# STREAM BANK EROSION AS A SOURCE OF POLLUTION: RESEARCH REPORT

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# STREAM BANK EROSION AS A SOURCE OF POLLUTION

## INTRODUCTION

According to a number of projects funded by various government agencies and private entities, stream bank erosion is a significant source of nonpoint sediment and nutrient pollution affecting watersheds across the state. In the past several years, DEP has spent millions of dollars on assessment and correction of unstable, erosive stream systems through Growing Greener and US Environmental Protection Agency (EPA) Section 319(h)-funded grants. However, the theory of stream bank erosion as a primary contributor to nonpoint source pollution has received little attention and recognition by federal and state programs. In watersheds where farming makes up a large percentage of the land use, *agriculture* is usually designated as the number one polluter. The Chesapeake Bay Tributary Strategy (Table 1) and EPA Total Maximum Daily Loads (TMDLs) for Pennsylvania identify agriculture as the main source of pollution for the majority of the watersheds. These documents do not list stream bank erosion as a potentially significant source of nutrient and sediment loading.

While high sediment and nutrient loading are directly correlated with agriculture as a land use (Pennsylvania's Chesapeake Bay Tributary Strategy 2004), current farming practices may not necessarily be the variable contributing most of the pollution to streams. Legacy sediments[1], for example, are easily erodible and contain high concentrations of nitrogen and phosphorous (Table 2). These nutrients have been accumulating for several hundred years and are a major source of pollution to the bay (Table 3).

**Table 1.* Nutrient and Sediment Load Sources**

| Pollution Source | N Load Sources | P Load Sources | Sediment Load Sources |
|---|---|---|---|
| % Agriculture | 49 | 63 | 72 |
| % Forest | 21 | -- | 17 |
| % Point Source | 11 | 18 | -- |
| % Developed Land | 7 | 7 | 5 |
| % Mixed Open Land | 7 | 8 | 6 |

**Pennsylvania's Chesapeake Bay Tributary Strategy* (2004). Harrisburg, PA: PA DEP, p 13.

[1] Legacy sediments refer to sediments that were deposited into watersheds as a result of early colonization which then accumulated in streams and river valleys (Legacy Sediments: A Brief History, www.landstudies.com, 2005).

**Table 2. Measured Concentrations of Soil Nutrients in Legacy Sediments**

| SANTO DOMINGO CREEK | Total Phosphorus | Total Nitrogen |
|---|---|---|
| Average Yield* | 1.43 lb./ton<br>713.6 ppm | 4.41 lb./ton<br>2,200 ppm |

**Santo Domingo Creek Sediment & Nutrient Load Study Lititz Borough, Lancaster County Pennsylvania* (2004). Lititz, PA: LandStudies, Inc., From Table 3: Measured Concentrations of Soil Nutrients.

**Table 3. Annual loads based on measured erosion rates and nutrient concentrations for four streams.**

| Stream Name | Length of Stream Studied (feet) | Annual Sediment Load (tons/year) from the stream length studied | Annual Total Phosphorus Load (pounds/year) from the stream length studied | Annual Total Nitrogen Load (pounds/year) from the stream length studied |
|---|---|---|---|---|
| Santo Domingo Creek* | 193 | 83 | 104 | 289 |
| Octoraro Creek* | 1,800 | 1,200 | 1,716 | 5,292 |
| Stony Run** | 1,392 | 912 | 330 | 133 |
| Long Draught Branch*** | 1,608 | 427 | 261 | 665 |
| **Totals** | **4,993** | **2,622** | **2,411** | **6,379** |

* Based on data collected for the *Santo Domingo Creek Sediment & Nutrient Load Study*. See Appendix A for complete reference.

** Based on data collected for the *Lower Stony Run Geomorphic Assessment Study*. See Appendix A for complete reference.

*** Based on data collected for the *Long Draught Branch Restoration/Stabilization: Semi-Final Design Report*. See Appendix A for complete reference.

## RESULTS

Based on the outcome of DEP-funded projects, stream bank erosion in the Lower Susquehanna Watershed of Pennsylvania is a major source of sediment and nutrient input to the Chesapeake Bay. Numerous project reports are stating that stream bank erosion is a major source of pollution, sometimes *the* major source of pollution, for the streams and watersheds studied (Tables 4, 5). Some of the reports also include annual tonnage estimates for input of sediment via stream bank erosion based on detailed bank erosion monitoring. These data are presented in more detail in Appendix A at the end of this report.

**Table 4.* Stream Bank Erosion as a Major Source of Pollution as Cited in DEP Growing Greener Grant Projects**

| Project Name | County | Description |
|---|---|---|
| Conewago Creek Initial Assessment | Adams | Stream bank erosion is adding significant amounts of sediment to the watershed. 10 feet of bank erosion was recorded over several years on a section of stream with 14 foot high banks. |
| Cowanshannock Creek Stream Restoration Project | Armstrong | Monitoring revealed severe stream bank erosion to be an average of 0.8' erosion/ year, which is a conservative estimate. |
| Lake Sheridan Watershed Assessment Study | Wyoming | "Soil erosion along streambanks is a major source of nonpoint pollution in watersheds." |
| North Branch Muddy Creek Watershed Assessment | York | With banks over 15 feet high, the largest source of sediment input for the stream was deemed to be stream bank erosion. "Bank erosion rates were monitored at six locations in the watershed which revealed significant erosion even during a historically low stream flow period." Over 35 miles of the stream was assessed to suffer from these issues, which was reported to be similar to neighboring watersheds. |
| Paxton Creek Stream Corridor and Watershed Assessment | Dauphin | Stream bank and channel erosion are the most significant problems for over 60% of the watershed's stream length. Areas of deep entrenchment and bank erosion are a "significant source of sediment loading." |
| Quittapahilla Creek Watershed Assessment | Lebanon | Stream bank and bed erosion, as well as sedimentation, are the main problems in this watershed. |
| Spencer Run | Blair | Extreme bank erosion was monitored, revealing lateral erosion rates ranging from 0.7 to 1.8 feet and up to 15 feet at one location after eight months. |
| The West Branch of Octoraro Creek Stream Restoration | Chester | Stream bank monitoring revealed that bank erosion contributed over 1,200 tons of sediment in one year (2000) alone. |
| Trout Run Wetland and Stream Restoration Project | Chester | Severe stream bank erosion characterizes the entire project, which is just less than 1000 feet. Banks are 3-5 feet high. |
| Wysox Creek Watershed Stream Bank Improvement | Bradford | Stream bank erosion is one of the three "major threats to the watershed's natural resources…" with flooding and gravel deposition being the other two. |

*References for Table 4 can be found in Appendix B at the end of this report.

**Table 5.* Stream Bank Erosion as a Major Source of Pollution Cited in EPA 319 Grant Projects**

| Project Name | County | Description |
|---|---|---|
| Bentley Creek Watershed Restoration Project | Bradford | A single storm event that occurred in 1994 eroded 4.5 acres of a 30.7 acre field, resulting in 52,925 tons of eroded streambank soil. Approximately 26,463 tons of soil from this event ended up in the Susquehanna River, which would cost $317,556 to remove. This single storm erosion event also added an estimated 71,450 pounds of nitrogen and 29,109 pounds of phosphorous to the Susquehanna River eventually ending up in the Bay. |
| East Branch of the Codorus Creek Stream Restoration Project Phase IV | York | "Stream bank erosion has been identified as the primary source of sediment loading to the stream." Proposed restoration reaches are "experiencing accelerated bank erosion and channel migration." Based on erosion monitoring, these reaches are contributing several thousand tons of sediment per year to the stream. |
| Tookany Creek Streambank Restoration Project | Montgomery | In one year, 10-12 feet in depth of bank erosion occurred. |
| Mclaughlin Run | Allegheny | Severe stream bank erosion was observed. |
| Boyce Mayview Park Stream Restoration Phase I | Allegheny | A conservative estimate revealed that 150 cubic yards of soil were lost from Tributary 1N alone and erosion continues to occur at an increased rate. |
| South Branch Codorus Creek Restoration | York | The South Branch Codorus Creek Watershed Assessment Report declares stream bank erosion as the primary source of sediment loading to the stream. |
| Oil Creek Stream Restoration | York | Stream bank erosion was found to be a major source of sediment in construction of the TMDL. |
| Bachman Run Stream Restoration | Lancaster | Because of extreme erosion, banks have widened from 5 to 10 feet wide. The banks are characterized as being 3 feet high of bare soil. |
| Octoraro WBR Watershed Assessment | Lancaster/Chester | Based on detailed monitoring, the lateral erosion rate for the headwaters was determined to be 1.5-2.0 ft/year, contributing thousands of tons of erosion each year from stream banks alone. |

* References for Table 5 can be found in Appendix C at the end of this report.

## DISCUSSION

The Conestoga Watershed is one of the more highly studied sub-watersheds in the Chesapeake Bay watershed. What is occurring there is typical of what is occurring in streams throughout the Piedmont Province. According to the United States Geological Survey, the Conestoga River Basin is the highest contributor of sediment to the Susquehanna River (Summary of Suspended Sediment Data for Streams Draining the Chesapeake Bay Watershed, Water Years 1952-2002 2004). The percentage of agriculture as a land use is very high in this area, and it is common for these areas to be high contributors of sediment (Pennsylvania's Chesapeake Bay Tributary Strategy 2004). Because of this correlation, it might be reasonable to assume that the majority of sediment input is coming from current agricultural practices. As research cited in this document shows, however, that may not be the case. A substantial amount of sediment and nutrient input could be the direct result of historical (18-20$^{th}$ centuries) rather than current land-use practices.

When the Piedmont region was settled, little was done to prevent erosion during land clearing and agricultural operations. Eroded soils ended up in the stream valleys and accumulated behind the thousands of mill dams (there were over 450 in Lancaster County alone) along the streams (Landis, 1964; Barton, 1998 in Merritts and Walter 2003). As mill-related industries declined, many of the dams were removed or deteriorated, allowing channel flow to increase, which, in turn, increased energy flow in stream channels. This increased energy, still a phenomenon in our stream channels today, erodes and scours stream beds and banks, sending thousands of tons of nutrient-rich legacy sediments into the bay (Doyle et al. 2003 in Merritts and Walter 2003).

As it flows today, over 80 percent (515 stream miles) of the Conestoga Watershed suffers from stream bank erosion and collapse (Conestoga River Sub-Watershed Research Project: Growing Greener Grant Submission March 2005). This stream bank failure contributes significantly to the Lower Susquehanna Watershed's designation as the highest sediment polluter to the bay (Merritts and Walter 2003).

Given the above overview of stream bank erosion as observed and measured in the field in numerous regional watersheds, organizations such as the DEP and EPA would be wise to acknowledge this major contributor to sediment and nutrient pollution from local watersheds on down to the bay. Once stream bank erosion is acknowledged as a major pollution source, Best Management Practices and other policies can be put into place to help achieve DEP's 2010 reduction goals of 18,500 tons/year for nitrogen, 550 tons/year for phosphorus, and 116,000 tons/year for sediment (Pennsylvania's Chesapeake Bay Tributary Strategy 2004). Floodplain restoration, which directly addresses stream bank erosion as a major source of N, P, and sediment pollution, is an essential technique that could allow Pennsylvania to be more effective and efficient in their approach to meeting its 2010 pollution reduction goals.

## REFERENCES

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*Pennsylvania's Chesapeake Bay Tributary Strategy* (2004). Harrisburg, PA: PA DEP

*Summary of Suspended Sediment Data for Streams Draining the Chesapeake Bay Watershed, Water Years 1952-2002* (2004). U.S.G.S.

*Total Maximum Daily Loads* (2005). Harrisburg, PA: Pennsylvania Department of Environmental Protection; 7 August 2005. < http://www.dep.state.pa.us/watermanagement_apps/tmdl/>.

## Appendix A

## Technical Information Exchange

Sharing information among watershed groups is an important function we provide through this newsletter. We invite your feedback on this issue to the author to see if others are identifying the same problems.

### Documenting Stream Channel Erosion – Bigger Problem Than Originally Thought

Watershed assessments funded by the Growing Greener Program and other programs have begun to document stream channel erosion as a much more serious source of non-point source pollution in watersheds than previously thought.

Studies in Adams, Armstrong, Chester, Lancaster, Susquehanna, and York counties and in Maryland have documented sediment loads from stream channel erosion that are orders of magnitude more than those documented in published studies that measured lateral bank erosion in stream channels around the world, including Pa.

*Legacy sediments in the Valley Creek Watershed, Chester County.*

In addition, studies show that 50 to 90 percent of the sediment load generated in a watershed is not coming from overland flow as previously thought, but from the stream channel banks themselves.

Some examples of stream channel sediment load versus what published studies by Prosser et al (2000), Rutherford (2001), and Green et al (1999) would predict for "problem areas" –

**Measured vs. predicted "problem area" erosion rates from stream banks in various areas of Pennsylvania and Maryland.**

| Creek (County or State) | **Length of Stream Studied (feet)** | **Measured Erosion Rates (tons per year) for study area** | **Predicted "Problem" Area Erosion Rates* (tons per year) for study area** |
|---|---|---|---|
| Choconut (Susquehanna)[1**] | 7,920 | 50,000 | 110 – 2,194 |
| Codorus - East Branch (York)[2] | 5,410 | 2,070 | 90 – 1,794 |
| Codorus Creek- South Branch Granary Rd. (York)[3] | 2,200 | 2900 | 56 – 1,122 |
| Codorus Creek- South Branch SBCC 026 (York)[4] | 400 | 450 | 9 – 180 |
| Codorus Creek- South Branch SBCC 015 (York)[5] | 550 | 578 | 8 – 160 |
| Codorus Creek- South Branch SBCC 025 (York)[6] | 600 | 1200 | 15 – 300 |

| | | | |
|---|---|---|---|
| Codorus Creek- South Branch Phase I (York)[7] | 1,770 | 1,083 | 15 – 304 |
| Codorus Creek- South Branch Phase II (York)[8] | 2,050 | 500 | 15 – 298 |
| Codorus Creek- South Branch Phase III (York)[9] | 4,170 | 2,180 | 33 – 654 |
| Conewago (Adams)[10] | 800 | 8,000 | 20 – 400 |
| Cowanshannock (Armstrong)[11] | 80 | 31 | 1 – 20 |
| Cowanshannock (Armstrong)[12] | 50 | 52 | 1 – 20 |
| Crabby (Chester)[13] | 400 | 1,444 | 4 – 80 |
| Long Draught Branch (Maryland)[14] | 1,607 | 427 | 19 - 380 |
| Octoraro -West Branch (Lancaster)[15] | 1,650 | 1,200 | 4 – 84 |
| Meetinghouse Creek<br>Nickel Mines Run<br>Stewart Run<br>Total for Octoraro WBR Headwaters (Lancaster)[16] | 43,058<br>53,704<br>60,429<br><br>157,191 | 4,764-5,928<br>5,195-6,438<br>4,415-5,459<br><br>14,374-17,825 | 188 – 3,766<br>206 – 4,110<br>187 – 3,744<br><br>573 – 11,458 |
| Santo Domingo (Lancaster)[17] | 193 | 80 | 2 – 32 |
| Spencer Run (Blair)[18] | 16,250 | 3,200-3,900 | 133 – 2,666 |
| Stony Run (Maryland)[19] | 1,392 | 912 | 12 – 238 |
| Trout Run (Chester)[20] | 50 | 20.5 | 1 – 20 |

* These values were calculated using lateral erosion rates of $1.0 \times 10^{-2}$ to $2.0 \times 10^{-1}$ meters/year as suggested by Evans *et al*, 2003.

** Superscripts correspond with references found in Appendix B.

These sediments also carry with them nutrients—nitrogen and phosphorus – that contribute to nutrient loading in bodies of water downstream.

Soil sampling revealed stream channel erosion in a 193-foot portion of the Santo Domingo Creek Watershed in Lancaster County, resulting in an estimated 104 pounds of phosphorus and 289 pounds of nitrogen per year going to the Chesapeake Bay – more significant than any other source, yet one that has not been documented thoroughly until now.

The origin of the problem in many areas apparently stems in part from the history of land use, in particular, massive land clearing and the location of mill dams by the thousands that dotted the landscape within the Chesapeake Bay watershed during the 18th and 19th centuries.

Franklin & Marshall College in Lancaster has documented many of the impacts of these old mills can have. Sediment from land clearing and poor agricultural practices accumulated behind the mills dams from just a few feet thick to more than 20 feet thick on top of the original floodplains.

As dams were removed or fell into disrepair, the streams began cutting down through the sediments and carrying those sediments downstream.

The policy impact of this more thorough understanding of the role stream channel erosion plays today in sediment and nutrient loading might be two-fold:

1. Programs such as Chesapeake Bay nutrient reduction strategies, modeling work done for water quality credit trading programs, the proposed Stormwater Management Manual, the Generalized Watershed Loading Function Model and TMDL planning that assign relative weights to pollution sources may need to be updated.

   At worst, underestimating stream channel erosion in some areas may result in improper burdens being placed on agriculture or other sources of non-point and point pollution to clean up their contributions to a stream's pollution problem.

2. Evaluating potential remedies for water pollution problems involving restoration, particularly in more developed areas, should include floodplain restoration, if these results hold. Thought should be given to developing a specific floodplain restoration best management practice.

LandStudies, Inc. of Lancaster County and Franklin & Marshall College have established a special Legacy Sediments webpage to provide additional background on their findings so far and to solicit information from other watershed groups and consultants on this topic to see if findings are similar in other areas.

"This is a good opportunity to learn from each other how significant the stream channel erosion issue is and its policy implications in a number of areas," said Mark Gutshall, LandStudies, Inc. "We look forward to sharing technical information with our colleagues all over Pennsylvania."

To offer feedback to LandStudies, visit the special Legacy Sediments webpage or email: land@landstudies.com.

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[11]*CCWA High School Property-On Site Pixs*. (2005). PA: LandStudies Inc., p 3.

[12]*Cowanshannock Creek River Conservation Plan*. (2002). PA: Skelly and Loy, Inc.; p 42.

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[16]*Headwater Assessment of the West Branch Octoraro Creek Watershed*. (n.d.) PA: LandStudies Inc., disk #1001.

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## Appendix B

**Table 4. Stream Bank Erosion as a Major Source of Pollution Cited in DEP Growing Greener Grant Projects**

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# Appendix C

**Table 5. Stream Bank Erosion as a Major Source of Pollution Cited in EPA 319 Grant Projects**

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