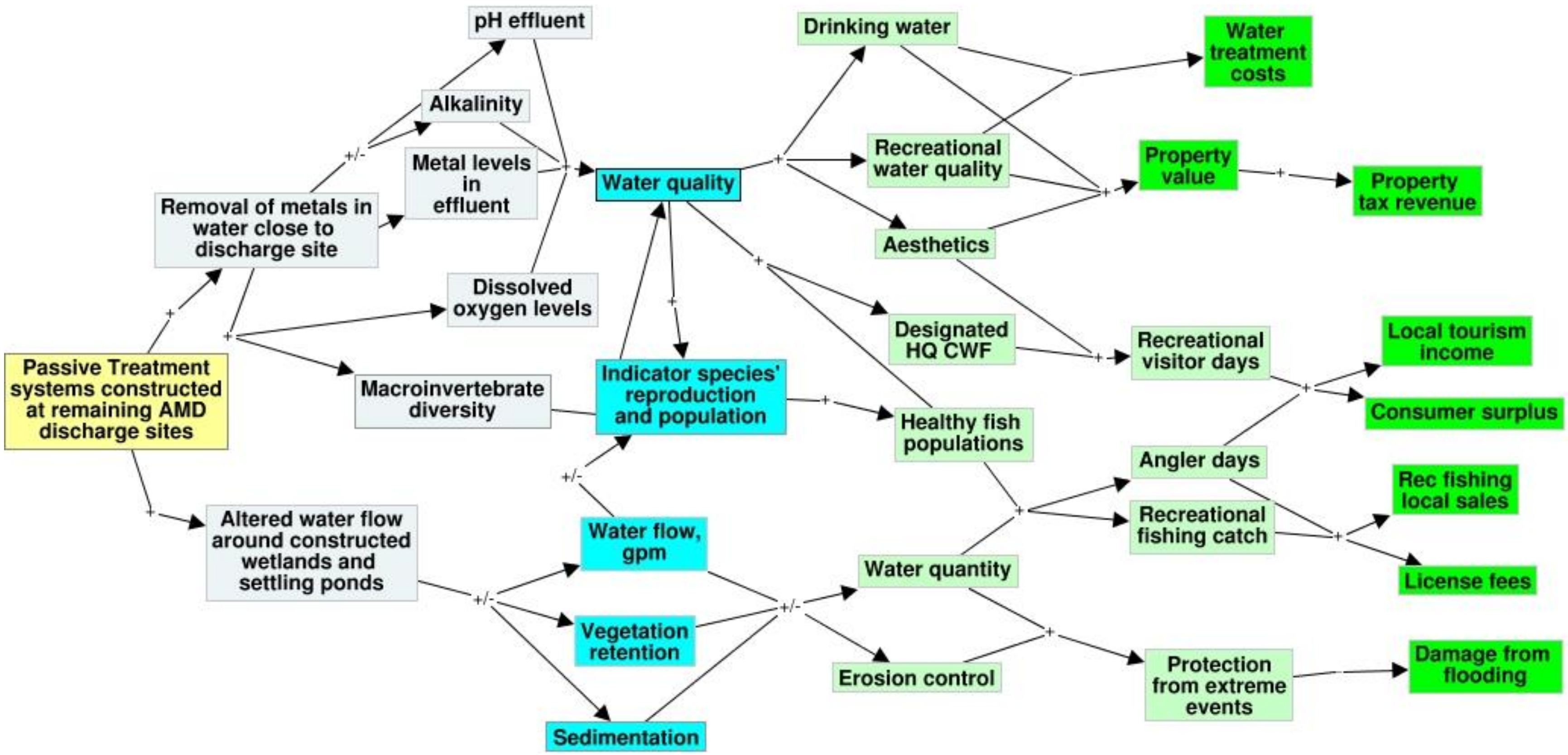
Ecosystem Outcome (& Indicators): These boxes contain outcomes and indicators of the ecological effects from the intervention and are often impacts that we can measure, such as stream temperature changes, fish population changes, and increased levels of turbidity in streams.

Ecosystem Service Supply (& Benefit-Relevant Indicators): The light green boxes are services provided by nature that we receive value from, such as drinking water, industrial water use, clean air, recreational fishing days, raw materials, etc. The quality of these services is impacted by the ecosystem outcomes and indicators in the blue boxes and can be measured as monetary changes in the societal benefit we receive.

Societal Benefit ($$): The endpoints of the diagram, in bright green boxes, allow us to estimate the change in benefit, in dollar terms, we receive from the proposed intervention or action. From our example of a new natural gas well, which may have impacts on the quality and quantity of drinking water, clean air, and downstream recreational fishing catch, we can estimate changes in health care costs, water treatment costs, and the change in recreational fishing quality (measured in willingness-to-pay for a unit of fish, or day of fishing).

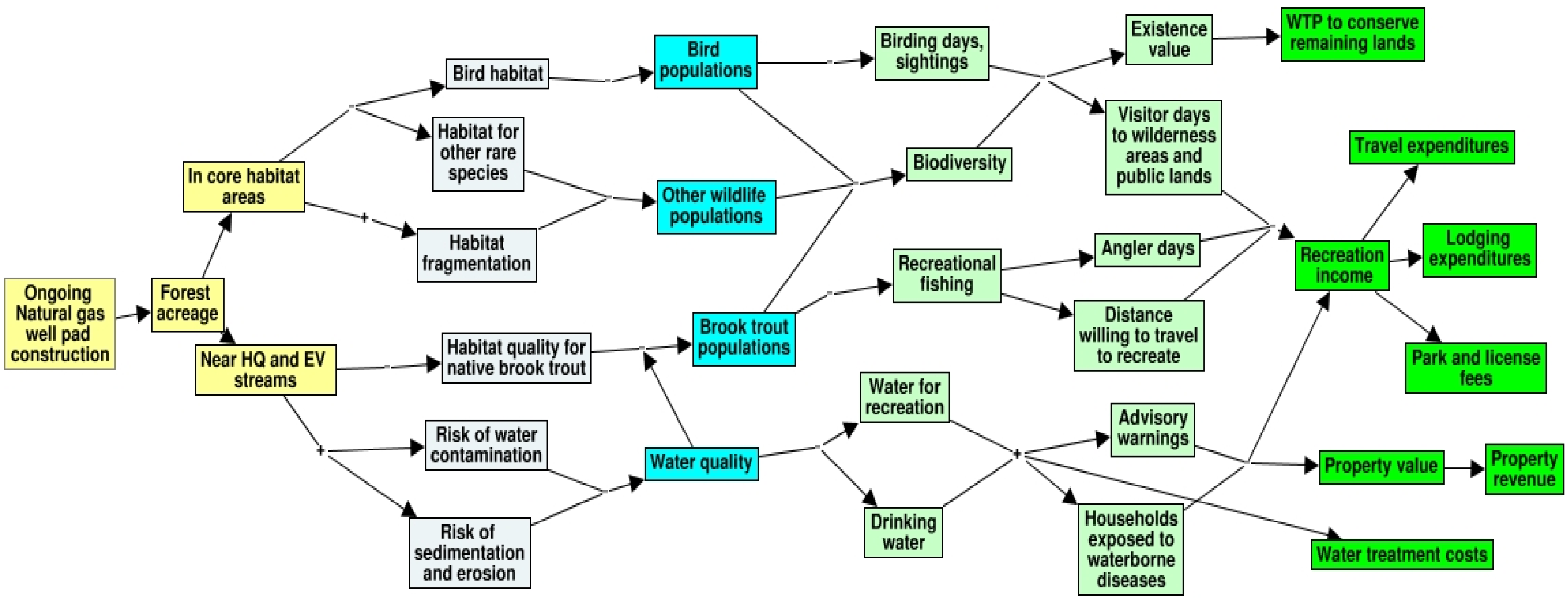
ES Concept Model 1: AMD Passive Treatment

Moving left to right, funding for AMD treatment, maintenance and operation improves biophysical outcomes including water quality, leading to societal benefits we can measure in dollar terms in the form of enhanced property values, consumer surplus, and economic activity from recreation.



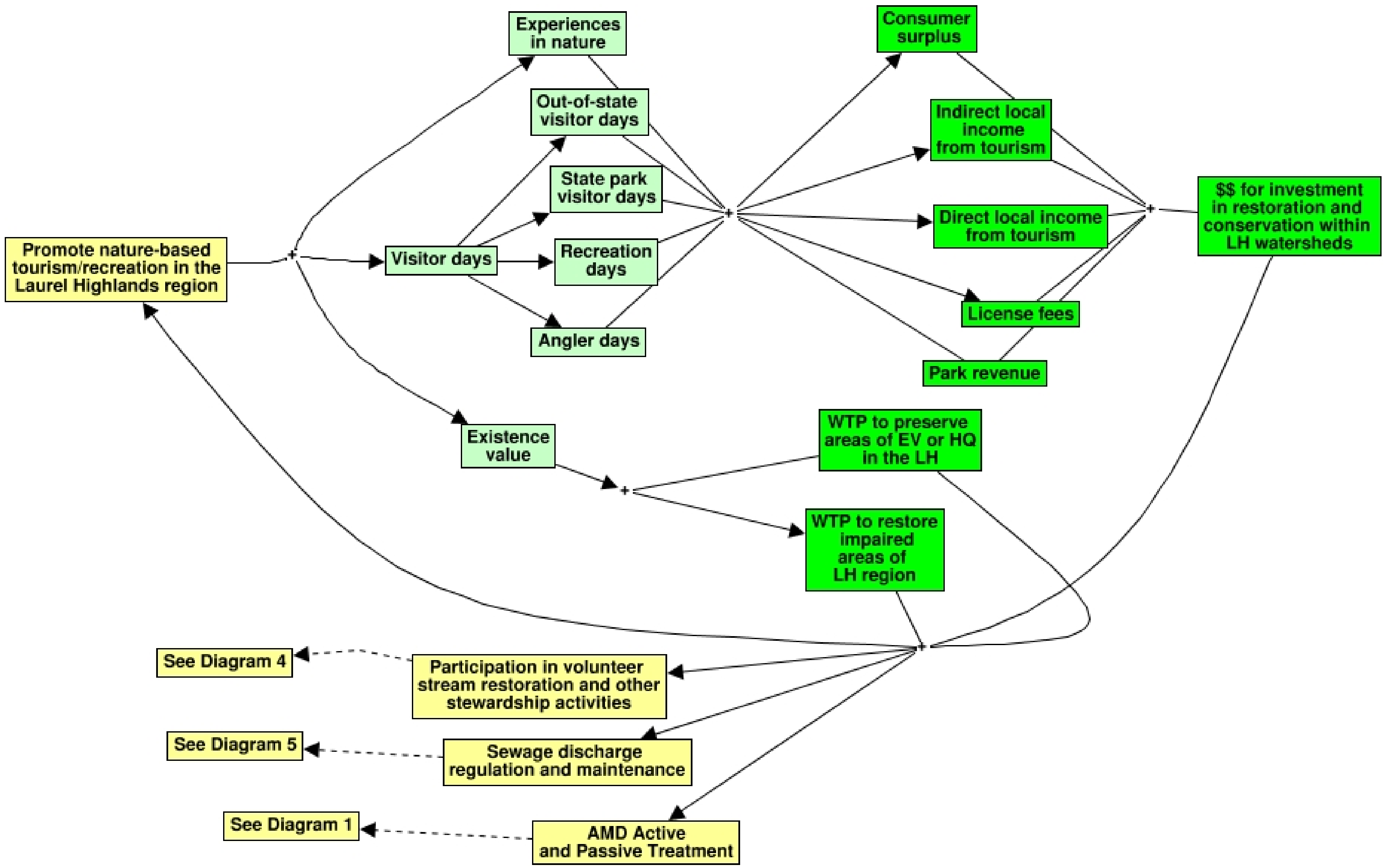
ES Concept Model 2: Natural Gas Development

Moving left to right, the loss of forest interior from additional natural gas well pads results in lost ecosystem services and lost societal benefits measured in terms of value for habitat and biodiversity, value of carbon storage in forests, and value of recreation.



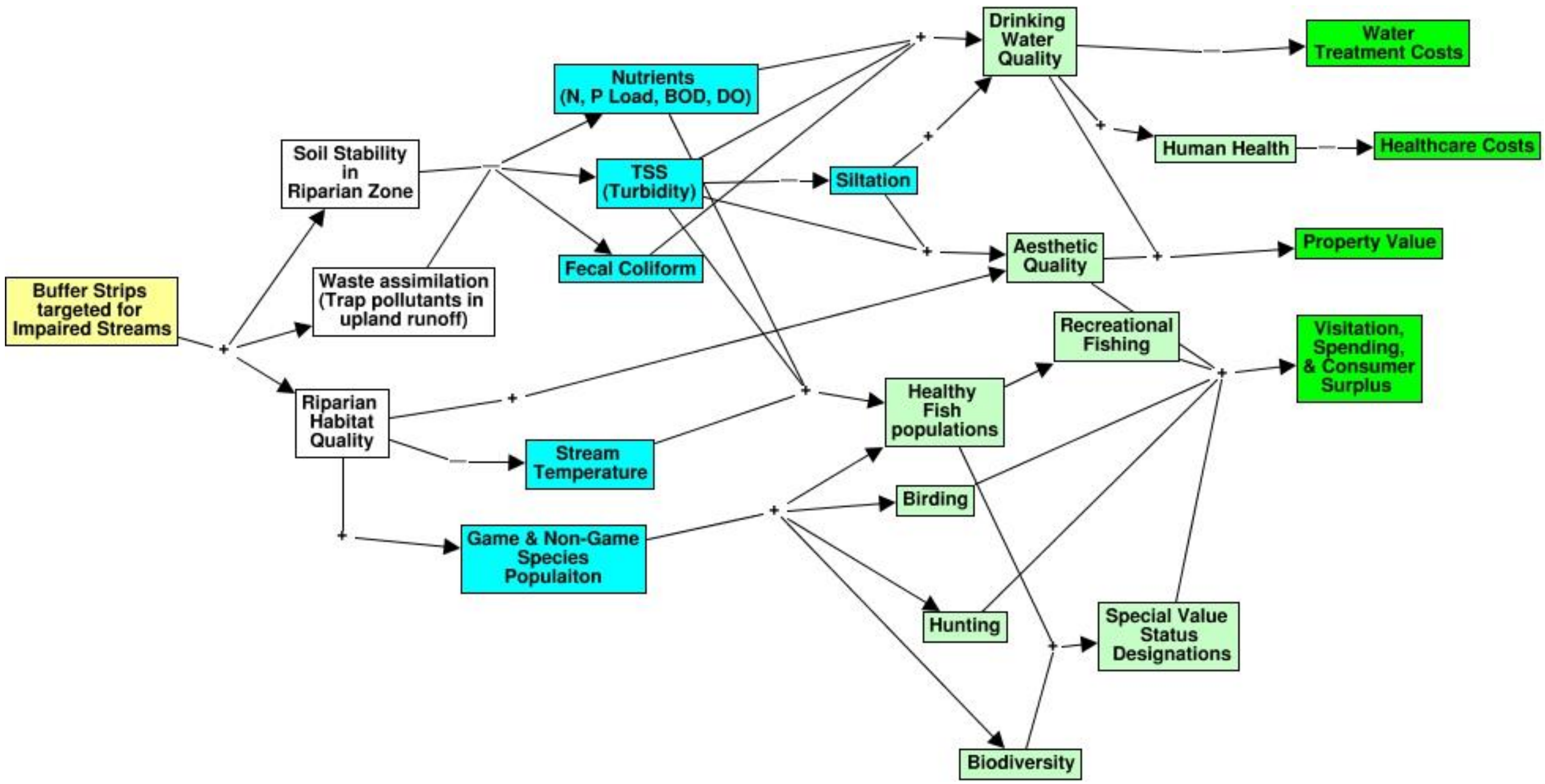
ES Concept Model 3: Economic Benefits from Water-Based Recreation

From left to right, promoting water-based recreation through improvements to water quality can lead to increased value for recreation in the region, both in terms of volume of activity and how much people are willing to pay (or value) the experience.



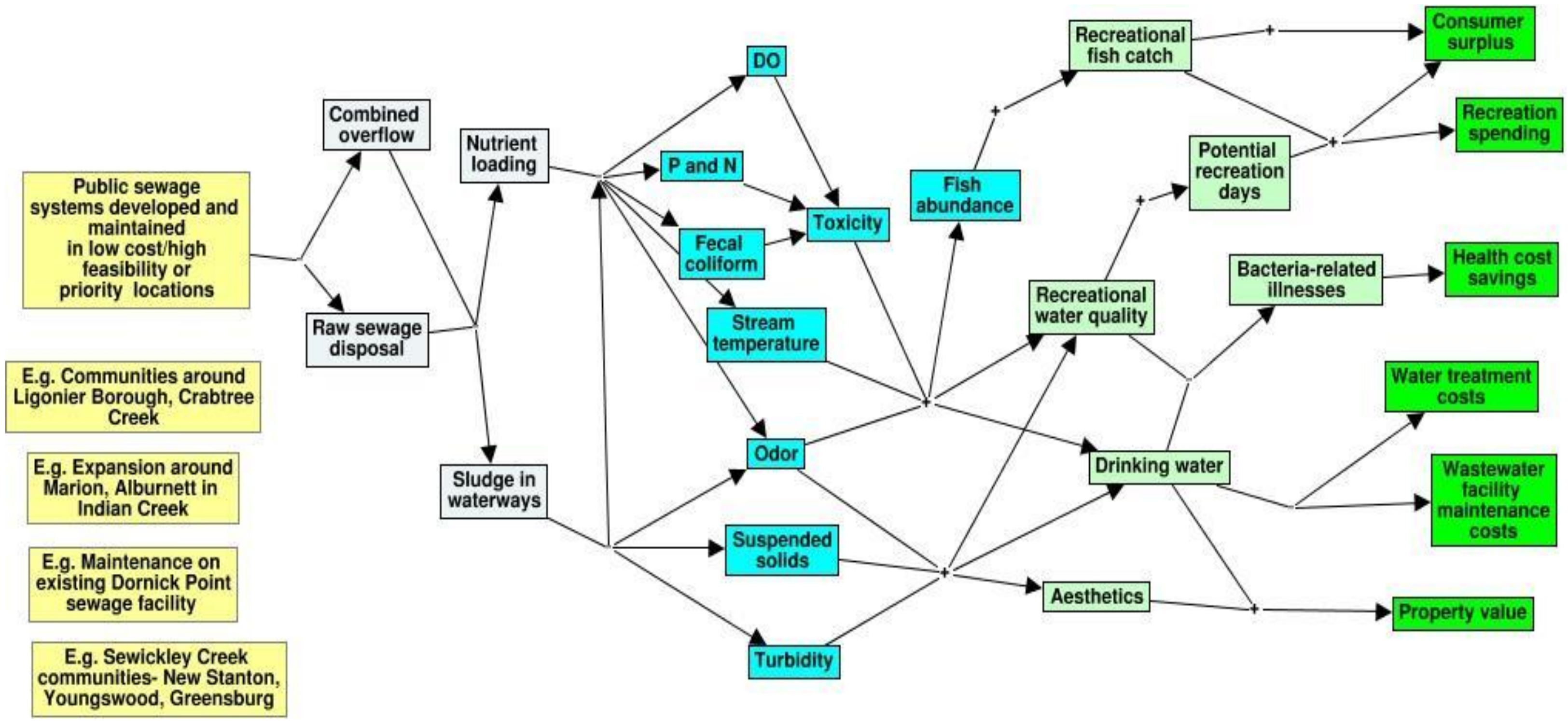
ES Concept Model 4: Increasing Natural Riparian Buffers

Increasing natural buffer around impaired streams can improve aquatic habitat and water quality, improving societal benefit through enhanced value of ecosystem services including water quality, recreation, nutrient retention, and aesthetics.



ES Concept Model 5: Sewage and Stormwater Management

Increasing public sewage systems, or quality of those systems, can lead to improved biophysical outcomes in terms of reduced nutrient loading, turbidity, and toxicity. Improvement of associated ecosystem services can lead to societal benefits including higher property values, health cost savings, or water treatment cost savings.



Appendix D: Methods

Abandoned Mine Drainage and Economic Benefits from Remediation

Ecosystem concept model 1 in Appendix C shows the pathways used to guide literature, data review, and analysis of potential ecosystem service values gained through passive treatment of AMD-impaired streams in the region. We can model how the delivery of key ecosystem services of aesthetics, recreation, and habitat for species will improve through several non-market valuation methods used in existing studies, including hedonic pricing and contingent valuation. We estimate potential returns to property values, return on recreational values of remediated streams, and consumer surplus gained from improved water quality in streams within the regional watersheds.

Property Value Estimation

Calculations for potential gains in property value in the study region rely on existing hedonic pricing studies performed in similar watersheds, namely the Cheat Watershed in West Virginia and the West Branch of the Susquehanna River in Pennsylvania (Thurston et al., 2009; Hansen, 2008). We assume our 21-watershed region would experience property value impacts within reasonable range of the studies performed in WV and PA, though we draw no conclusion about how similar the total impact may be to one study versus the other. We draw relevant primary data from the region, including median housing values, where possible.

The two hedonic pricing studies specifically estimate property value gains for properties adjacent to AMD-impaired streams and provide differing estimates on both the level of impact and the distance ranges of impact. Hansen et al. (2008) conducted a study of parcel data in Clearfield County, PA and found that residential properties within 200 feet of AMD-impaired streams experienced a 5% loss in property value. Thurston et al. (2009) performed a similar analysis in the Cheat River Watershed in West Virginia and found that properties within a quarter mile of AMD-impaired streams experienced a 12.8% value discount. We use the two estimates as a range for potential property value gains from AMD remediation in the study region.

We used Pennsylvania's Chapter 93 data on stream impairment to estimate 876 miles are damaged by AMD, and block group data to estimate household counts near impaired streams (U.S. Census Bureau, 2017; PA DEP, 2018a). We created buffers of both 200 feet and a quarter mile, as defined by the two studies, around the 876 miles of AMD-impaired streams and intersected those buffers with spatial block group data for the study region to obtain a count of households within the respective ranges.

The number of households within the range of influence varies widely between 200 feet and a quarter mile; 6,629 households with a median value of $103,275 are estimated to be within 200 feet of an AMD-impaired stream, while almost 54,000 households with a median value of $100,398 fall within a quarter mile. Potential property enhancement is estimated by the following equation:

Total Property Value within Zone of Influence/Current Property Value Loss

Where:

Total Property Value within Zone of Influence = Number of Households (6,629 within 200 feet and 54,000 within a quarter mile) x Average Property Value ($103,275 within 200 feet and $100,398 within a quarter mile)

- Property Value Discount (5% within 200 feet and 12.8% within a quarter mile)

Because of the significant range in household count in the different zones of influence, the total property value that could benefit from remediation ranges from $684.6 million in property value gains for households within 200 feet compared to $5.42 billion in property value gains for households within a quarter mile.

Examining the extent of potential benefit from remediation:

- Property value benefit (Low)
    - $684,609,975 (total property value within 200 feet)/0.95 (applying a 5% potential gain in property value) = $720,642,079 in potential property value
    - $720,642,079 - $684,609,975 (potential value – current value) = **$36,032,104**
- Property value benefit (High)
    - $5,421,090,408 (total property value within a quarter mile)/0.875 (applying a 12.5% potential gain in property value) = $6,216,846,798 in potential property value
    - $6,216,846,798 - $5,421,090,408 (potential value – current value) = **$795,756,390**

These estimates suggest that the potential property value gained remediation ranges from $36,032,104 to $795,756,390, based on evidence from two hedonic pricing studies in the West Susquehanna Basin of Pennsylvania and the Cheat River Watershed in West Virginia. This would average $41,133 to $908,398 in property value gains per mile of remediation.

We estimated potential benefits to property tax revenue streams for the five counties in the region. Remediation of AMD-impaired streams could contribute between $489,316 and $10,806,372 in additional property tax revenue associated with property value gains. This calculation uses the 2018 average property tax rates in Fayette, Westmoreland, Indiana, Cambria, and Somerset Counties, for an average rate of 1.34%. The additional revenue translates to $559-$12,336 in annual benefit to counties per average stream mile restored.

Recreational Fishing Benefits from Restored AMD-Impaired Streams

The economic benefit study from AMD remediation performed in the West Susquehanna Basin in Pennsylvania provides a roadmap for estimating potential benefits to recreation from AMD-remediation in Pennsylvania streams (Hansen et al., 2008). The American Fisheries Society provides average values per recreational fishing trip, characterized by the type of fishing (warm water fisheries, trout stocked fisheries, and wilderness trout fisheries) (Hansen et al., 2008).

Based on average use and harvest rates from Pennsylvania Fish and Boat Commission, Hansen et al. calculated annual economic benefits from recreational fishing per stream mile for water fisheries (WWF), trout stocked fisheries (TSF), and wilderness trout fisheries (WT). Values per stream mile are provided in Table D-1.

Table D-1. Average Recreational Benefits by Fishery Type

Type of Fishery	Annual Recreational Value per Stream Mile (2017$)
Warm Water Fisheries (WWF)	$18,800
Trout Stocked Fisheries (TSF)	$89,960
Wilderness Trout (WT)	$34,623

No values are calculated for cold water fisheries (CWF), although stream miles obtaining their designated use as CWF have positive recreational economic benefits. TSF have significantly higher values per stream mile than WT; this is likely a result of much higher use rates on trout-stocked streams and may reflect the higher accessibility of trout-stocked streams to anglers, or show how many anglers value their experience. For example, many anglers may not care whether the trout they catch was wild or stocked and are more likely to recreate in streams where they know they are more likely to catch fish. However, other recreational anglers who choose their experience based on the challenge of catching a wild trout or simply fishing in an aquatic environment that is still 'wild', may place a much higher value on a mile of WT stream than TSF stream. These anglers may not be as willing to consider fishing in a trout-stocked stream as a close substitute for their experience in a WT stream. We note this particularly because the dollar values per stream mile should not be interpreted as, or conflated with, the value of the aquatic habitat.

In order to estimate potential recreational fishing benefits from AMD remediation in the region, we first assess the overlap between AMD-impaired streams and Chapter 93 designated use streams. Of the 876 stream miles impaired by AMD in the region, 126 miles are designated TSF, 286 miles are designated WWF, and 1 mile is designated WT (PA DEP, 2018d; 2019). Using these values, potential recreational fishing benefits to gain from remediation of AMD-impaired streams are calculated as follows:

- Total Recreational Fishing Benefits: **$16,758,864/year**
  - Warm Water Fishery (WWF) Benefits: 286 miles of potential WWF streams x $18,800/stream mile/year = $5,376,870/year
  - Trout Stocked Fishery (TSF) Benefits: 126 miles of potential TSF streams x $89,960/stream mile/year = $11,334,907/year
  - Wilderness Trout Fishery Benefits: 1.36 miles of potential WT streams x $34,623/stream mile/year = $47,087/year

The average annual recreational benefit received per stream mile restored in the study region is estimated at $19,131. This is a conservative estimate given that it does not consider the positive economic benefits associated with recreational angling in cold water fishery streams and other water-based recreation that would likely occur in AMD-restored streams.

Regional Consumer Surplus from AMD Remediation

Consumer surplus is the economic benefit people receive from an action that they would have been willing to pay to receive a particular outcome (or avoid a particular outcome). Willingness-to-pay values are a key component of estimating consumer surplus because they indicate how much people value an outcome or service. When a desirable outcome is achieved (or an undesirable outcome is avoided) without the public having to pay for it, the amount the outcome is valued is considered consumer surplus.

Many willingness-to-pay (WTP) studies have been conducted in the region, some particular to water quality improvements in general (see recreational benefits section) and some particular to restoration of AMD-impaired streams. Willingness-to-pay measures are often framed in the context of a hypothetical policy, such as a tax or fee, in order to gauge how much people value a resource or action (i.e. a one-time tax to restore AMD-impaired streams).

A WTP survey to households within and outside of the West Susquehanna Basin asked respondents (households) for their maximum, one-time tax increase they would be willing to pay to clean up AMD in the watershed (Hansen et al., 2008). Based on the rate of response and the range in values, they identify an average WTP for households responding to the survey and an average WTP for households that did not respond to the survey, within and outside of the basin. We solely estimate WTP estimates within the study region, although we believe there is a positive WTP for AMD remediation outside the Loyalhanna-Conemaugh and Youghiogheny watersheds as well.

Within the West Susquehanna Basin, the average survey respondents' one-time WTP for a tax increase to remediate AMD is $30.40 to $34.06 and the average non-respondents' one-time WTP is estimated to be $9.73 to $30.40 (Hansen et al., 2008). In order to calculate estimated WTP for households within the Laurel Highlands study region, we use the respondent and non-respondent rates from the survey and apply estimates from respondents within the West Susquehanna to households in the Laurel Highlands near AMD-impaired streams. We believe this is a reasonable and conservative application considering survey responses indicated a lack of awareness on the environmental issue of AMD in the region and found a higher average willingness-to-pay by households in Pennsylvania outside of the watersheds receiving treatment.

Applying the same respondent rate (and subsequent WTP values) to the number of households in the study region, we get a proxy for the assumed variation in WTP values in the region:

- Households Willing to Pay for Remediation
    - 257,080 households in the region x 0.16 (estimated respondent rate for households willing to pay for remediation) = 41,133 households
    - 257,080 households in the region x 0.84 (estimated non-respondent rate for households in the region) = 215,947 households

Under these assumptions, the consumer surplus households within the Conemaugh and Youghiogheny watersheds of the Laurel Highland would gain from AMD remediations is:

- Consumer Surplus (low estimate):
  41,133 households (proxy for respondent households in the region) x $30.40 (one-time WTP for AMD remediation) = $1,250,334

  \+

  215,947 households (proxy for non-respondent households in the region) x $9.73 (one-time WTP for AMD remediation) = $2,100,562 = **$3,350,896**

- Consumer Surplus (high estimate):
  41,133 households (proxy for respondent households in the region) x $34.04 (one-time WTP for AMD remediation) = $1,400,374

  +

  215,947 households (proxy for non-respondent households in the region) x $30.40 (one-time WTP for AMD remediation) = $6,564,255 = **$7,964,629**

This consumer surplus represents a one-time benefit that regional households would gain from AMD remediation within the study region. It is important to note that this benefit does not correspond one-to-one with any single ecosystem service value that would improve from AMD remediation and stream restoration; a household may be willing-to-pay a certain dollar amount because they know their nearby aesthetic landscape, reflected in their property values, would gain value, or they may have a positive WTP for knowing aquatic habitat for wild trout would improve and potable water would become easier to clean. Therefore, this dollar value likely encompasses value estimates for property value enhancement and recreational fishing benefit. Additionally, these WTP calculations only reflect potential consumer surplus *within* the region and does not capture the benefit of regional AMD remediation to outside visitors.

Future Natural Gas Well Pads & Associated Ecosystem Service Losses

The second ecosystem concept model in Appendix C shows pathways used to guide literature and data review and analysis of potential ecosystem service values lost from land-use and water-use changes associated with natural gas well pad construction and operation in the regional watersheds. We estimate losses from key ecosystem services like recreation, habitat and biodiversity, and water supply & quality based on land-use disturbance from the construction of new natural gas well pads and unconventional wells.

Estimates on Land-Use Change and Well Pad Construction

In order to perform these projections, we rely on land cover data from the National Land Cover Database and The Nature Conservancy's 2030 projections for natural gas well pad development (Johnson, 2010; Homer et al., 2015). The Nature Conservancy projections include spatial data for three scenarios—low, medium, and high—of future natural gas development[28] in the Marcellus Shale region based on models that incorporate active and projected drilling permits. This analysis focuses on the medium well pad development scenario to determine an estimate of potential ongoing and future ecosystem service losses in the study region from natural gas development.

Existing literature on natural gas well pads in the Marcellus Shale region shows that the average well pad and its associated infrastructure disturbs 8.8 acres and indirectly disturbs an additional 21 acres (Johnson, 2010). [29] In the medium development scenario, six wells are drilled per pad, and pads are

[28] The projections include potential unconventional natural gas development until 2030.
[29] Indirect disturbances can include disturbances to recreation, habitat and biodiversity, aesthetic values.

spaced approximately 4,000 feet apart (Johnson, 2010). In total, 1,466 well pads may be constructed by 2030 in the medium development scenario.

Using this information, we overlay the spatial distribution of projected well pads with land cover data to determine where land use change will occur due to well pad construction and operation. A 30-acre zone of influence was created around well pads projected to be in forested areas and an 8.8-acre zone of influence around well pads in all other land cover types. We assume well pads are classified as "barren" land cover and offer zero to minimal ecosystem service value.[30] Table D-2 shows the distribution of acres lost/disturbed by land cover type and Table D-3 gives the distribution of projected well pads across critical categories such as protected lands and designated waters and habitat. Using this information, we estimate the total acreage disturbed in critical categories as 13,048 acres, with other forested land lost (i.e. not in critical categories listed in Table D-3) estimated at 11,668 acres.

The estimated total forest disturbed is about 5,000 acres less than the calculated acres within a 30-meter buffer of the 982 well pads in forests, which accounts for acreage in the buffer-zone that may be developed, grassland, or another land cover.

Table D-2. Agricultural and Forest Land Cover Disturbed in Medium Development Scenario

Land Cover	Acres Lost
Forest	24,717
Critical Categories	13,048
Other	11,668
Agriculture	6,112

This analysis focuses on ecosystem service losses associated with well pads in forested acres and agricultural land, as they account for most of the land cover projected to be converted. In order to capture some heterogeneity in potential ecosystem service losses associated with biodiversity & habitat and recreation, we identify well pads that would be constructed in protected lands such as state parks and state forests, as well as well pads constructed near high-quality or exceptional-value designated streams and within brook trout habitat. We apply the higher values in the range of ecosystem service values[31] to well pads projected to be within state lands, within brook trout watersheds and/or within half a mile of high-quality or exceptional-value waters. Table D-3 provides the distribution of well pads and the land cover lost at these critical intersections.

[30] For example, barren lands have $0/acre/year of ecosystem service value for recreation and habitat.
[31] We use the high estimates in the range of ecosystem service values as protected and high-quality waters reasonably supply a higher than average ecosystem service value.

Table D-3. Profile of Well Pad Construction Disturbance Near and in Special Waters and Lands

Critical Categories*	Number of Well Pads
Fall within state parks	22
Fall within state forests	32
Fall within game lands	64
Disturbed forest buffer intersects state lands	21
Total on State Lands	**139**
Fall within state lands and within half-mile of HQ/EV designated streams	3
Fall within state lands, within half-mile of HQ/EV designated streams, and within brook trout watersheds	13
Fall within state lands and within brook trout watersheds	58
Within brook trout habitat	116
Within a half-mile of HQ/EV designated streams	238
Within a half-mile of HQ/EV designated streams and brook trout habitat	47
Total Near Important Waterways	**375**
*Well pad numbers do not overlap the listed categories. For example, 116 well pads are ONLY within brook trout habitat.	

Recreation Value Lost from Converted Forests

This model pathway assumes that acres converted for natural gas development under the medium development scenario are converted from forest land to barren land with no annual ecosystem service value. We also assume that forested acres located in state lands and state forests, or within brook trout watersheds, have a higher relative recreational value.

The values for recreation in land cover classified as mixed forest (See Appendix B) are applied from studies performed in the Appalachian region of the United States. The two-tiered loss estimates are calculated as follows:

- Annual recreation value loss (state & other protected lands):
  13,048 acres (total forested acres disturbed in critical categories) x $522/acre (average high recreational value of forests, 2017$) = **$6,811,056**
- Annual recreation value loss (other forested lands):
  11,668 acres (forested acres disturbed outside critical categories) x $2.88/acre (average low recreational value of forests, 2017$) = **$33,604**

Wildlife and Habitat Value Lost from Converted Forest Land

As with the recreation pathway we also make assumptions about wildlife and habitat value in acres converted in the medium development scenario. We assume forested acres located in state lands and state forests, or within brook trout watersheds, have a high relative habitat and biodiversity value because of their forest connectivity, protection status, and/or conditions already identified by state and regional agencies (i.e. Eastern Brook Trout Venture).

For the range of values that we select to apply benefit transfer method to forested acres in the region, we use the high values for forests lost in the critical categories listed and both the low and high values for the remaining forested acres to provide a range in habitat and biodiversity value lost from the conversion of forest land. The values for recreation in the land cover classification mixed forest are all applied from studies performed in the Appalachian region of the United States, with a focus on Pennsylvania. The low and high loss estimates are calculated as follows:

- Annual wildlife habitat and biodiversity value loss (state & other protected lands):
  13,048 acres (forested acres in state parks, forests, and game lands, or within brook trout watersheds) x $448/acre (average high wildlife value, 2017$) = **$5,845,504**
- Annual wildlife habitat and biodiversity value loss (other forested lands, low estimate):
  11,668 acres (other forested acres) x $77.4/acre (average low habitat and biodiversity value, 2017$) = **$903,103**
- Annual wildlife habitat and biodiversity value loss (other forested lands, high estimate):
  11,668 acres (other forested acres) x $448/acre (average high wildlife value, 2017$) = **$5,227,264**

Water Quality and Regulation Value Lost from Converted Forest Land

As with the recreation and habitat pathways, we assume the acres converted in the medium development scenario will become barren, rendering their ecosystem service value for water quality and regulation to $0/acre/year. Unlike habitat value and recreation value, we assume the value of water quality and regulation will be uniform across all forested acres, whether they are state lands or unprotected forest acres.

The total number of forested acres with ongoing water quality service values that could be lost by 2030 is 24,717 acres, which includes forested acres indirectly disturbed by natural gas infrastructure construction and development. The value per acre for watershed services applied in these calculations are also from the Appalachian region averaging $58.25 per acre per year (Boettner et al., 2014). Using these values, we arrive at the following calculation for the annual loss to water regulation and quality from converted forested acres:

- Potential annual water quality value loss from converted forests:
  - 24,717 acres (total forested acres affected by medium development scenario of well pad construction) x $58.25 (2017$/acre/year) = **$1,439,765**

Carbon Storage Value Lost in Forests

Previous studies have identified the amount of carbon stored above and below ground in forested lands. The value of this storage in dollar terms is the same as the cost to society that the release of the stored carbon would impose. Assuming that forested acres will be converted to barren land, the amount of carbon stored above (in trees and other plants), and beneath (in roots and soils) what is currently forested land will be released into the atmosphere and will contribute to global warming and other effects of climate change. For these calculations, we make the conservative assumption that the only (currently forested) area affected are those that would be used for additional natural gas well pads themselves, not for other infrastructure like access roads. Assuming 8.8 acres per well pad, and 982 well pads projected, we estimate that a total of 8,462 acres would be converted.

Barren land stores no carbon, developed land stores 16 metric tons of carbon per acre, and forests can store between 69 and 82 metric tons of carbon per acre depending on the forest type. Thus, the conversion of each acre of forest to barren and developed land results in a loss of between 61 and 74 metric tons, or an average of 67.5 metric tons (Rempel & Buckley, 2018).

Applying the differences in our scenario using the average metric ton loss per acre yields:

- 8,642 acres (forested acres converted to barren land) x 67.5 metric tons per acre (average net storage lost) = 583,335 metric tons

This 583,335 metric tons of carbon stored is multiplied by the social cost of carbon, which captures costs and damages associated with a metric ton of emission, including changes in flooding, human health, and wildfire (Rempel & Buckley, 2018). We apply the 2015 estimated social cost of carbon, valued at $31.81/metric ton (2017$), to the amount of carbon that would be released through natural gas development in the region to obtain an estimate of societal costs from the conversion of forestland in the region.

The calculations are as follows:

- Carbon storage loss per acre
  - 67.5 metric tons per acre x $31.81/metric ton = **$2,147/acre**
- Total carbon storage lost in the study region annually
  - 8,642 acres (forested acres converted to barren land) x $2,147/acre = **$18,554,374/year**

This calculation does not consider the rising social cost of carbon, which is projected to increase 3% annually through 2050 (Nordhaus, 2017). Carbon emitted today is valued at a lower rate than a carbon emitted in the future. In this case, the annual loss attributed to forgone carbon storage potential is conservative and annual costs will increase over time. Additionally, this annual loss does not include forgone carbon storage value from forests converted for accompanying natural gas infrastructure.

Agricultural Land: Productivity and Carbon Storage Loss

The value of raw materials from agricultural land, including crop and livestock production, will also decrease in the region if agricultural land is converted to natural gas infrastructure. In the study region, approximately 6,112 acres of cropland and pasture/hay land will be lost by 2030 under the medium development scenario (Table D-2). In the study region counties, the average value of crop, poultry, and livestock is $445/acre/year (USDA National Agricultural Statistics Service, 2017). Using these values, we estimate the annual loss from agricultural productivity in the region due to projected natural gas development:

- Potential lost agricultural productivity
    - 6,112 acres (agricultural land converted) x $445/acre/year = **$2,719,840** lost annually

The conversion of agricultural land to barren land also results in carbon storage loss. Agricultural land stores less carbon than forests, 28 metric tons of carbon per acre rather than 69 to 82 metric tons of carbon per acre (Rempel & Buckley, 2018). Applying the same methods as the forest calculations above, we estimate the following loss from carbon storage on agricultural land converted for well pads:

The calculations are as follows:

- Carbon storage loss per acre
    - 20 metric tons per acre (net carbon storage loss assuming a mix of barren and developed land) x $31.81/metric ton = **$636/acre**
- Total carbon storage loss from agricultural land conversion
    - 6,112 acres (agricultural acres converted to barren land) x $636/acre = **$3,887,232/year**

Water-Related Recreation and Value of Water Quality

Survey results suggest that residents in the region (both stream users and non-users) would be willing to pay between $57 and $82 per year (2018$) per household for a five-year period to have stream quality improved from moderately polluted to unpolluted. To improve water quality from a severely polluted to unpolluted condition, households would be willing to pay between $140 and $180 per year (2018$) for five years.

In order to determine how residents in the study region would value improvements in water quality specifically for recreation, we first multiply the number of households in the region by the percentage of streams in the region defined as AMD- or otherwise impaired by the Pennsylvania Department of Protection. Because fish and other aquatic life cannot survive in AMD-impaired streams, these segments are considered severely polluted (878 miles), and the rest of the impaired streams (797 miles of 1,675 total impaired miles) are considered moderately polluted (PA DEP, 2018d).[32] This results in an estimate of the number of households willing to pay for each level of water quality improvement.[33]

- Households in the study region willing to pay for improving severely polluted streams
    - 15% (878 miles of the 6,000 stream miles) of streams AMD-impaired x 277,063 households = **41,559** households

[32] While we recognize the 797 miles of non-AMD impaired streams have conditions in which fish and other aquatic life cannot survive, AMD impairment is the most prevalent stream impairment in the region and is used to categorize “severe” vs “moderate” pollution. We believe this is a reasonable assumption because AMD impairment is more visible than many environmental stressors in the region, and the primary regional study relies on surveyed residents’ perception of pollution.

[33] This assumes households are evenly spatially distributed among unpolluted, moderately polluted, and severely polluted stream areas.

- Households in the study region willing to pay for improving moderately polluted streams
    - 13% (797 miles of the 6,000 stream miles) otherwise impaired x 277,063 households = **36,018** households

We then multiply the number of households by the amount each household is willing to pay for the improvement of water quality to an unpolluted condition (using the conservative lower bound values from Farber & Griner, 2000, above). This results in a region-wide estimate to improve impaired streams to an unpolluted state:

- Severely polluted to unpolluted
    - 41,559 households (willing to pay for improving severely polluted streams) x $140 per household (low WTP estimate for improving severely polluted streams to unpolluted) = **$5.8 million**
- Moderately polluted to unpolluted
    - 36,018 households (willing to pay for improving moderately polluted streams) x $57 per household (low WTP estimate for improving moderately polluted streams to unpolluted) = **$2.1 million**
- Regional value of water quality improvements
    - $5.8 million + $2.1 million = **$7.9 million**

This $7.9 million estimate is then adjusted to account for the portion of residents that engage in water-based recreation activities. We first multiply by the percentage, 56%, of Pennsylvanians that participate in outdoor recreation and then by the share of recreation activity participation that is water-related, 25%[34] (Mowen et al., 2015; Outdoor Industry Association, 2017). The resulting estimate of $1.1 million represents the potential benefit of improving water quality of streams currently classified as impaired to people who participate in water-related recreation activities (2018$).

Natural Riparian Buffers on Siltation-Impaired Streams

Siltation-Impaired Stream Data & Riparian Buffer Zone

Data from PA DEP indicates that 654 miles of the study region's streams are impaired by siltation from agriculture, road and residential runoff, development, and urban runoff (PA DEP, 2018d). Because a variety of sources can produce the same impairment, we focus on the impairment and estimate the benefits of increasing natural riparian buffer cover for the streams in the region impaired by excessive siltation.

Overlaying spatial siltation-impairment stream data with land cover data, we find that there are 15,563 acres in the riparian zone within 30 meters (98 feet) of siltation-impaired streams.[35] There are 5,852 acres, or 37.6%, of the riparian zone comprised of non-natural land cover (e.g., pasture/hay, developed, and cropland). Of the 5,852 non-natural acres along siltation-impaired streams, 2,756 acres are classified as pasture/hay land and 460 acres are classified as cultivated cropland. Our target scenario converts

[34] Based on Pennsylvania State Park data.

[35] 30 meters or 100 feet is commonly used as guidance for a natural riparian zone that can support habitat and water quality.

25% of those 5,852 non-natural acres, or agricultural 1,463 acres, to natural riparian acres and estimates benefits (or avoided costs) that can accrue. We target agricultural acres in the riparian zone because of both the water quality impacts of nutrient inputs in the riparian zone and the existing incentive programs for farmers.

Property Value Enhancement

Natural riparian buffers are estimated to have a property value benefit for nearby households ranging from 1-26% (Young, 2016). We estimate there are 1,175 households with a median household value of $117,321 in the 30-meter riparian zone along the 654 miles of siltation-impaired streams in the study region watersheds (U.S. Census Bureau, 2010). The estimated total property value along these streams is $34,448,379. By applying the average property value benefit established by Young (2016) to the 1,175 households in the region that could benefit from natural riparian buffers, we arrive at a property value increase that captures potential economic benefits from increased aesthetic value and flood protection:

- Total property value gains
    - $34,448,379 (total estimated property value along siltation-impaired streams) x 13.5% (average estimated property value increase from adding natural riparian buffers) = **$4,650,531** in total property value gains or **$3,968** per household

Nutrient Retention

Economic benefits provided by natural riparian buffers include nutrient retention and avoided costs of excess phosphorous, nitrogen, and sediment loads in waterways. The Riparian Buffer Expert Panel estimates that an acre of riparian buffer can treat (retain) the nitrogen input from four upstream agricultural acres and the phosphorus and sediment input from two upstream agricultural acres (Rempel & Buckley, 2018).

The combined mid-range values of nutrient retention of phosphorus and nitrogen agricultural land to natural buffered acres are an estimated $296-$1,406/acre/year and $3.10-$20.80/acre/year for cost-savings from reduced sedimentation (Rempel & Buckley, 2018).

Assuming 1,463 acres are converted, this land could provide cost-savings to downstream water users:

1,463 acres (land converted to natural riparian buffers) x $863/acre/year (average total value of nutrient retention) = **$1,262,424/year** in nutrient retention

- $851/acre/year in reduced phosphorus and nitrogen loads = $1,244,942/year
- $12/acre/year in reduced sediment delivery = $17,482/year

Carbon Storage

Previous studies have identified the amount of carbon stored above and below ground in riparian forests, which can then be valued in dollar terms using the estimated social cost of carbon (Rempel & Buckley, 2018). An acre of agricultural land stores 28 metric tons of carbon per acre, and depending on forest type, forests can store between 69 and 82 metric tons of carbon per acre. This represents an increase of 41 and 54 metric tons of carbon stored per acre (or an average of 47.5 metric tons per acre) compared to agricultural lands (Rempel & Buckley, 2018). Given these increases in carbon storage between agricultural and forest land in our scenario, the "upgrade" of 1,463 acres of agricultural land to riparian forest buffers could mean an increase of between 59,963 and 79,002 metric tons of carbon stored. The calculations are as follows:

Using the average of the potential net gain in carbon storage per acre:

- 1,463 acres (agricultural acres converted to natural riparian buffer) x 47.5 metric tons per acre (average net gain in carbon storage) = **69,493** metric tons

Using the low estimate of net gain in C storage per acre:

- 1,463 acres (acres converted to natural riparian buffer) x 41 metric tons per acre (low net gain in carbon storage) = **59,963** metric tons

Using the high estimate of net gain in C storage per acre:

- 1,463 acres (acres converted to natural riparian buffer) x 54 metric tons per acre (high net gain in carbon storage) = **79,002** metric tons

To arrive at an economic benefit from this additional carbon storage, we multiply the average gain of 69,493 metric tons by the "social cost [per metric ton] of carbon". That cost represents the economic/financial costs to society due to damages associated with the emission of one metric ton of carbon. The damages and their costs include more severe damage from flooding and other extreme weather events, human health effects, and increased risks of wildfire (Rempel & Buckley, 2018) The estimate of these costs in 2015 (adjusted for inflation to 2017 dollars) is $31.81/metric ton. Thus, each acre converted to a forested riparian buffer area produces and average of $1,511 each year in carbon storage value. (That's 47.5 metric tons per acre times $31.81 in avoided social costs of carbon per metric ton.) In total, we estimate **$2,210,572** in additional carbon storage value. (This is calculated as 69,493 metric tons in additional storage times $31.81 per metric ton stored.)

Recreation

A USDA study on the recreational benefits from activities including wildlife viewing and recreational freshwater fishing associated with conserved riparian buffers found a total per-acre recreational benefit associated with the Conservation Reserve Program of $59.21 (Hansen et al., 1999).

Table D-5. Estimated Recreational Benefit from Riparian Buffers by Type

Recreation Activity	Recreational Benefit (2017$/acre/year)
Wildlife Viewing	$52.14
Pheasant Hunting	$3.47
Freshwater Recreational Fishing	$3.60
Source: Hansen et al., 1999. Values applied from the North East region of the US, which includes Pennsylvania.	

These values help capture the recreational benefit of converting 1,463 acres, particularly agricultural acres, to natural riparian buffer around siltation-impaired streams in the regional watersheds. We apply the average recreational benefit of just wildlife viewing and freshwater recreational fishing to estimate additional economic benefits associated with natural riparian land buffers:

- Recreational benefits gained from converting non-natural land cover to natural riparian buffers
  - 1,463 acres (acres converted to natural riparian buffer) x $55.74/acre/year (recreational benefit measured in CRP programs in the Northeastern states) = **$81,547** a year of additional benefits to local recreators

Cost of Natural Riparian Buffers

We account for both the establishment cost of forested riparian buffers, as well as the forgone revenue/rent of acres that would otherwise be used for agriculture. The establishment cost represents a one-time cost incurred by the landowner, which includes the cost of planting, materials and labor (PA DEP, 2010):

- One-time costs of establishing natural riparian buffers in the study region
  - 1,463 acres (agricultural acres converted to natural riparian buffer under targeted 25% scenario) x $1,740 ($/acre cost of establishment) = **$2,545,475**

By incorporating the average opportunity cost of converting an acre of agricultural land in the riparian zone, we can estimate the annual net economic benefit of increasing natural land cover in the riparian zone across siltation-impaired streams in the region. This cost-benefit analysis assumes that all 1,463 acres converted to natural buffer would otherwise be used for agricultural purposes. In the five-county study region, the average value of crop, poultry, and livestock per acre is $445 (USDA, 2017). Using these values, we estimate the annual opportunity cost of converting agricultural lands to natural buffers:

- Forgone agricultural production
  - 1,463 acres x $445/acre/year = **$651,035**/year

On-Lot Sewage

General Data

Study Region Stream Impairment Data

Data from PA DEP indicates that 40 miles of streams in the five-county study region are impaired by on-site wastewater sources, including from nutrients, organic enrichment/low dissolved oxygen, suspended solids, siltation, and excessive algal growth (The Pennsylvania Geospatial Data Clearinghouse, 2019).

- A single stream can be impaired by multiple sources, for example by AMD and on-site wastewater. For this analysis, we identify all streams in the study region that have impairments from on-site wastewater rather than streams only impaired by on-site wastewater.

- The PA DEP data also includes why a stream is non-attaining, either because there have been impairments to aquatic life use attainment, fish consumption use attainment, recreational use attainment, and potable water supply use attainment. The PA DEP reports that on-site wastewater only impairs aquatic life use attainment in the five-county study region.

Study Region Housing Data Related to On-Lot Sewage

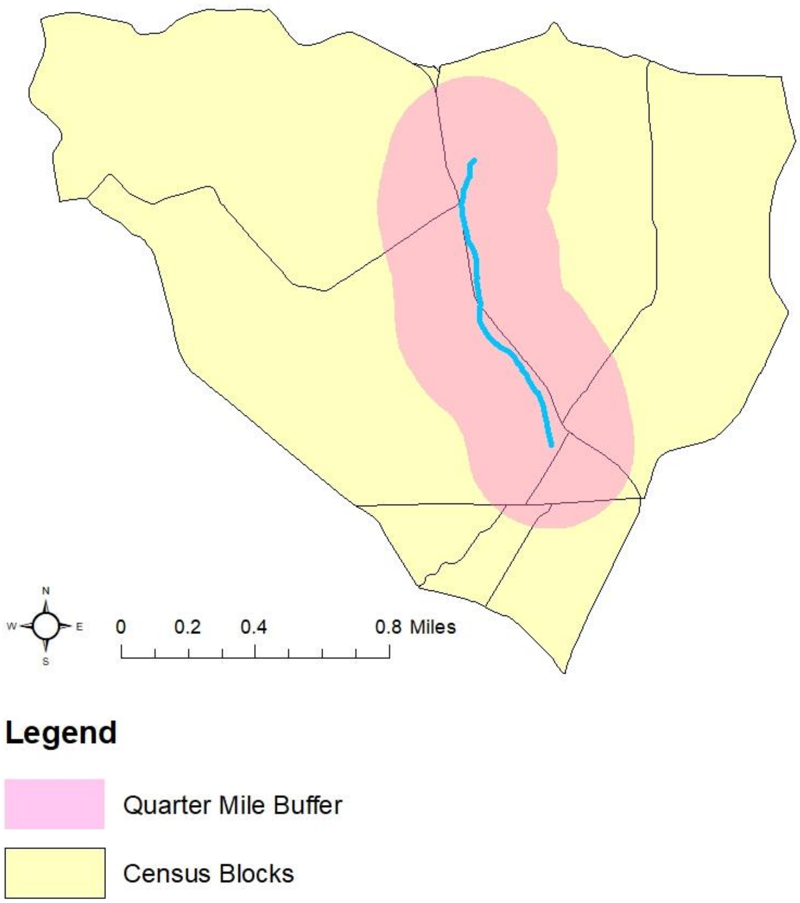
There are 4,568 households in the study region within a quarter mile of streams impaired by on-site wastewater[36]. The process for collecting baseline household counts are as followed:

1. Identify the total number of households in census blocks within a quarter mile of an on-site wastewater impaired stream (U.S. Census Bureau, 2010).
    - To our knowledge, no regional literature exists defining what distance households with failing on-lot systems need to be away from streams in order to avoid contributing to impairment. This distance estimate could also vary by stream depending on topography, soil type, and other hydrological factors of the area. In absence of distance estimates established by literature or hydrological modelling not covered in the scope of this study, we adopt a conservative buffer and assume that only households within a quarter mile on each side of streams impaired by on-site wastewater in the region contribute to water quality degradation.
2. Calculate the proportion of households that are within a quarter mile of on-site wastewater impaired streams.
    - Census blocks have irregular shapes and sizes. Incorporating household data for all census blocks that intersect the quarter mile buffer would lead to an overestimate of household counts. Therefore, to avoid an overestimation, we calculated the overlapping area for each census block (yellow polygons in Figure D-1) and the quarter mile buffer (pink shaded area in Figure D-1), the proportion of the overlapping area and the entire census block, and applied that proportion to the total number of households by census block. What results is an estimate of the proportion of households within the quarter mile buffer based on the area of a census block that overlaps the buffer.

The Pennsylvania State Council of the American Society of Civil Engineers (2018) estimates that 30% of homes across the state are served by on-lot systems and system failure rates range upwards of 20%, with even higher rates in rural areas. If 30% of the 4,568 households near impaired streams have an on-site wastewater system, then 1,370 households in the study region have an on-lot septic system. Furthermore, if 20% of the 1,370 households with on-lot systems have failing systems, then 274 households in the study region have a failing system.

[36] The data does not include businesses in the region with failing systems. Lack of adequate sewage treatment capacity for businesses is also a concern regionally.

Figure D-1. On-site Wastewater Impaired Stream and Surrounding Census Blocks



Limitations

The estimate of households with on-lot systems and failing systems in the region is a conservative underestimate. Estimates suggest that more than 30% of households in rural areas of Pennsylvania are served by on-lot systems. We would expect there would be a higher concentration of households served by on-lot systems near streams impaired by wastewater. It is also reasonable to assume that more than 20% of households within the quarter mile buffer have failing systems. If a stream is classified as impaired by on-site wastewater, it is likely that most households near the stream have failing systems.

For example, Figure D-1 shows a single stream segment in the region impaired by on-site wastewater. We estimate that 67 households are located within a quarter mile on either side of the impaired stream, which translates to 20 households with on-lot systems, and four with failing systems. Given that this stream segment is only impaired by on-site wastewater, we would expect that more than four households contribute to the stream's impairment status.

Furthermore, gathering this data could be problematic because systems are on private property and people may be reluctant to "own up" to the fact that their system is antiquated due to the costs of refurbishment/replacement.

Action 1: Connecting Homes with Failing On-Lot Septic Systems Near Impaired Streams to Public Sewage Systems in Potential Low Cost and High Feasibility Areas

In order to estimate what economic benefits could be expected from connecting homes with failing on-lot septic systems near impaired streams to public sewage systems, data needs to be collected on:

- Whether public sewage exists within a certain geographic area
- The number of households near impaired streams with on-lot septic systems,
- The number of households with failing on-lot septic systems,
- The service area of sewage treatment facilities,
- Whether sewage facilities can handle additional capacity,
- The average cost to treatment facilities to add a new household, and
- What water quality improvements could be expected.

"High feasibility areas", in this case, are defined as areas near impaired streams with a high concentration of failing septic tanks that also fall under an existing public sewer service area. Areas with a high density of failing systems near an impaired stream already under an existing public sewer service area would be feasibly cheaper to extend service compared to less populated areas not served by a public sewer authority.

Existing Sewage Areas

There is a lack of accessible spatial data on existing public sewer service areas in the five-county region. High feasibility areas were not identified as it is unknown which specific authorities serve households near impaired streams. Once service areas are identified in future analysis, areas that have a high density of households with failing systems near impaired streams could be overlaid with public sewage service areas to determine initial candidates for analysis.

PA DEP provides spatial data for public water service areas[37] and descriptions of municipal on lot sewage service and their authorities[38] (Pennsylvania Department of Environmental Protection, 2018c & Pennsylvania Department of Environmental Protection, 2015). However, having public water service does not translate to having public wastewater treatment.

In Cambria and Fayette Counties, fewer areas are served with public wastewater treatment than public water and areas served by public sewer service are documented online by municipality (Herbert,

[37] Public water service areas include the present service boundary of the water system but does not contain locations of surface and groundwater sources, storage facilities, transmission and distribution system lines, and interconnections with other water systems (PA DEP, 2018c).

[38] This data provides details on which local agencies are responsible for carrying out on-lot septic system permitting and enforcement activities.

Rowland & Grubic, Inc., 2000 & Cambria County Planning Commission, 2011). Data of that specificity was not available for the other counties in the study region. Fayette County documents each sewer authority, where they operate, their capacity, and vague descriptions of the service area such as "serves a few neighborhoods in Redstone Township." Because the plan was last updated in 2000 and existing service areas have most likely changed, this information is useful for a qualitative analysis but does not provide enough geographic specificity to determine the extent of an authority's service area. Cambria county's comprehensive plan includes a map of existing sewage areas, but it is not available online for download and use.

Sewage Authority Capacity

Each county's sewer authority was contacted to obtain spatial data on service areas or any estimates of how much it would cost to connect a household to service, but no sewage authorities responded. Because many authorities on the municipal level function almost autonomously from county-level authority, future analysis should focus on collecting information on the municipality level, given that the number of people served, capacity of treatment for the authority, and ability to add on new customers, ranges widely. Furthermore, future analysis should incorporate a survey which should be sent out to every sewage authority operating in the Laurel Highlands watersheds that asks for:

1) Whether spatial data on the authority's service area exists
2) What the capacity for treatment of the authority is and whether they can handle any new capacity
3) Any plans for (a) establishment of a public sewer system or (b) its expansion
4) The average cost of adding a new household in an existing service area

Water Quality Improvements

To our knowledge, no data or literature specific to the region details what expected water quality improvements could be from connecting failing septic systems to public systems. There are also no studies, to our knowledge, demonstrating the incremental contribution of failing on-lot septic systems to pathogen loading in surface waters in the study region. A study completed in Waco, Texas found that out of three systems, a decentralized aerobic system, an on-lot septic system, and a centralized municipal wastewater treatment plant, wastewater treated by the on-lot system was the most degraded after treatment (Garcia et al., 2013). While the study's results affirm the choice that water quality benefits can be expected by the action (connecting failing systems to public water treatment), due to the age of many of the public treatment systems in the region, and given that they frequently overflow during storm events, the same results may not be realized in the Laurel Highlands.

Action 2: Repairing Failing On-Lot Septic Tank Systems Near Impaired Streams

In order to estimate what economic benefits can be expected from repairing failing on-lot septic tank systems near impaired streams data needs to be collected on:

- The number of households near impaired streams with on-lot septic systems,
- The number of households with failing on-lot systems,

- Septic system failures and the nature of failures,
- Average cost of repairing a failing system, and
- Regional monitoring data that differentiates between baseline and incremental water quality improvements

Septic System Failures: Reasons and Costs

In lieu of failure rates, repair rates can be used as a proxy for system failures and at a minimum provide conservative estimates for costs and reasons for system failures. However, it should be noted that repair rates may not be truly indicative of failure rates because many failing systems are not reported to regulatory authorities in a timely manner.

In a phone survey of all homeowners that had received a repair permit in 2004 in the northeast and south-central PA DEP region, 60% of repairs were for systems installed prior to 1972. About half of homeowners surveyed had noticeable problems with their systems prior to repair, 20% noticed problems during inspection, and 25% did not have any noticeable problems during inspection but updated their system to meet current standards (Day, Zhu, Bruce, & Franklin, 2008). Most municipalities do not have any type of on-site inspection unless they have a Sewage Management Program, which requires the municipality to conduct periodic on-site inspections (Day, Zhu, Bruce, & Franklin, 2008).

The survey also indicated that repairs on average cost $3,500, but have wide-ranging costs, which is to be expected given that systems fail for different reasons. Roughly 60% of repairs cost less than $5,000, but almost 15% of repairs cost more than $10,000. If the 274 households with failing systems near impaired streams have similar issues to the households surveyed, it would collectively cost $959,000 to repair failing systems in the region. This is a conservative estimate as it includes costs of repairs for the 25% of households surveyed without a failing system. Future analysis would be informed by improved estimates on the costs of repairing failing systems.

Water Quality Improvements

To our knowledge, no literature on expected water quality improvements from repairing failing septic systems exists within the study region. There is also a lack of literature demonstrating the incremental contribution of failing on-lot septic systems to pathogen loading in surface waters in the region. Monitoring efforts should be put in place specifically in streams impaired by on-lot septic systems, in communities identified by watershed plans as having large numbers of failing systems, and in communities with newly repaired systems (or a new development with on-lot septic systems).

Limitations & Further Research

The two actions identified make several assumptions that may or may not hold true and are largely driven by costs and the availability of potential funding. Both plans require capital investment either by the treatment authority or the individual homeowner and unless opportunities arise where capital costs can be passed, there may not be sustained water quality improvements. Action one, connecting areas with a high concentration of failing systems to public treatment systems, depends extensively on funding. Unless sewage treatment plants are given grants to upgrade existing systems, antiquated systems in the region may not be able to handle treating more capacity. Similarly, action two, repairing failing systems near impaired streams, requires that homeowners repair their system (at an average cost of $3,500) and maintain their system to prevent future failure. Additional costs to the homeowner can include pumping the treatment tank and inspections which can range from $850 to $1,400 (PennState Extension, n.d.). We also assume that in action two, no systems need to be replaced, just repaired. If the system is failing beyond repair, this could cost the homeowner $10,000 to $40,000 to install or replace the existing system (PennState Extension, n.d.).

The information provided above should be used as an outline for future analysis that examines what benefits and water quality improvements would accrue from addressing on-lot sewage issues. Before a region-wide analysis is completed, we believe an important first step is to start with a case study approach in just one watershed or even one high priority area. Because data gathering, monitoring efforts, etc., are more easily completed on a smaller geographical scope, a case study would be a perfect way to examine if the data gaps addressed above are feasible to obtain on a region-wide scale. This focused case-study can then be applied and used as a template for other watersheds in the region.

Table D-6 provides additional literature to be included in further studies and other general water quality studies for review.

Table D-6. Sewage-Related Studies to include in Future Analysis

Benefit	Study Title	Quantified Estimates	Specific Source of Impairment	Location	Notes	Source
Property Value	Evidence of the Effects of Water Quality on Residential Land Prices	A change of 100 fecal coliform counts per 100 mL is estimated to produce about a 1.5% change in property prices.	Fecal coliform	Chesapeake Bay	None	Leggett & Bockstael, 2000
Property Value	The Impact of Water Quality on Florida's Home Values	A one foot-increase in average Secchi disk depth raised property values in two counties in Florida by $969 million.	Clarity	Florida	The study also includes information on how property values are impacted by chlorophyll, dissolved oxygen, and turbidity.	Florida Realtors, 2015
Property Value	The Effect of Water Quality on Rural Nonfarm Residential Property Values	Uses real-estate prices to determine value of improvements in water quality in small rivers and streams in Pennsylvania.	Acidity, dissolved oxygen, biochemical oxygen demand, and nitrate and phosphate levels	Pennsylvania	The study also compares residential properties along clean streams and polluted streams.	Epp & Al-Ani, 1979

Table D-6, Continued.

Benefit	Study Title	Quantified Estimates	Specific Source of Impairment	Location	Notes	Source
Drinking Water-Willingness to Pay	Willingness to pay for improvements in drinking water quality	The median estimated WTP was $5.49 per month above current water bills for people on public systems and $7.38 for those using private wells	Groundwater contamination	Georgia	None	Jordan & Elnagheeb, 1993
Water Quality Improvement-Willingness to Pay	Valuing Preferences for Water Quality Improvement in the Ichetucknee Springs System: A Case Study from Columbia County, FL	The mean willingness to pay was estimated to be $16.20 per household per month over the course of ten years	Nitrate	Florida	This study focuses on improvements in water quality arising from changes in septic tank technology	Foster, 2008
Recreation	The Economic Valuation of Environmental Amenities and Disamenities: Methods and Applications	Water quality improvements improve recreational amenities and aesthetic amenities	Dissolved oxygen	Florida	None	Mendelsohn & Olmstead, 2009
Recreation	The Value of Clean Water: The Public's Willingness to Pay for Boatable, Fishable, and Swimmable Quality Water	The study estimates willingness to pay for improving waters from non-boatable to boatable, boatable to fishable, and fishable to swimmable	Water quality index	Nationwide	None	Carson & Mitchell, 1993

Table D-6, Continued.

Benefit	Study Title	Quantified Estimates	Specific Source of Impairment	Location	Notes	Source
Recreation-Willingness to Pay	Regional Cooperation for Water Quality Improvement in Southwestern Pennsylvania	Benefits of water quality improvements (from boatable to swimmable) at recreational sites on the Monongahela in the early 80's were estimated to be $1295 and $56.39 (in 1998 dollars)	Not specified	Pennsylvania	None	National Research Council, Division on Earth and Life Studies, Water Science and Technology Board, & Committee on Water Quality Improvement for the Pittsburgh Region, 2005
Health	Regional Cooperation for Water Quality Improvement in Southwestern Pennsylvania	Costs of a 1983 water contamination event in Pittston ranged between $23 million and $55 million (in 1984 dollars).	Giardiasis	Pennsylvania	None	National Research Council, Division on Earth and Life Studies, Water Science and Technology Board, & Committee on Water Quality Improvement for the Pittsburgh Region, 2005
Ecosystem Services	Small Streams and Wetlands Provide Beneficial Ecosystem Services	None	None	Nationwide	General information about the importance of small streams and the ecosystem services they provide.	Meyer, 2003
General Study on Septic Tanks	Do septic tank systems pose a hidden threat to water quality?	Failing septic systems can become long-term, chronic sources of nutrient pollution	Nutrients	Multiple case studies	None	Withers, Jordan, May, Jarvie, & Deal, 2013

Appendix E: AMD and AML Treatment Data

The following tables provide data on passive treatment sites reported by Datashed.org in the study region watersheds, as well as PA DEP reported cost data on abandoned mine land (AML) reclamation.

Table E-1 lists the 67 passive treatment systems documented on Datashed.org in the 21 watersheds of the study region.

Table E-1. Passive Treatment Sites in the Study Region

Passive Treatment Site	Watershed	County
Webster Mine Discharge	Blacklick Creek	Cambria
AMD & Art Vintondale	Blacklick Creek	Cambria
Coal Pit Run Upper System	Blacklick Creek	Cambria
Coal Pit Run Lower System	Blacklick Creek	Cambria
Coalpit Run AMD 11 (2416)	Blacklick Creek	Cambria
Gray Run	Conemaugh River	Cambria
Bear Rock Run	Little Conemaugh River	Cambria
Mineral Point (Saltlick Run) AMD 11(0632)101.1	Little Conemaugh River	Cambria
Puritan Discharge Treatment System	Little Conemaugh River	Cambria
South Fork AMD50	South Fork Little Conemaugh	Cambria
South Fork AMD60	South Fork Little Conemaugh	Cambria
South Fork AMD67	South Fork Little Conemaugh	Cambria
Brence (AMD85)	South Fork Little Conemaugh	Cambria
Permapress	Indian Creek	Fayette
Gallentine	Indian Creek	Fayette
Sagamore	Indian Creek	Fayette
Kalp Discharge Romney North	Indian Creek	Fayette
Melcroft Mine Drainage Treatment System	Indian Creek	Fayette
Harbison Walker Phase II	Middle Youghiogheny River	Fayette
Harbison Walker Phase I	Middle Youghiogheny River	Fayette
Glade Run	Middle Youghiogheny River	Fayette
Cucumber Run	Middle Youghiogheny River	Fayette
Morgan Run Amd Remediation	Middle Youghiogheny River	Fayette
Laurel Run #2	Blacklick Creek	Indiana
Laurel Run #1	Blacklick Creek	Indiana
SR 286 Passive Treatment System	Conemaugh River	Indiana

Table E-1, Continued.

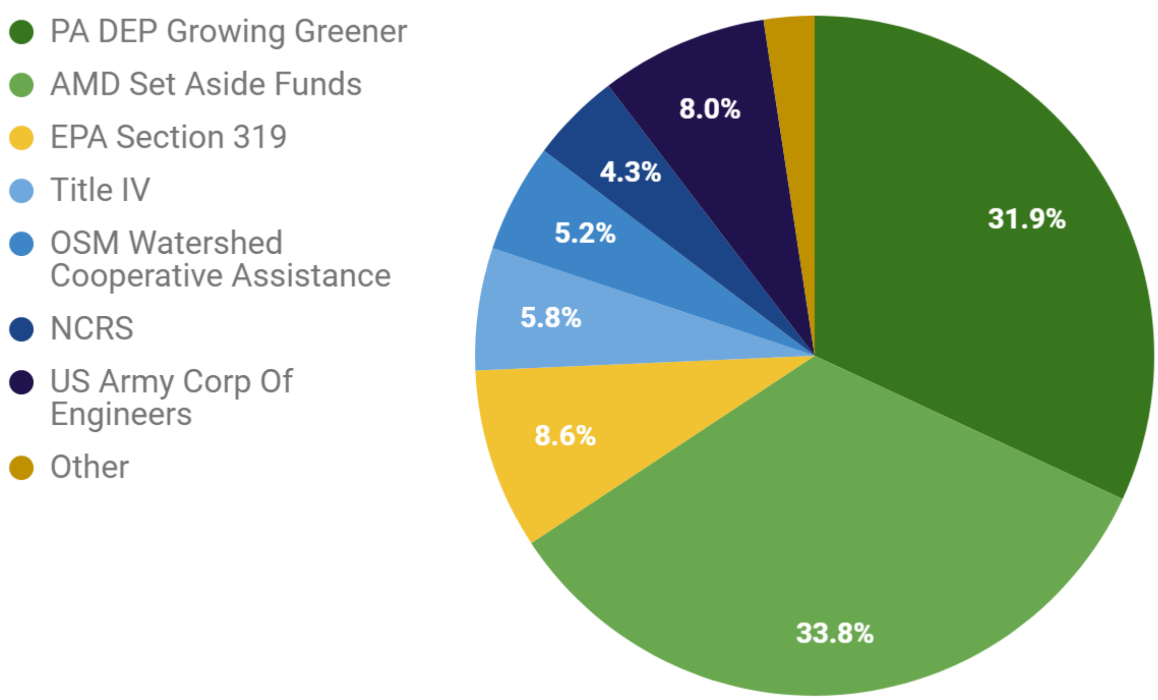
Passive Treatment Site	Watershed	County
Reeds Run AMD Remediation Project	Conemaugh River	Indiana
Neal Run Restoration Project	Conemaugh River	Indiana
Richards - Systems 1, 2A & 2B	Two Lick Creek	Indiana
Penn Hills #2 - Systems A, B, and C	Two Lick Creek	Indiana
Lucerne 3A Treatment System	Two Lick Creek	Indiana
Yellow Creek 1B	Yellow Creek	Indiana
Yellow Creek 2C	Yellow Creek	Indiana
Yellow Creek 2A & 2B	Yellow Creek	Indiana
Yellow Creek 1A	Yellow Creek	Indiana
Tide Mine In-Situ Bioremediation Demonstration Project	Yellow Creek	Indiana
Boswell	Quemahoning Creek	Somerset
Jenners	Quemahoning Creek	Somerset
Laurel Run Reitz #1 Discharge	Shade Creek	Somerset
Shingle Run Ald	Shade Creek	Somerset
Swallow Farm Coal Run	Shade Creek	Somerset
Md 19 Reels Corner	Shade Creek	Somerset
Cottagetown	Shade Creek	Somerset
Wells Creek Skeria # 6	Stonycreek River	Somerset
Wells Creek Onstead	Stonycreek River	Somerset
Wells Creek Moore No. 7	Stonycreek River	Somerset
Oven Run Site B	Stonycreek River	Somerset
Oven Run Site A	Stonycreek River	Somerset
Oven Run Site F	Stonycreek River	Somerset
Oven Run Site D	Stonycreek River	Somerset
Oven Run Site E	Stonycreek River	Somerset
Lamberts Run	Stonycreek River	Somerset
Rock Tunnel	Stonycreek River	Somerset
Weaver Run D10	Stonycreek River	Somerset
Hinemyer	Stonycreek River	Somerset
Weaver Run D8A	Stonycreek River	Somerset
Weaver Run D8B	Stonycreek River	Somerset
Metro	Upper Casselman River	Somerset

Table E-1, Continued.

Passive Treatment Site	Watershed	County
Keystone Phase 1 & 2	Loyalhanna Creek	Westmoreland
Monastery Run Wetland 1	Loyalhanna Creek	Westmoreland
Monastery Run Wetland 2	Loyalhanna Creek	Westmoreland
Monastery Run Wetland 3	Loyalhanna Creek	Westmoreland
Upper Latrobe Mine Drainage Treatment Project	Loyalhanna Creek	Westmoreland
Friedline Mine System	Loyalhanna Creek	Westmoreland
Laurel Run	Loyalhanna Creek	Westmoreland
Wilson Run Discharge	Sewickley Creek	Westmoreland
Brinkerton	Sewickley Creek	Westmoreland
Lowber	Sewickley Creek	Westmoreland
Source: Datashed.org		

Figure E-1 summarizes volunteer-reported data also compiled from Datashed.org, detailing the landscape of reported funding sources for operating passive treatment sites in the region.

Figure E-1. Percent of Total Funding Reported by Funding Source for Passive Treatment Systems
Source: Stream Restoration Inc. & 241 Computer Services, 2018 (Datashed.org)



Tables E-2 and E-3 show a snapshot of the heavy metal and acid treatment performed by an average passive treatment system in the region. The average passive treatment system treats 133,508,233 gallons annually. Please note these averages are calculated using the data voluntarily reported to Datashed.org.

Table E-2. Profile for an Average Passive Treatment System in the Region

Treatment	Influent	Effluent
Alkalinity (mg/L)	56.07	68.95
pH	3.84	5.84
Total Iron (mg/L)	52.3	19.2
Manganese (mg/L)	8	7.37
Aluminum (mg/L)	26.5	18.24
Sulfate (mg/L)	609	570

Table E-3. Heavy Metal Removal for an Average Passive Treatment System in the Region

Treatment	Load Removal (lbs/day)
Manganese Load Removal	11.9
Iron Load Removal	413.3
Aluminum Load Removal	3.1

Table E-4 shows the average cost across the state to cleanup abandoned mine lands. For both PA DEP and contracted cleanup, the cost per acre increased substantially in the recent years.

Table E-4. Average Cost per Acre to Cleanup AML from 2012-2018

Year	In House Cost/Acre Average	Contract Cost/Acre Average	In House and Contract Cost/Acre Average
2012	$26,570	$22,145	$24,357
2013	$13,370	$38,721	$26,045
2014	$16,905	$30,692	$23,798
2015	$17,861	$42,837	$30,349
2016*	$19,487	$81,314	$50,401
2017*	$15,859	$88,568	$52,213

Table E-4, Continued.

Year	In House Cost/Acre Average	Contract Cost/Acre Average	In House and Contract Cost/Acre Average
2018*	$25,891	$86,329	$56,110
Average of Last 7 Years	$19,420	$55,801	$37,611
Average of Last 5 Years	$19,201	$65,948	$42,574
Average of Last 3 Years	$20,412	$85,404	$52,908
Source: Hewitt, 2019 *PA DEP took on Emergency Projects from OSMRE in 2015			

Table E-4 gives background on the cost of AMD damage to water treatment plants in the nearby West Susquehanna Basin.

Table E-5. Summary of West Susquehanna Basin Water Treatment Cost Survey Results

Water Treatment System	Treatment Costs ($/million gallons)	Current Pollutants	Pollutant Source	Cost Estimate
1	Not calculated	N/A	AMD	PA DEP estimate to treat AMD
2	3,000	Low pH	Acid precipitation	Chemicals
3	87	Iron	Rock form.	Chemicals
4	1,390	None	N/A	Total
5	2,100	Low pH	Rock form.	Staff, utilities, chemicals
6	2,500	Yes	AMD	Entire facility
Source: (Hansen et al., 2009)				