Removing Legacy Impairments to Promote Ground and Surface Water Quality

FINAL REPORT

NRCS CONSERVATION INNOVATION GRANT

NRCS CONSERVATION INNNOVATION GRANT

Final Report

Grantee Entity Name: The Great Legacy Sediment Restoration Project, LLC

Project Title: Removing Legacy Impairments to Promote Ground and Surface Water Quality

Agreement Number: 69-3A75-17-12

Project Director: Joseph Sweeney

Contact Information: Phone Number (717)579-2514

E-Mail: p-three@comcast.net

Six Month Period Covered by Report: 10/1/16 to 3/31/17

Project End Date: 09/30/2018

Executive Summary

Legacy sediment (LS), an environmental consequence of post European settlement farming, milling and forestry practices has become a commonly recognized source of water quality impairments throughout the coastal plain, ridge and valley and piedmont regions of the mid Atlantic United States. Our inquiry focused on the results of a long-term scientific experiment that removed LS from a marginal pasture section of the Big Spring Run (BSR) watershed in Lancaster County, Pennsylvania with the goal of restoring a buried Holocene era valley bottom to a functioning wetland/stream complex. Using the BSR results as a baseline the CIG initiative focused on four primary areas: 1) Develop and refine methodology to locate, quantify and prioritize LS sites in Lancaster County using lidar (light detection and ranging) technology and on-site verification, 2) Examine the cost effectiveness of the practice compared to other commonly used BMPs for nutrient and sediment reduction, 3) Identify potential funding sources and approaches to incentivize restoration opportunities on private lands , and 4) Determine potential uses for the excavated soil to encourage both landowner participation and private sector investment in the practice.

Our program has developed a county wide map of legacy sediment sites, erosion rates and “hot spots” with high rates of sediment removal that can be determined on a parcel, stream length or watershed scale. Field verification has confirmed these results with a 90%~ certainty which allows the user with high confidence to prioritize potential restoration sites and other BMPs with desk top technology.

The project has produced a detailed analysis quantifying the cost effectiveness of the practice at reducing nutrients and sediment that clearly demonstrates the competitiveness of the practice compared to other commonly used agricultural BMPs. Our review of existing public incentives to promote reduction and restoration practices has led to the identification of several additional

funding opportunities for landowners. We have determined that there are both current and future markets that can be developed for the removal of sediment and associated nutrients to encourage the adoption of the practice on private land. In combination the economic advantages of LS restoration provide interested landowners with a new potential source of funding for income or investment in other agricultural BMPs while delivering a cost-effective practice to reduce nutrient and sediment loads and restore wetland stream systems.

Two publications have been produced to support and demonstrate our conclusions and recommendations. The first, "Cost Effectiveness of Legacy Sediment Mitigation at Big Spring Run in Comparison to Other Best Management Practices in the Chesapeake Bay Watershed", formed the basis for an article which appears in the Journal of Soil and Water Conservation. *See*: Fleming, P.M., D.J. Merritts and R.C. Walter, 2019. Legacy Sediment Erosion Hotspots: A Cost Effective Approach for Targeting Water Quality Improvements. Journal of Soil and Water Conservation, 74(4): 67A-73A, doi: 10.2489/jswc.74.4.67A. The full report is available on the WSI website. www.waterscienceinstitute.org

Legacy sediment restoration at both headwater and impaired valley bottom sites needs to be recognized as a unique opportunity to deliver a range of scalable, cost effective results to local watersheds and larger public environmental goals such as the Chesapeake Bay total maximum daily load (TMDL). Public funders should begin to accept that nutrient loads are often the result of legacy impairments within the stream and not solely the result of inadequate farming practices. In many instances the purchase of a farm with a stream is not just the acquisition of an unrecognized pollution source but an important conservation opportunity. Government programs should adjust funding strategies in order to promote holistic "edge of field" and "in stream" reduction strategies as a comprehensive approach and not simply as "one-offs" to comply with program parameters. Many of these recommendations are in practice at the BSR site and the results, while not directly related to this project, are worthy of further review.

Introduction

This project was proposed with the goal of examining the economic benefits and incentives that landowners could derive from the adoption of legacy sediment (LS) restoration projects on their properties and to determine the ability of technology to identify potential landowner projects. It was conceived to answer several key questions that arose from the widely studied Big Spring Run (BSR) stream and wetland restoration project on a working farm in West Lampeter Township, Lancaster County, Pennsylvania. Those questions included: (i) How cost effective was the practice?; (ii) Was there a viable use for the soil removed in the restoration?; (iii) Were their sources of funding that could be accessed to restore additional sites?; and (iv) What constituted a viable set of metrics to determine site selection? The time frame for this examination was December 2016 through December 2018.

Our chief objectives based on these questions were:

1) To develop a set of models that quantify the economic sustainability of LS restoration and promote its adoption and financing by private sector markets.

2) Generate additional income and conservation opportunities in restricted or underutilized riparian corridors on working lands through the development of landowner incentives.
3) Create and promote methodologies, techniques, and possible tools for the measurement of LS sites that identifies their location, characteristics and restoration potential.
4) Develop a protocol to precisely quantify restoration outcomes to encourage the adoption of this practice by landowners, municipalities and states as a Green Infrastructure (GI) alternative to traditional point source upgrades and/or other non-point conservation practices.

This project focused in part on the results and costs that were produced by the BSR project and it was the continuous goal of the project principals to relate those results to present costs. Every effort was made to create an apples-to-apples basis for the evaluation. Where available, we used current practice, professional and contractual data to estimate the present cost of a restoration like BSR. We then compared these costs to the most relevant Lancaster County practice data. Data to develop comparative BMP effectiveness were obtained from sources including NRCS practice costs, Farm Service Agency (FSA) Conservation Reserve Enhancement Program (CREP) rates, local bulk soil rates, United States Geological Survey (USGS) gauge date and the Chesapeake Assessment Scenario Tool (CAST) model utilized by the Chesapeake Bay Program Office to assess BMP costs and effectiveness.

To develop a county-wide map hot map for identifying erosion hot spots, the project used publicly available lidar point cloud data sets from 2008-2014 to produce digital elevation models (DEMs) and then to difference the data sets to determine county-wide erosion rates for a 6.6-year period (fig 1). This information was then field tested for accuracy using a range of standard measurement techniques and tools. Further refinements for accuracy used drone photogrammetry and error analysis to arrive at a standard deviation measure. Additional accuracy and efficiency were achieved by the development of proprietary "open source" code which enhanced the ability of the team to locate more accurate stream centerlines and identify legacy terraces (areas with high volumes of legacy sediment). Data for publicly available parcel information was provided by the Lancaster County GIS department and a canopy layer developed by the project consultant was incorporated into the final product.

With the organization of this data on an ARC GIS platform an accurate parcel to watershed scale program of data layers are available to provide practitioners and policy makers with a tool for evaluating LS sites, LS hotspots, annual erosion loads, canopy, stream length, historic dams or other impoundments, and related factors useful in evaluating potential restoration opportunities and the siting of related riparian BMPs. Using a "triage" approach these metrics can determine where LS restoration or other practices can best benefit a stream segment measured by the CAST model. In a demonstration for PA NRCS the project developed a list of the top 100 County sites based on stream length, ownership and annual erosion (fig. 1). A second demonstration using similar metrics was provided to PA NRCS to develop a potential funding program for the Chiques watershed. The project continuously receives requests from public and private entities for access and analysis of the results for use in other County clean water initiatives.

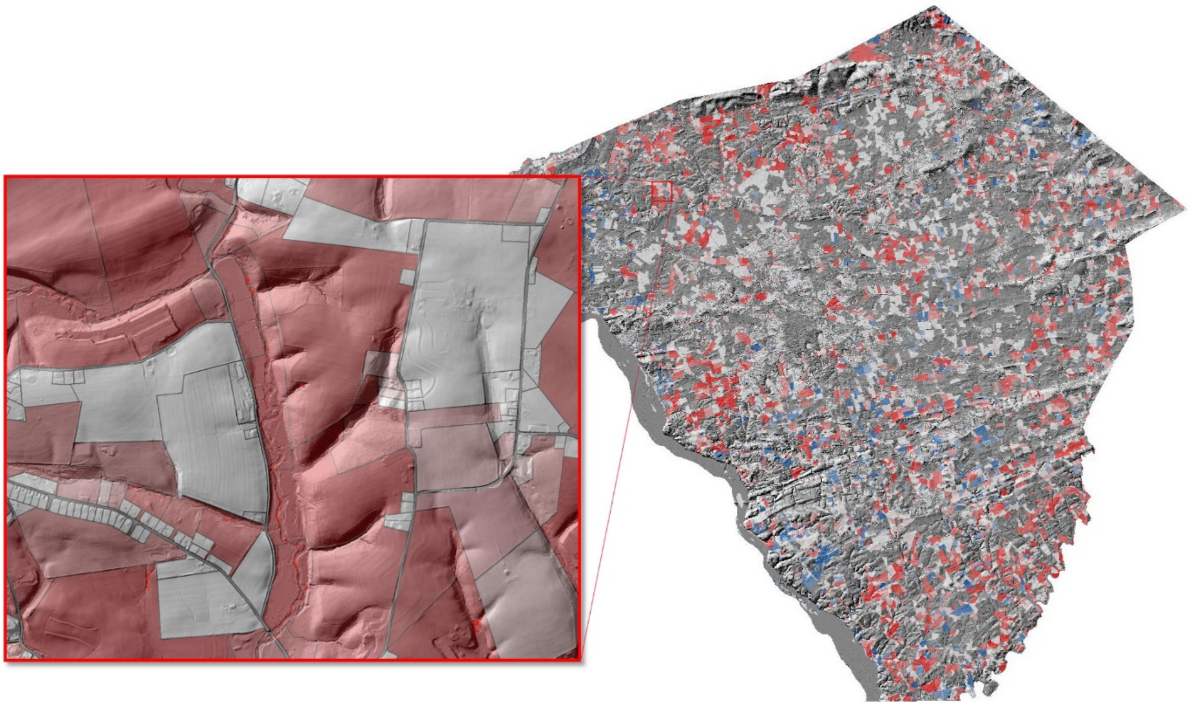

Figure 1. Parcel mapping assigns the appropriate erosion and streamlength to individual parcels and allows for the identification of "hotspot" parcels where elevated rates of erosion are occuring. Figure by E. Lewis.

The project was led by Joseph Sweeney, Manager of The Great Legacy Sediment Restoration Project, LLC, (TGLSRP) with field and data development led by Dr. Dorothy Merritts, Dr Robert Walter and Michael Rahnis who produced many of the technical innovations central to the outcome. Linda Sweeney, the project's chief volunteer, provided invaluable organizational, editorial and administrative contributions. Additional support came from Evan Lewis, Shelby Sawyer and Logan Lewis through extensive field and GIS analysis and interpretation. The project contracted with Dr. Patrick Fleming to produce the cost effectiveness analysis; with Mike Peck, a local soil entrepreneur and developer of the "Compost Tumbler", to review soil costs and marketing opportunities and with Cimbria Capital to advise on potential strategies to promote the project's program. The TGLSRP contracted services to the Water Science Institute (WSI) with Mr. Sweeney serving as executive director of WSI and Drs. Merritts and Walter as WSI's chief scientists.

Numerous agencies and individuals are involved in supporting and promoting the project results particularly the Pennsylvania office of NRCS, the Pennsylvania Department of Environmental Protection (PADEP), The Chesapeake Bay Commission, The Nature Conservancy of Pennsylvania and Maryland, and the Pennsylvania State Conservation Commission.

The Steinman Foundation of Lancaster County provide a grant of $150,000 to WSI and additional in-kind commitments were provided by the project principals.

Background

The dense concentration of historic mill dams and valley bottom impairments throughout the Eastern United States has had a dramatic and largely unrecognized impact on the original ecology and functions of valley bottom ecosystems. Breached, abandoned and removed dams have been steadily releasing millions of tons of previously stored nutrients and sediments (Legacy Sediment because of its origin in post European settlement land use practices) retained in millpond reservoirs (terraces) while simultaneously burying thousands of acres of bottom land habitat that originally served as functioning wetland stream systems.

The restoration experiment at BSR in Lancaster County, Pennsylvania, which involved the removal of LS and the rehabilitation of the buried wetland ecosystem, demonstrated that this approach has a significant potential for improving surface and groundwater quality while reestablishing wetland habitat and functions (fig. 2). The experiment was conducted on a working farm that continues to produce row crops and utilize adjacent pasture for grazing and hay production. Approximately 5 acres of degraded bottomland were transformed to create the wetland system and install other riparian BMPs.

Now entering its 8th growing season the restoration has become an extraordinary success documented by a wide range of researchers and agencies including Franklin and Marshall College (F&M), The Pennsylvania Department of Environmental Protection, The United States Geological Survey, the Environmental Protection Agency and over 20 other research initiatives. The site has clearly demonstrated its ability to quickly establish an efficient and low maintenance "green infrastructure" (GI) alternative to traditional stream and storm water approaches while providing a wide range of ecosystem benefits including habitat, stormwater retention, water temperature and clarity while essentially eliminating sediment and nutrient bank loading within the restoration reach. Post restoration two questions continually emerged from presentations. "How much did it cost and what was done with the soil?" In our grant we've expanded on those two queries to develop the four objectives stated in the Introduction.

Figure 2. Post-restoration aerial view of multi-branching channel at BSR, Lancaster County.

One aspect of the economic analysis was to examine how the excavated soil could be repurposed to serve as a potential landowner incentive and/or to reduce or eliminate the project's cost. Prior to the CIG funding of this project, the BSR soil had been sold to a local contractor for use in a brownfield reclamation project. Part of the reason for the sale was the narrative that accompanied the sale. The primary scientific underpinning of the BSR project had been initiated by F&M scientists and the soil was being purchased to reclaim a contaminated site acquired by the College for future redevelopment. The sustainability story was very compelling in developing the larger narrative of the restoration although it limited the project's ability to explore other soil product and market opportunities.

A complimentary area of inquiry was to examine the number of possible sites that could be identified as opportunities for landowners within the county and to examine their potential to reproduce the BSR results. Previous independent research by F&M scientists had identified the location of over 400 milldams in Lancaster County watersheds that were considered a primary source of sediment and nutrient loads to county watersheds. The project built upon this primary work using lidar to determine the extent to which mill dams and other land use changes were contributing load volumes to 1st, 2nd and 3rd order streams which account for over 80% of the stream segments within the Chesapeake Bay watershed. Current practice typically selects restoration opportunities determined on a "local knowledge" basis that addresses a specific site based on landowner concerns, availability of funding and regulatory opportunity to satisfy permitting requirements. There is no quantitative basis for selecting sites or determining their relative effectiveness compared to other watershed investment opportunities. This program provides practitioners and policy makers with a more efficient alternative. Lidar imaging techniques developed for the project also have the added benefit of providing additional information for more effective siting of other riparian BMPs, particularly grass and forest buffers.

While the restoration methods were considered radical ten years ago, it was the cost which attracted the most interest. Since the permitting of the BSR restoration other projects have been authorized by regulatory agencies but the high initial price associated with this practice has remained a significant barrier to greater adoption by conservation funders. This grant was designed to begin to address that central question by examining the results in "cost per pound (unit) of pollution reduced" compared to other common BMPs and to examine the reclaimed soil as a product opportunity that could further reduce or eliminate the per unit cost of the practice. In answering those questions through a verifiable methodology, the project could develop public, regulatory and policy knowledge of the practice and identify income streams or incentives for landowners to consider.

Review of Methods

The project used traditional and innovative technological approaches to develop its results and combine them into a potential program to evaluate, prioritize and allocate resources for the reduction of sediment and nutrient loads within Lancaster County, Pennsylvania. In parallel with our project the 8-year pre and post restoration scientific and technical results from F&M and the USGS to assess the BSR project's effectiveness were analyzed and released. Together they permitted our inquiry to base its results on verifiable scientific data to support the project's economic conclusions. Using the cost effectiveness approach the project can demonstrate the benefit of the studied practice compared to other widely accepted "low cost" nutrient and sediment reduction BMPs. While some of the costs for other practices had to be accepted based on available models or earlier studies, the project made every attempt to use current (2017-2018) Lancaster County figures as a comparison.

For the BSR restoration analysis the project used current contractor practice data to determine what the contemporary cost of design, permitting, construction and monitoring/maintenance of a restoration project in the County would entail. The benefits of each practice were measured for their effectiveness if implemented today, not based on costs or pollution loads in 2009 when the BSR project was funded (fig. 3). It was the consensus of the grant participants that this conservative approach would more adequately provide policy makers and practitioners with a baseline for evaluating future conservation investment strategies. All practices' loads were modeled using CAST since it is the Chesapeake Bay Program's standard for crediting reductions. For legacy sediment restoration CAST has several limitations which creates a bias potentially limiting adoption of the practice and its benefits. These are discussed in the Conclusions, Findings and Recommendations segments of this report.

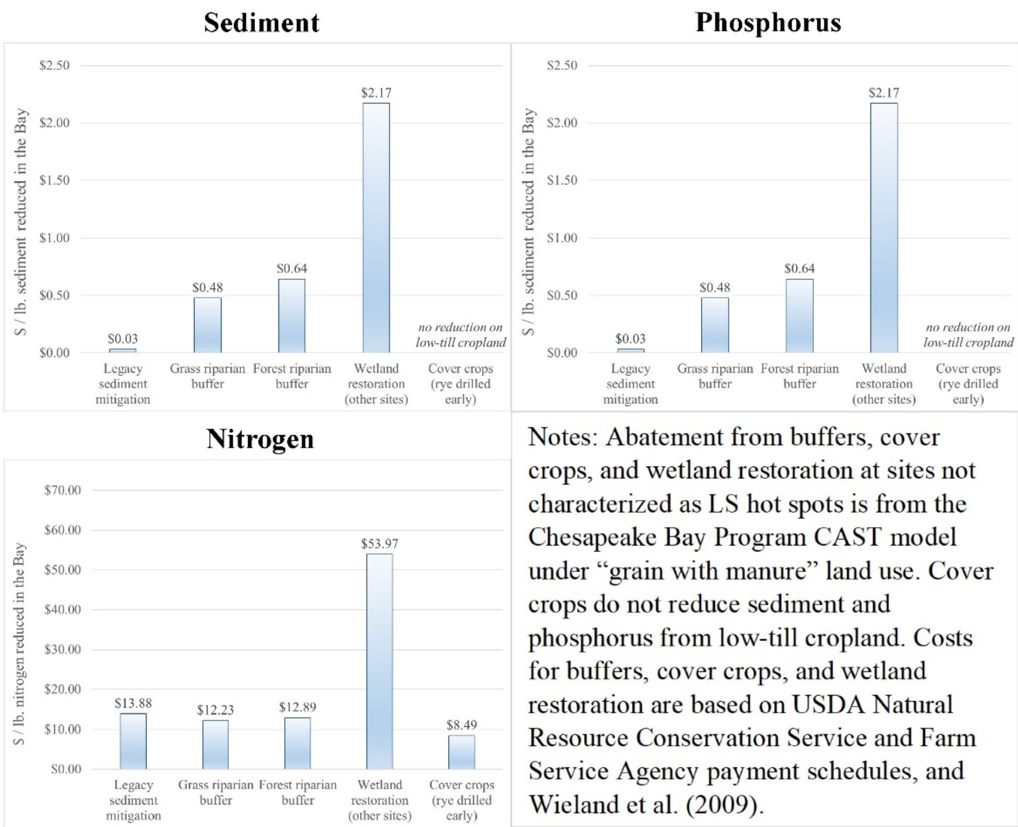

Figure 3. Cost effectiveness of abatement in the Chesapeake Bay watershed. Figure by P. Fleming.

Lidar technology and DEM differencing were key components of the project's mapping and prioritization process. Utilizing lidar data from early 2008 and late 2014 for Lancaster County our general approach was to evaluate changes in county stream banks over a 6.6-year time period. These changes enabled us to quantify amounts and rates of bank erosion during that time period (fig. 4).

We produced county-wide DEMs to evaluate stream bank erosion in the County's twelve watershed. We then calculated a difference raster for changes in elevation that occurred between 2008 and 2014. We performed a level of detection (LoD) change analysis at the 90% C.I. with a variable, roughness-dependent level of uncertainty. The county-wide detection provided a basis for our initial erosion hot spot ranking. This approach can be further refined at specific sites with photogrammetry from drone and field surveys and as new lidar data sets become available. Field surveys in several watersheds, particularly Chiques Creek and Mill Creek, provided on site data to further evaluate accuracy.

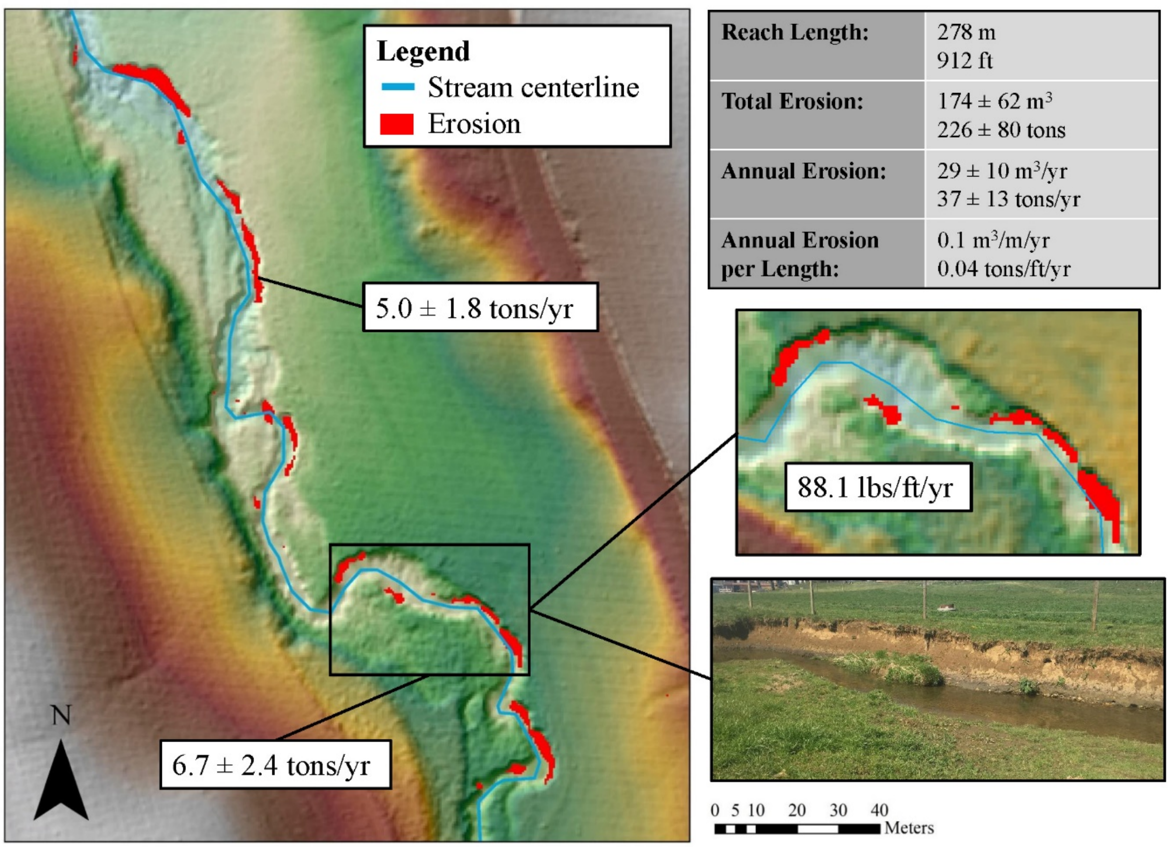

Figure 4. LiDAR-derived change analysis as a tool for remotely quantifying stream bank erosion through time. Field work is used to verify select sites. Figure by S. Sawyer.

The project supported (and WSI continues to support) change detection from DEM differencing, stream channel mapping, legacy sediment terrace mapping and quantification of stored sediment upstream of former milldams (fig 5). While all are important new enhancements of lidar technology for developing conservation strategies, terrace mapping is particularly useful since it provides practitioners and policy makers with a clear metric for assessing potential load reduction opportunities and pricing of appropriate BMPs. The project team continues to refine differencing techniques to improve the accuracy of its measurements and reduce uncertainty.

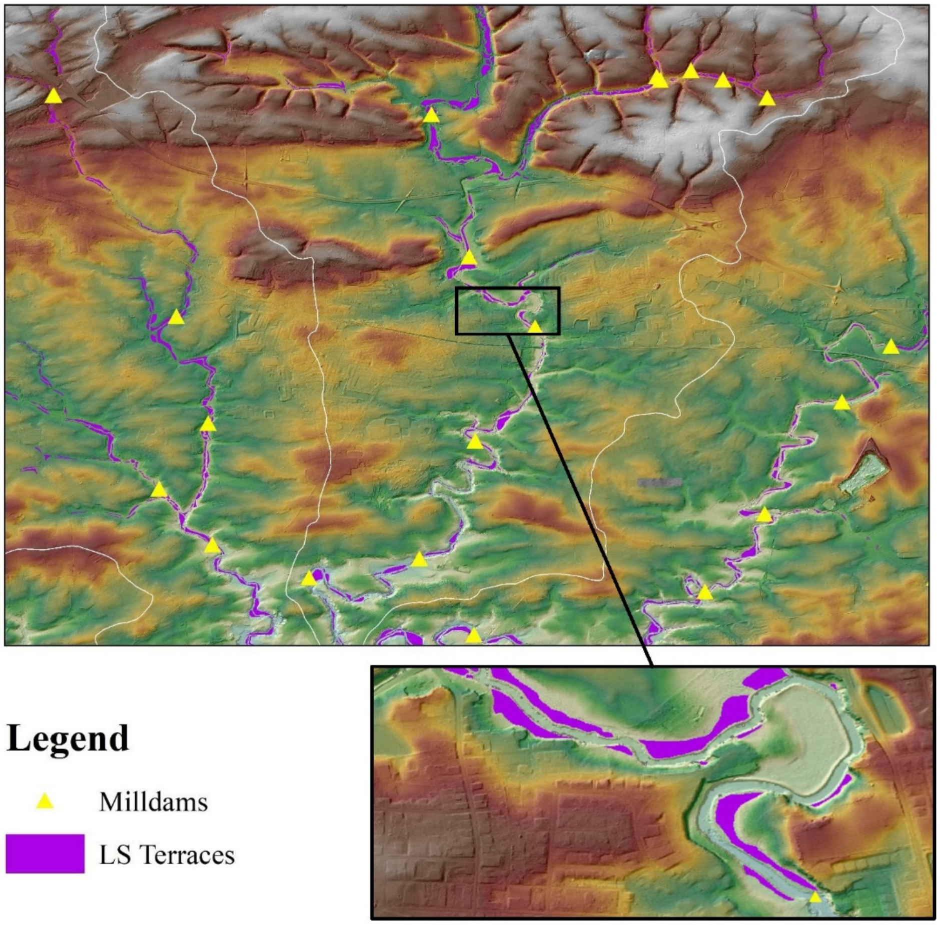

Figure 5. Mapped legacy sediment terraces provide valuable information about stored sediment, sediment load potentials, and applicable restoration methods. Figure by S. Sawyer.

The project had a wide range of discussions with soil brokers, contractors, composters and designers to determine the raw value of the post construction soil. Additional discussions were held with sod farm, landfill, golf course and composting operations to determine potential uses for the soil.   In Lancaster County it was determined that the value of reclaimed soil was $3-5 per ton subject to local market and product conditions. Soil value at that level in the supply chain is established by factors including the degree of rock and moisture, transportation, access and the nutrient, organic and mineral content of the product. We used the actual payment of $66,000 in our economic review - $3 per ton at 22,000 tons - to assign a value to the product. Subsequent information regarding the quality of this bottomland indicates that a $4-5 per ton cost is a fair current price in the local market. At this low end of the supply chain, if sold, LS would write down approximately 10-12% of a contemporary restoration project. These results were noted in the cost-effectiveness report of practices but not used as part of the evaluation of LS restoration costs in order to remain conservative in assessing the relative cost/benefit of each practice.

The project team did a further examination of processing the product for the retail market which would potentially enhance the value of the raw material. The project concluded that while a higher value may be achieved by enhanced marketing and/or blending it with compost, bio char or other natural supplements, the high cost of overhead associated with the retail process did not allow a restoration to achieve break even although in our projections the project costs were significantly reduced, perhaps by as much as 80-90%.

There are two significant caveats to consider in this analysis. The first is scale. Investing in the capacity to produce a higher value product requires reasonable capital requirements for processing the soil, contractual relationships to assure markets and adequate on-site storage for the raw and finished product. Only with a steady supply of excavated soil would it be economically feasible to develop this option. The second caveat is the lack of restoration opportunities. While the 22,000 tons of legacy impairment removed from the BSR site produced a significant environmental benefit it is an insignificant supply of material to develop the scale required for regular production of a higher value product for the commercial marketplace. In Lancaster County, during the two-year period of the project, only one similar restoration site was constructed, and another is now awaiting design and permitting. WSI continues to identify sites of similar potential to BSR for future LS restoration projects (fig. 6).

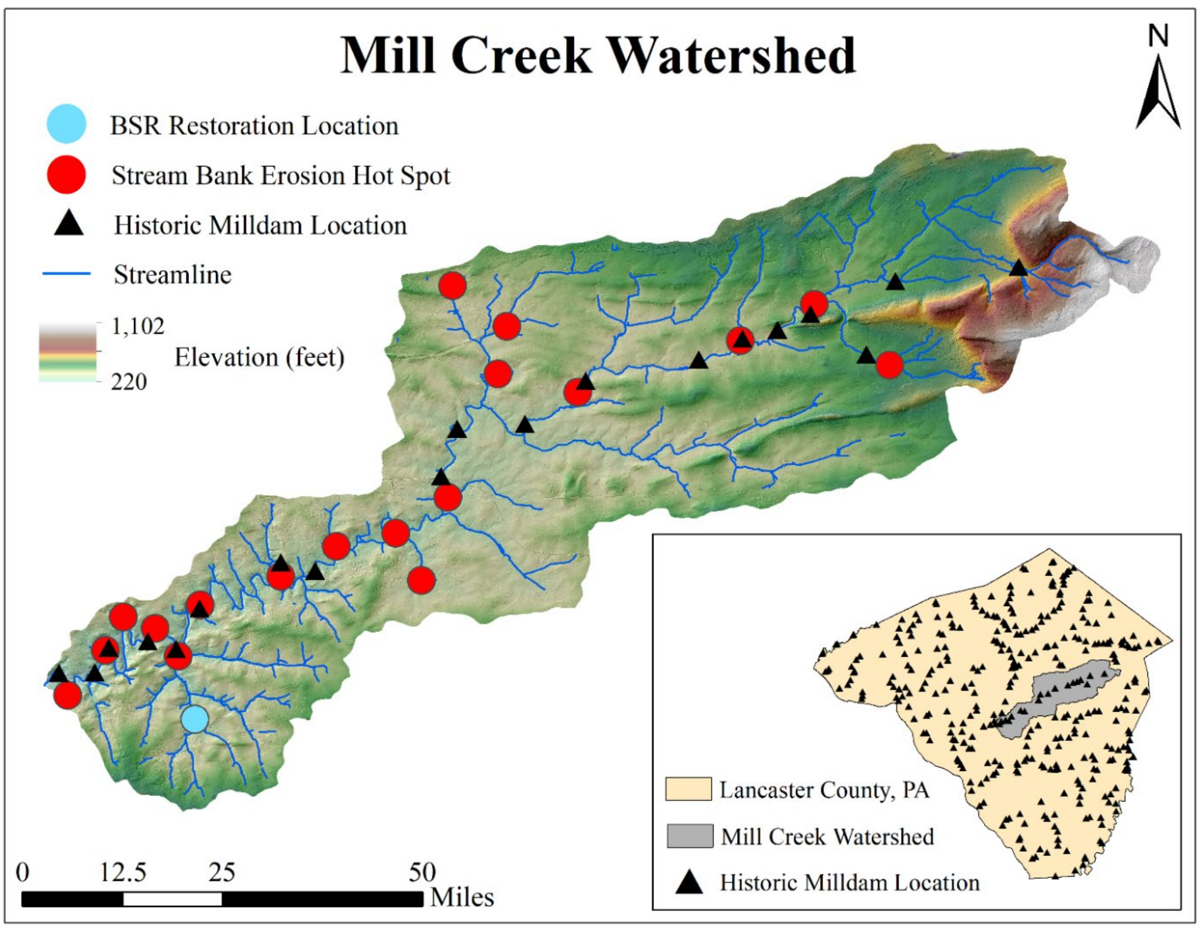

Figure 6. An erosion hotspot map of the Mill Creek watershed, where legacy sediment restoration projects, similar to BSR, could be explored. Figure by L. Lewis.

Our conclusion from this review is that a new combination of regulatory, policy, valuation and finance initiatives will help create a marketplace that allows LS restorations to be developed as break even or profitable initiatives.

In addition to the value of the soil the project team focused on two potential ways to create landowner incentives for restoration projects. The first is to recognize that the soil has a market value and as such could be donated and deducted for income tax purposes. The second is that as a result of this project's demonstrated cost effectiveness, the Pennsylvania State Conservation Commission, which administers the Resource Enhancement and Protection (REAP) program, determined that it was an eligible practice for up to $250,000 in state tax credits. These credits may be sold to third party investors or used by the landowner for their tax purposes for a period of up to seven years.

Using the metrics of the 4.7-acre BSR site a landowner could generate from $14,000 to $67,000 per acre in potential cash and/or tax benefits through a combination of these incentives. A larger site would likely produce a larger soil sale number while reducing the per acre tax advantage since the tax credit is capped. While not a part of this project's evaluation it may also generate additional income for nutrient and carbon reductions in addition to the value provided by a range of ecosystem services such as increased pollinators and decreased flooding.

Findings

Legacy sediment restoration is a cost effective and efficient method for reducing sediment and nutrient loads to local stream systems with the additional benefit of returning valley bottom ecosystems to their original functions. Compared to other common agricultural BMPs – including forest and grass buffer and cover crops - it provides a per unit (pound) cost reduction of 79-95% and 86-99% for Total Suspended Sediment (TSS) and total phosphorus (P). For Total Nitrogen (N) reduction, LS costs per unit are competitive and roughly equal to those of grass and forest riparian buffers under most agricultural land uses. Compared to all other practices, N costs are essentially equal when the sale of soil is considered in the analysis. As stated, to provide a conservative guide for policy makers we did not use soil sales in our report. Further, the annual benefits of denitrification and sediment storage in the restored area were not assigned reduction or cost values in the economic report although the latest EPA study determined that carbon sequestration was occurring at >7,000 pounds annually. Among the practices evaluated, cover crops were by far the most cost-effective practice for reducing N, but this practice is assigned no reduction value for TSS and P on low-tilled agricultural land in the CAST model. It is also important to note that LS restoration is the most land efficient BMP examined in our project. For example, to achieve the same restoration reduction results in CAST would require 497 (TSS), 1698 (P) and 23 (N) acres of forest riparian buffer. With Lancaster CREP payments in the $500-600 per acre range and program transaction costs, maintenance and landowner outreach significant cost centers of conservation program budgets, land efficiency is an important cost advantage for restoration projects.

Lidar differencing is a highly effective method for identifying, targeting and quantifying areas of erosion that contribute to high stream bank sediment loads. We determined that in many areas of the county hot spot load rates are likely to be substantially underestimated at the watershed scale due to limitations with the resolution of early LiDAR (e.g. the 2008 LiDAR for Lancaster County). Differencing results are more accurate for higher resolution data sets such as that available from 2014. In the future we will be able to compare 2014 data with recently acquired 2019 LiDAR data for Lancaster County to develop significantly improved accuracy. The project has created the format for policy makers, funding agencies and practitioners to "triage" sites with high nutrient and sediment loads and design conservation strategies to address their effects. As a result of our project significant advances in data interpretation, methodology and error analysis have been developed to provide a more effective and efficient use of human and capital resources. LiDAR analysis from our mapping can be used to site multiple BMP practices more effectively. This approach might be especially useful when combined with high-resolution flow path and wetness indexing data layers.

Conclusions and Recommendations

Legacy Sediment restoration is a scalable, cost effective, land efficient and sustainable approach that should be more widely adopted and recognized as a separate Best Management Practice distinct from traditional stream and wetland programs and crediting. USDA cost share programs and EPA Chesapeake Bay Program policies should be examined for opportunities to adapt funding guidelines to encourage the use of this practice. Legacy sediment restoration remediation should be recognized as a separate BMP by the Chesapeake Bay Program.

Legacy sediment research and restoration results need to be more widely distributed and funded to promote general acceptance of the economic and conservation benefits to landowners and local watershed health.

The effects of stream bank erosion and sediment terrace hotspots from dams and other historic watershed impediments are widely discounted as a significant source of sediment and attendant nutrient loading that affects both local water quality and larger TMDL challenges such as the Conowingo Dam strategy. This disconnect often targets resources towards less efficient and cost-effective upland practices with limited benefit to local and regional water quality goals.

A more effective approach to future watershed restoration strategies will strongly consider the role of "in stream" practices, and particularly LS restoration, as a primary driver of nutrient reduction and ecosystem service delivery when compared to other "low cost" alternatives. Development of targeted technological and science based comprehensive pollution mitigation strategies that include legacy sediment sites will provide practitioners and policy makers with a greater likelihood of successful high yield reduction outcomes.

Lidar and other technologies such as photogrammetry have transformed the ability of policy makers and practitioners to develop cost effective targeting of BMP opportunities. Investments in the continual updating of Lidar point cloud data and software analysis capabilities will provide enhanced opportunities to reduce costs and increase successful conservation outcomes.

Legacy soil markets are in their infancy and for the immediate future will be subject to the "spot" market driven by local opportunities. Creating a set of policy, regulatory and crediting models can substantially transform the practice to achieve a sustainable and profitable scale that can further reduce costs and incentivize landowners. Even at the basic level of individual projects the returns on small areas of highly eroding pasture and cropland are significant. Encouraging policies that promote sustainability and scale for this restoration practice has the potential to create competitive products and systems to more cost effectively promote conservation goals for local and regional water quality.

The removal of LS for restoration provides landowners and funders with a unique incentive to replace high erosion, low margin acreage with a sustainable alternative. These incentives, including soil sales and tax deductions, present the opportunity for direct, immediate economic benefits to landowners participating in restoration projects. Adoption of a watershed strategy of legacy sediment restoration projects could provide the basis for the creation of local economic development and reverse auction systems for landowner participation.

The rate and scale of delivered ecosystem services' benefits (stacked benefits) such as lower water temperature, flood storage, habitat and pollinator enhancement, carbon storage, denitrification, and improved local water quality need to be quantified and incorporated into the economic model to provide further understanding of the value provided by sediment mitigation and wetland system renewal.

The Chesapeake Bay Program CAST model and Stream Protocols need to be reviewed to provide a more accurate crediting of high load removal and restoration projects. Crediting for successful project implementation that recognizes the large and immediate pollution reduction from a restored site will provide the market incentives to more widely consider this practice. Crediting on an annual basis for a pollutant that has been immediately and permanently removed from the watershed is a disincentive to adoption and a disservice to taxpayers supporting clean water objectives. A practice that removes 25 years of pollution in one year should not have its benefits credited over 25 years.