<u>DAM REMOVAL FORUM PROGRAM</u>

May 17, 2022

Susquehanna River Basin Commission Conference Center

WELCOME!

This Forum is an opportunity for stakeholders engaged in removing, regulating, monitoring, and funding dam projects to discuss their professional responsibilities and promote a wider understanding of current dam removal practices, policies, and objectives. The Forum will primarily focus on the role of Pennsylvania practitioners in dam removal and examine how the Commonwealth's approach promotes local and Chesapeake Bay water quality goals. To support these objectives, representatives of local, state, and national organizations will provide their expertise with the overall goal of developing sustainable, cost-effective removal strategies that promote multi-layered environmental benefits.

The Dam Removal Forum is supported by funding to the Water Science Institute from the Pennsylvania Department of Environmental Protection's Growing Greener Program and the cooperation of the Susquehanna River Basin Commission. The Water Science Institute promotes innovative, sustainable, and science-based solutions in water conservation, restoration, and management through research and development projects grounded in the interrelation of water and its surroundings.

8:30am REGISTRATION

9 AM INTRODUCTIONS AND WELCOME

- Joe Sweeney, Executive Director, Water Science Institute
- Andrew Dehoff, Executive Director, SRBC
- Jeff Hartranft, Chief, Environmental and Geological Services Section, Bureau of Waterways, Engineering and Wetlands, Pennsylvania Department of Environmental Protection

9:15 – 10:15 AM

THE STATE OF DAM REMOVAL PRACTICE-PRESENTATION AND DISCUSSION

Review of current roles, responsibilities, and regulatory requirements of various government agencies in the administration and development of dam removal activities. The intent is to give participants an overview of the process and parties responsible for dam removal practice and policies; how they interact, and how they collaborate with other stakeholders.

1. PENNSYLVANIA DEP – ROLE OF THE COMMONWEALTH – REGULATORY AND RESTORATION

- Jeffrey Hartranft, Chief, Environmental and Geological Services Section, Bureau of Waterways, Engineering and Wetlands, PADEP
- Kirk Kreider, Acting Division Chief, Dam Safety
- Josh Fair, Water Program Specialist

a) Dam Safety and Encroachments Act and Title 25 Environmental Protection Chapter 105 and Chapter 102.

b) Dam Safety Program History and Resources

c) Dam definitions and Size and Hazard Categories

d) Regulatory Requirements-Engineering and Environmental

e) Regulatory Process

f) Application to Draw off water from Impoundment

g) Section 404 of the Clean Water Act

Questions and Discussion

10.15 – 11:30AM

DAM REMOVAL: MONITORING AND OUTCOMES

PRESENTATIONS AND DISCUSSION

Presenters will discuss current removal practices that contribute to and challenge local water quality goals. The focus is on how dam removal promotes biological, geomorphic, and natural aquatic resource potential through collaborative, natural, and sustainable, restoration approaches. Case studies will highlight environmental outcomes and challenges associated with removal.

- Dr. Dorothy Merritts, Franklin and Marshall College and the Chesapeake Watershed Initiative
- Scott Cox, Water Program Specialist, Licensed Professional Geologist, PADEP
- Jessie Thomas-Blate, Director of River Restoration, American Rivers

- Jeff Hartranft, Chief, Environmental and Geological Services Section, Bureau of Waterways, Engineering and Wetlands, PADEP

Questions and Discussion

11:30 AM– 12:15 PM Lunch Break

12:15 – 1:30 PM

DAM REMOVAL – STAKEHOLDER ROUNDTABLE

Dam removal has multiple objectives for stakeholders. This section will focus on stakeholder engagement in the process; why they participate, and where they think challenges and opportunities exist to improve dam removal strategies. The intent is for parties engaged in the removal process to understand practitioner motivations and concerns that promote desired environmental benefits.

- Jesse Thomas-Blate, Director of River Restoration, American Rivers
- Denise Coleman, State Conservationist, PA NRCS
- Jamie Shallenberger, Manager, Monitoring and Protection, Susquehanna River Basin Commission
- Dave Goerman, Water Program Specialist, PADEP
- Dr. Dorothy Merritts, F&M-Chesapeake Watershed Initiative
- Graham Boardman, GreenVest, LLC

Questions and Discussion

1:30 -2:15 PM

FUNDING SOURCES AND INCENTIVES TO PROMOTE DAM REMOVAL, FISH PASSAGE, AND RIPARIAN RESTORATION – ROUNTABLE PRESENTATION AND DISCUSSION

Agencies and other stakeholders have funding sources available for dam removal, post removal stream and floodplain restoration, riparian management practices, and improved stream recreational opportunities. Each has its own set of regulations, requirements and objectives which define, limit, or sometimes prevent collaborative partnerships and coordination among interested stakeholders. A better understanding of funder requirements may promote more collaborative, holistic and efficient resource allocations when planning dam removal projects. A related area is identification of incentives that could be developed to encourage private sector investment and incorporate nontraditional funding such as MS4 crediting, into current dam removal and restoration strategies.

- Denise Coleman, State Conservationist, PA NRCS - P.L. 566 Chiques Creek Watershed Project
- Jesse Thomas-Blate, Director of River Restoration, American Rivers - Federal Funding Programs Overview
- Graham Boardman, Greenvest, LLC Private Sector Perspective
- Dave Goerman or Jeff Hartranft - PADEP “In Lieu Fee”

Questions and Discussion

2:15 – 2:35 PM

WHITEBOARD BRAINSTORM SESSION

Breakout to gather ideas and suggestions from participants on how to enhance removal strategies and policy to maximize environmental outcomes.

2:35 – 3:00 PM

POLICY AND PRACTICE ROUNDTABLE DISCUSSION – WHAT WORKS, WHAT COULD BE IMPROVED TO MAXIMIZE STAKEHOLDER BENEFITS AND PROMOTE WATER QUALITY GOALS

Review of the Forum presentations and Brainstorm session to identify potential areas of collaboration to promote and incentivize policy and regulatory practices for sustainable dam removal and stream/floodplain restoration outcomes.

3:00 PM

FINAL REMARKS, NEXT STEPS AND ADJOURNMENT

For Immediate Release
6/11/2020

Contact: Joe Sweeney, Executive Director
717-579-2514

Water Science Institute's "Legacy Landscapes" Story Map Illustrates How Historic Dam and Land Use Practices Affect Lancaster County and the Chesapeake Bay Watershed

Lancaster, PA – The Water Science Institute (WSI) today officially released its latest education and research tool "Legacy Landscapes" to support Chesapeake Bay Watershed Awareness Week and ongoing water quality improvement initiatives throughout the region.

https://storymaps.arcgis.com/stories/e3e256312be94bae9ed9c3c98ba1b822 illustrates how historic dam removal and land use practices affect Lancaster County and the Chesapeake Bay watershed with an emphasis on nutrient and sediment releases and mitigation efforts to alleviate their effects on water quality. The map is part of the Water Science Institute's (WSI) examination of dam removal practices and policies with funding from the Pennsylvania Department of Environmental Protection's Growing Greener program.

Utilizing research from WSI and Franklin and Marshall scientists the project focuses on the current contributions of dam breaches to high nutrient and sediment loads using a combination of field investigation, academic analysis, lidar imagery, digital elevation modeling and drone surveys. The combination of historic and contemporary sources is integrated into a visual narrative demonstrating the significance of stream bank erosion that affects local and Bay water cleanup goals.

Pre and post removal examples trace the consequences of nutrient and sediment loads from the Susquehanna River flats of the upper Bay to their origins in current "hotspots" at the Conowingo Dam and in Lancaster County's Chiques Creek watershed.

Other highlights of the map provide viewers with aerial and scientific results of the Growing Greener funded Big Spring Run restoration and an accompanying synopsis of best management practice (bmp) cost effectiveness which together demonstrate the conservation opportunities that can be attained through well designed dam removal and restoration projects.

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PO Box 4095 Lancaster, Pennsylvania 17604 www.waterscienceinstitute.org

Bulk density and sediment particle size for legacy sediment sites

Robert Walter and Dorothy Merritts
WSI and Franklin and Marshall College

Bulk density: Bulk density, a measure of mass per unit volume (e.g., g/m^3) for unconsolidated sediment, is used to convert estimates of volume of sediment eroded (e.g., in m^3) to the weight of sediment that could become suspended load in a stream, e.g., in grams, kilograms, or tons. The weight of sediment is calculated as the product of volume and bulk density (e.g., g = m^3 * g/m^3). Of importance is the fact that bulk density includes the density of an aggregate of solid particles plus the pore spaces between the particles. For a soil or sediment, the particles themselves might have a particle density of 2.6 g/cm^3, but the aggregate bulk density might be only 1.2 g/cm^3 because the bulk density includes 50% void spaces that have volume but no mass.

Bulk density was calculated for 62 samples of legacy sediment collected from top to bottom of stream banks at 5 sites in York, Dauphin, and Lancaster Counties (#2, 3, 4, 5, and 6 in Table 1 below, with site location information). The average values of bulk density for legacy sediment at these 5 sites are

2. 1.05 +/- 0.10 g/cm^3, n = 15
3. 1.15 +/- 0.07 g/cm3, n = 31
4. 1.16 +/- 0.05 g/cm3, n = 9
5. 1.07 +/- 0.02 g/cm3, n = 4
6. 1.09 +/- 0.02 g/cm^3, n = 3

This range of mean values, from 1.05 to 1.16 g/cm^3, with small standard deviations, is consistent with sediment samples that are largely fine-grained in texture, less than 180 to 250 microns in diameter (i.e., fine sand, very fine sand, silt, and clay; see Arshad et al, 1996[1]).

Bulk density and particle size: The samples for which we calculated bulk density are mostly fine grained. Both bulk density and grain size were measured for multiple samples collected from top to bottom of legacy sediment stream bank outcrops for 4 of the sites listed above for which we measured bulk density (#3, 4, 5, and 6). The mean percent fines, defined here as <180 to 250 microns, for each of these 4 sites is as follows:

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[1] Arshad, M.A., Lowery, B., Grossman, B. (1996): Physical tests for monitoring soil quality. In: J.W. Doran and A.J. Jones(eds.) Methods for assessing soil quality, Soil Sci. Soc. Am. Spec. Publ. 49:123-142, SSSA, Madison, WI, USA.

3. 78 +/- 10% <180 microns, n = 31
4. 37 +/- 24 % <180 microns, n = 9[2]
5. 82+/- 19% <180 microns, n = 3
6. 58% <180 microns, n = 1

These grain sizes and their bulk densities are similar to those of silt loams, silts, sandy clays, silty clays, and clay loams on upland soils. Coarser grain sizes are likely to have slightly higher bulk densities, >1.4 g/cm^3, as is typical for sands and loamy sands.

The bulk density of legacy sediments exposed to erosion along stream banks is of little value if the banks contain a large proportion of sediment particles greater than fine sand in size, because sediment that is coarser is not likely to be carried far in suspension. Sediment that is most likely to be carried in suspension in mid-Atlantic region streams is the <250-micron (0.250 mm) fraction, which includes fine sand (125-250 microns), very fine sand (62.5-125 microns), silt (3.9-62.5 microns), and clay (<3.9 microns). In general, sediment <180 microns is the most likely to go into suspension in this region.

We measured grain size only (not bulk density) for an additional 253 samples from 3 sites (#7, 8, and 9, see Table 1 for site location information) in Lancaster and Cumberland Counties of PA, and Baltimore County in MD, as follows:

7. 99% +/- 1% <250 microns, n = 174
8. 81 +/- 26% <250 microns, n = 59
9. 63 +/- 7% <180 microns, n = 20

In comparing 7 sites for which we have grain size data for 297 samples (site # 3-9), all of which are legacy sediment from stream banks, the mean percent of the bank that is sufficiently fine to be carried as suspended load is 58% or greater, with only one exception (#4).

Given that the bulk density values that we have measured thus far are generally the same (1.05 to 1.16 g/cm^3, with small standard deviations), and that legacy sediment stream banks are generally but not completely fine grained, we conclude that particle size is an important measure that is essential to estimating potential sediment loads derived from stream bank erosion.

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[2] We note that the samples for #4, from the Paxton Creek watershed in Dauphin County, were from small tributaries in the hilly region of the northern part of the county, and are generally more sandy than other legacy sediment samples presented here.

TABLE 1. Bulk density and particle size data for legacy sediment in Lancaster, Cumberland, and Dauphin Counties, PA, and Baltimore County, MD, and for recently deposited sediment at the Big Spring Run aquatic wetland-floodplain restoration site in Lancaster County, PA

<u>Bulk density data only</u>

1. Big Spring Run, deposition on restored floodplain, Lancaster County, PA	Bulk density: 1.03 +/- 0.48 g/cm3, n = 19
2. East Branch Codorus Creek, upstream of breached milldam, York County (top to bottom at 160 cm, 2 sites)	Bulk density: 1.05 +/- 0.10 g/cm^3, n = 15

<u>Bulk density and grain size data</u>

3. Big Spring Run, Legacy sediment, Lancaster County, PA, pre-restoration (top to bottom at 110 cm at 3 sites)	Bulk density: 1.15 +/- 0.07 g/cm3, n = 31 Fines: 78 +/- 10% <180 microns, n = 31 Minimum % fines = 56%, Maximum % fines = 94%
4. Paxton Creek tributaries, Legacy sediment, Dauphin County, PA	Bulk density: 1.16 +/- 0.05 g/cm3, n = 9 Fines: 37 +/- 24 % <180 microns, n = 9 Minimum % fines = 16%, Maximum % fines = 92%
5. Chiques Creek upstream of Krady dam, Legacy sediment, Lancaster County, PA	Bulk density: 1.07 +/- 0.02 g/cm3, n = 4 Fines: 82+/- 19% <180 microns, n = 3 Minimum % fines = 62%, Maximum % fines = 98%
6. Indian Run, Legacy sediment, Lancaster County, PA	Bulk density: 1.09 +/- 0.02 g/cm^3, n = 3 Fines: 58% <180 microns, n = 1

<u>Grain size data only</u>

7. Big Spring Run, Legacy sediment Lancaster County, PA, pre-restoration (top to bottom at 13 sites)	Fines: 99% +/- 1% <250 microns, n = 174 Minimum % fines at site = 97% Maximum % fines at site = 100%
8. Mountain Creek, upstream of Eaton Dikeman Dam, Cumberland County, PA (top to bottom at depth of 275 cm at 3 locations)	Fines: 81 +/- 26% <250 microns, n = 59 Minimum % fines = 15% Maximum % fines = 100%
9. Little Falls, legacy sediment, Upstream of dam, Baltimore County MD, (top to bottom at 190 cm)	Fines: 63 +/- 7% <180 microns, n = 20 Minimum % fines = 47% Maximum % fines = 74%

Bank Erosion Rates from Lidar DEM Change Detection and Repeat Surveying

Robert Walter and Dorothy Merritts
WSI and Franklin and Marshall College

To date, we have prepared digital elevation models (DEMs) for 6 counties in our CIG 2 project (York, Dauphin, Cumberland, Adams, Franklin, and Lebanon) using two sets of lidar data, and stream centerlines for two of those counties (York and Dauphin). In addition, for all 6 counties we have made a new raster for the change that occurred between the dates of the older and more recent lidar data sets. This method of identifying change that has occurred is referred to as DEM differencing, and in the case of stream bank erosion we are measuring volume of change from lateral retreat of banks as they erode. The change raster provides polygons of areas of bank erosion, and volumes of change for each polygon.

For the 2 counties (York and Dauphin) for which we have developed stream centerlines of sufficient quality to evaluate stream bank erosion along the stream lines, we evaluated the spatial variability in annual bank erosion rates. Using a method known as neighborhood block statistics, we evaluate change as cubic meters of erosion in "neighborhoods", or adjacent areas of detectable change, during the period between dates of lidar acquisition. We calculate erosion initially as volume of change during the period of measurement, or m^3/yr, but can convert this volume to m/yr of bank erosion lateral retreat by dividing the volume of erosion over the length and average height of the eroding bank at that location. In this way, we can compare erosion rates for areas with different bank heights.

We find that erosion "hotspots"—places of unusually high bank retreat rates—are eroding at rates of about 0.1-4 m/yr. For these rates and a bulk density of 1.1 g/cm^3, banks that are 1 m in height would produce ~1.1 to 4.4 tons of sediment per meter of stream length per year. Banks that are 2 m in height, in contrast, would yield 2.2 to 8.8 tons of sediment per year. As discussed below, the only locations with higher rates of bank erosion are those where a dam was removed within the past few years, or where some other channel disturbance has occurred (e.g., culvert lowered, low bridge removed, or tree fall led to scour). We have found that the bank heights in these counties generally range from 0.5 to 3 m, but on average are about 1.2 to 2 m in height. Only at a few locations, typically where milldams were unusually high, are banks >3 m in height.

Bank height and lateral erosion rate matter greatly when estimating volume of sediment eroded by bank erosion. Higher banks produce more sediment when eroded, and higher rates of lateral erosion produce more sediment. As a consequence, the greatest loads of sediment from bank erosion tend to be where banks are both high and eroding rapidly. The interplay of these two factors is shown in Figure 1, in which we plot the range of lateral bank erosion rates that we have measured from a combination of lidar DEM differencing and repeat surveying with GPS and drone technology. For example, if a bank height is 2 m and its bank erosion rate is 1 m/yr, then from Figure 1 we can determine that 2 m^3 of sediment is eroded from that bank per m of channel length per year. Depending on the bulk density and grain size of the bank sediment, tons of sediment can be calculated from this eroded volume.

This diagram illustrates an important finding in our work. Given the range of bank heights (usually 0.5 to 3 m) and erosion rates (usually 0.1 to ~5) that we have measured in this region, the typical range of erosion volume estimates at locations where bank erosion occurs is 1 to 8 m^3 per m of channel length. If the bank height is 1 m, this range corresponds to a bank retreat rate of 1 to 8 m/yr. If the bank height is 2 m, it corresponds to a slower retreat rate of about 0.5 to 4 m/yr. In other words, a bank that is 2 m high produces twice as much sediment as a 1-m high bank for the same lateral bank erosion rate.

Lower erosion rates of 0.05 to 0.1 m/yr still produce relatively large amounts of sediment with time. For example, a site with 2 m banks eroding at 0.1 m/yr would produce 0.2 m^3 of sediment per m of channel length, or about 200 m^3 of sediment over a distance of one km of stream. For a bulk density of 1.1 g/cm^3, this would yield ~220 tons of sediment from bank erosion per year for a km of stream, and 2200 tons over a decade.

For select locations within these 6 counties and Lancaster County, our ongoing repeat surveying with benchmarked cross sections and drone flyovers (for photogrammetry) provide annual estimates of bank erosion volumes and, in particular, the ability to determine whether or not bank erosion rates diminish with time after dam removal, as we have found at other dam removal sites (Fig. 2).

After the Krady milldam removal on Chiques Creek (3rd historic milldam upstream from mouth) in July 2018, we measured approximately 1680-2730 m^3 of bank erosion of 2.1-m high banks of legacy sediment over 210 m of channel length from July to December, 2018. Our methods combined pre-dam removal bathymetric surveys and post-dam removal laser level surveying. The average bank erosion rates were ~4-9 m/yr, typical rates that we have gotten for other sites where dams were removed within the previous 5-10 years (see Figure 1). Using a bulk density of 1.1 g/cm^3 yields an estimate of 1866-3033 tons of sediment eroded into Chiques Creek along this 210-m stretch during this ~0.5 yr period.

From April to May 2019, we measured via repeat GPS surveying another >70 m^3 (~77 tons) of bank erosion along a relatively short distance of ~20 m at a portion of the bank undergoing rapid slumping due to undercutting from the lowered water level (Fig. 3). At this site located ~400 m upstream of the breached dam, the 2.1-m high bank eroded laterally ~4 m in just 0.1 yrs, indicative of the spatial and temporal variability of bank erosion that is associated with channel response to water level lowering after dam removal. Bank erosion at this location is associated with recent breaching of a debris jam that had formed at the channel constriction just prior to dam removal. This debris jam can be seen at left in Fig. 3. Water level lowering from milldam removal enabled the channel to cut down beneath the 2.1-m bank and then erode laterally to breach the debris jam. As a result, a new wave of bed incision and bank erosion is occurring upstream along the former millpond reservoir sediment for at least another 400 m.

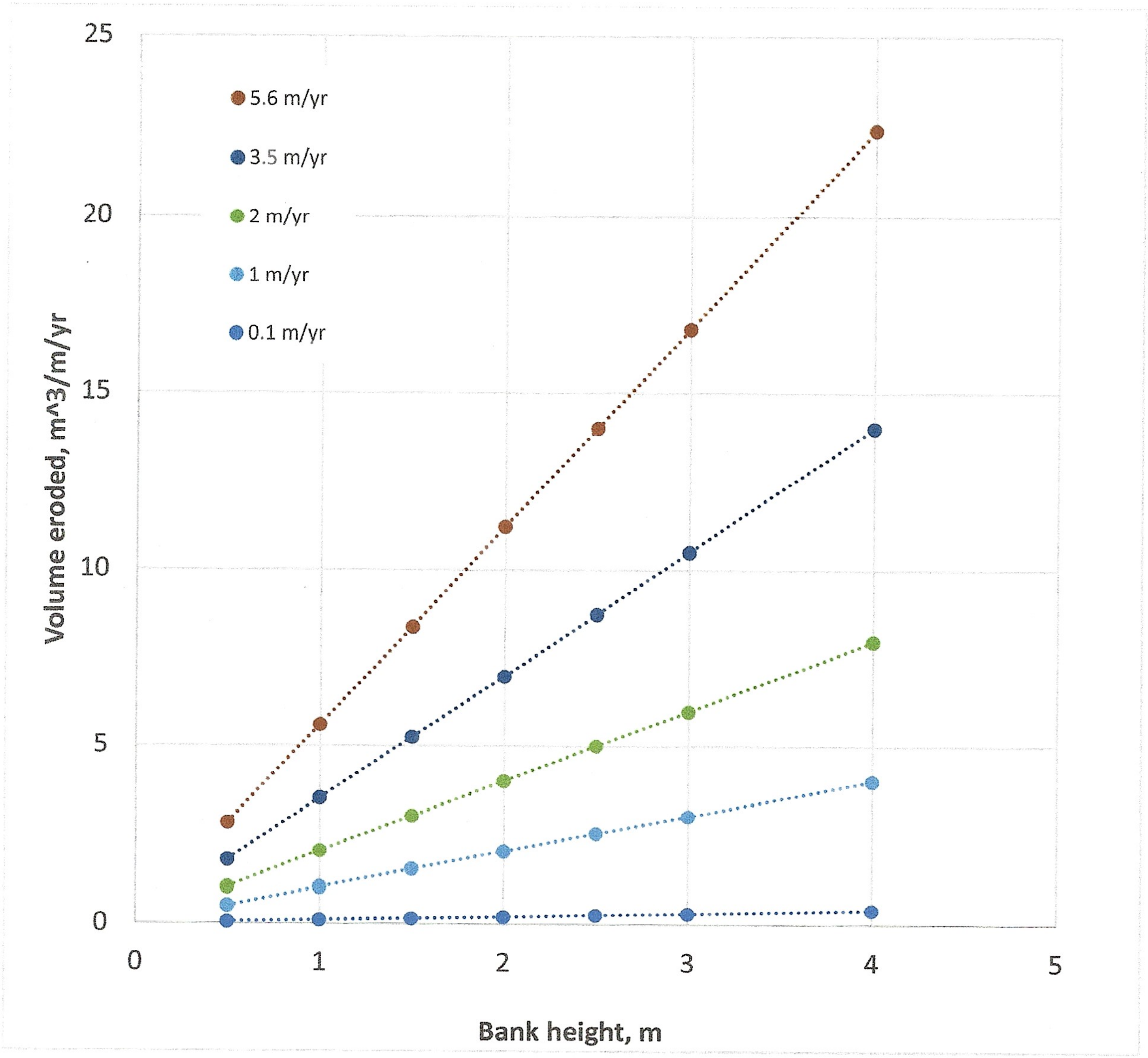


Figure 1. Volume of sediment eroded per meter of length along a channel by bank erosion plotted on y-axis, in units of $m^3/m/yr$ for different bank heights (x-axis) and lateral bank erosion rates (slope of different colored lines with corresponding colored dots).

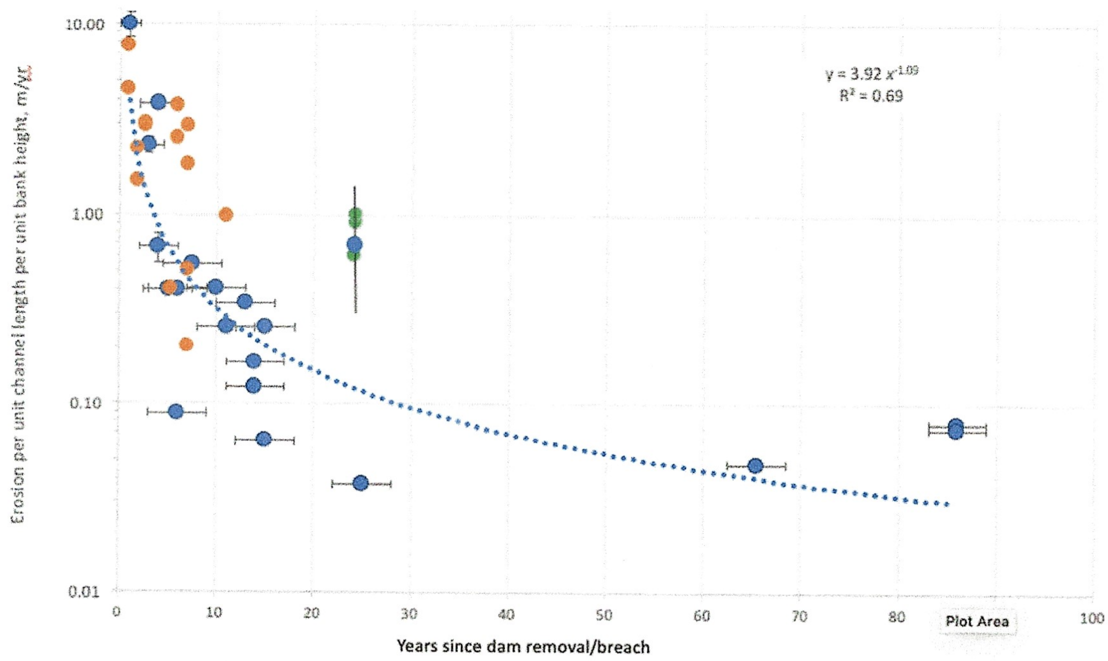
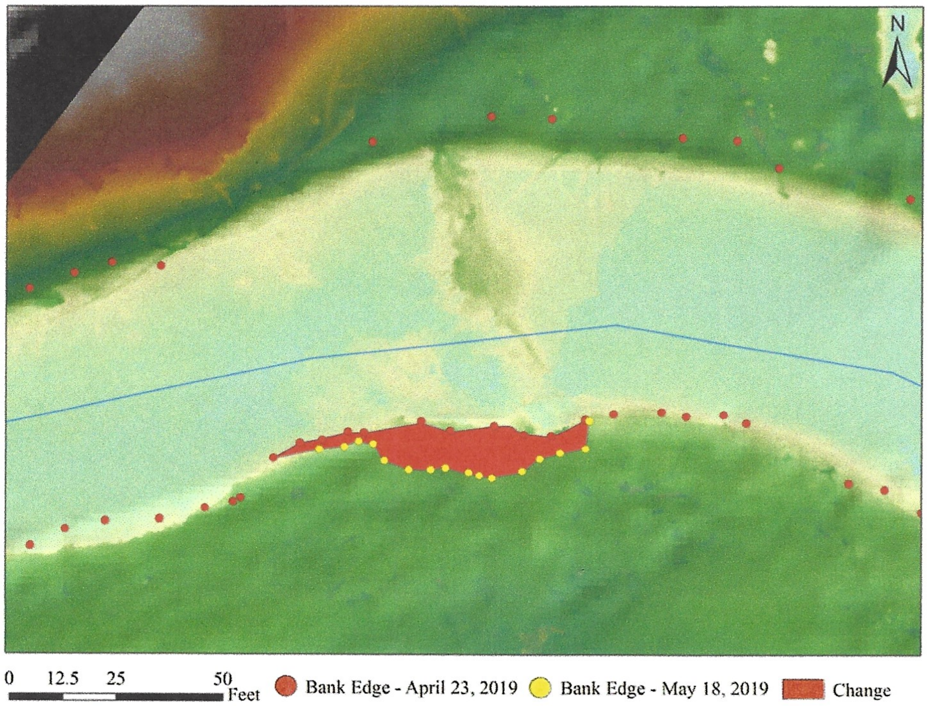


Figure 2. Survey data (orange and green) and lidar dem differencing (blue, from 2008-2014 data sets) erosion rates per unit bank height for 19 breached reservoirs in multiple watersheds throughout Lancaster and Cumberland Counties. Note that our erosion estimates from both surveying and dem differencing are similar. The uppermost blue dot at left represents the highest erosion rate measured upstream of the Krady milldam removal on Chiques Creek.

(a)



(b)

Fig. 3. (a) Repeat GPS surveying (red and yellow circles) along Chiques Creek upstream of the Krady milldam that was removed in July 2018. The dam was located ~400 m downstream, and its removal resulted in newly exposed high banks of former reservoir (i.e., millpond) sediment, as shown for the left bank as viewed upstream in (b). This location is about midway along the red polygon indicates recently eroded legacy sediment in Fig. 3a. Note person and 3-m-high stadia rod for scale at center of photo.

Figure 1: View of Roller Mill Dam with stored sediment.

Phase 3 WIP; Legacy Sediment, Dam Removal and Threats to Water Quality in Lancaster County

DEP Growing Greener Grant Final Report

Submitted by: Joseph V. Sweeney, Executive Director

Water Science Institute

C990000663

May 24, 2022

Phase 3 WIP; Legacy Sediment, Dam Removal and Threats to Water Quality in Lancaster County

FINAL REPORT

Narrative Description

<u>What was the project supposed to accomplish?</u>

The project was designed to examine the effects of dam removal in the Chiques Creek Watershed of Lancaster County, Pennsylvania and develop data and discussion on how to better accomplish water quality goals related to the Commonwealth's Phase 3 Watershed Implementation Plan (WIP).

<u>What was accomplished and how does it differ from the plan?</u>

The project developed field data thru site surveys, soil analysis, UAV flights, and game camera footage. Extensive discussion and review of existing and proposed dam removal projects was initiated with stakeholders to develop a baseline for areas of collaboration on dam removal. The field collection and collaborative discussion were organized into three separate deliverables: a joint paper authored by Franklin and Marshall College with data from the Water Science Institute Growing Greener project, (WSI); a story map entitled Legacy Landscapes; and The Pennsylvania Dam Removal Forum hosted at the Susquehanna River Basin Commission Conference Center. All deliverables are on the WSI website and have been made available to other stakeholders and interested parties upon request.
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The plan had originally called for the hosting of 6 webinars to be produced by the project which, with the permission of DEP, was modified to develop the Dam Removal Forum. This change was driven by the Covid pandemic health safety protocols instituted by the Commonwealth and other stakeholders and the nearly 50 % reduction in funding requested in the original application.

What were the successes and reasons for success?

Overall, the deliverables were successful compilations of the acquired data that allowed the project to communicate its findings to general and scientific audiences. The project approach was to accept that every stakeholder had a valid interest in dam removal and no one outcome was necessarily better than another. However, it is understood that dam safety concerns are a priority for regulators that may justify removal regardless of other potential environmental benefits or consequences.

What problems were encountered and how were they handled?

Managing a remote workforce and coordinating with other stakeholders during the pandemic was the main challenge. Health protocols restricted travel and data acquisition during portions of the project and placed additional burdens on field research and administrative staff who were required to reconfigure schedules for remote communication. The reduction in project funding challenged the team's research and communication schedule which was exacerbated by the pandemic. Despite these challenges the project was able to develop additional field research that allowed the team to continue its outreach and education goals.

How did the project contribute to solution of original problems?

Previous research, supplemented by project data and heightened awareness of dam removals in the watershed, highlighted that significant erosion was occurring over long periods of time following removal, not just from the initial channel sediment release, but from bank retreat that followed lower stream levels. Because the project occurred during a period of actual removals, various stakeholders had begun communicating their knowledge of stream conditions following removals. Often this was the result of active investigation of dam removal sites but in at least one instance a dam was intentionally breached with limited communication with stakeholders. The result was the loss of water quality monitoring equipment and concern about a Log Perch restoration project which were directly impacted by the large release of channel sediment following the breech. Discussion among stakeholders following this event led to the recommendation that subsequent dam removals incorporate an "alternative analysis" into dam removal projects to determine the long-term effects of sediment release, identify potential downstream impacts, consider investments in floodplain restoration and habitat improvement, and develop cost effectiveness scenarios to fund alternatives. That recommendation is now being implemented at the Roller Mill dam site.

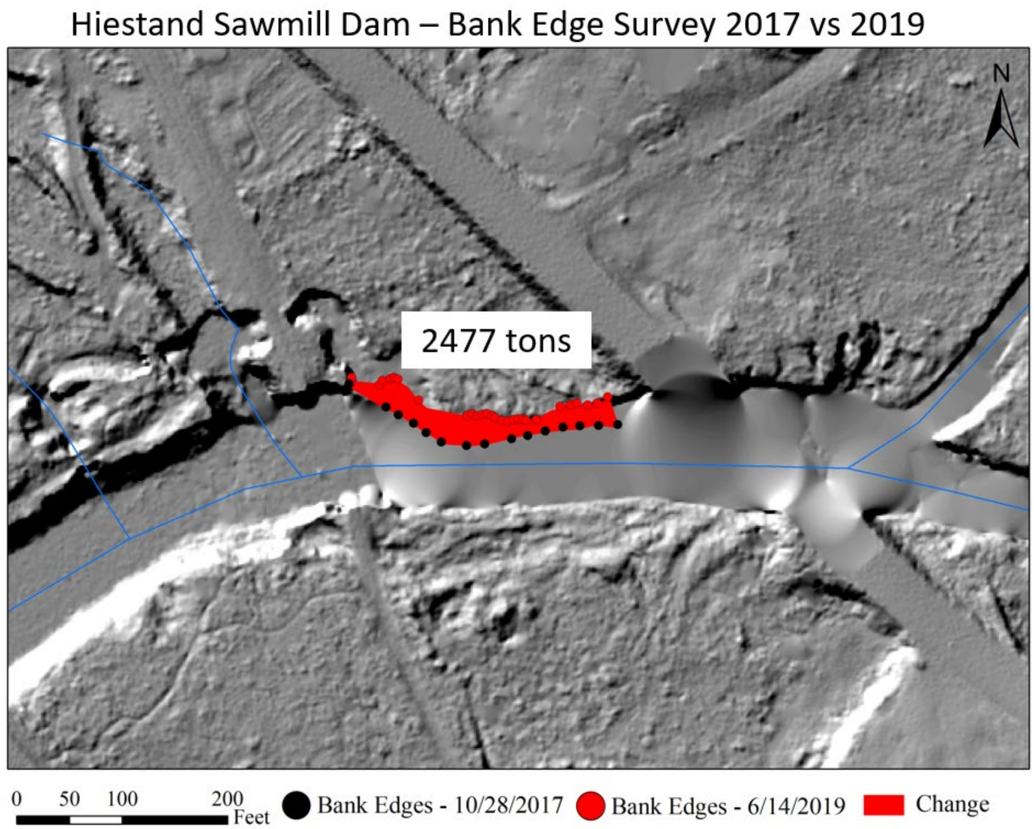

Figure 2: Erosion mapping with Digital Elevation Model differencing

What else needs to be done, and what additional efforts are underway or planned?

The alternative analysis recommendation has been complimented by additional efforts that are contributing to the development of a more comprehensive removal policy. Awareness among stakeholders has substantially increased and led to greater engagement with dam removal professionals and funders. Pa DEP, the Natural Resources Conservation Service (NRCS), the Susquehanna River Basin Commission (SRBC), academic institutions and local officials have contributed personnel, funding, research, equipment, and regularly participate in stakeholder discussions. PADEP has taken the lead in reviewing dam removal practices with the goal of promoting a wider range of beneficial environmental outcomes. NRCS has increased its financial and technical support of dam removal practices, recognizing that investment in upland conservation practices is being offset by short- and long-term sediment loading following breaches.

Municipal officials and the Lancaster Clean Water Partners (LCWP), the coalition of county organizations responsible for implementing the local TMDL reduction strategy, have suggested that crediting for dam removals be considered by the Commonwealth and the Chesapeake Bay Program. This approach has been precipitated by two contradictory requirements of the Chesapeake Bay WIP: MS4 permitting and the proposed Conowingo Dam TMDL. Municipalities are increasingly frustrated that they're investing large sums of taxpayer dollars into sediment reduction/prevention programs while a permitted dam removal in their jurisdiction/watershed can annually release thousands of tons of sediment and nutrients. The LCWP, in written testimony commenting on the proposed Conowingo Dam TMDL strategy, expressed concern that resources could potentially be diverted from existing sources to address the Conowingo storage capacity issue while tens of thousands of tons of sediment were being mobilized in county watersheds by current and past dam removal practices.

The Water Science Institute recently convened a forum (see attached program) to discuss the current state of dam removal that focused primarily on the Chiques watershed but with lessons applicable to other removal projects. A list of areas for future examination and discussion was developed by conference presenters and participants (attached w audio of session on WSI website) and there was general agreement that follow up discussion and additional stakeholder participation would be useful.

What are the plans for disseminating the project results?

Project deliverables have been released as they are produced. The Chesapeake Bay Program and the Pennsylvania Environmental Digest published the release (see attached media advisory) of the Legacy Landscapes story map which remains available on the Institute's website. Several reports using WSI project data and personnel have been produced and are available on the WSI website as are most recordings and presentations from the May 17, 2022, Forum. The project presented at numerous venues, provided regulatory and policy comment, conducted dam site tours, and was the subject of several media stories on dams and dam removal.

How well did spending align with the budget request?

We spent considerably more to produce the project deliverables largely because of the pandemic induced time constraints and the budgetary modifications required by the reduction in the original funding request.

pennsylvania
DEPARTMENT OF ENVIRONMENTAL PROTECTION

COMMONWEALTH OF PENNSYLVANIA
DEPARTMENT OF ENVIRONMENTAL PROTECTION
CHESAPEAKE BAY OFFICE

Growing our Economy
Growing our Communities
Growing Greener

Growing Greener Watershed Protection and AMD Set-Aside Goals & Accomplishments Form

This form represents *(choose one)*:
☐ Project Goals
☒ Project Accomplishments *(to be submitted with final report)*

Project Title Phase 3 WIP: Legacy Sediment, Dam Removal and Threats to Water Quality in Lancaster County

Application ID # W535992 **Contract #** C990000663

Grantee Water Science Institute **Grant Amount** $60000

County Lancaster **Municipality** ____

Is this project located within the Chesapeake Bay watershed? ☒ Yes ☐ No

Partners:

Partner Name* *(Add additional rows if needed)*	**Role**	**Organization Type**	**Match Amount**	**Cash or In-Kind**
		Choose an item	$	
		Choose an item	$	
		Choose an item	$	
		Choose an item	$	
		Choose an item	$	

*Do not list individual volunteer or private landowner names.

Education Project/Outreach

Schools reached	NA	number
Children reached	NA	number
Adults reached	200	number
Brochures distributed		number
Newspaper articles	2	number
Radio/TV spots		number
Magazines		number
Website hits		number
Training sessions held		number
Training session attendees		number
Workshops held	1	number
Workshop attendees	40	number

Describe activities not defined completely by above selections:

The project developed a story map incorporating many of the research data sets, supported a report on dam removal consequences and related legacy sediment research, led tours of dam removal sites, provided information on dam removal activities, commented on dam removal policies with regulatory and Chesapeake Bay Program personnel and organized an all day forum on dam removal subjects with reports and presentations posted to the Water Science websites

Challenges & Opportunities 1

- Infrastructure Mapping
- One Call
- Fish Passages/dams/culverts
- More PMs
- REAP tax credits for LS
- Lack of consistent design standards & terminology
- Market Demand
- Soil transportation/ disposal

- Resarch & Monitoring on Erosion
- Cross-Program Coord.
- Inter-agency task force
- ↑ Stakeholder involvement
- ↑ stakeholder incentives
- MD → tree protection
- Bay model credit
- Protection more important than impairment recognition
- Finding good sites

Report prepared for American Rivers by Dr. Dorothy Merritts and Dr. Robert Walter, Franklin and Marshall College, with input from research of Michael Rahnis (Franklin and Marshall College), and Logan Lewis, Shelby Sawyer, Evan Lewis, and Sam Feibel of the Water Science Institute, February, 2020.

NOTE: Readers can skip to #2 below if they want to know only specifics about the Roller Mill dam. However, much of what is in item 1 is of relevance to removal of the Roller Mill dam and its likely aftermath.

Our research is regional, including parts of Pennsylvania and Maryland, where we have been collecting historic records, maps, and photos of mills and dams along dozens of streams in Pennsylvania and Maryland since 2002. We began investigating the Chiques Watershed over ten years ago, but it became a primary area of focus for us in 2017 after removal of several dams in the watershed. Since the Roller Miller dam became a high priority for possible removal, we have increased our efforts to gather information on this site.

Our overarching research goals are to document and quantify:

- Where historic dams exist and when they were built
- How much historic sediment is stored in valleys,
- How rapidly that sediment is eroded as a result of dam breaching and or removal,
- The processes that cause erosion,
- The nature of the streams and floodplains that existed before historic damming, and that now are buried under historic sediment.
- The age and origin of the stream bank sediments and their composition (including but not limited to bulk density, particle size, nutrients, trace metals, and fallout radionuclides).

In addition to using historic records, surveying, and lidar, we install game cameras at specific field sites--including along the Chiques--to achieve all of these goals.

1. For the Chiques watershed (including the Roller Mill dam), we have determined the following:

    - At least 54 historic dams were built along the main stem and tributaries of the Chiques since 1720, and most were built before ~1880 (Figure 1). We think an unrecorded dam also existed between dams 3 and 4 on the main stem, given our mapping of historic sediment in that reach and a bridge named after a mill.
    - Most of these milldams were roughly 8 to 14 ft high.
    - Historic maps and other documents clearly indicate that the original millponds were large and backed up water for at least 1 km from the dams, even into adjacent tributaries, especially in the lower reaches of the Chiques watershed where stream gradients are very low. Our longitudinal profile of the Chiques water surface AND legacy sediment

terrace surfaces from 2014 airborne lidar shows extreme backwater effects, especially for the 10 dams on the lower Chiques south of the Furnace Hills in the headwaters.

- We have mapped historic sediment terraces--the subplanar benches adjacent to the stream--for the entire Chiques watershed, with exception of a few small, steep headwater tributaries (see Figure 1).
- Each millpond reservoir stores about 50,000 to 150,000 tons of historic (aka legacy) sediment.
- From grain size analysis we have determined that most historic sediment in these millponds, including the Roller Mill dam, is fine grained and dominated by silt. Silt is the primary component of silt loam soils--the most common soil type in the region--on hill slopes, and the hills were the source of sediment to millponds during two to three centuries of erosion.
- Once dams breach or are removed, the streams cut down to the level of the original valley bottom, typically the groundwater table, unless local grade control structures or remnants of dams exist. At the Krady mill dam removal site (third dam upstream on the mainstem in Figure 1), for example, banks were <1 m high before dam removal, when water was slowed, but are now >3 m high for ~1.5 km upstream. Furthermore, sediment, leaves, etc that had been in the channel with low water velocity before dam removal formerly buttressed the banks of older legacy sediment (the early 20th c. Krady dam was lower than original 18th c. dam and hence legacy sediment terrace), but that buttress now is gone.
- The silty historic sediment that dominates banks after dam removal is cohesive and has substantial strength, especially during summer months when dry. This enables banks to remain nearly vertical even as bank erosion occurs.
- Beneath the silty historic sediment we find the following, from oldest to youngest:
  1. Bedrock.
  2. Pebbly to bouldery colluvium on the toe of slope that is Pleistocene and periglacial (freeze-thaw from times of permafrost during ice ages) in origin. This usually is poorly sorted and matrix supported, and originated from hillsides through mass movement (slumping and earthflow type processes as permafrost thawed).
  3. Holocene (~11,000 yrs to present) hydric soils in lowest parts of valley bottoms, at and near the level of the groundwater table, are formed on top of the Pleistocene (>11,000 yrs BP) rubble.
- Only eight of the 54 dams (15%) in the Chiques remain unbreached. Roller Mill dam is one of these eight.
- Four of the 54 known dams in the Chiques were removed since 2013, with two of those on the main stem (dam 1 at the mouth, Heistand saw mill, removed 2015, and dam 3, Krady mill dam, removed in 2018; see dams on Figure 1) and two on the Little Chiques near and upstream of Mount Joy (SICO removed in 2015, and Cove Outlook Park removed in 2019).
- We observe extremely high erosion rates and sediment yields one to two years after dam breaching, and are most pronounced for the sediment within the wetted area of the impoundment. However, we emphasize that background bank erosion rates remain high and sediment loads are substantial for decades to centuries.

- Just after dam breach we observe that wet stream bank sediment slumps and oozes readily, and is easily washed away. At the Krady dam removal site (removed in 2018, for example), the amount of sediment released in the first year was >>5,000 tons; frequent large storms soon after dam removal probably enhanced this situation, but we have documented similar processes and rates elsewhere.
- We have quantified the changing erosion rates with data from dozens of dam breach sites in the region, including at the Krady mill dam site (removed in 2018) downstream of the Roller Mill dam. Erosion of historic sediment upstream of breached dams with silty reservoirs is rapid in the first few years after dam removal and diminishes thereafter, but remains relatively high for several decades because of the importance of freeze-thaw and needle ice processes in the winter, and because of bed incision and lateral meander migration that result in undercutting of high banks (see Figure 2 of the Chiques 1.5 years after the Krady dam removal, for example). Undercutting of the banks upstream of the Krady mill dam, for example, is leading to active slumping, other types of mass movement, and extensive dropping of whole live trees into the stream channel.
- Given our analyses of multiple sites, we are able to predict bank erosion rates after dam removal with confidence, if passive sediment release is the option selected. We are willing to work with American Rivers, PA Fish and Boat Commission, and other interested parties to provide specific predictions of the loads (and rates) of sediment and nutrients that we predict would emanate from bank erosion along Chiques Creek at the Roller Mill dam site if passive sediment release is selected.
- At the Krady dam removal site, the channel has cut through the historic sediment and the underlying Holocene hydric soils in several places, and now has begun eroding into Pleistocene rubble (see Figure 2). The organic-rich dark Holocene soils contain seeds of sedges that indicate an obligate wetland environment. We predict that the first sand and gravel bars will begin to form this year now that the stream has access to this gravel underlying the Holocene wetland soils. Gravel bars tend to steer and direct flow to opposite banks, and will likely accelerate bank erosion locally.
- Beneath the Pleistocene and Holocene sediment is highly fractured limestone bedrock with numerous springs. Flow from these springs--now that they are exhumed since dam removal and bank erosion--is substantial in places.

2. For the Roller Mill dam specifically, we have determined the following:

- The Roller Mill dam is the 7th known historic dam on the main stem (see Figure 1).
- The earliest dam for water-powered milling at the Roller Mill site was built in 1729 or 1730.
- This mill site was described in “Historical papers and addresses of the Lancaster County Historical Society 1896”, as follows: "Above Barr's mill at the crossing of the old Paxtang and Conestoga road Samuel Scott located and built a Grist and Saw Mill on the west side of the creek about the year 1729 or 30; after the above road was built, in 1732 he built an Ordinary, which became a famous tavern during the French and Indian wars, and during the Revolutionary period. When the officers and troops marched to join

Braddock's and Forbes' armies they invariably halted at Scott's tavern to dine, it being a convenient distance from Lancaster."

- The backwater effects, based on our mapping and field analysis of historic sedimentation, extended at least 2.5 km upstream.
- The amount of historic sediment stored between the dam and the bridge on Rt 283 is likely to be about 40,000 to 50,000 tons. Another ~50,000 tons or more is likely to exist upstream of the Rte 283 bridge over a distance of about 2 km, but the legacy sediment thins upstream and laterally to valley margins.
- Bob Walter at Franklin and Marshall College currently is analyzing historic sediment from the Roller Mill dam site for nutrients, trace metals, and fallout radionuclides. In the future, we can provide this data upon request.
- The first Pennsylvania state record of the dam, identified by the state as D36-198, is from a June 17, 1919, inspection. The standard Form 22 REPORT ON SMALL DAMS that was used by the precursor to the current PA Dam Safety Program and identifies C.F. Bacon as the owner. The purpose of the dam was water power for a flour mill. At the time, the dam was 10 ft high, which was higher than the modern dam. It was described as 10 ft high by 130 ft wide, with an "earth embankment with drywall on downstream side" & "dry masonry timber crest spillway 80 ft long."
- The Roller Mill pond was described in 1919, when the dam was 10 ft in height, as having "a considerable amount of sediment in it".
- The Roller Mill dam was rebuilt at least once, in 1930, and the spillway was lowered about 2 feet. A permit for this work was issued on July 12, 1930, to the Frey brothers. Although a blueprint was submitted for the proposed work, a photo taken on October 10, 1930 shows that something different was done for the repairs. Instead, it appears that the spillway was lowered in elevation and capped with concrete. We view this lowering as the reason that a slightly elevated bench of historic (legacy) sediment exists ca. 2-3 ft above and along both sides of Chiques Creek upstream of the dam.
- Another repair permit for the Roller Mill dam was issued by the state in 1938 and accompanies a photo. This repair permit notes that the right abutment is 38 inches above the spillway crest and the left abutment is 30 inches above the spillway crest.
- Given the coring data from 5 wells installed by Shree Inamdar and Evan Lewis (Univ. of Delaware) and our observations during their coring, about 10 ft of silty sediment forms the terrace along Chiques Creek upstream of the Roller Mill dam. This terrace thins to valley margins, where we predict that excavation would reveal Pleistocene rubble and/or bedrock, similar to that we have mapped elsewhere in the Chiques and adjacent watersheds.
- Note that our mapping shows that **no such terrace of silty sediment exists immediately downstream of the Roller Mill dam**, but does exist farther down approaching dam #6 on the main stem of the Chiques. The valley geometry just downstream of the Roller Mill dam and bridge is a good reference for the valley geometry upstream of the dam that underlies historic sediment.

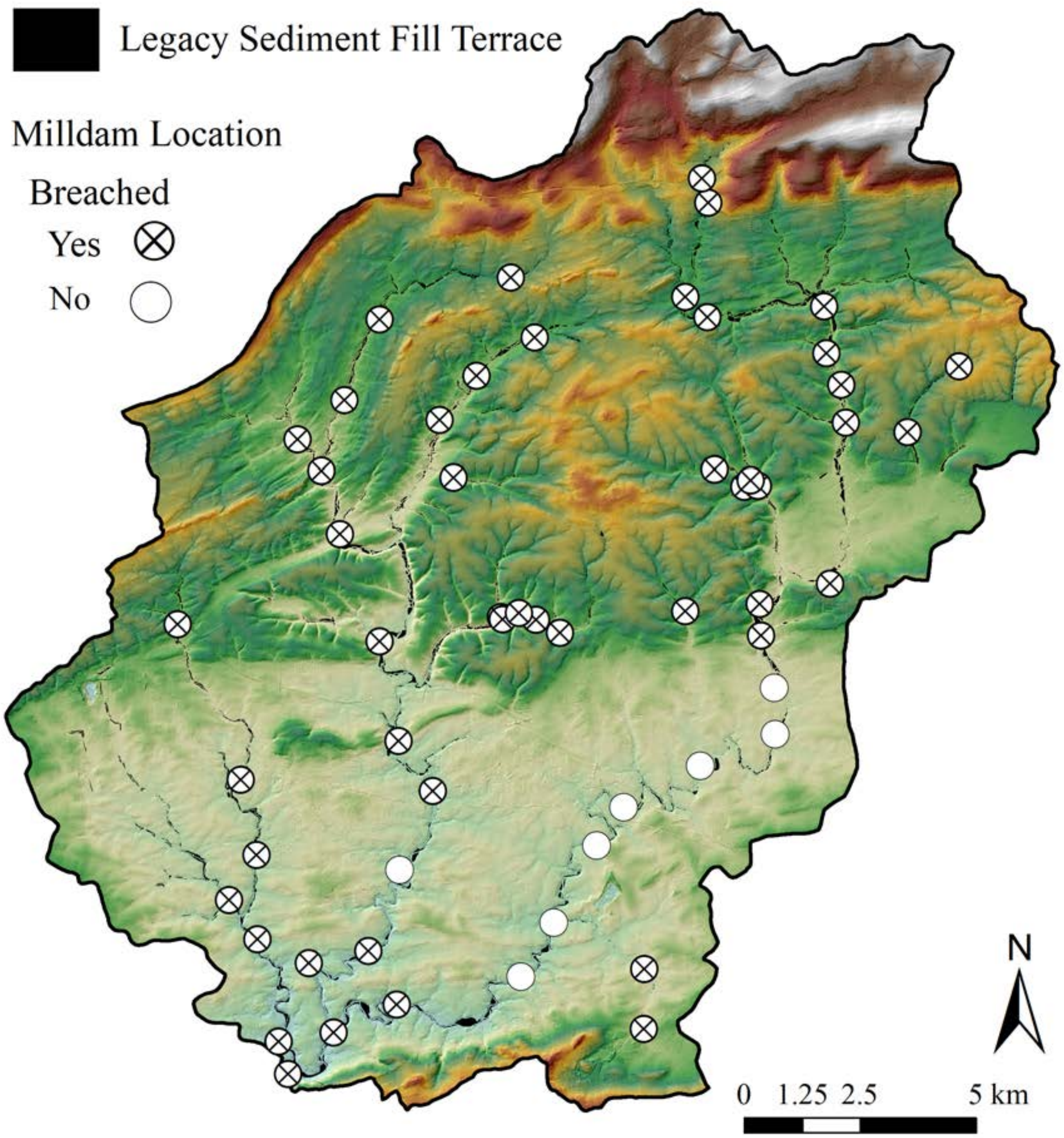

Figure 1. We mapped 54 historic dams (breached and unbreached) in the Chiques watershed, and used historic reports, documents, aerial photographs, and other sources to determine breach condition. We mapped historic sediment (black) using airborne lidar from 2014. This work began as a senior independent study project by Logan Lewis in 2017-2018. Logan has continued and built upon this work at WSI since then. (Figure is copyright WSI; please request permission to use.)

Figure 2. Deep incision of Chiques Creek since removal of the Krady milldam in July 2018 resulted in ~3.1 m high banks and from top down has exposed 1) historic legacy sediment that is mostly silt, 2) dark organic-rich Holocene sediment from a pre-European settlement wetland, and 3) slightly oxidized pebbly, cobbly colluvium from mass wasting that is likely Pleistocene in age and the result of permafrost thaw. Limestone bedrock underlies these sediments. Note that the legacy sediment and underlying Holocene wetland soils thicken to the right because they are draped over the pre-existing valley topography with a small hill to the left.