11.0 FLUX Modeling Results

The water quality modeling program FLUX was used to calculate total annual flow volume in cubic hectometers, total annual loads for water quality parameters, as well as flow-weighted means for all stream monitoring sites. This program uses continuous flow data and available sampling data to determine yearly totals and averages for water quality parameters. The modeling completed for the Clearwater Lake watershed shows that, during the study period, the most water quality degradation on the Clearwater River came from two of the six subwatersheds that were monitored. The first is the watershed of the reach of the Clearwater River that lies between Clearwater County Road 25 (Site #128) and 3-mile road (excluding the Walker Brook subwatershed). The other is the watershed of the Clearwater River reach between 3-mile road and the Clearwater Lake inlet (excluding the Buzzle Lake outlet and everything upstream of 3-mile road). Other subwatersheds either minimally contribute to the degradation of water quality in the Clearwater River or actually help improve the water quality (a diluting effect) in the river in some cases. There are some of the subwatersheds that do not greatly contribute to sediment and nutrient loadings due to their low flows, but they still, in some cases, have their own water quality problems.

Water from Walker Brook enters the Clearwater River on the southeast edge of the city of Bagley. When comparing the flow weighted means before and after this confluence (at the #128 and 3-mile road water quality monitoring sites, respectively), water quality is degraded for TSS, TP, OP, TDS, Nitrates and Nitrites, and DO after the confluence and Walker Brook may appear to be the source. However, when loads (tons/year) from the Walker Brook watershed and the 3-mile road watershed are compared, the 3-mile road subwatershed is more likely to be the primary source of the degradation. It contributes higher loads than Walker Brook. Some parameters that appeared to be improved from #128 to 3-mile road include COD, TKN, Ammonia, and Fecal Coliform.

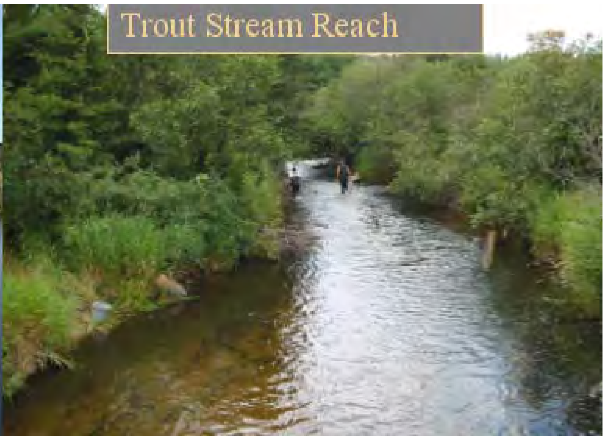
How do the watersheds of Walker Brook and #128 compare? Walker Brook has a slightly higher weighted average curve number, which means that a higher percentage of water will run off of the landscape during a storm. Walker Brook has higher TP levels but has lower TSS concentrations, which says that much of the phosphorus at this site may be dissolved in the water. Monitoring data reinforces this observation. The ratio of soluble reactive phosphorus (OP) to total phosphorus was twice as high at the Walker Brook monitoring site as it was at #128. Walker Brook is worse in terms of orthophosphorus concentrations, total dissolved solids concentrations, and peak discharge when compared to the #128 monitoring site on the Clearwater River. Walker Brook has lower concentrations of TSS, ammonia, fecal coliform, and a lower amount of peak runoff. Ammonia was not very high at either location when compared to the minimally impacted stream levels for the ecoregion.

The reason Walker Brook had higher average levels of phosphorus when compared to #128 may be attributed to a period of elevated concentrations in July and August of 2002 at the Walker Brook monitoring site. When examining sample results for individual dates, Walker Brook sometimes had lower concentrations of TP than #128. The lower values may be a result of the settling of sediment when the combination of the landscape and beaver dams cause water in the stream to pool and decrease the velocity of the water. When there is a storm event, higher levels of flow, or beaver dam removal, sediment and nutrients that are settled out may be swept downstream, causing a rise in concentrations.

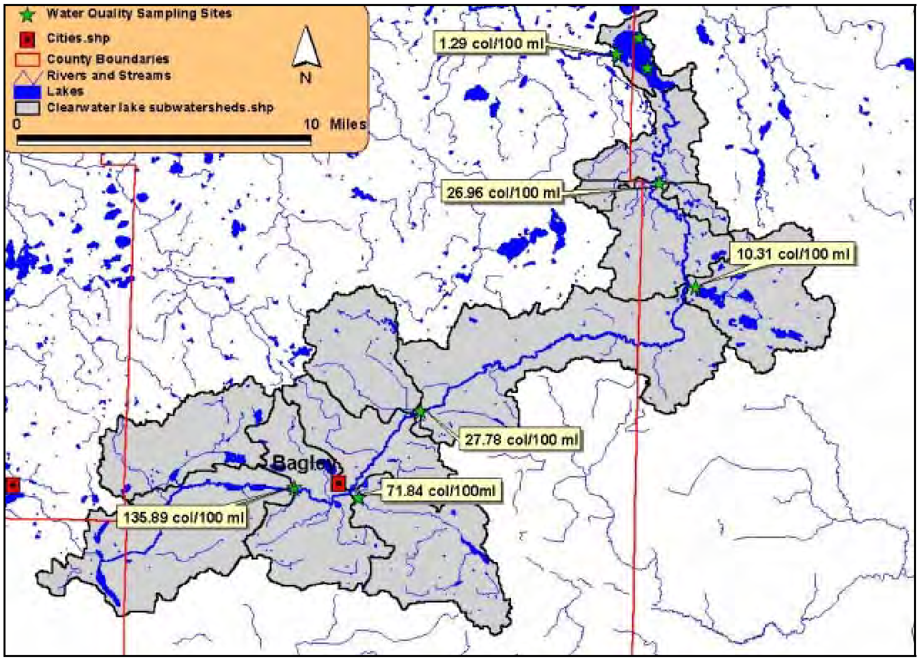
A high spike in fecal coliform of 1584 col./100ml was recorded at the #128 monitoring site. This accounts for the higher average levels of fecal coliform for that watershed. This spike came during relatively high flows and there was precipitation occurring at the time the sample was collected. Walker Brook also experienced some spikes, although not quite as dramatic. Both sites experienced spikes that greatly exceeded the EPA standard of 200 col./100 ml.

The channel of the Clearwater River has a relatively low slope in the upper reaches from the headwaters downstream to the confluence with water coming from the Buzzle Lake subwatershed. After this point, the channel grade increases significantly. The geology of the area, restricted flow through the culvert at 3-mile road, beaver dams, and beaver dam remnants are all factors that may be acting to keep the river in a relatively flooded state in the upper watershed of the Clearwater River. This flooded state helps to increase the temperature of the water, increase the depth of the water, and reduce the velocity of the water. A beaver dam was present just downstream of the #128 monitoring site in late summer and throughout the fall. During pre-study reconnaissance, beaver dam remnants were found by RLWD and Clearwater SWCD staff downstream of the 3-mile road site. Relatively high stage levels and relatively low flows showed that water was “backed-up” at the Walker Brook monitoring site in early June and in middle to late August of 2002, most likely because of downstream beaver dams.

Fecal coliform bacteria grow better in warmer temperatures and in deeper, more stagnant water. Although they grow better in warm-water temperatures versus cold-water temperatures, fecal coliform bacteria do not survive when exposed to too much sunlight. The deeper the water, the lower the amount of sun that can penetrate it. The shallower the water, the more sun can penetrate it. Prior to 3-mile road (upstream of the trout-stream reach), the Clearwater River and Walker Brook are both very deep and ponded when compared to the trout stream portion of the Clearwater River, even though there is a lower volume of flow in the upper watershed. It is impossible to wade far from shore in the upper watershed of the Clearwater River due to ponded water and a mucky bottom. Most of the lower watershed (trout-stream reach) is easily wadeable and has a firmer, sandier bottom. The fine sediment deposited in the upper watershed, of which the mucky bottom is composed, is most likely another factor contributing to the high growth rate of fecal coliform as well as the depletion of dissolved oxygen in the #128 watershed.



Monitoring data supports the theory that the suitability for fecal coliform bacteria growth in the river decreases from the headwaters downstream to the trout stream reach. The weighted average mean concentrations decrease in the Clearwater River from the headwaters to the Clearwater Lake inlet. This is shown in the following map.



Another reason for the decrease in fecal coliform concentrations from the headwaters to Clearwater Lake could be time of travel. Fecal coliform only has a life span of 12 hours to 5 days. So, not all the fecal coliform traveling through the #128 monitoring site will make it downstream to Clearwater Lake. The shallower water (more sunlight) and time of travel within trout stream portion of the river would help minimize the fecal coliform concentrations at that monitoring site. According to the Clearwater River Time of Travel Study of April 1991, dye traveled at an average rate of about 1 mile per hour between the Clearwater Lake outlet and the beginning of the channelized portion of the Clearwater River. The flow during that study was similar to the flow recorded at the Clearwater Lake Inlet during the Clearwater lake Water Quality Model Study. However, the flow during the study was as much as 3 times as high as the flows in the upper watershed of the Clearwater at sites such as Walker Brook and #128. The limited life span of fecal coliform can explain the fluctuation of fecal coliform levels within the #128 and Walker Brook subwatersheds. The low flow from these two watersheds would minimize the amount of fecal coliform being swept downstream. So, much of the life cycles of the fecal coliform bacteria in these two watersheds would be carried out before they get carried past 3-mile road. The life cycle of fecal coliform, including its decomposition would also consume DO. This could be one more factor contributing to the low dissolved oxygen levels in these two subwatersheds.

Construction activity within the Walker Brook watershed during the study period may have an exacerbating effect on the increase of sediment and nutrient levels during storm events. The TP levels within the Walker Brook watershed exceeded the ecoregion value for minimally impacted streams in 57.9% of the samples taken during the study. There is also a relatively high level of

COD in Walker Brook, which consumes oxygen, which, in turn, leads to low dissolved oxygen levels, which then can lead to anoxia and the release of phosphorus from sediment. Walker Brook also has a low DO problem due to organic soils, low flow and stagnant water, geologic factors such as the inflow of ancient oxygen depleted groundwater, and the highest COD levels of all the monitoring sites.

Nitrates and nitrites were rarely detectable at most of the sites in the Clearwater Lake watershed with the exception of the Clearwater Lake Inlet site. The concentrations at the Clearwater Lake inlet monitoring site exceeded the standards for minimally impacted streams within the Northern Lakes and Forests ecoregion for 42.1% of the samples taken while the all of the other sampling sites did not once exceed the minimally impacted levels for their respective ecoregions. This site had a significantly higher loading of nitrates and nitrites from its subwatershed. Since agricultural runoff is one of the sources of this pollutant, a buffer strip program and the implementation of other conservation practices should be implemented to help alleviate this problem.

The 3-mile road subwatershed had the highest amount of peak runoff of all the subwatersheds. The development around the City of Bagley may be a contributing factor to this runoff. Stormwater ponds have recently been constructed to capture the rapid runoff from the city and remove sediment and other pollutants from the water before it enters the river. Now that the stormwater runoff from Bagley will be treated with stormwater retention ponds, the runoff from this subwatershed should have less of an impact upon the water quality of the Clearwater River.

The Buzzle Lake watershed had the least amount of peak runoff, which helps explain the good water quality coming from this subwatershed, along with the lack of development or agricultural activity within the subwatershed. Much of the watershed is well vegetated and wooded so there is minimal runoff of nutrients and sediments. Plus, part of what does run off the landscape is retained in Buzzle Lake. When spatially examining the average concentrations, Buzzle Lake appears to improve water quality in the Clearwater River for total suspended solids, total phosphorus, total dissolved solids, chemical oxygen demand, total Kjeldahl nitrogen, and dissolved oxygen concentrations. It has a high peak discharge when compared to the 3-mile subwatershed and the Clearwater Lake inlet subwatershed, but has the lowest peak runoff rate of all the subwatersheds. This indicates that, although a large amount of water may flow from this subwatershed during a storm event, there is not a lot of overland flow or erosion, so there is a lower amount of sediment and nutrients being carried to the stream from the land. This results in lower concentrations of sediment and nutrients within the stream. The flow of this high quality water into the Clearwater River in between 3-mile road and the Clearwater Lake inlet may help explain the observed improvement in concentrations of certain water quality parameters in this reach of the river.

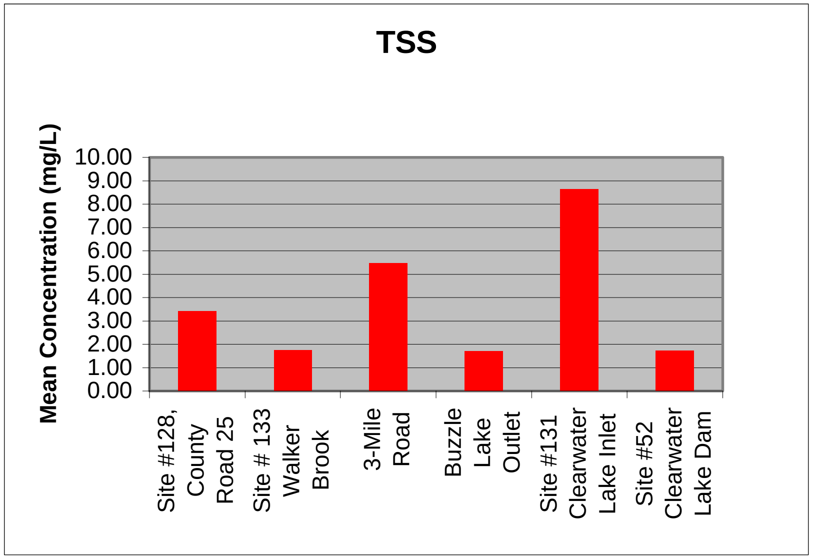
A comparison of modeling results for the Clearwater Lake inlet and the Clearwater Lake outlet shows that about 260 tons of sediment and over a ton of phosphorus are deposited in the lake each year. Determining how much phosphorus and suspended sediment is coming from the immediate watershed of the lake can not be directly measured from monitoring data, but was estimated by the BATHTUB modeling program based upon monitoring data from the Clearwater Lake Inlet monitoring site and land use data from the lake’s immediate watershed. One interesting fact, however, is that the amount of total dissolved solids increases from the inlet to the outlet. Dissolved solids entering the lake are less likely to be deposited in the lake than suspended solids. The annual dissolved solids load at the outlet exceeded the load at the inlet by 17,444 tons in 2002, even thought the concentration decreased. Some potential sources of dissolved solids on Clearwater Lake are sewage, wetlands, erosion and runoff from lake lots. Another possible explanation for the increase may be the fact that the continuous stage (water surface elevation) recording device at the Clearwater Lake outlet retrieved more data during the heavy storm events in June of 2002 because it was safe and dry while the stage recorder at the inlet was flooded and damaged. The data at the outlet includes some of the high flows recorded during this time period. The loads of Ammonia and Total Kjeldahl Nitrogen also increase from the inlet of the lake to the outlet of the lake. The most likely source of these two constituents in Clearwater Lake is decaying plant matter and animal waste. The following pages show the results from the FLUX modeling in table and graphical form.

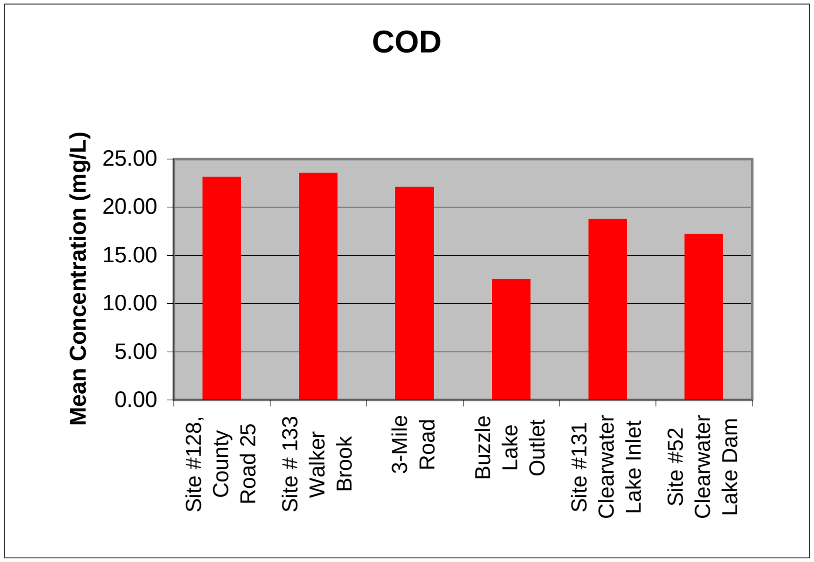
	TSS mg/L	**TDS mg/L**	**COD mg/L**	**TKN mg/L**	**AMMONIA mg/L**	**OP mg/L**	**TP mg/L**	**Fecal Coliform col./100ml**
Minimally Impacted	6.40				0.20		0.05	20.00
EPA Standards	25.00	500.00						200.00
Site #128, County Road 25								
Total annual flow	11.76	11.76	11.76	11.76	11.76	11.76	11.76	11.76
Total annual loads (tons)	44.28	2967.84	300.46	8.17	1.59	0.12	0.45	17615.24
Mean Conc	3.42	228.94	23.18	0.63	0.12	0.01	0.04	135.89
Site # 133 Walker Brook								
Total annual flow	9.23	9.23	9.23	9.23	9.23	9.23	9.23	9.23
Total annual loads (tons)	17.79	2842.64	239.93	6.40	0.87	0.34	0.71	7309.09
Mean Conc (mg/L)	1.75	279.39	23.58	0.63	0.09	0.03	0.07	71.84
3 Mile Road								
Total annual flow	38.51	38.51	38.51	38.51	38.51	38.51	38.51	38.51
Total annual loads (tons)	232.88	12184.07	938.89	36.14	4.05	1.86	2.77	11794.47
Mean Conc (mg/L)	5.49	287.02	22.12	0.85	0.10	0.04	0.07	27.78
Buzzle Lake Outlet								
Total annual flow	5.76	5.76	5.76	5.76	5.76	5.76	5.76	5.76
Total annual loads (tons)	10.80	1377.10	79.74	1.85	0.49	0.04	0.07	655.03
Mean Conc (mg/L)	1.70	216.74	12.55	0.29	0.08	0.01	0.01	10.31
Site #131 Clearwater Lake Inlet								
Total annual flow	46.20	46.20	46.20	46.20	46.20	46.20	46.20	46.20
Total annual loads (tons)	356.69	14163.01	882.98	19.93	5.74	0.75	2.73	13811.18
Mean Conc (mg/L)	7.00	278.11	17.34	0.39	0.11	0.01	0.05	27.12
Site #52 Clearwater Lake Dam								
Total annual flow	109.34	109.34	109.34	109.34	109.34	109.34	109.34	109.34
Total annual loads (tons)	201.88	31607.29	2091.64	47.89	14.44	0.86	3.43	1554.91
Mean Conc (mg/L)	1.67	262.24	17.35	0.40	0.12	0.01	0.03	1.29

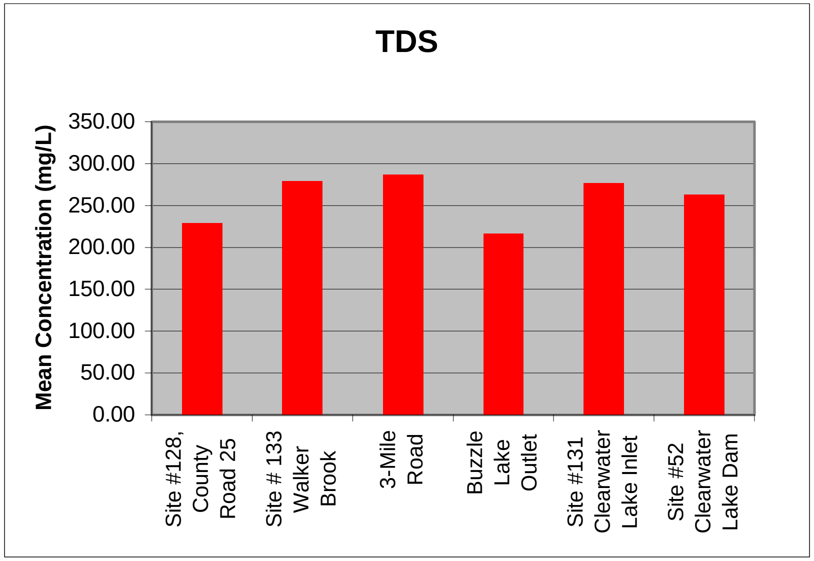
Section Break (Next Page)

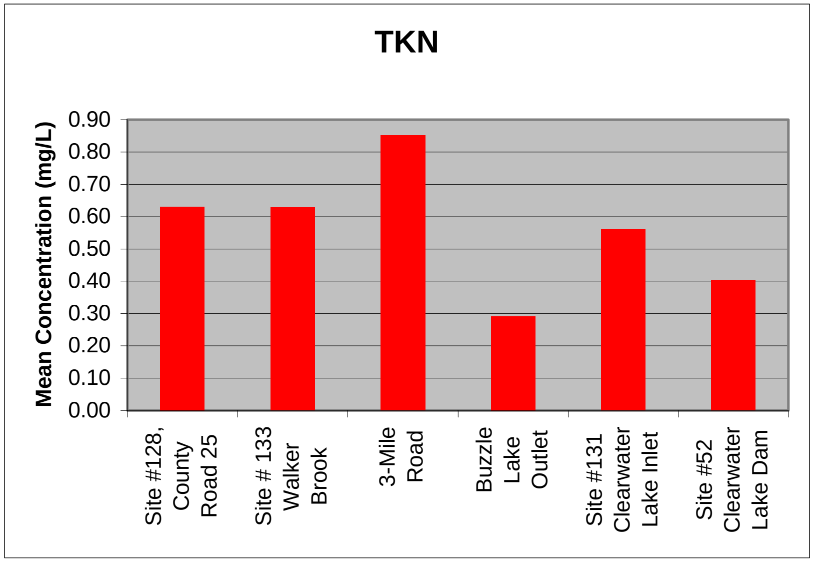
FLUX Modeling Results

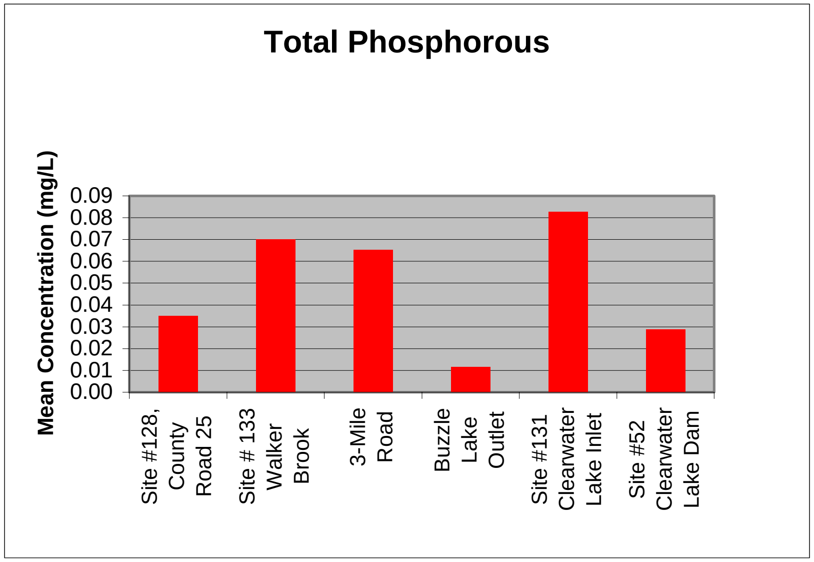
Page Break

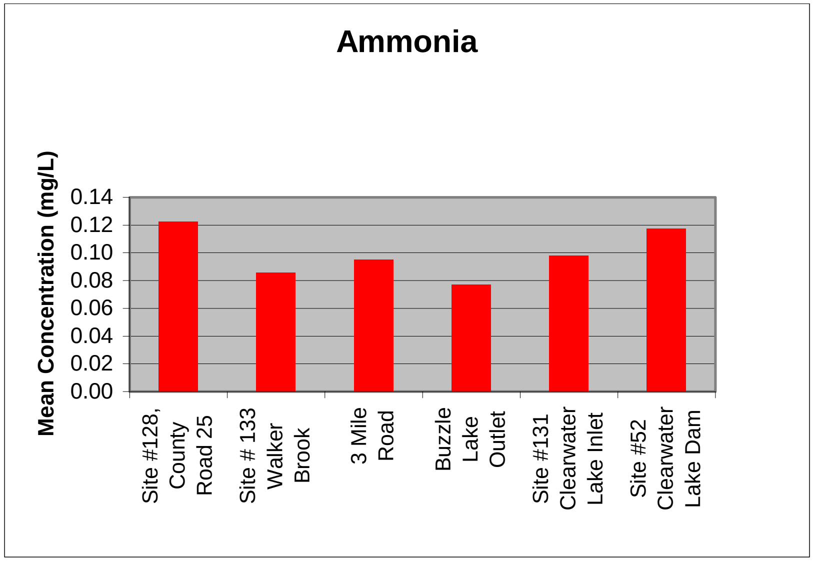


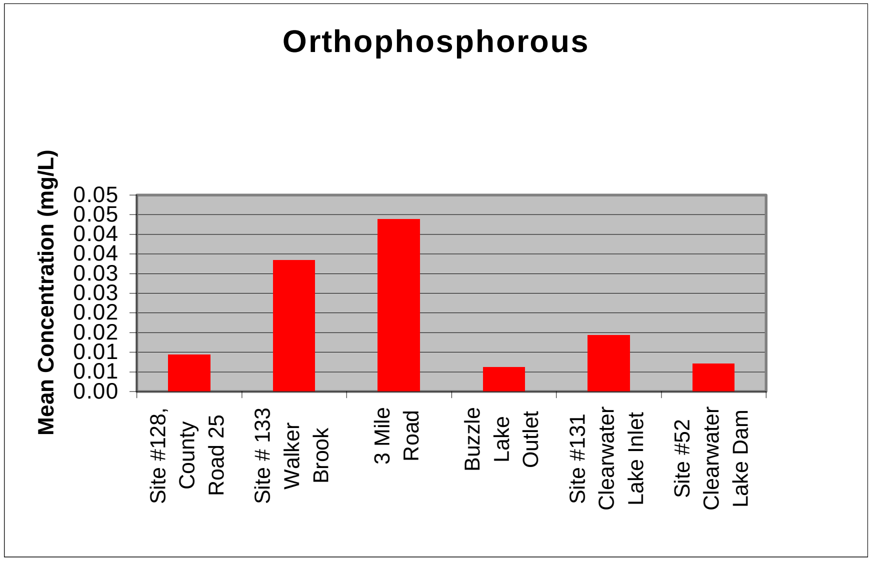


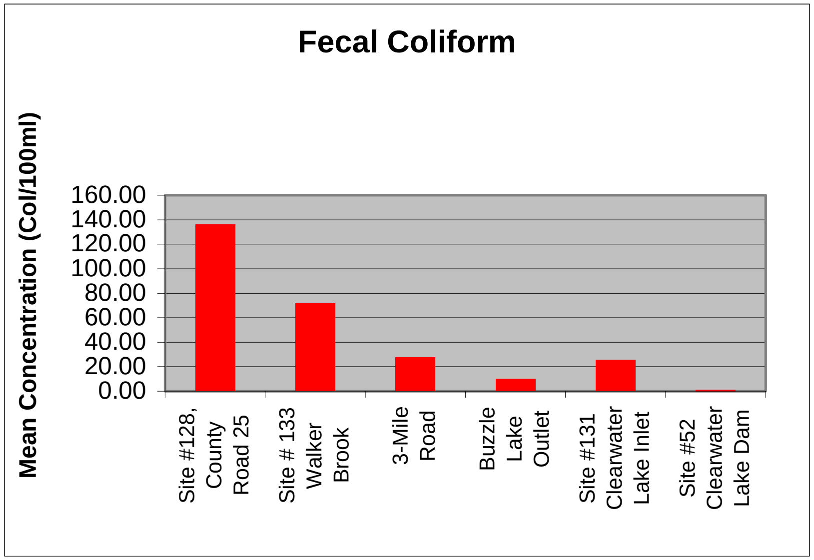


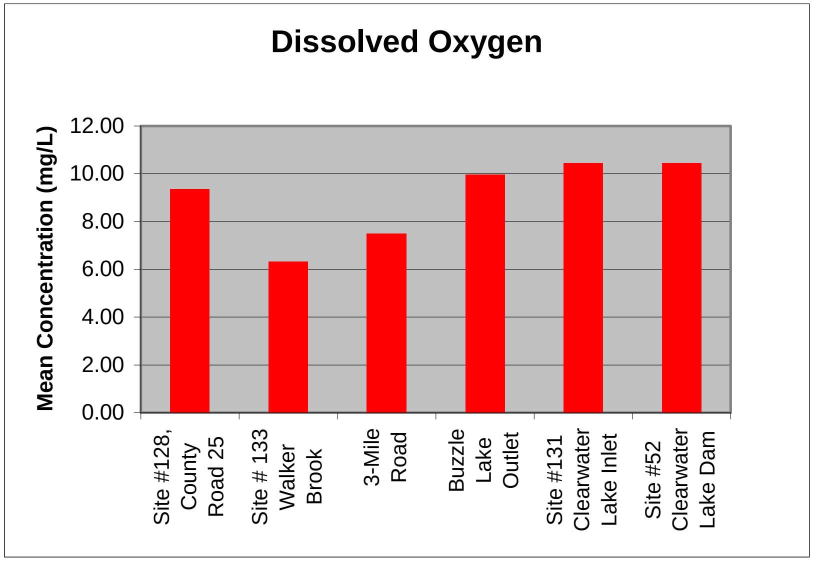

TKN
Mean Concentration (mg/L)
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
Site #128, County Road 25
Site # 133 Walker Brook
3-Mile Road
Buzzle Lake Outlet
Site #131 Clearwater Lake Inlet
Site #52 Clearwater Lake Dam

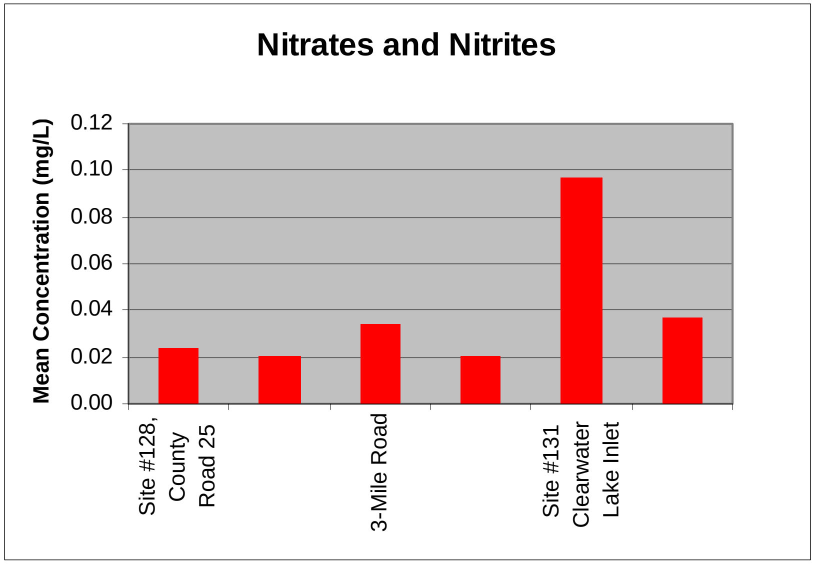

Total Phosphorous
Mean Concentration (mg/L)
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0.00
Site #128, County Road 25
Site # 133 Walker Brook
3-Mile Road
Buzzle Lake Outlet
Site #131 Clearwater Lake Inlet
Site #52 Clearwater Lake Dam


Ammonia
Mean Concentration (mg/L)
0.14
0.12
0.10
0.08
0.06
0.04
0.02
0.00
Site #128, County Road 25
Site # 133 Walker Brook
3 Mile Road
Buzzle Lake Outlet
Site #131 Clearwater Lake Inlet
Site #52 Clearwater Lake Dam


Orthophosphorous
Mean Concentration (mg/L)
0.05
0.05
0.04
0.04
0.03
0.03
0.02
0.02
0.01
0.01
0.00
Site #128, County Road 25
Site # 133 Walker Brook
3 Mile Road
Buzzle Lake Outlet
Site #131 Clearwater Lake Inlet
Site #52 Clearwater Lake Dam


Fecal Coliform
Mean Concentration (Col/100ml)
160.00
140.00
120.00
100.00
80.00
60.00
40.00
20.00
0.00
Site #128, County Road 25
Site # 133 Walker Brook
3-Mile Road
Buzzle Lake Outlet
Site #131 Clearwater Lake Inlet
Site #52 Clearwater Lake Dam


Dissolved Oxygen
Mean Concentration (mg/L)
12.00
10.00
8.00
6.00
4.00
2.00
0.00
Site #128, County Road 25
Site # 133 Walker Brook
3-Mile Road
Buzzle Lake Outlet
Site #131 Clearwater Lake Inlet
Site #52 Clearwater Lake Dam


Nitrates and Nitrites
Mean Concentration (mg/L)
0.12
0.10
0.08
0.06
0.04
0.02
0.00
Site #128, County Road 25
3-Mile Road
Site #131 Clearwater Lake Inlet

Section Break (Next Page)

12.0 PROFILE and BATHTUB Modeling Results

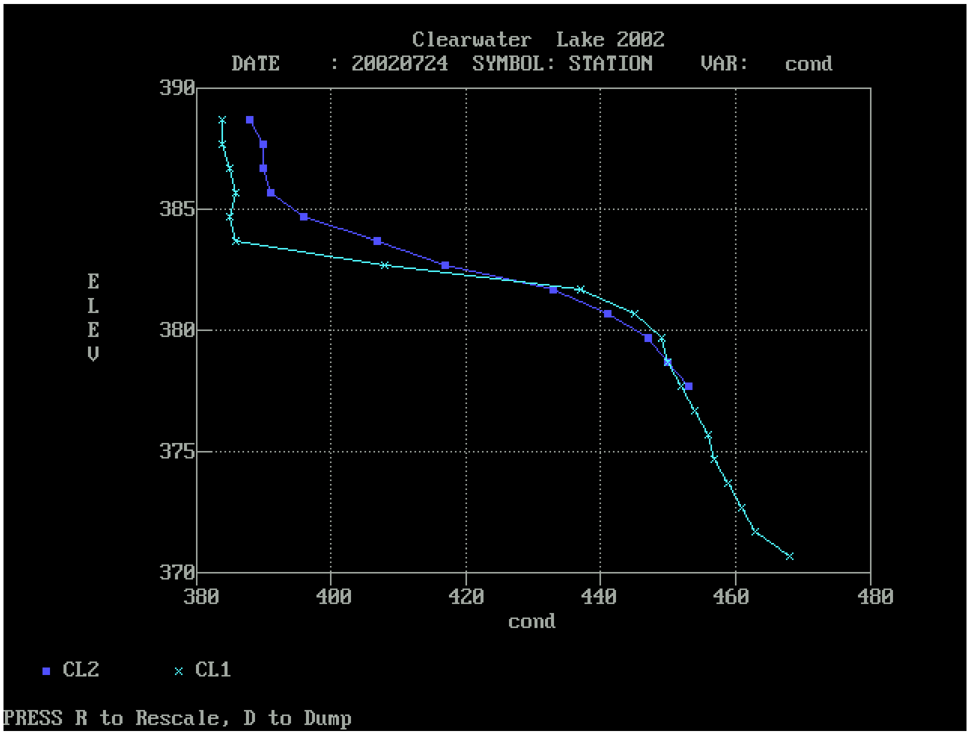
Water quality modeling with the PROFILE program was conducted using the data collected at sites CL1 and CL2. In addition to the generation of graphs and box plots, this program calculated areal and volumetric oxygen depletion rates for the hypolimnion and the metalimnion layers. The mean and maximum depths for these layers were also determined. The mean depths for the hypolimnion and metalimnion, respectively, were 2.02 m and 2.17 m. The maximum depths were 5.01 m and 3.00 m, respectively. The program also predicted mean concentrations of all input parameters based upon observed data and provided error mean coefficients of variance for these predictions. The coefficients of variance equal "the standard error of the estimate expressed as a fraction of the predicted value." In other words, the higher the coefficient of variance (CV), the greater the possibility of error. Below is a table of the water quality statistics generated by PROFILE for each monitoring site.

CL1 - Deep Site					
Parameter	***Number Of Samples***	***Min***	***Max***	***Mean***	***Coefficient Variance***
Water Temperature	311	0.7	27.3	9.70	0.671
Dissolved Oxygen	311	0.0	16.4	6.80	0.659
Total Phosphorus	76	3.0	609.0	48.9	1.948
Chlorophyll-A	41	0.0	16.0	6.10	0.880
Secchi	232	1.0	5.0	2.40	0.398
Conductivity	311	299.8	589.0	427.2	0.113
Total Kjeldahl Nitrogen	48	5.0	770.0	444.4	0.585
Total Suspended Solids	48	1.0	7.0	2.30	0.862
Total Dissolved Solids	48	140.0	312.0	251.6	0.179
CL2 - Shallow Site					
Parameter	***Number Of Samples***	***Min***	***Max***	***Mean***	***Coefficient Variance***
Water Temperature	192	0.20	28.3	10.20	0.712
Dissolved Oxygen	192	0.20	15.3	8.20	0.459
Total Phosphorus	75	5.0	203.0	30.70	0.870
Chlorophyll-A	32	0.0	18.0	9.80	0.612
Secchi	140	2.0	3.0	2.20	0.179
Conductivity	192	303.7	653.7	430.1	0.120
Total Kjeldahl Nitrogen	44	5.0	750.0	427.3	0.512
Total Suspended Solids	44	0.0	7.0	2.30	0.784
Total Dissolved Solids	44	164.0	320.0	258.7	0.150

Several observations were made possible by the PROFILE modeling process. Profile graphs aided in determining when the lake was stratified and when it was mixed. The extent of hypolimnetic hypoxia was also calculated. Dissolved oxygen levels in the hypolimnion were below the 5 mg/L level (EPA standard for the minimum amount of dissolved oxygen necessary for aquatic life to thrive) for most of the sampling dates. The only sampling dates that did not have hypolimnetic hypoxia or anoxia were those from April 30th through May 29th and the final October 15th sampling date. The lake was mixed on these sampling dates.

Total phosphorus profiles for the lake showed that, during periods of stratification, phosphorus levels were generally highest in the hypolimnion. During stratification, there was a gradual decrease in phosphorus levels in the metalimnion and the lowest levels were found in the epilimnion. When the lake mixed in the spring, however, total phosphorus levels seemed to be highest in the metalimnion. During the fall mixing, phosphorus levels were relatively similar throughout the water column, differing by only 3 ppb.

Conductivity profiles showed that, during stratification, there was normally a gradual increase in conductivity levels within the epilimnion, a sharp increase in conductivity in the metalimnion, and then another gradual increase in the hypolimnion. No pattern was evident in conductivity levels throughout the water column while the lake was mixed. The following graphic is an example of a conductivity profile that was recorded while the lake was stratified.



PRESS R to Rescale, D to Dump

When the time series plot of conductivity is compared to that of TDS, there appears to be a positive relationship between the two parameters. This makes sense, since the two parameters are related. The more dissolved solids in the water, the better it will conduct electricity. Temperature has a definite inverse relationship with dissolved oxygen as can be expected since warmer water holds less oxygen and colder water holds more. Total Kjeldahl nitrogen levels varied little with depth and time. Total phosphorus and chlorophyll-a fluctuations appeared to correlate until the month of June, where they suddenly diverge into an inverse relationship until the fall mixing. Zooplankton activity may be the cause of another observation. Chlorophyll-a measurements correlate with temperature in the spring and then suddenly have an inverse relationship beginning with the month of June. The two preceding observations may be due to zooplankton activity that normally peaks around the month of June. The increased zooplankton activity would mean increased consumption of algae and reduced Chlorophyll-a levels.

Several load reduction scenarios were run using the BATHTUB program. The first scenario tested the effect of the sediment reduction within the City of Bagley. The estimated amount of sediment reduction from the stormwater treatment ponds is 82%. The amount of total phosphorus reduction from the project was estimated at 47%. The watershed of the City of Bagley was analyzed for land use and total runoff volume. The amount of runoff volume was then compared to the total amount of runoff volume for the 3-mile road subwatershed and the amounts of TSS and TP load reduction were quantified in Kg/yr and then subtracted from the loads at the Clearwater Lake inlet monitoring site. The new concentrations for TSS and TP were then entered into BATHTUB.

The other type of load reduction scenarios modeled the reductions in sediment and nutrient concentrations in runoff for the entire watershed of the lake. These scenarios essentially predicted how the water quality within the lake would be affected by the implementation of best management practices. The concentrations for each parameter were reduced incrementally. Sediment and nutrient concentrations in nonpoint runoff entering the river and in runoff from the lake’s immediate watershed were reduced by 10%, 20%, 30%, and 40%. The results of this modeling are listed in the table on the next page.

Load Reductions:	**Original Data (0%)**		**80% from Bagley**	**10% Load Reduction**	**20% Load Reduction**	**30% Load Reduction**	**40% Load Reduction**
	Observed	**Estimated**	**Estimated**	**Estimated**	**Estimated**	**Estimated**	**Estimated**
Segment 1 - Shallow Site (CL2)							
TSS (ppm)	2.3	8.1	7.86	7.3	6.49	5.68	4.88
Total P (ppb)	30.7	32.74	31.77	30.61	28.39	26.03	23.53
Total N (ppb)	427.3	218.21	218.21	200.5	182.17	163.21	143.41
Chlorophyll-a (ppb)	9.8	1.68	8.55	8.34	7.9	7.4	6.82
Secchi Disk (m)	2.2	1.26	4.16	5.24	7.46	15.03	18.72
Organic N (ppb)	304.67	211.15	367.76	362.84	352.85	341.45	328.38
Ortho P (ppb)	23.3	3.86	16.09	15.7	14.92	14.03	13.01
HOD-V (ppb/day)	46.15	25.04	56.51	55.79	54.31	52.57	50.5
MOD-V (ppb/day)	14.56	25.92	58.48	57.74	56.2	54.4	52.26
TSI-P	53.53	54.46	54.02	53.49	52.40	51.15	49.69
TSI-Chl-a	52.99	35.69	51.65	51.41	50.88	50.23	49.43
TSI-Secchi	48.64	56.67	39.46	36.13	31.04	20.95	17.78
TSI-Average	**51.72**	**48.94**	**48.38**	**47.01**	**44.77**	**40.78**	**38.97**
TSI Improvement			**1.15%**	**3.94%**	**8.51%**	**16.68%**	**20.37%**
Segment 2 - Deep Site (CL1)							
TSS	2.3	8.1	7.86	7.29	6.49	5.68	4.88
Total P	48.9	31.5	30.6	29.52	27.45	25.24	22.87
Total N	756.9	215.8	215.8	198.44	180.44	161.8	142.29
Chlorophyll-a	6.1	1.53	7.79	7.6	7.2	6.75	6.24
Secchi Disk	2.4	1.29	4.28	5.42	7.79	16.43	18.72
Organic N	444.4	211.67	354.6	350.14	341.13	330.85	319.05
Ortho P	39.4	4.88	16.03	15.69	14.98	14.18	13.26
HOD-V	46.15	25.04	56.51	55.79	54.31	52.57	50.5
MOD-V	14.56	25.92	58.48	57.74	56.2	54.4	52.26
TSI-P	60.24	53.90	53.48	52.96	51.91	50.70	49.28
TSI-Chl-a	48.34	34.77	50.74	50.50	49.97	49.33	48.56
TSI-Secchi	47.38	56.33	39.05	35.65	30.42	19.66	17.78
TSI-Average	**51.99**	**48.33**	**47.76**	**46.37**	**44.10**	**39.90**	**38.54**
TSI Improvement			**1.20%**	**4.07%**	**8.76%**	**17.45%**	**20.26%**
Area Weighted Mean							
TSS	2.3	8.1	7.86	7.3	6.49	5.68	4.88
Total P	37.92	32.25	31.31	30.18	28.02	25.72	23.27
Total N	558.05	217.25	217.25	199.68	181.48	162.65	142.96
Chlorophyll-a	8.33	1.62	8.25	8.04	7.62	7.14	6.59
Secchi Disk	2.28	1.27	4.2	5.31	7.59	15.58	18.72
Organic N	360.1	211.36	362.54	357.8	348.2	337.25	324.68
Ortho P	29.69	4.26	16.07	15.7	14.95	14.09	13.11
HOD-V	46.15	25.04	56.51	55.79	54.31	52.57	50.5
MOD-V	14.56	25.92	58.48	57.74	56.2	54.4	52.26
TSI-P	56.57	54.24	53.81	53.28	52.21	50.98	49.53
TSI-Chl-a	51.40	35.33	51.30	51.05	50.52	49.88	49.10
TSI-Secchi	48.12	56.56	39.32	35.94	30.79	20.43	17.78
TSI-Average	**52.03**	**48.71**	**48.14**	**46.76**	**44.51**	**40.43**	**38.80**
TSI Improvement			**1.16%**	**4.01%**	**8.62%**	**17.00%**	**20.33%**

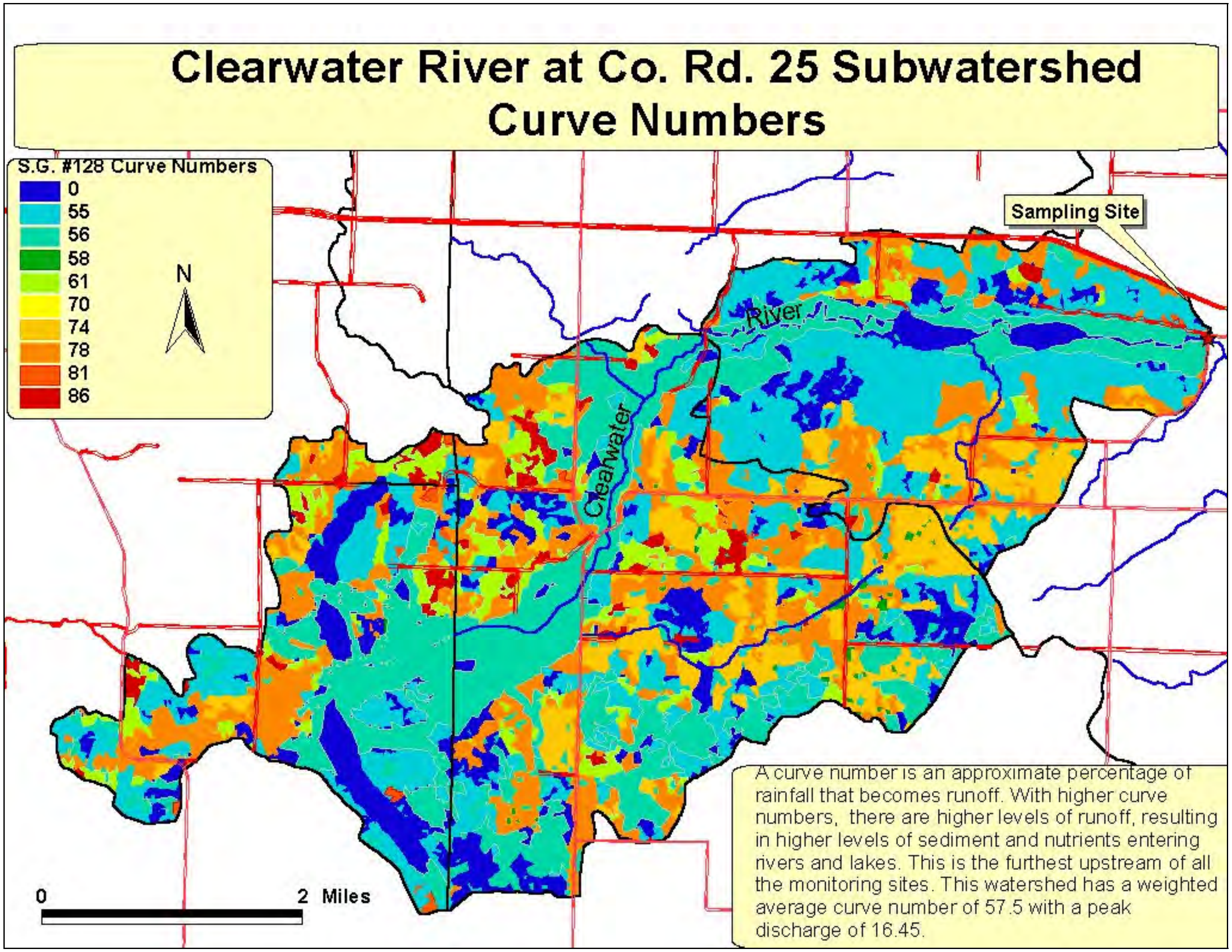
13.0 Conclusions

One goal of the Clearwater Lake Water Quality Model Study was to determine focus watersheds for water quality improvements. Total phosphorus loading was highest from the subwatersheds of the 3-mile road, Clearwater Lake inlet, and Clearwater Lake outlet monitoring sites. Something within the watershed between 3-mile road and the Clearwater Lake inlet is causing an increase in fecal coliform loads, even though the concentration decreases between these two sites. Dissolved oxygen levels are not of concern to the lake because the weighted averages were quite high for the inlet and outlet sites. However, the low levels in the upper reaches of the Clearwater River may have a negative impact upon aquatic life and water quality in the river.

The Clearwater River does not violate EPA standards for total suspended solids at any of the sites, but is minimally impacted according to the ecoregion standards at the monitoring site near the inlet. Much of this sediment is deposited in the lake. This explains the shallower lake levels near the higher prevalence of weeds, higher levels of total phosphorus near the inlet. Making sure all septic systems are in compliance should be a priority for maintaining the water quality of the lake. This should help minimize the increase in dissolved solids and total Kjeldahl nitrogen from the lake’s immediate watershed. Public education about lakeshore restoration and other methods for minimizing the contribution of sediment and nutrients from individual lake lots should be implemented.

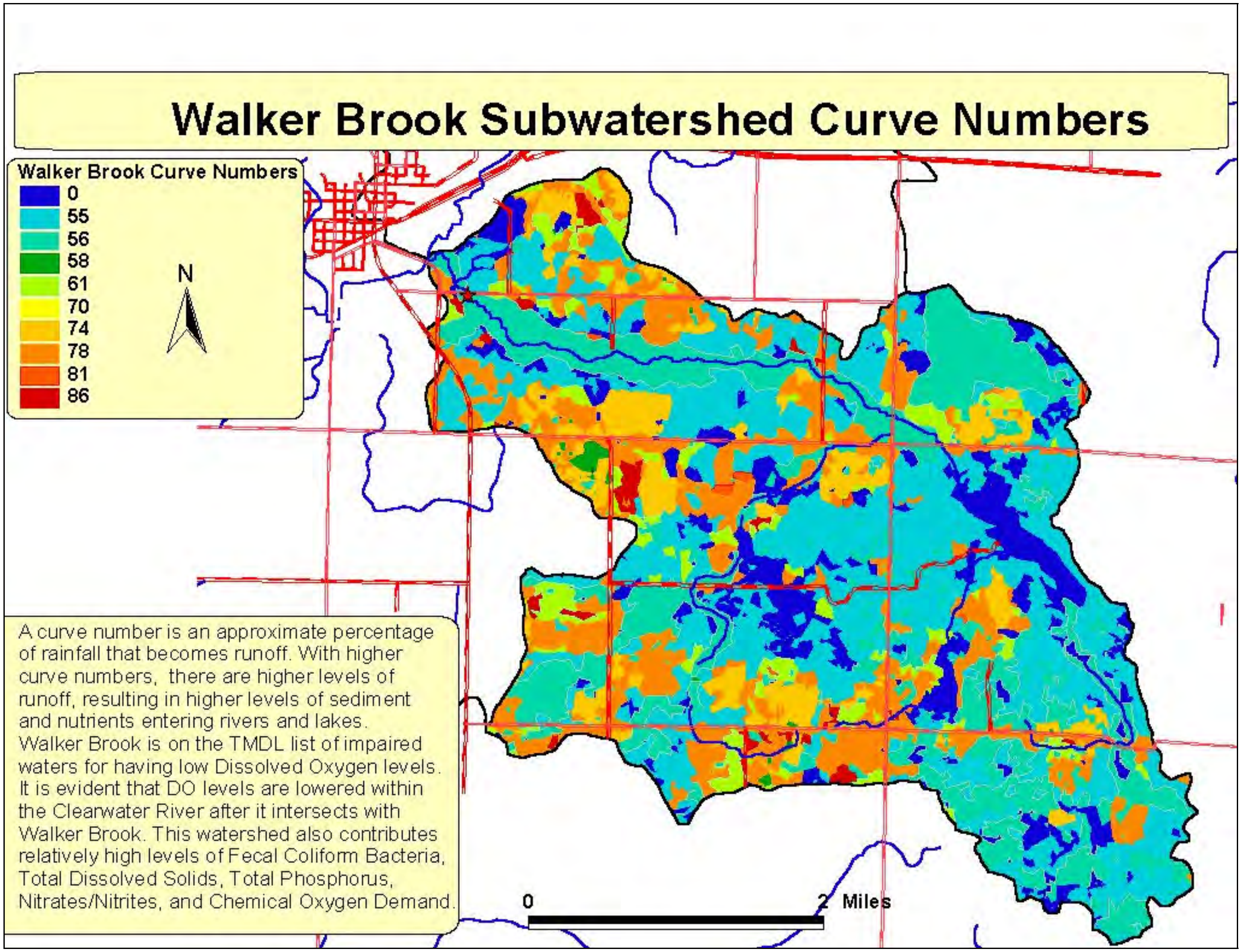
In order to reduce the amount of sediment and nutrients flowing into Clearwater Lake, the amount of sediment and nutrients that are being carried into the stream via runoff should be reduced. The two subwatersheds with the highest contributions to the sediment and nutrient loads in the river are the 3-mile road subwatershed (Bagley) and the Clearwater Lake inlet subwatershed (excluding the Buzzle Lake watershed and everything upstream of 3-mile road). See the map of sites and their corresponding subwatersheds on page 6. The sediment loads coming from the 3-mile road subwatershed should be decreased by the Bagley Urban Runoff Reduction Project, for which three stormwater treatment ponds have been constructed. This project was designed to reduce the amount of sediment entering the river from the watershed of the city of Bagley by up to 80%. In the Clearwater Lake inlet subwatershed, it appears that the areas with the highest runoff potential are located next to streams and ditches. This subwatershed should be targeted for the implementation of best management practices (BMPs) such as buffer strips. Buffer strips consist of land along rivers, streams, and lakes that is vegetated with grass and trees in order to filter sediment (soil particles and pollutants) from runoff before it enters the water. The vegetation in buffer strips also helps to reduce erosion from the stream channel by holding soil in place. The implementation of best management practices has been included in the goals for implementing the Clearwater Lake Management plan. Areas with high runoff potential can be targeted for BMP implementation. The following pages contain runoff potential maps for each of the monitoring site subwatersheds. Following the maps is a list of BMPs from the Clearwater River Nonpoint Study that may be considered for implementation within this subwatershed.

Section Break (Odd Page)



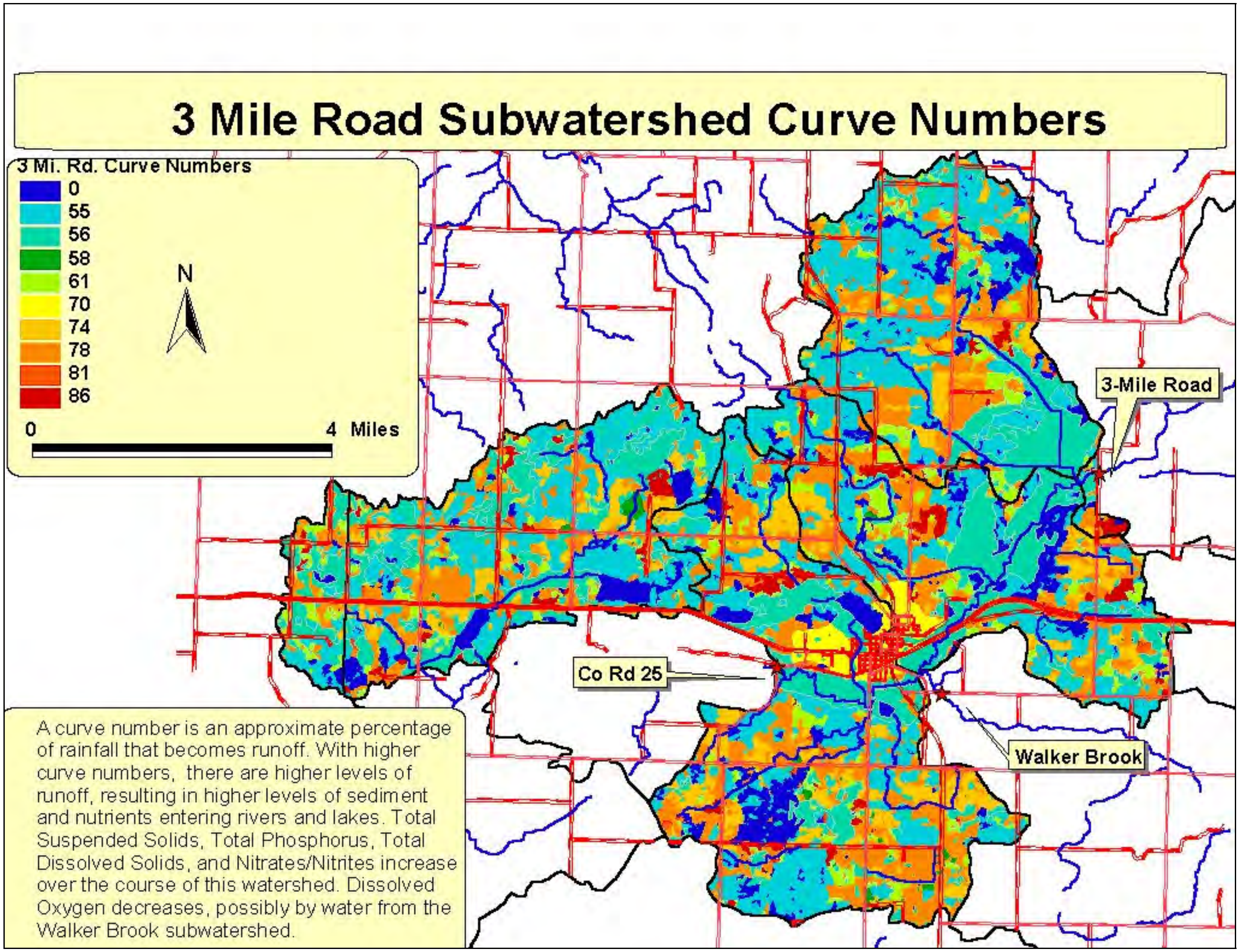
Clearwater River at Co. Rd. 25 Subwatershed Curve Numbers

A curve number is an approximate percentage of rainfall that becomes runoff. With higher curve numbers, there are higher levels of runoff, resulting in higher levels of sediment and nutrients entering rivers and lakes. This is the furthest upstream of all the monitoring sites. This watershed has a weighted average curve number of 57.5 with a peak discharge of 16.45.

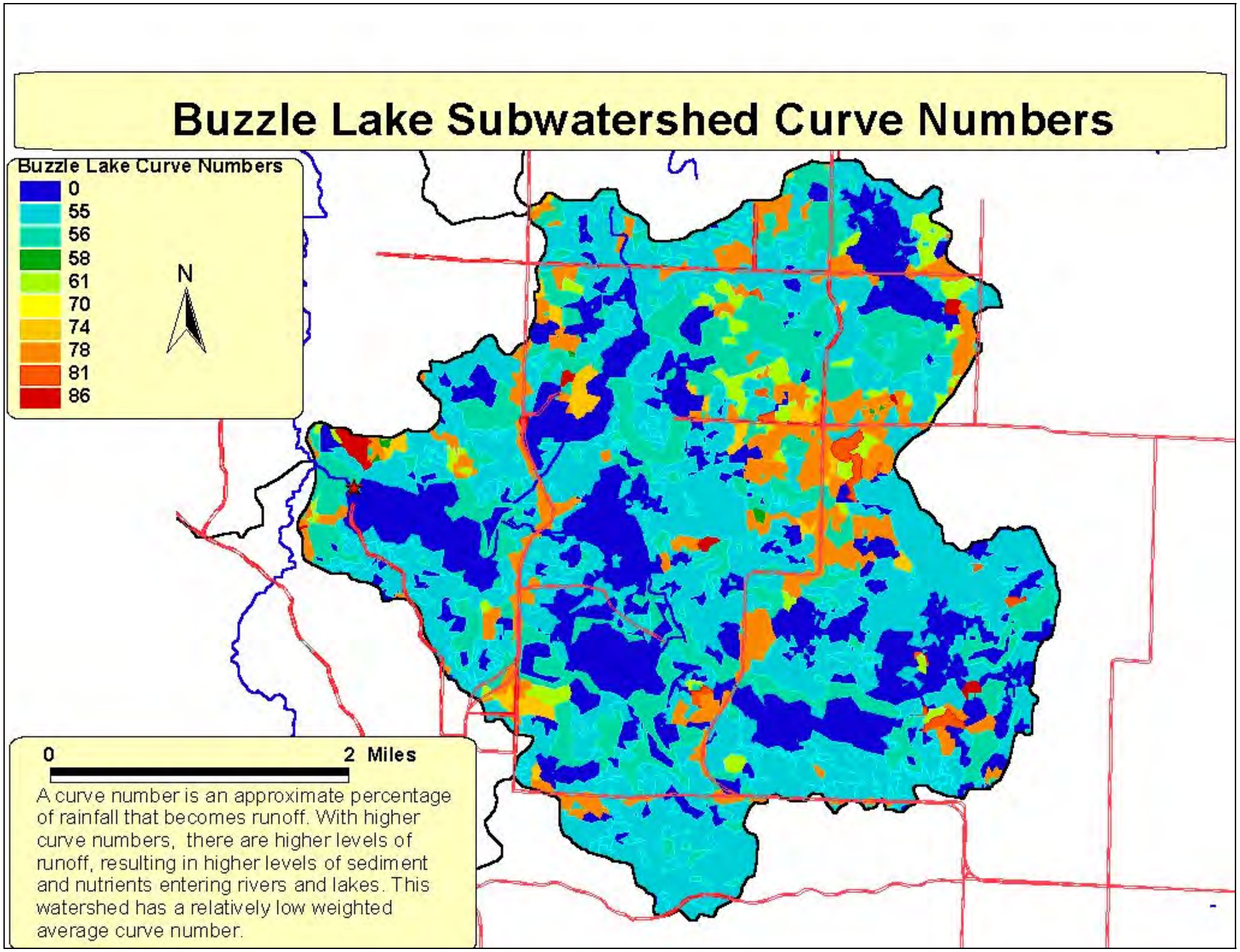


Walker Brook Subwatershed Curve Numbers

A curve number is an approximate percentage of rainfall that becomes runoff. With higher curve numbers, there are higher levels of runoff, resulting in higher levels of sediment and nutrients entering rivers and lakes. Walker Brook is on the TMDL list of impaired waters for having low Dissolved Oxygen levels. It is evident that DO levels are lowered within the Clearwater River after it intersects with Walker Brook. This watershed also contributes relatively high levels of Fecal Coliform Bacteria, Total Dissolved Solids, Total Phosphorus, Nitrates/Nitrites, and Chemical Oxygen Demand.



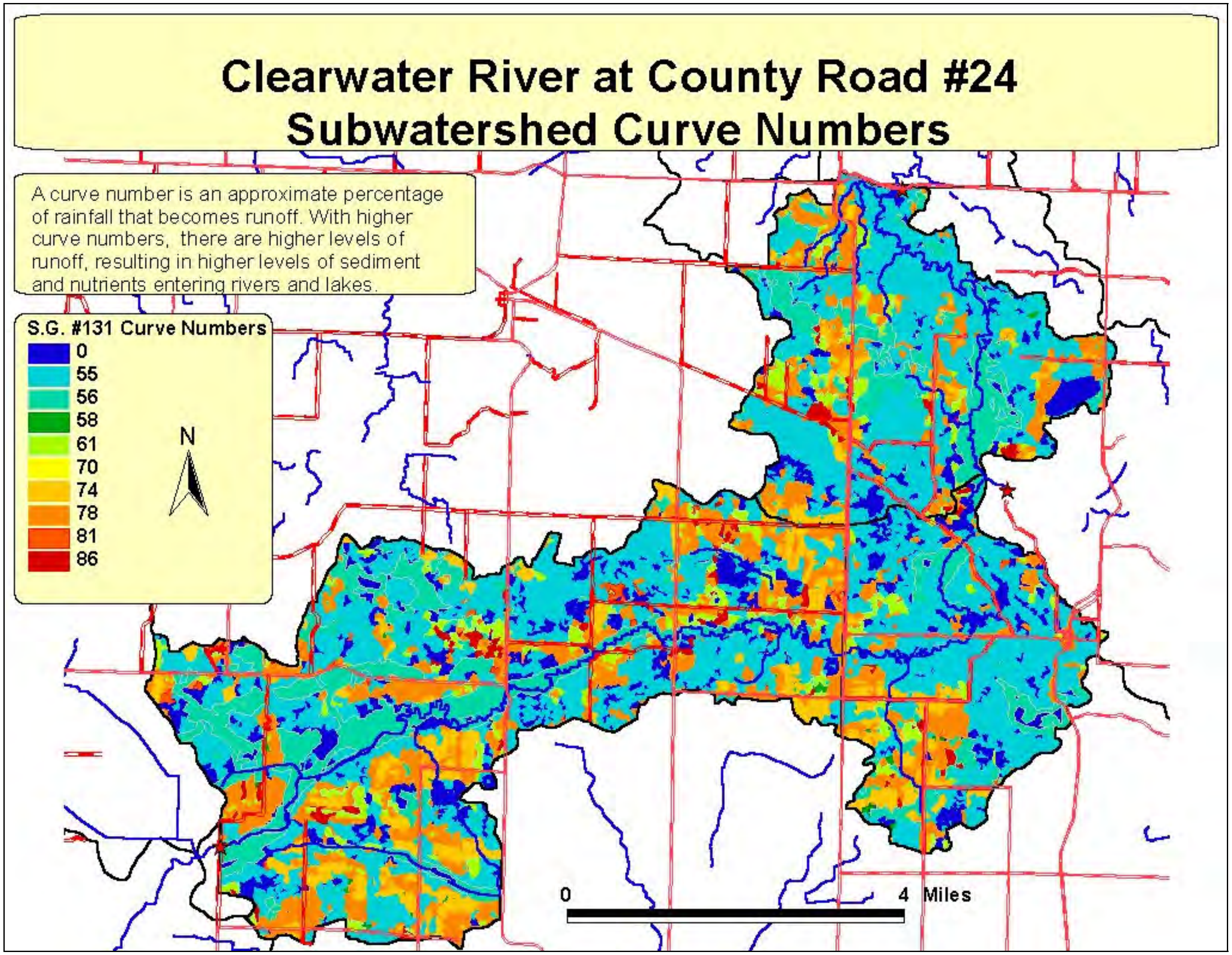
A curve number is an approximate percentage of rainfall that becomes runoff. With higher curve numbers, there are higher levels of runoff, resulting in higher levels of sediment and nutrients entering rivers and lakes. Total Suspended Solids, Total Phosphorus, Total Dissolved Solids, and Nitrates/Nitrites increase over the course of this watershed. Dissolved Oxygen decreases, possibly by water from the Walker Brook subwatershed.



Buzzle Lake Subwatershed Curve Numbers

A curve number is an approximate percentage of rainfall that becomes runoff. With higher curve numbers, there are higher levels of runoff, resulting in higher levels of sediment and nutrients entering rivers and lakes. This watershed has a relatively low weighted average curve number.

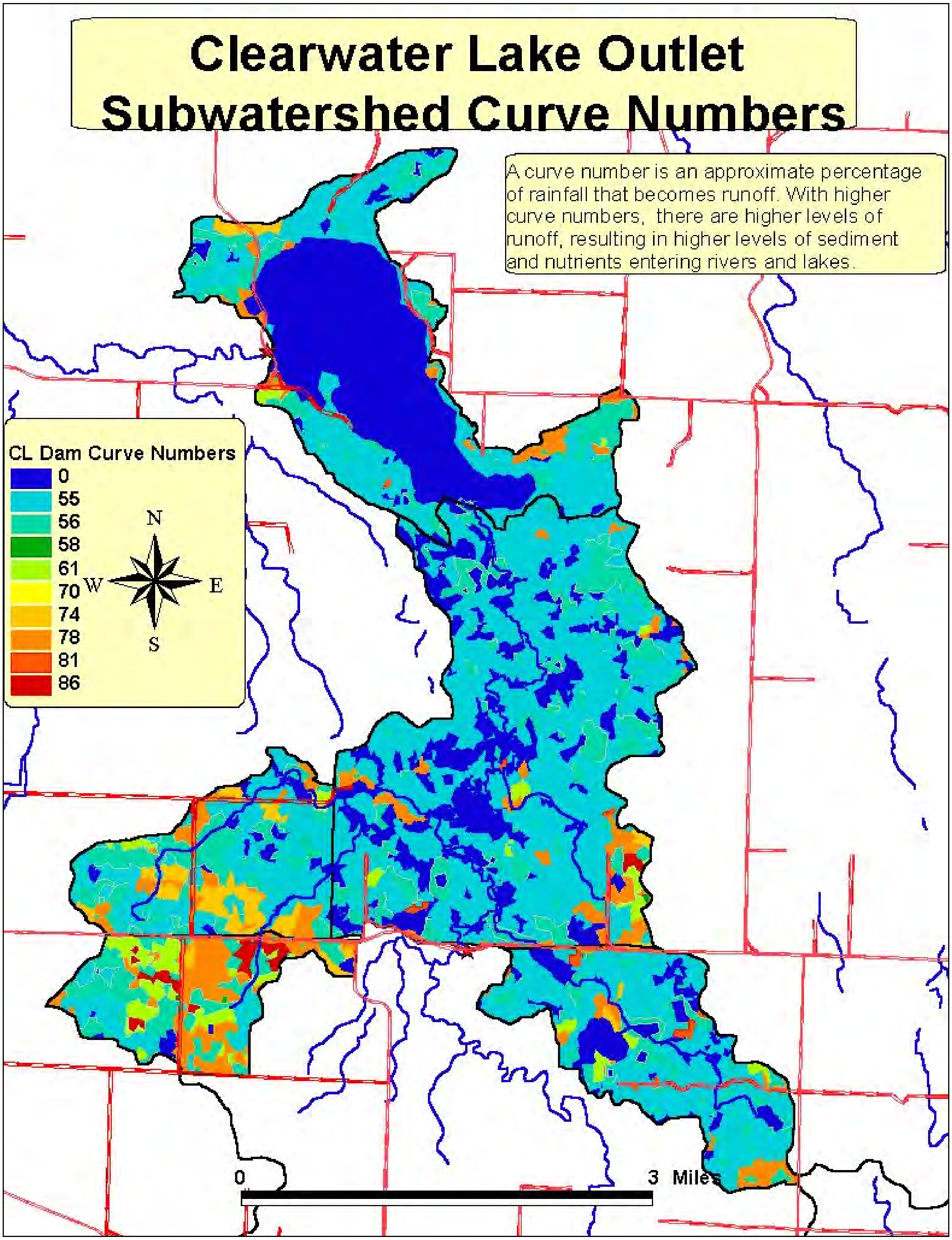
Section Break (Odd Page)



Clearwater River at County Road #24 Subwatershed Curve Numbers

A curve number is an approximate percentage of rainfall that becomes runoff. With higher curve numbers, there are higher levels of runoff, resulting in higher levels of sediment and nutrients entering rivers and lakes.

Section Break (Next Page)



Clearwater Lake Outlet Subwatershed Curve Numbers

A curve number is an approximate percentage of rainfall that becomes runoff. With higher curve numbers, there are higher levels of runoff, resulting in higher levels of sediment and nutrients entering rivers and lakes.

Best Management Practices	
Conservation Cover	Establishing and maintaining perennial vegetative cover to protect soil and water recourses on land retired from agricultural production.
Conservation Tillage	Conservation tillage includes a number of different planting, tilling, and cultivating methods designed to leave a vegetative residue on the soil.
Contour Farming	Farming around the slopes, which reduces erosion and increases infiltration. Erosion rates can be reduced up to 50% using this practice.
Cover and Green Manure Crop	A crop of close-growing grasses, legumes, or small grain grown primarily for seasonal protection and soil improvement.
Critical Area Planting	Planting vegetation, such as trees, shrubs, grasses, or legumes on highly erodible or critically eroding areas.
Crop Residue Use	Using plant residues to protect cultivated fields during critical erosion periods.
Diversion	A channel constructed across a slope to collect water and prevent damage to the area below the diversion.
Field Border	A strip of perennial vegetation established at the edge of a field by planting or converting it from trees to herbaceous vegetation of shrubs.
Filter (Buffer) Strip	A strip or area of vegetation intended to remove sediment, organic matter, and other pollutants from runoff and wastewater.
Grade Stabilization Structure	Grade stabilization structures involve pipe outlets or drop spillways and are used to allow water to drop to a lower elevation while protecting the soil from gully erosion or scouring.
Grassed Waterway	A natural or constructed channel that is planted with suitable vegetation to protect the soil from erosion by concentrated storm event flows.

Best Management Practices (continued)	
Grasses and Legumes in Rotation	Establishing grasses and legumes or a mixture of them and maintaining the stand for a definite number of years as part of a conservation cropping system.
Sediment Basin	Basins constructed to collect and store debris or sediment.
Contour Strip-Cropping	Growing crops in a systematic arrangement of strips or bands on the contour to reduce water erosion.
Field Strip-Cropping	Growing crops in a systematic arrangement of strips or bands across the general slope (not contour) to reduce water erosion.
Terrace	An earthen embankment, a channel, or combination ridge and channel constructed across the slope to intercept runoff.
Tile Intake Buffers	Tile intake buffers are intended to filter sediment and nutrients from cropland runoff prior to being discharged to ditches and streams.
Water and Sediment Control Basin	An earthen embankment or a combination ridge and channel constructed across gullies and watercourses with underground outlets. Effective for preventing gully erosion, trapping sediment, and reducing downstream peak flows.
Wetland Development/Restoration	Wetland Development involves creating an artificial wetland or restoring a previously drained wetland. Wetlands act as sediment and nutrient traps, and can also reduce peak flows.
Agricultural Waste/Feedlot Management	An agricultural waste management system is a combination of practices used to properly store manure and other wastes from feedlots until they can be properly applied to cropland. A runoff management system is designed to control polluted runoff from a feedlot.
Pasture Management/Livestock Exclusion	Livestock exclusion involves the fencing off of areas where grazing would cause erosion of stream banks or allow water quality to be lowered by livestock activity. The quality of pastureland can also be maintained.
Nutrient Management	Using proper rates, placement, and timing of fertilizer applications to reduce nitrogen and phosphorus losses from cropland.