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INTRODUCTION

Water quality impacts from "man-made" impoundments have been debated for some time, especially in the Red River Basin. The stored water is eventually released when flood peaks have dissipated downstream. Water stored on previously dry ground undergoes a myriad of chemical and physical reactions that may have detrimental effects on downstream water quality.

Beaver also construct water holding areas that may affect water quality. The Red Lake Watershed District received matching funds from the Red River Watershed Management Board to study beaver ponds and determine the effect these naturally constructed "impoundments" have downstream on water quality.

METHODS

Site Selection

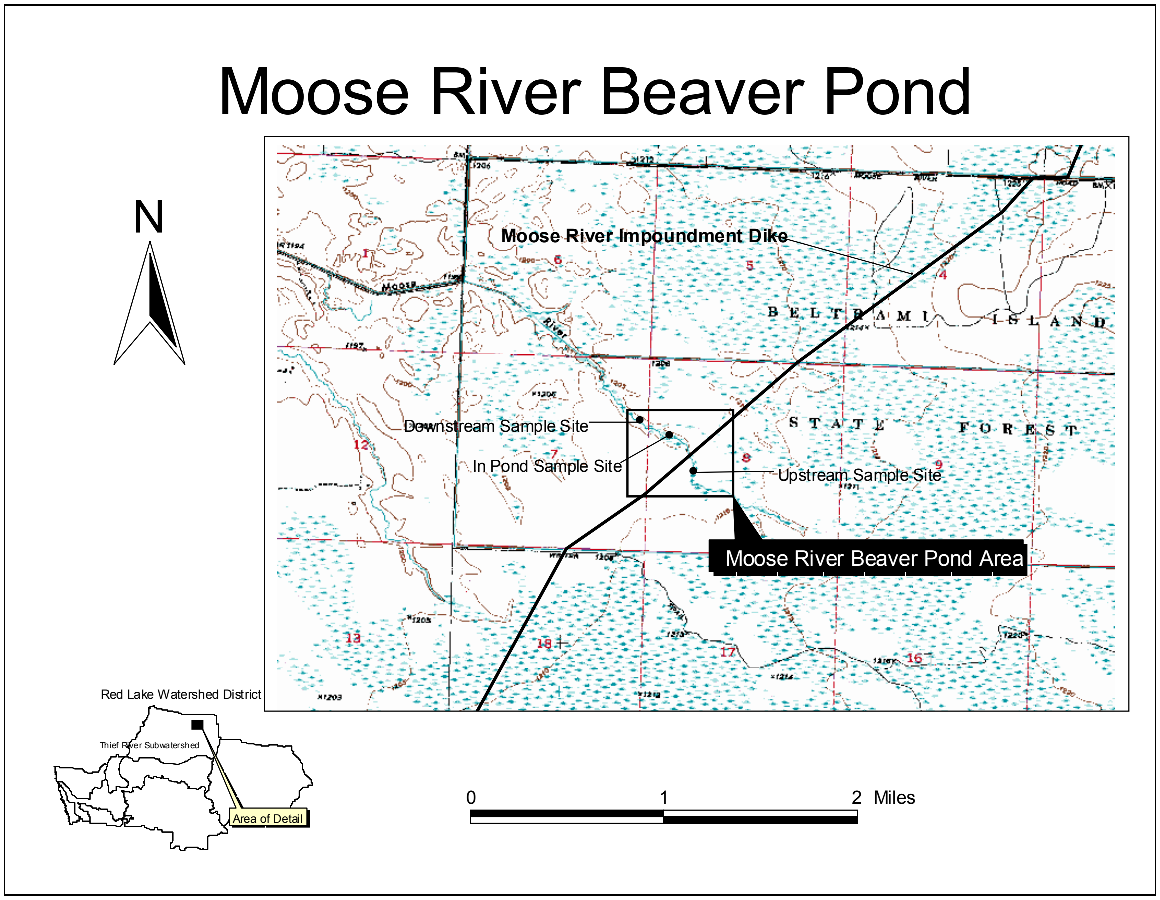
In 1995 and 1996 RLWD staff collected water quality data in two beaver ponds. A third beaver pond was not located. The two beaver ponds studied became inactive after 1996 likely due to high water (Leach 2000). One sample was taken in July of 1997. The data from this sample was not used since was the only sample taken in 1997.

The first beaver pond was located downstream of the Moose River impoundment on the Moose River on sections 6, 7 or 8 on an unorganized territory in Beltrami County, township 157 N, range 37 W (Figure 1). The upstream sampling location was on the Moose River impoundment outlet structure. The beaver pond itself was situated approximately 1mile downstream of the outlet (Sanderson 2000). The downstream sampling location was approximately ¼ mile downstream of the beaver pond.

Relatively little distance exists between the Moose River beaver pond pool and the Moose River Impoundment. Flow through the Moose River beaver pond is likely from the Moose River Impoundment outlet. The Moose River Impoundment is a large impoundment located within the Northern Minnesota Wetlands Ecoregion, an area of wetlands, peat bogs and marshes (MPCA 1997). The impoundment itself is divided into (north and south) pools (Figure 1). The south pool outlet is the origin of the Mud River. The north pool outlet is the origin of the Moose River. The north pool has a capacity of 12,000 acre-feet.

Since the beaver pond is located near the impoundment, the water quality in the Moose River near the beaver pond could be influenced by factors within the Moose River Impoundment. Several factors contribute to impoundment water quality including wind, ice and snow cover, biological activity and others (Olem and Flock 1990).

Figure 1: Moose River Beaver Pond Map



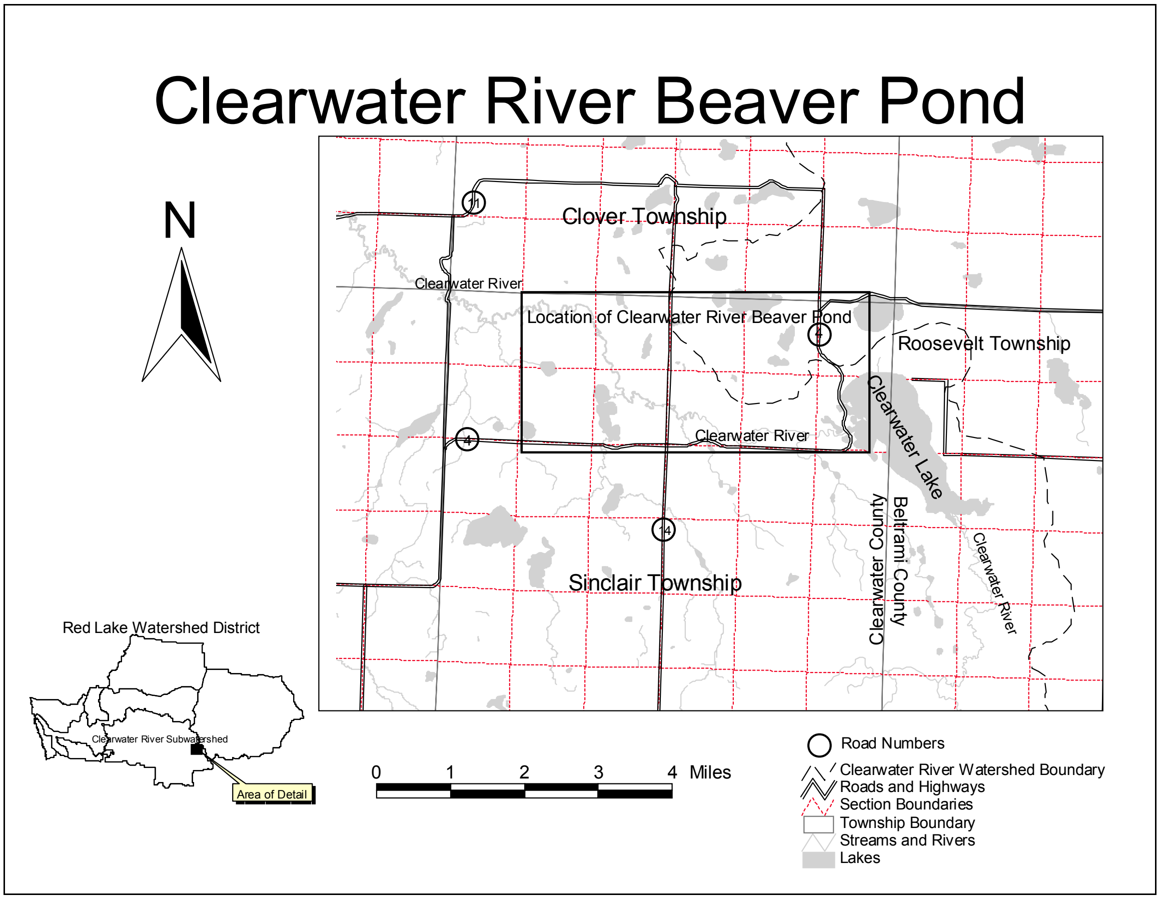
The second beaver pond was located downstream of the Clearwater River dam, (Figure 2). This dam creates Clearwater Lake. The beaver pond was approximately 1 to 5 miles downstream of the dam in Sinclair Township, Clearwater County (Leach 2000). Due to employee transition within the RLWD, the exact locations of the upstream and downstream sampling sites are unknown. Discharge measurements were not recorded and no estimates are available for this report.

Water Quality

The samples were taken using either a kemmerer bottle or a dip method as described in the "Quality Assurance Manual" from the University of Minnesota Crookston (UMC) water quality laboratory. Samples were analyzed at the UMC water quality laboratory. Methods are described in the "Procedure Manual" from the UMC water quality laboratory. The UMC water quality laboratory is certified by the Minnesota Department of Health.

The number of parameter measurements for the Moose River sites varies from about 7 to 15 measurements. The samples for the Moose River sites were taken from June 6, 1995 to October 28, 1996. The number of parameter measurements for the Clearwater River sites varies from 1 to 5 measurements. The samples for the Clearwater River sites were taken from June 12, 1996 to October 28, 1996 (Appendix A).

Figure 2: Clearwater River Beaver Pond Map



Statistical Analysis

Statistical tests were used to determine what the collected water quality data actually means. Since water quality data was gathered upstream and downstream of the beaver ponds, the two sites represent the water quality on the Moose River before and after water passes through the beaver pond. Also, the samples are collected from essentially the same water, i.e. the data is considered to be from the same population before and after a treatment. A paired t-test provides inferences about the difference between two means from the same population.

The paired two-sample t-test for population means was performed on all of the available data from the Moose River beaver pond and the Clearwater River beaver pond. The t-tests pair the upstream and downstream measurements. Since the alternative hypothesis includes detrimental or beneficial effects, the t-test is a two tailed test (McClave and Dietrich 1988). To format the data for the t-test, the sets need to have an equal number of measurements taken at the same time. If data were present for one site but not the other, the sampling dates were not used. If data points appeared to be outliers they were not included, e.g. a measurement of 83 mg/L for total suspended solids on 2/17/96 for the downstream site of the Moose River beaver pond. These measurements may be the result of sampling or analysis error. All measurements listed as below detectable limits (BDL) were set to zero. The results of all the t-tests are listed in Appendix B.

The paired comparison tests were performed using the data analysis tools in Excel spreadsheets. The spreadsheet provides output values including the Pearson Correlation, degrees of freedom, the t statistic, the probability statistic, and the critical value of the t statistic. Of most interest in this study is the t statistic as compared to the critical value of the t statistic. If the absolute value of the t statistic is greater than the critical value of t, the alternative hypothesis was accepted. If the absolute value of the t statistic is less than the critical value of t, the null hypothesis is accepted. Also of interest is the Pearson Correlation, which determines whether or not the relationship between upstream and downstream measurements in the paired comparison test is linearly correlated. If the Pearson Correlation (r) had an output value of less than the critical value for r, the upstream and downstream measurements were not correlated. If r was greater than the critical value for r the measurements were considered linearly correlated. The critical values of the Pearson Correlation are found in Appendix C. The confidence coefficient was set at 0.05.

If the alternative hypothesis is accepted, the beaver ponds could be acting in two different ways. The first is when the Pearson Correlation suggests a linear correlation. In this case the beaver pond may simply be adding a certain amount of the given parameter to the stream flow. The second is when the Pearson Correlation does not suggest a linear correlation. In this case the beaver pond may be acting differently or in an unknown fashion.

The study originally proposed sampling periods for three years with 15 samples taken annually for a total of 45 samples per site. The sampling sites near the Moose River beaver pond have from 7 to 15 measurements, while the Clearwater River beaver pond sites range from 1 to 5 measurements (Appendix A). A larger number of measurements taken allows for accepting the alternative hypothesis when there are smaller differences (McClave and Dietrich, 1988). Sample sizes of 10 to 20 are reasonable in this situation.

RESULTS AND DISCUSSION

Most of the t-tests performed, confirmed the null hypothesis of no difference in water quality between the upstream and downstream sites. These paired comparison tests display a probability statistic which is larger than 0.05 and a t statistic which is less than the critical value of t. Nothing more about these parameters is known than before performing the paired comparison test. Since there are often observation numbers of less than 10, this suggests a need for more measurements.

Table 1: Moose River Alkalinity, Paired Two Sample t-Test for Means

	Downstream	Upstream
Mean	203	176
Variance	3728	2800
Observations	9	9
Pearson Correlation	0.85	
Hypothesized Mean Difference	0	
df	8	
t Stat	2.48	
P(T<=t) one-tail	0.019	
t Critical one-tail	1.86	
P(T<=t) two-tail	0.038	
t Critical two-tail	2.30	

The mean for alkalinity was statistically larger at the downstream site for the Moose River beaver pond (Table 1). The Pearson Correlation confirms a relationship between the upstream and downstream sites. The beaver pond is adding a certain amount to the alkalinity of the Moose River. The Clearwater River beaver pond only had two measurements so this t-test was not performed.

The paired comparison test for nitrate means in the Moose River beaver pond shows a difference in upstream and downstream means (Table 2). The downstream mean is larger, suggesting that the beaver pond is adding nitrates to the Moose River. Since the Pearson Correlation confirms a linear relationship, the beaver pond is adding nitrates to the Moose River. The paired comparison test for nitrate means in the Clearwater River beaver pond confirmed the null hypothesis. The small amount of measurements taken on the Clearwater River beaver pond again suggests a need for more observations.

Table 2: Moose River Nitrates, Paired Two Sample t-Test for Means

	Upstream	Downstream
Mean	0.0067	0.0185
Variance	4.56E-05	0.0002686
Observations	15	15
Pearson Correlation	0.52	
Hypothesized Mean Difference	0	
Df	14	
t Stat	-3.25	
P(T<=t) one-tail	0.0029	
t Critical one-tail	1.76	
P(T<=t) two-tail	0.0058	
t Critical two-tail	2.14	

According to the paired comparison test for total phosphorus means in the Moose River beaver pond, the alternative hypothesis is accepted (Table 3). The result shows that the downstream total phosphorus mean is larger. The Pearson Correlation confirms a linear relationship between the upstream and downstream sites, indicating the beaver pond is adding total phosphorus to Moose River.

The Clearwater River beaver pond t-test for total phosphorus also confirmed the alternative hypothesis, although the analaysis displayed a larger upstream mean. The Pearson Correlation does not confirm a linear relationship between the upstream and downstream sites. The Clearwater River beaver pond paired comparison test results conflict with the results from the Moose River beaver pond. The small number of measurements from the Clearwater River beaver pond suggests that more observations are needed.

Table 3: Moose River Total Phosphorus, Paired Two Sample t-Test for Means

	Upstream	Downstream
Mean	0.071	0.111
Variance	0.003	0.012
Observations	15	15
Pearson Correlation	0.90	
Hypothesized Mean Difference	0	
df	14	
t Stat	-2.52	
P(T<=t) one-tail	0.012	
t Critical one-tail	1.76	
P(T<=t) two-tail	0.025	
t Critical two-tail	2.14	

The paired comparison test for specific conductance means on the Clearwater River beaver pond confirms the alternative hypothesis with the upstream mean being larger (Appendix C). The Pearson Correlation does not confirm a linear relationship. This result should be viewed with skepticism since only three measurements were available for the test. The Moose River beaver pond paired comparison test for specific conductance means confirmed the null hypothesis (Appendix C). This test is accepted since there were more measurements. The Pearson Correlation confirmed a linear relationship.

All of the parameter line graphs for the Moose River beaver pond are given in Appendix D. The dissolved oxygen graph of the Moose River beaver pond shows a definite lack of oxygen during the late winter measurements on 2/07/96 and 3/12/96. The low oxygen conditions correspond to high total phosphorus, chemical oxygen demand, total kjeldahl nitrogen, specific conductance and organic phosphorus, along with a lowered pH. This also corresponds to an extended period of very low discharge, from 1 to 6 cfs, from the Moose River Impoundment RLWD (1995 - 1996). Fecal coliform bacteria counts rise noticeably during the summer period at upstream, downstream and in pond measurements. Peaks in nitrate concentrations are noted in September 1995 and again in March 1996 in upstream, downstream and in pond measurements. Orthophosphorus concentrations show a spike in March 1996 at all three sites and again at just the beaver pond and downstream in September 1996.

ACKNOWLEDGEMENTS

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