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The Influence of Sediment Bays on Reducing Incoming Sediment in Holmes Lake: Lincoln, Nebraska

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THE INFLUENCE OF SEDIMENT BAYS ON REDUCING INCOMING SEDIMENT IN HOLMES LAKE: LINCOLN, NEBRASKA

by

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ABSTRACT

Lakes in the urban environment are often challenged with issues of water quality. Holmes Lake, located in Lincoln, Nebraska, has experienced such problems. In an effort to improve water quality in Holmes Lake, the city installed several control devices. One of the devices installed were sediment bays. This study evaluated the effectiveness of those sediment bays by measuring turbidity and suspended sediment after rain events at different locations in and out of the bays. The study found that the bays helped to reduce sediment in some cases, but in other cases no reduction was shown.

INTRODUCTION

As the world's population increases and becomes more urbanized, it places immense stress on the earth's natural resources. Water, a resource of vital importance, is particularly of concern. Urbanization has led to the degradation of streams worldwide, reducing water quality and changing flow characteristics. Streams in the urban environment undergo changes such as channelization, erosion, and sediment and nutrient increases. All of these changes impact animal life not only in the stream itself, but any water body downstream. Ecologists have called this trend the urban stream syndrome, and it is characterized by increased susceptibility to flooding, elevated concentrations of nutrients and contaminants, altered channel morphology and stability, and reduced biotic richness, with increased dominance of tolerant species (Walsh et al. 2005).

When land that was previously covered with vegetation is developed and converted to streets, parking lots, and buildings it reduces the perviousness of the land surface and increases runoff from storms and snowmelt, which leads to a flashier hydrograph (Paul & Meyer 2001).

Elevated concentrations of nutrients and contaminants in lakes and streams decrease water quality and increase microorganism growth, which depletes oxygen needed for higher level organisms and reduces biotic richness. All of these factors lead to the overall degradation of water resources. Lakes with poor water quality can lose their aesthetic and recreational value, cause health problems to the public, and cost the public money since it is very costly to rehabilitate a lake.

One lake, located in Lincoln, Nebraska, is an example of an urban body of water which has experienced issues of eutrophication due to the extensive changes in its watershed over the last 40 years. The watershed has a drainage area of approximately 5.4 square miles, and is composed primarily of urban residential and commercial land use, with additional land for parks and open space (Watershed Assessment 2007). The county has increased in population from 155,000 in 1960 to just over 250,000 in the year 2000, with an estimated population in 2009 of just over 280,000 (U.S. Census Bureau). Much of the growth in Lancaster County has taken place in the city of Lincoln, which had a population of 225,000 in the 2000 census, and an estimated population of 250,000 in 2009. The Holmes Lake watershed has become almost completely developed over the last 40 years. This development has led to sediment and nutrient runoff from the clearing of land for construction and increased runoff from lawns, parking lots, and roads. As a result of these influences, stream and lake water quality in the watershed decreased in the years following.

In 2005 the city of Lincoln drained and renovated Holmes Lake. Renovation projects included shoreline stabilization measures, improved fisheries, wetlands, and the construction of sediment bays. In addition to the renovation, the city of Lincoln conducted a watershed assessment in 2007 to evaluate the conditions of the streams that drain into Holmes Lake and identify potential improvements and areas of concern in the watershed. The assessment proposed seven primary projects of high priority and highlighted 23 more projects to be initiated in the future (Watershed Assessment 2007). The proposed projects center on improving stream water quality in Antelope Creek, the main tributary leading into Holmes Lake, and the tributaries leading into Antelope Creek.

This study was conducted to evaluate the effectiveness of the two sediment bays installed after the 2005 renovation of Holmes Lake. The purpose sediment bays serve is to slow down incoming water and runoff so that any suspended sediments can settle out before entering the main body of water. Turbidity and total suspended solids measurements were taken from samples gathered after rain events at the two sediment bays to see whether the bays helped in controlling sediment inflow. If sediment bays act to reduce incoming sediment, then suspended sediment and turbidity should decrease between the areas of inflow and the main body of water.

LITERATURE REVIEW

The rising concern of the quality of our freshwater resources has prompted a number of studies centered on improving and restoring aquatic ecosystems that have experienced degradation due to anthropogenic causes. A major focus of these studies has been lake eutrophication and sedimentation. Eutrophication of lakes happens as a result of excess nutrients being introduced to the lake from storm runoff. Often, phosphorus is the limiting nutrient in lakes leading to eutrophication (Schindler, 1974). Modern agriculture and urbanization can be claimed as the leading factors attributing to lake eutrophication in many areas (Sondergaard & Jeppeson, 2007). Widespread clearing of land for agriculture and construction has changed the landscape of many watersheds. Unprotected soil can be washed away during large storms and carried downstream into lakes and reservoirs, carrying nutrients such as phosphorus and nitrogen with it. Not only does a problem arise from the volume of sediment being deposited into lakes and reservoirs, but the nutrients allow for algal blooms, which decrease water clarity and dissolved oxygen needed for other organisms to thrive (Gulati & van Donk, 2002).

Many techniques have been used for reducing sediment and improving water quality in eutrophied lakes. Two main strategies are applied when trying to improve lake water quality. The first is to reduce external loading of phosphorus coming from sediment by encouraging best management practices in targeted watersheds. The second is to reduce the internal loading of phosphorus in lake-bottom sediment. Often these approaches have to be utilized together to achieve the desired improvements in water quality.

Reitzel et. al (2003) tested the effects of aluminum addition in reducing internal phosphorus in a shallow eutrophied lake. The aluminum acted as a binding agent, keeping the phosphorus from becoming active and usable by microorganisms. Their results showed that water clarity increased following the aluminum addition in their experimental enclosures, while it remained the same in their controls, indicating that aluminum addition could be a viable option to capture internal phosphorus. These results were supported in another study by Reitzel et. al (2005), when aluminum was used again. They found that internal phosphorus was reduced by 93% in the two post-treatment years.

A similar strategy was used by Hart et. al (2003) to reduce internal phosphorus. They tested 3 different forms of calcium carbonate: limestone, SoCal (A German product), and ESCal (An Australian product). Calcium carbonate acts in much the same way as aluminum by demobilizing internal phosphorus. Their experiment found that SoCal was the most efficient at reducing mobile phosphorus (100 times less phosphorus released than control), but that ESCal (15 times less phosphorus release) was a more economical product for their use. Salonen and Varjo (2000) tested gypsum in reducing internal phosphorus loading under anoxia induced conditions. Anoxia was induced by isolating the water column to prevent mixing from surface currents caused by wind. They used two sets of three basins, applying gypsum in four of the basins and using the other two for control. Their results indicated that gypsum decreased internal phosphorus release in comparison to their control groups.

To combat external loading of phosphorus, different management practices can be employed in the watershed of the targeted lake or stream. Most lakes or streams that experience problems of eutrophication can be found in one of two watershed types, urban or agricultural. In urban watersheds soil management techniques are used on construction sites. A study conducted by McLaughlin et. al (2009) looked at three different water quality control devices installed on a construction site. The control devices consisted of three different variations of catchment basins designed to stop and hold runoff to allow suspended sediment to settle out. They concluded that standard sediment control practices on construction sites do not remove enough sediment from storm runoff and that a combination of different practices should be utilized to best reduce the transfer of sediment.

Marttila and Klove (2009) tested a peak runoff control device designed to reduce the rate of water flow and improve settling of sediments. The device can be installed in drainage canals and ditches that are susceptible to erosion. They found that the peak runoff control devices forestalled sediment bed erosion and transport and that suspended sediment transport during storm runoff decreased by as much as 94 percent.

Best management practices are another option for improving water quality in watersheds. Moore et. al (1992) used a hydrological simulation program called FORTRAN to evaluate the implementation of several proposed best management practices. The practices included converting cropland to grassland, conservation tillage, and reservoir construction. They found that converting cropland to grassland was the most effective method to reduce watershed erosion and stream sediment loads. The principal of this management practice has been applied in the urban landscape by creating vegetative buffers and green spaces.

METHODS AND MATERIALS

The site for the study is Holmes Lake, which is located in southeastern Nebraska within the City of Lincoln in Lancaster County. The watershed has a drainage area of approximately 5.4 square miles and the lake is a 110-acre reservoir formed after the construction of a dam in 1962 by the US Army Corps of Engineers. The lake was built to reduce flood damages in Lincoln and also provide recreation to the Lincoln community. In 2005 the entire lake was renovated and shoreline stabilization measures, wetlands and fisheries were improved, and two sediment bays were created (Watershed Assessment 2007). Since 2005, the city of Lincoln has worked to improve the Holmes Lake watershed by improving stream water quality in Antelope Creek, as well as the surrounding tributaries. The purpose of this study is to evaluate the effectiveness of the two sediment bays in Holmes Lake. To accomplish this, water samples were taken from three different locations at each sediment bay. These locations radiated out from the stream inlet, towards the main body of water. The water quality characteristics measured were turbidity and total suspended solids, since these are the primary characteristics sediment bays seek to improve.

Water samples were collected directly after rain events between the months of June and October 2010. Samples were also taken during periods when no rain event occurred within 48 hours to establish a measurement for base flow to be compared with flows after rain events. A telescopic pole with a bottle at the end was used to collect the samples, and 500mL Nalgene bottles were used to store the samples. A Hach 2100p turbidimeter was used to measure turbidity. After all six samples were taken from each site, the water collected in the Nalgene bottles was agitated to resuspend any settled particles and transferred to the sample cells used by the meter. The turbidity was measured in NTU's, or Nephelometric Turbidity Units, which is a measure of the cloudiness or haziness of the water. After turbidity was measured, samples were then taken to the Lincoln wastewater laboratory for analysis of total suspended solids. This was usually done the day following the rain event.

Samples were taken from three locations at two sites. These locations were labeled A, B, and C for each site. At site 1, location A was at the stream inlet under 70th Street, location B was just off of the rock jetty that formed the east bay, and location C was under the east bridge. At site 2, location A was at the bridge in Colonial Park, location B was off the fishing dock, and location C was under the west bridge.

Aerial imagery indicating locations A through C for sites 1 and 2.

RESULTS

It appears from the data that the location that had the most variability between rain samples and non-rain event samples was location A at both sites. Locations B and C fluctuate, but not to the degree of location A. At site 1, location A usually had the highest turbidity and suspended sediment reading (*Tables 1 & 3*). The highest turbidity reading between both sites was taken from site 1, location A (*Table 1*). The August 4th and 17th rain samples decrease in both turbidity and suspended sediment from location A to C. This may be because the samples were taken longer after the rain had stopped than in the other sample sets, allowing the runoff plume to flow further from the inlet.

Location A at site 2 consistently had low turbidity readings, with little suspended sediment (*Tables 2 & 4*). This may have been due to the park area around it acting as a buffer to catch any runoff. Locations B and C were always higher than location A in both turbidity and suspended sediment. The August 17th suspended sediment reading was significantly higher at both sites than all the other sample sets (*Tables 3 & 4*). This may have been due to algae or error in analysis. However, algae were not quantified or measured in any way, leaving no way to tell.

Turbidity Data (NTU's) - Site 1

Sample Type/Date	Rain/ 22-Jun	Rain/ 12-Jul	Rain/ 4-Aug	Rain/ 17-Aug	Rain/ 13-Sep	Non-Rain/ 2-Aug	Non-Rain/ 26-Aug	Non-Rain/ 7-Oct
A	28.4	39.1	6.38	9.48	21.1	6.5	5.72	3.26
B	11.3	18.4	12.3	12.5	17.6	11.5	14.0	5.7
C	11.3	16.3	26.0	15.5	17.1	9.57	14.6	8.22

Table 1

Turbidity Data (NTU's) - Site 2

Sample Type/Date	Rain/ 22-Jun	Rain/ 12-Jul	Rain/ 4-Aug	Rain/ 17-Aug	Rain/ 13-Sep	Non-Rain/ 2-Aug	Non-Rain/ 26-Aug	Non-Rain/ 7-Oct
A	3.01	9.93	5.83	10.4	5.58	1.06	2.14	1.29
B	7.44	9.94	16.0	13.4	22.6	11.2	15.4	5.22
C	5.17	13.1	18.8	15.6	23.1	15.5	19.4	10.6

Table 2

Total Suspended Solids Data (mg/L) - Site 1

Sample Type/Date	Rain/ 22-Jun	Rain/ 12-Jul	Rain/ 4-Aug	Rain/ 17-Aug	Rain/ 13-Sep	Non-Rain/ 2-Aug	Non-Rain/ 26-Aug	Non-Rain/ 7-Oct
A	14	45	6	140	59	9	8	6
B	8	22	11	140	15	14	13	28
C	9	12	22	170	17	12	16	34

Table 3

Total Suspended Solids Data (mg/L) - Site 2

Sample Type/Date	Rain/ 22-Jun	Rain/ 12-Jul	Rain/ 4-Aug	Rain/ 17-Aug	Rain/ 13-Sep	Non-Rain/ 2-Aug	Non-Rain/ 26-Aug	Non-Rain/ 7-Oct
A	2	10	3	100	4	4	2	8
B	6	17	14	140	23	18	13	28
C	3	17	15	130	29	21	18	76

Table 4

Total suspended solids decreased at Site 1 in three sample sets, and increased in two. Site 2 saw an increase in suspended solids in all five sample sets (*Table 5*). The change in turbidity followed the same pattern in all sample sets as the change in TSS (*Table 6*). The non-rain event readings increased in all sample sets for both turbidity and suspended sediment.

Change in TSS (mg/L) between Locations A and C *Table 5*

Sample Type/Date	Site 1	Site 2
Rain/22-Jun	↓5 (35.7%)	↑1 (33.3%)
Rain/12-Jul	↓33 (73.3%)	↑7 (41.2%)
Rain/4-Aug	↑16 (72.7%)	↑12 (80.0%)
Rain/17-Aug	↑30 (17.6%)	↑30 (23.1%)
Rain/13-Sep	↓42 (71.2%)	↑25 (86.2%)
Non-Rain/2-Aug	↑3 (25.0%)	↑17 (81.0%)
Non-Rain/26-Aug	↑8 (50.0%)	↑16 (88.9%)
Non-Rain/7-Oct	↑28 (82.4%)	↑68 (89.5%)

Change in Turbidity (NTU's) between Locations A and C *Table 6*

Sample Type/Date	Site 1	Site 2
Rain/22-Jun	↓17.1 (60.2%)	↑2.16 (41.8%)
Rain/12-Jul	↓22.8 (58.3%)	↑3.2 (24.2%)
Rain/4-Aug	↑19.6 (75.5%)	↑13 (69.0%)
Rain/17-Aug	↑6 (38.8%)	↑5.2 (33.3%)
Rain/13-Sep	↓4 (19.0%)	↑17.5 (75.8%)

Non-Rain/2-Aug	↑3.11 (32.5%)	↑14.4 (93.2%)
Non-Rain/26-Aug	↑8.88 (60.8%)	↑17.3 (89.0%)
Non-Rain/7-Oct	↑4.96 (60.3%)	↑9.31 (87.8%)

The change in turbidity and suspended solids was determined by subtracting the values for Location C from Location A.

In the case of the three sample sets at Site 1, the turbidity and TSS decrease, supporting the assumption that if turbidity and suspended solids decrease, then the sediment bays are helping to reduce sediment entering the lake. However, there are two sample sets from Site 1 that show contradicting data, so the results aren't definitive.

On the whole, the data doesn't allow for one to draw any definitive conclusions. At one site it looks like suspended sediment and turbidity are reduced by the sediment bays, while at the other there seems to be the opposite effect. Since algal growth is common at Holmes Lake it is likely that algae influenced the data at both sites. However, the water samples collected were not analyzed for algae, making it difficult to determine the degree of influence that it had.

DISCUSSION

The data leaves no definitive answer to how well the sediment bays work in reducing suspended sediment. In some samples there was evidence for the sediment bays acting to reduce sediment inflow, while other samples show otherwise. Sediments naturally settle out in water over time. Larger particles settle out first, followed by smaller particles. Depending on how fast the water was flowing from location A to location C, there may not have been enough runoff from some of the storms to cause an adequate amount of flow for the sediment bays to have a noticeable effect on suspended sediment. Additionally, algae were likely to influence the samples taken at several locations. Floating algae would cause higher turbidity and suspended solid readings which would not be accurate of storm runoff.

The study has other limitations as well, including sample timing, sample size, no control, and the location of site 2 sampling locations. Samples were taken at the first opportunity to get to the sites, so time after the rain event differed each time, possibly influencing the amount of sediment left in suspension. A larger sample size of rain events would have provided a more accurate picture of the trends associated with rainfall and sediment, and the effects of the sediment bays in reducing sediment. Having a control bay would have also been beneficial to show the difference between a bay constructed to reduce suspended sediment, and one without any device to control sediment. The site 2 sampling sites were chosen for their ease of access. As a result, locations B and C both lay outside the sediment bay. Ideally, location A would have been closer to the lake, location B would have been from the sediment bay rock jetty, and location C would have been where location B was. These locations would have been a closer replica of the site 1 locations, and allow for better comparison between the two.

CONCLUSION

The sediment bays in Holmes Lake are likely effective at reducing sediment inflow from storms that produce a large amount of runoff. However, with storms that do not have large amounts of runoff and do not significantly increase stream flow, sediment is more likely to be settled out close to the inlet before it reaches the sediment bay barriers. From the samples I collected, it doesn't appear that there is a great amount of sediment entering the lake, indicating that the watershed improvement projects that have been implemented have been successful. Also, since the watershed is almost completely developed, there is no longer a large amount of soil exposed from construction sites and agriculture. The algal blooms that Holmes Lake sees in the summer months are not likely due to incoming sediment. The nutrients allowing the algae to grow in the summer may be from fertilizer runoff in the watershed, internal phosphorus being released from the lake sediments, or a combination of both. Future studies may want to focus on the origin of the nutrients leading to large algal growths in the summer.

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