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Correlating present erosion risk with streambank vegetation and soil composition in the Macatawa Watershed

Lake Macatawa is an 1800 acre drowned river mouth located in Southern Ottawa County. Given its location and proximity to the greater Holland area, the lake receives fairly heavy recreational traffic during the summer months, and is also an important harbor for receiving shipments of coal and many other supplies. The lake has two large bays (Big bay, Pine creek bay) fed by multiple tributaries (Winstrom, Pine creek) draining the surrounding area. The watershed feeding the lake includes 110,000 acres, two counties, and multiple townships.

In 1996 the Macatawa river, the South Branch of the Macatawa river, and the Pine river were placed on the Michigan Department of Environmental Quality's 303(d) list due to poor aquatic habitats and communities (State of Michigan 2008). In accordance with the Clean Water Act (1977), the State and local governing bodies were required to perform a study on the watershed to determine the Total Maximum Daily Load for phosphorus discharging into Lake Macatawa from surrounding tributaries. The study revealed a staggering problem; despite a huge excess of phosphorus discharging into the lake and creating a hyper-eutrophic environment, ninety-one percent of the excess was attributable to non-point source pollution (Higgins 2008).

Due to the nature of non-point source pollution, stopping the flow of phosphorus into the Lake has been difficult. While some progress has been made through grassroots efforts and new regulations including a ban on fertilizers containing phosphorus in some areas (Ottawa County 2006), the problem has yet to be remedied. The state is required to monitor progress on studies such as the Macatawa Watershed Plan, and with 2009 approaching the results from local efforts and summaries of actions taken will have to be presented in order to have the plan renewed to ensure progress.

In recent years the practice of treating the afflicted watershed as a whole and using as many natural management methods as possible to combat the complex nature of non-point source pollution has become more popular. One area of watershed management that has received a large amount of focus in the last decade is the assessment of erosion and its risk factors. Erosion itself is a naturally occurring process that is important to stream ecology and structure. Streams generally pick up sediments from erosional (outside) banks and deposit them in other areas like the inside bank of a bend or a wetland area. While some areas naturally undergo more erosion than others, highly urbanized areas are prone to greater erosion as a result of various factors (Evans 2003). In areas where erosion is high, the amount of sediment runoff is greatly increased, contributing to problems like high turbidity and non-point source pollution (Rosgen 2008).

In the Macatawa watershed large amounts of agricultural activity and urban development over the last 150 years have re-shaped the natural structure of the watershed. Once naturally flowing streams have been straightened and re-routed and much of the watersheds natural storage areas have been removed contributing to the potential of increased erosion and subsequently increased amounts of pollutant containing sediment runoff entering the stream system. The assessment and subsequent prevention of high levels of erosion in the Macatawa watershed could greatly contribute to lowering phosphorus levels and meeting State and Federal mandates for water quality. Indeed studies in similarly afflicted watershed have shown that stream restoration efforts greatly reduce the effects of erosion, thereby decreasing the amount of runoff and the pollutants it contains (Yanwei 2005).

Our main goals for this research were to find out if stream bank erosion is a growing concern in the Macatawa watershed as a potential contributor to non-point source pollution. Further, we wanted to find out if there were any major differences between erosion risk in major sub watersheds. If some areas are much worse than others it could be useful to concentrate efforts intended to decrease erosion and sediment runoff. We also wanted to investigate what the main contributors to erosion risk are in the area. We expected erosion risk to be high in general due to the changed structure of the watershed and prevalence of sandy soils in the area (SOIL MAP REFERNCE?). Soil composition and vegetative state were hypothesized to be the main contributors with stream banks characterized by high clay content and thick, woody vegetation displaying a lower risk of erosion.

At the conclusion of our project we hope to be able to assess and analyze various factors that contribute to streambank erosion, and produce definitive correlation between those factors and the severity of erosion that a stream is likely to undergo. There will be two categories used in classifying a stream – the first is soil composition, and the second is streambank plant composition and density. Using these categories and measuring the erosion using the Rosgen’s Bank Erosion Hazard Index (BEHI) will allow us to draw conclusions regarding the connection (if any) between soil composition, plant composition, plant density, and erosion severity. Plant classification and the BEHI measurements will be taken in the field, and collected soil samples from each site will be analyzed in the lab.

Materials and Methods

Stream sites where field sampling was performed were chosen from a list of road stream crossing sites obtained from the Macatawa Area Coordinating Council. A total of 30 sites were sampled with the majority coming from the Pine Creek and Lower Macatawa subwatershed, and a few representative high risk sites from the South Branch subwatershed. At each site a Bank Erosion Hazard index survey was performed to quantify erosion risk. Two soil samples were taken from each site, one 6 inches above the water line and another on top of the bank. A vegetative survey was also performed to determine the type and density of vegetation present.

Figure 1- A site from the Macatawa Watershed that scores low on the BEHI scale.

The Bank Erosion Hazard Index (B.E.H.I.) is an assessment of current erosion risk that consists of four metrics which are observational. The first observational metric is the ratio of root depth to bank height, giving a value between 0 and 100 percent based on how far down the bank the roots extend. In areas where vegetation is present up to the waterline, the metric would be 100 percent, and in the case of a bare bank with no vegetation the metric would be 0. The second is root density, a percent score of the streambank slope surface covered by plant roots. Bank angle is the angle as estimated from the waterline to the top of the bank. Finally the surface protection measurement is the percentage of the streambank covered by logs, rocks, woody vegetation, anything that would prevent sediment from being washed away. At least 35 meters of stream reach with a relatively uniform character and a minimum of one meander were required for sample sites. Both banks were observed with any significant differences between the two noted. The outside edges of bends were generally avoided due to erosion levels that are uncharacteristic of the rest of the stream, and in some cases of high variability, two percentages were chosen and the corresponding point values were averaged later. This procedure is taken and modified slightly from Rosgen 2001.

Figure 2- A site from the Macatawa Watershed that scores high on the BEHI scale

The method for plant classification consisted of two qualitative, observational measurements. The first was to decide whether or not the vegetation was primarily forested or grass, based on the amount of woody plants present along the stream bank. The second was to qualitatively assess surface plant density, and assign a thick, thin, or moderate rating. BEHI measurements require at least 35 meters of bank, so the plant assessments will be made four times per stream, twice on each side of the bank, within a random 5x2 meter square (the longer edge following the stream). No root density count was made because it’s a factors already present in the BEHI. Instead, a stem count was used to assign the qualitative density label to a given patch. This procedure is adopted and modified slightly from Anderson et al. 2004.

Soil samples will be collected at the site from 2 points at the location; one approximately 6 in. above the water level to determine the soil type and composition where the erosion is occurring. The second point at each location was taken from the top of the bank to determine the type of soil the vegetation was growing in as well as to potentially look at the soil type prior to any erosion. After each sample was brought back to the lab each was labeled, weighed and placed in a drying oven overnight. After the water in the soil was removed the sample was weighed again and the water’s weight recorded. The samples were then set out to absorb latent moisture in the air to reduce the static between the very fine particles of the sediment. Finally each sample was dry sieved to determine the composition of each soil size, using standard sieve sizes 5,10,35,60,120,230 and a final basin to catch the finest sediment. The percentage of sediment in each sieve was determined and used to look at the overall sediment size at each location.

The data will be analyzed using Principle Component Analysis (PCA) with four of our variables (percent clay at water level, percent sand at water level, vegetative type, and vegetative density) to determine if there is any trend towards clustering. This will be performed for both the BEHI scores and an arbitrary sub-watershed score, to see if there any significant differences between the sub-watersheds that we tested.

Results and Discussion

While we were hoping for a clear and strong correlation between the BEHI scores and either the soil classification or vegetative classification, the results we found were more complex. For starters, based just on our sieving data, we determined that stream banks in the Macatawa Watershed have a large degree of variance in their soil types. We had assumed that virtually every stream would be primarily sand, just due to our proximity to the beach, and the fact that, historically, much of this area was covered in sand dunes. However, the sand percentages ranged from the low 20s to the upper 70s, with clay varying from trace amounts to 15%. Such a large variance was not present in the BEHI scores, with the majority clustered at the low-risk end, so there was no obvious correlation between soil types and BEHI. Fortunately, our first PCA enabled us to tease our two clusters from the main body of data (Fig. 3). The first cluster is of our four data points where we found a high BEHI score. This tells us that, to a degree, we do have some predictive power for a site's BEHI score based off of soil and vegetative classifications. The second cluster (to the left of the first cluster) is four more sites that all had exceptionally high clay percentage scores. So while we can't differentiate between low and medium BEHI sites based off of our measured variables, we can see a trend emerging with the high sites.

The second PCA was performed using the same four variables as above, but with the addition of the actual BEHI score. The data was then graphed based on which sub-watershed the site was found in (Fig. 4). We do see one cluster, of all of our South Branch Macatawa samples, but can't distinguish the Pine Creek and Lower Macatawa

Tributary sites. While we can't draw any major conclusions from this, it does tell us that some of the different sub-watersheds are distinct, and have distinct soil types, vegetative types, and erosion risks. The take-home message is simply that one blanket solution for the entire Macatawa Watershed will not be effective, as different areas are experiencing different problems, or different degrees of the same problem.

We experienced two major problems performing this experiment, the first being with the way we measured erosion. While the BEHI is an interesting tool to provide an at-a-glance erosion risk assessment, it does have its problems. For starters, it's a metric that was designed based on data from hundreds, if not thousands, of watersheds around the country, making it only really accurate for a watershed that is entirely average. The Macatawa Watershed is notably flashy, given to large and sudden increases or decreases in the water level from moderate precipitation events or droughts, respectively. The BEHI also provides only a snapshot of risk, instead of actually measuring erosion over time. Actually measuring erosion is, of course, more difficult and more time-intensive, but it smoothes out the peaks that would represent day-to-day differences. Finally, the BEHI is a subjective determination, making it possible that two different technicians would arrive at a different score even given the same site conditions.

Our second problem lay in assuming that soil and vegetative classifications would be enough to predict erosion risk. While we knew that other variables do affect erosion, we assumed that would be second or third-order effects compared to soil and vegetation. As it turns out, this was rather short-sighted. Erosion is determined by not only a much larger number of variables (nearby land use, stream velocity, stream load to name a few), but by complex interactions between these variables. Just looking at our two variables, for example, it became apparent that clay (associated with less erosion) supported larger woody plants whose canopy meant that there were far fewer plants on the bank (associated with more erosion). The reverse was true with sand, as it is more prone to be eroded, but can't support large trees, leaving room for a larger density of grasses. A more complete study would have included more of these variables (especially stream velocity), and would have teased apart the interactions between our suite of factors.

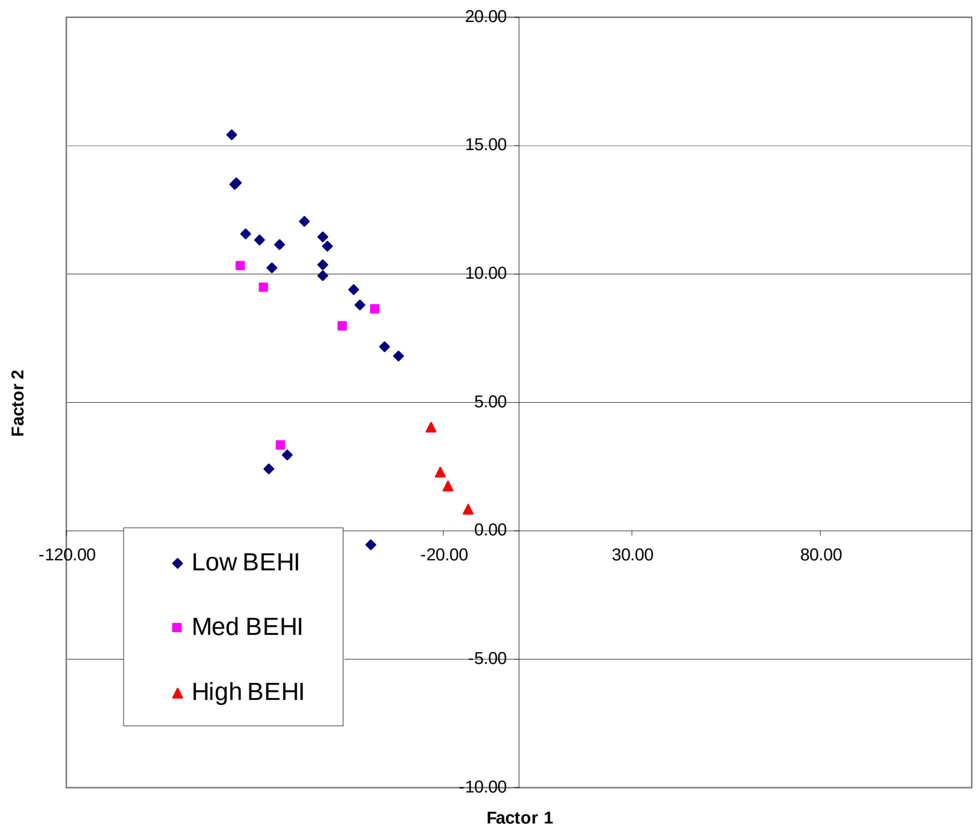

Figure 3. A principle component analysis based on percentage of clay at the water level, percentage of sand at the water level, vegetative type, and vegetative density. The data was then graphed using their BEHI scores.

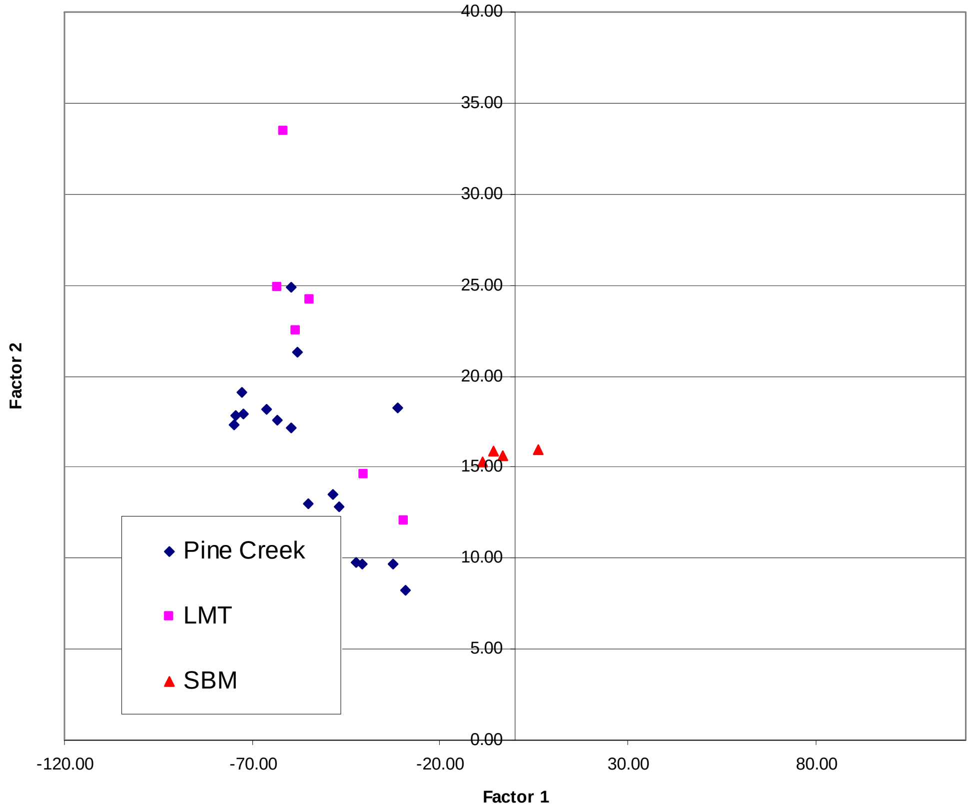

Figure 4. A principle component analysis based on percentage of clay at the water level, percentage of sand at the water level, vegetative type, vegetative density, and BEHI. The data was then graphed based on their sub-watershed

Future Research

The research which was done is a very good start in looking at the various influential factors of stream erosion. We also feel however, that it would be beneficial to have further research done in several capacities. First, we would like to be able to explore having locations that have not been modified as extremely as the sites that we were able to get data from. Next we would like to be able to look at a larger number of sites as this would increase the likelihood of the statistics we were able to get. Finally we would like the opportunity to look at other variables that might have to do with the erosion of streams. One variable in particular that we feel would have the best effect would be to look at is the effect of time on our data. We feel that in general the various methods we used to determine the amount of erosion might change drastically depending on the time of year, or as the stream matures and possibly begins to meander again.

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