# Effectiveness of Retention Basins within the Macatawa Watershed

Cynthia Bannink

Matthew DeBoer

Melissa Powell

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Abstract

Retention basins may prove to be useful in lowering Total Suspended Solids (TSS) and Phosphorous levels within the Macatawa watershed. Three basins of varying dimensions were used for this investigation. Four parameters of retention basins were investigated; volume, depth, flux of inflow and outflow, and velocity of flow within the basin. It was found that the velocity of flow within the basin was the most important parameter in determining the effectiveness of these basins. Retention basins within the watershed are 58% effective during dry measurements and 40% effective

during rain events in their settling of TSS. It was concluded that further investigation needs to be done to determine if retention basins would be useful and feasible to implement within the Macatawa watershed.

## Introduction

Phosphorus levels in Lake Macatawa have been proven to be five times higher than acceptable levels. In the years 1996 and 1997 the Macatawa Watershed deposited approximately 138,000 pounds of phosphorus into Lake Macatawa annually, which caused concentrations to average 127 μ g/L. The present goal for reduction of phosphorus in the watershed is to decrease concentrations to 50 micrograms per liter (ug/l) or the total phosphorus load to 55,000 pounds per year.

Over twenty-five strategies for phosphorus reduction have been suggested, but the effectiveness of these methods has not been proven under local conditions. The testing of these methods is important for their implementation in the reduction of phosphorus in the Macatawa Watershed. This investigation will focus on the effectiveness of retention basins for the settling of suspended materials. Retention basins are depressions in the ground where runoff water is collected and stored to allow suspended solids to settle out. Retention basins were chosen because they are estimated to be 50% effective in reducing suspended solids and may provide a partial solution to the high phosphorus concentration problem. Very few studies have been documented that investigate the effectiveness of retention basins. However, a few articles were found that indirectly assessed this question. One study by Ingram et al found that of the 975 tons of nitrogen calculated to be entering the river, only 4 tons were measured leaving the river over the dam in Ipswich. Among other removal mechanisms, they suggested that part of this decrease was due to the sedimentation of materials in reduced flow areas. Another investigation, examining the effectiveness of retention basins and baffle installation, also suggests that an increase in pollutant removal through sedimentation processes have been inferred from a comparison of retention time distributions. Based on these investigations, retention basins may be part of the solution in the settling out of pollutants and suspended materials.

The question addressed in this investigation is whether or not local retention basins are effective in the removal of suspended solids, and if so, what basin dimensions are most effective. Three basins of varying dimensions were studied to determine ideal parameters. The parameters measured to answer these questions were flow rate, volume, depth, and velocity of flow within the basin.

## Methods

*Surveying:* The surveying phase included locating basins within the watershed whose parameters best fit the requirements for this experiment. A basin was broadly defined as a significant widening of the stream, or an actual pond. The basins that were chosen had to have a measurable inflow and outflow stream for gauging methods to be effective. Three basins were found to fit these criteria and were used in this experiment, one in a residential area, and two in agricultural areas. Site one is located on the corner of 32nd Street and Graafschaap Rd. This is the largest basin, with a estimated volume of 4.5 $E^8$ $cm^3$. Site two is located off 24th Street, just south of Van Raalte Farm. It has a volume of 1.5 $E^8$ $cm^3$. Site three is located off 146th Avenue near the 96th Avenue intersection. It had the smallest volume at 7.0 $E^7$ $cm^3$. The location of each of the three basins can be viewed on the watershed map in figure 1. Pictures of each of the ponds can also be seen in figure 2.

*In the Field:* Initial measurements were made at each of the three locations. These measurements included; constructing stream profiles of inflow and outflow streams, measuring total surface area of the basin, and measuring depth of the basin. Using a meter tape and meter stick, stream profiles were constructed by creating a transect across the stream and measuring the depth at 20 cm intervals. These measurements were then transposed into stream profile drawings. Surface area was estimated by measuring the distance across the basin at 5-10 meter intervals along the length of the basin. Depth of the basin was determined by wading through the pond or extending a meter stick from a canoe and measuring depth at consistent intervals. From the depth and surface area measurements, volumes of each pond were constructed using the Computer Aided Design (CAD) program. It should be noted that initial measurements were repeated when the parameters of the basins changed due to the effects of the rain events. New surface area, depth, and volume measurements were made to account for these changes. Also, stream profiles were reconstructed as the water levels of inflow and outflow streams varied.

Wet and dry measurements were taken to more accurately gage the effectiveness of these retention basins over varying conditions. We were able to collect 7 dry measurements and 4 wet measurements. Dry measurements included conditions of no recent rainfall, and wet measurements were those taken within 24 hours of a significant rain event.

When arriving at a basin, measurements were always taken first at the outflow of the stream then moving up to the pond measurements and finally, the inflow measurements. This was to ensure that any turnover caused by wading through the stream would be washed downstream and not skew results. During each sampling event, we recorded the velocity of flow at the outfow, within the pond, and the inflow using a flow meter. If the flow of water was not fast enough for the flow meter to detect the velocity of flow, then the meter stick method was used, timing how long it takes for a particle to travel a meter. Flow measurements were taken at 0.5-meter intervals across the inflow and outflow transects and spot checked throughout the pond. Water samples were also collected at the three areas of the basin. These were later used in measuring turbidity and Total Suspended Solids (TSS).

*In the Lab:* Turbidity and TSS measurements were obtained using the collected water samples. A turbidity meter was used to measure turbidity. A comparison of measurements was used to make sure that turbidity measurements stayed the same if measured in the field or in the lab. It was found that these measurements were constant, and therefore, reliable to be done in the lab.

A standard procedure for measuring TSS was used. A vacuum filtration system was used to clean the filters and filter the water samples. Glass fiber filters were rinsed using ultra-pure water, placed in labeled aluminum pans, cooked in a 100 C oven, cooled in dessicators, and weighed. To filter the water samples, the glass fiber filters were placed in bucchner funnels. A total of 300 ml of each water sample was filtered using the vacuum filtration system. Filters containing the TSS sample were carefully transferred to respective dishes and placed in the 100 C oven to remove excess water. After baking, sample dishes were left to cool in dessicators and then weighed. Samples were re-baked until the change in weight was less than four percent. From this procedure, the amount of TSS in a measured volume of sample was determined.

The excel program was used to compile our results and construct graphs. From these we were able to determine the parameters that are most important in determining the effectiveness of retention basins.

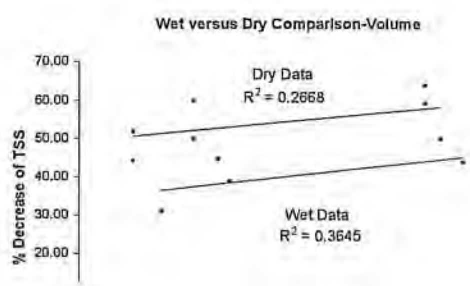
## Results

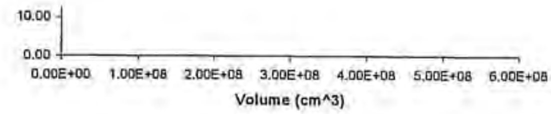
From our TSS results, we were able to determine that retention basins within the Macatawa watershed are 40% effective in decreasing Total Suspended Solids. This value of 40% is an average percent decrease in TSS over the four rain event samples. A 58% decrease in TSS was also determined as the average for the seven dry measurements (see table 1.).

Table 1. The percent decrease in TSS for wet and dry measurements. This is determined by subtracting the outflow from the inflow and dividing by the initial inflow TSS. The average percent decrease was 58% for dry measurements and 40% for wet measurements.

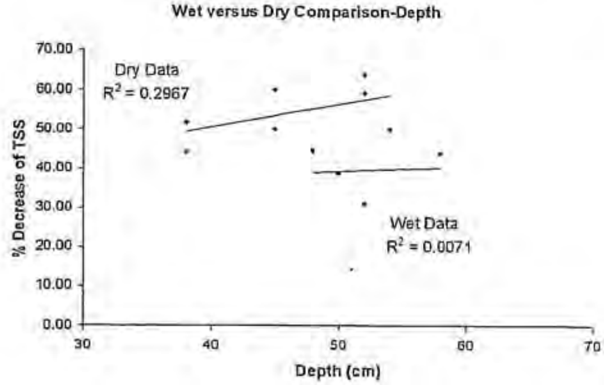
| Site (Wet or Dry) | TSS of Inflow (mg) | TSS of Outflow (mg) | Percent Decrease in TSS |
|---|---|---|---|
| #1 Dry | 2.70 | 1.10 | 59.26 |
| #1 Dry | 2.50 | 0.90 | 64.00 |
| #1 Dry | 1.20 | 0.60 | 50.00 |
| #2 Dry | 0.30 | 0.15 | 50.00 |
| #2 Dry | 0.50 | 0.20 | 60.00 |
| #3 Dry | 5.20 | 2.90 | 44.23 |
| #3 Dry | 2.70 | 1.30 | 51.85 |
| #1 Wet | 1.60 | 0.90 | 43.75 |
| #2 Wet | 9.20 | 5.10 | 44.57 |
| #2 Wet | 3.10 | 1.90 | 38.71 |
| #3 Wet | 5.80 | 4.00 | 31.03 |

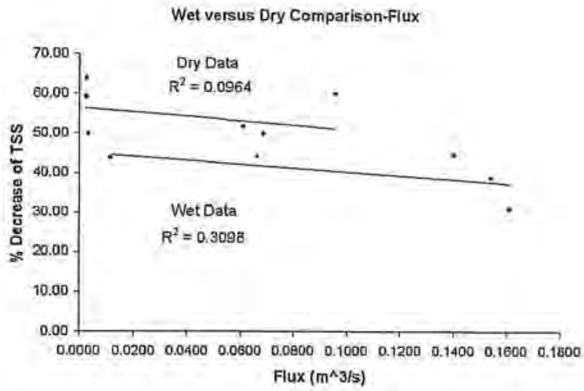
The following graphs were constructed to show the percent decrease in TSS as a result of volume, depth, flux, and basin flow. These plots were produced by compiling all the data from the three ponds. $R^2$ correlation values are provided.

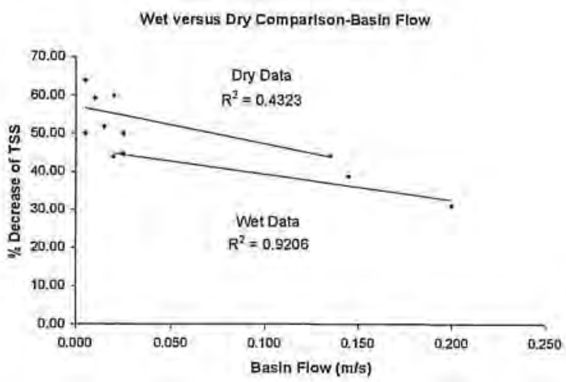





Figures 3 + 4.




Figures 5 + 6.

The one parameter that seems to be the greatest indicator for decreased TSS is the velocity of flow within the basin. Figure 3 shows that the percent decrease in TSS declined as the velocity of flow within the basin increased. This suggests that decrease in TSS is partially dependent on basin flow velocity. A correlation value of 0.43 for dry events and 0.92 for wet measurements was provided, suggesting this to be a good correlation. The other parameters studied did not show as high of a correlation.

Other parameters that were studied included volume, depth, and flux in and out of the basin. Correlation for these three parameters are no greater than 0.36, suggesting that they are not consistent in their effectiveness in reducing TSS. Figure 4 shows the comparison of wet and dry measurements in their decrease in TSS as a result of basin volume. The correlation for volume is not great, but suggests that volume may be a factor in basin effectiveness. Average basin depth was also used to compare wet versus dry conditions. No significant trends were seen in this comparison (figure 5). Flux ($m^3/s$) was also studied and was found only to have slight correlation for wet measurements (figure 6).

Site one, on the corner of 32nd street and Graafschaap Rd, was the most effective in decreasing TSS. This can be seen in table one. Site 1 had an average decrease in TSS of 54.25%, compiled from the four measurements. Site 2 showed a 48.32% decrease and site 3 displayed a decrease of 42.37%. These trends may be due to the varying parameters of the three basins.

## Discussion

From these results we can conclude that retention basins may be effective for implementation within the Macatawa watershed. A 40% average decrease in TSS was observed as the lower limit to the effectiveness of the basins studied. During dry events, the basins were found to be 58% effective in settling out suspended materials. Retention basins can only be evaluated accurately during rain events because during these events, a smaller percent of a greater abundance of TSS is entering the basin. This is due to the increased erosion of soil during rain events. A heavy rain will wash soil from fields and empty the sediment into a nearby stream. The increased velocity allows the stream to carry larger soil particles and a greater mass of particles, and therefore increasing TSS in the water system.

We were only able to investigate four parameters that determine the effectiveness of retention basins; volume, depth, flux of inflow and outflow, and basin velocity. We believe other parameters such as shape, amount of vegetation, and soil type will also all effect TSS and phosphorus levels in the water system. However, these last three parameters could not be controlled within the scope of this experiment. Because we were not able to control these parameters, the results obtained show trends of only the four parameters investigated.

These trends suggest the following about the dimensions of the most effective basins for the settling out of suspended materials. Basins of greater volume will be more effective because the velocity will more likely decrease significantly for the materials to settle out. Therefore, slower basin flow is also more effective. These two parameters seem to be more important in basin effectiveness as they display appreciable correlation in the figures above. The depth of the basin and flux of the inflow and outflow stream are also taken into account. The data suggest that shallower basins are more effective here. Also, a decreased flux is advantageous as the overall flow will be decreased as a result. This brings us into a discussion of residence time.

Residence time describes the time it takes for a particle to settle in a body of water with a constant flow and a known depth. The grain size and distribution of sediments would need to be determined for these stream and basin areas. With the three sites surveyed, several fluctuations and assumptions would have to be considered for a definite calculation of residence time to be determined. To incorporate residence time, assumptions about grain size, consistency in depth, and the uniform flow of water throughout the basin would need to be established. Another means of determining residence time would be more effective and hopefully more accurate. To consider residence time as a factor in the settling of TSS, an artificial basin could be constructed to find a precise value for residence time. With a model basin, these fluctuating parameters could be controlled. Based on the above results and knowledge of residence time, we believe that ideal ponds would be shallow and long. A competition between settling velocity of the particle and basin flow and depth of the basin arises.

*Future Studies:* To further investigate the effectiveness of retention basins, further studies in this area are suggested. Here are some possibilities for future studies:

-A more detailed inspection of one pond to eliminate variables such as shape, vegetation, and soil type which were not able to be studied or controlled in this experiment.

-Multiple measurements should be taken on a consistent basis. The data obtained here was enough to show trends, however, it is inconclusive.

-TSS measurements were assumed to be a direct correlation to the reduction of phosphorus levels. However, a more direct measurement of phosphorus would be helpful.

-An artificial basin could be used to determine which parameters are most significant in the reduction of TSS/phosphorus. Optimal ratios between the varying parameters could be determined as experimenters could alter conditions to see what are most effective.

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