LandStudies' Reply to:
An Evaluation of the Pollution Reduction Benefits of the Santo Domingo Floodplain Restoration Project in Lancaster County by Dr. Barry M. Evans dated December 2004

The Santo Domingo Creek floodplain restoration project, located in New Street Ecological Park, Lititz, Pa., was constructed in August/September of 2004. This restoration effort was performed to improve the water quality in the Santo Domingo and Lititz Run watersheds, both of which lie within the Conestoga River watershed. The project also is being used to explore potential nutrient-trading credits for sediment, nitrogen (N), and phosphorus (P) that could be generated in the Conestoga River watershed. Dr. Barry Evans of the Penn State Institutes of the Environment performed a watershed assessment **based primarily on a Generalized Watershed Loading Function (GWLF) model** to determine the potential load reductions as a result of decreased streambank erosion within the restoration site and treatment of instream loadings entering the restored floodplain.

We believe that Dr. Evans's report and the model provide, in general, reasonably accurate results for the Santo Domingo Floodplain Restoration Project. We also believe that, to obtain more accurate results for reduction in sediment loads and P, more accurate measurements regarding rates of sediment and P inputs must be incorporated. It is also important to consider the magnitude of the N, P, and sediment load reductions based on the size of the restoration site with respect to the contributing drainage area and total length of streambank restoration and floodplain restored.

IMPORTANT POINTS OF REVIEW:
1) An assessment of effectiveness of the restoration should be based on the size of the floodplain restoration area and stream restoration length relative to the total contributing watershed area and total stream length.
2) An assessment of the effectiveness of the restoration should be viewed in terms of the potential reduction in loads generated from within the project site itself.
3) Steady flow assumptions used in hydrologic modeling are inadequate to simulate complex floodplain interaction with flood flows of typical hydrographs. Therefore, estimation of load reductions associated with flood flow interaction with the floodplain is grossly inaccurate and, we believe, underestimated.
4) Estimates of bank erosion rates are highly site-specific and episodic, requiring at least regional but preferably local watershed data on bank erosion rates to develop more reasonable estimates of loads associated with bank erosion materials.

ESTIMATES OF LOADS AND EFFECTIVENESS OF LOAD REDUCTIONS FROM UPSTREAM SOURCES:
Dr. Evans estimated that total annual loads of approximately 1,150 tons of sediment, 60,834 pounds of N, and 2,930 pounds of P are being delivered to the project site from the Santo Domingo Watershed. (Loads are assumed to come from streambank erosion and overland flow.) Using a generalized GIS-based technique developed by Dr. Evans and others, the load delivered to the project site from upstream bank erosion was estimated to be 10 percent of the total sediment, 1 percent of the total N, and 1 percent of the total P. Dr. Evans estimates that the Santo Domingo floodplain restoration project will reduce sediment by 7.0 percent, N by 2.5 percent, and P by 3.5 percent for loads from a watershed of 2,080 acres. Traditional BMPs such as wet ponds, infiltration, and filtering practices have efficiencies in the range of 80-90 percent for sediment, 30-50 percent for N, and 50-70 percent for P, according to the *Chesapeake Bay Program Best Management Practices*; however, because of space limitations and the potential

damaging influence of backwater effects, these BMPs are typically limited to drainage areas of fewer than 10 acres. Dr. Evans's computed reductions for the floodplain restoration as a BMP in (the Santo Domingo) watershed are highly significant in comparison to other traditional BMPs, which are typically designed to collect site runoff from small subwatersheds with concentrated loads in urban or agricultural land. Even though the efficiencies of the Santo Domingo floodplain restoration BMP may be lower than traditional site-specific BMPs, floodplain BMPs can operate on a watershed scale, which appears to compensate for the lower efficiency and potentially makes this BMP more effective in overall load reductions.

For the Santo Domingo project, the ratio of the restoration site area to the total contributing watershed area is quite small. The area of the restoration amounts to only 0.05 percent of the total contributing drainage basin (watershed area approximately 2,080 acres and floodplain restoration area 1.1 acres). In addition, the restored channel length comprises only a small fraction (1.9 percent) of the total length of channel flowing to the restoration site. The length of existing straightened channel and floodplain restored was approximately 750 feet. The increased sinuosity of the restored channel increased the length to approximately 950 feet. The total length of open channel flowing to the restoration site from the Santo Domingo watershed is approximately 8.0 miles.

ESTIMATES OF LOADS AND EFFECTIVENESS OF LOAD REDUCTION FROM ON-SITE SOURCES:

According to Dr. Evans's modeling, bank erosion from the Santo Domingo Creek, prior to restoration and within the limits of the restoration project site, generated annual loads of 62.9 tons of sediment, 209.7 pounds of N, and 71.7 pounds of P. Dr. Evans's modeling assessment shows that after restoration the project site annual loads were reduced to 3.1 tons of sediment, 10.5 pounds of N, and 3.6 pounds of P, yielding annual reductions of 59.8 tons of sediment, 199.2 pounds of N, and 68.1 pounds of P. These annual load reductions are achieved solely by decreasing streambank erosion within the floodplain restoration site.

Along stream channels of larger watersheds where nutrient-enriched groundwater and/or erosion of nutrient-rich streambank materials are major sources of stream channel pollutants, traditional site-specific BMPs may be impractical or detrimental to stream ecological functions (e.g. habitat and geomorphology). Furthermore, traditional, site-specific BMPs are ineffective at reducing, collecting, and treating sediment and nutrients generated from streambank erosion or groundwater where watersheds are too large for their practical implementation. Fine-grained sediments and nutrients adsorbed to these sediments can be a major source of pollution according to studies performed by LandStudies, Dr. Evans, Dr. David Rosgen, and others.

ESTIMATES OF LOAD REDUCTIONS FROM OVERSIMPLIFICATION OF MODELING FLOODPLAIN FLOW AND CHANNEL FLOW INTERACTION:

Dr. Evans estimated the sediment and nutrient reductions expected through the interaction of flood flows with the restored floodplain area of the restoration site. The results of Dr. Evans's GWLF model indicate annual reductions of 83.4 tons of sediment, 1,523 pounds of N, and 105 pounds of P. LandStudies' review of Dr. Evans's assessment of the restored floodplain treatment concludes that assumptions used in the modeling led to significant underestimation of floodplain inundation and, therefore, an underestimation of the frequency of floodplain treatment of sediment and P loadings. The LandStudies review is discussed in detail here.

Dr. Evans's model assumes an existing channel capacity of 8.3 cubic feet per second (cfs). This leads to an assumption of a monthly flow of 21,500,640 cubic feet of water flowing through the restoration site without access to treatment in the floodplain. The model also assumes that the flow carries a typical and continuous load of sediment, N, and P. In addition, the model assumes that all flows through the restoration site, whether generated from runoff (high flow) events or base flow, carry the same concentrations of sediment, N, and P.

We agree that the N concentrations may not vary significantly between runoff-generating storm events and base flows. However, LandStudies believes that the volumes and concentrations of sediment and P increase significantly with higher storm events. Dr. Evans's analysis makes only 50 percent of the sediment, N, and P loads available for removal in the floodplain restoration site. This may be reasonably accurate for N. However, because volumes and concentrations of sediment and P increase significantly with higher flows, we contend that approximately 80 to 90 percent of the total volume of sediment and P will be available for treatment in the restored floodplain. This would significantly increase the volumes of sediment and P removed from the stream within the restored reach.

Also, the estimated 8.3 cfs that flows in-channel before entering the floodplain was based on an existing post-restoration typical section. There are locations within the restored channel that carry approximately 4.0 cfs. These locations allow for more frequent flow onto the floodplain and more frequent treatment than the assumed 8.3 cfs. Over time, as vegetation encroaches into the active channel, almost all but the smallest of base flows will be available for treatment, thereby increasing the removal rates and volumes of sediments, N, and P.

The restored floodplain area will improve the quality of in-stream flows based on multiple treatment measures including denitrification, groundwater infiltration, and vegetative filtration. The detention time and frequency of treatment opportunity in the restored area is increased significantly over the pre-restoration condition.

UNDERESTIMATION OF BANK EROSION RATE:

Another point on which opinions differ greatly is the assumed rates of bank erosion that are used in Dr. Evans's model. The Santo Domingo project site yielded detailed, pre-restoration bank erosion rates, which were not directly incorporated into the model. Instead, Dr. Evans used revised rates related to the generalized rates developed from his GIS-based streambank erosion model. The sediment and P loads coming from bank erosion throughout the remaining channels within the upstream watershed use general erosion rates. The typical range of annual erosion used by the GWLF model was between 1×10^{-3} and 1×10^{-5} meters, which is based on Dr. Evans's and Dr. Scott Sheeder's paper "A Spatial Technique for Estimating Streambank Erosion Based upon Watershed Characteristics," 2003. We believe that these erosion rates, in general, significantly underestimate the total loadings of sediment and P resulting from bank erosion. Dr. Evans's rates of erosion are not based on actual measured erosion rates.

Studies completed by Dr. Rosgen, "A Practical Method of Computing Streambank Erosion," 1993, show annual erosion rates between 1×10^{-2} and 1.2 meters, based on field measurements across the United States. To put the erosion rates in perspective, Evans's and Sheeder's estimates would require between 3,333 years to 300,000 years for the entire stream to migrate laterally 3.3 meters (10 feet). Dr. Rosgen's estimates would require 2.5 years to 300 years for the entire stream to migrate laterally 3.3 meters or 10 feet. We have measured rates of erosion in the Piedmont of Pennsylvania and Maryland that typically fall between the estimates of Evans and Sheeder and that of Dr. Rosgen. We have also visually observed and field surveyed episodic or local rates of erosion that are significantly higher than Rosgen's published limits.

Determination of the proper erosion rate is difficult because stream adjustment is episodic and not uniform throughout the entire stream length. Some reaches of a stream erode much faster than others, and massive bank erosion or new channel formations may be viewed as local and infrequent; however, our experience in the Piedmont of Pennsylvania and Maryland indicates that high bank-erosion rates are common and frequent. As a consequence, sediment supplied by bank erosion at these high-rate locations may dominate the volume of sediment entering the stream system or leaving a watershed.

As one recent example, a head-cut has formed in Crabby Creek, a Chester County, Pa., stream. The rate of migration, according to members of the local watershed group, is approximately 100 meters (300 feet) over an 18-month period, or 200 feet in 12 months. In the last six months, LandStudies has seen the headcut migrate approximately 100 feet upstream, where it has temporarily stopped at a sewer line crossing. The exact amount of time required for the cut-off to form is unknown; however, the site was visually surveyed over the last 18 months. Given average channel dimensions of 7.5 meters (25 feet) wide by 2 meters (6 feet) deep, the magnitude of the bed and bank erosion – the total volume of sediment released – by this head-cut is more than 800 cubic meters (30,000 cubic feet) in 12 months. Although other head-cuts of this size were not observed in the watershed, debris jams and significant bank erosion were observed throughout many reaches of the watershed. The newly cut channel is only one of many reaches within the same watershed that is experiencing much higher rates of erosion than the typical reach. Based on our observations, this condition is typical of the streams in the Pennsylvania and Maryland Piedmont region.

Based on the rates of bank erosion determined in Evans's and Sheeder's "A Spatial Technique for Estimating Streambank Erosion Based upon Watershed Characteristics" study, a length of 400 to 40,000 kilometers (240 to 24,000 miles) of eroding stream bank is required to equal the volume of sediment that was released into the system from the recent headcut in Crabby Creek over 12 months. That calculated length is significantly greater than the available stream length in the Crabby Creek watershed. Dr. Rosgen's data indicates that the same volume of material available from bank erosion would require 0.3 to 40 kilometers (0.2 to 24 miles) of bank length. More accurate estimates of bank erosion rates are necessary to accurately model sediment and P loads supplied by bank erosion. LandStudies' observations and field surveys indicate that Dr. Rosgen's erosion rate estimates are more representative of the conditions in the Pennsylvania and Maryland Piedmont streams than are Evans's and Sheeder's. Our frequent visual observations indicate that the majority of channel reaches in the Pennsylvania and Maryland Piedmont have migrated over five feet within the last two decades. Many reaches of substantial length have migrated laterally over 50 feet during this same period.

Bank erosion rates from Dr. Rosgen's data and field observed by LandStudies indicate that the actual volume of sediment coming from the banks is from 10 to more than 1,000 times those assumed by Dr. Evans. It may also mean that, at a minimum, in urban and agricultural watersheds, 50 to 90 percent of the sediment load generated by the watershed is coming not from overland flow but from the streambanks themselves. We believe that Dr. Evans's model may require different assumptions or more accurate field-surveyed data to provide a more accurate analysis of sediment and P reductions in an area of stream and floodplain restoration. Because much of the P load may be attached or adsorbed into the streambank sediments, understanding the source of the sediment supply is critical to improving water quality.