Section 3: Water Quality Assessment

Introduction

This section provides a summary of the monitoring data collected over the course of the study as well as the SWAT model development and calibration. A brief overview of monitoring sites, data collection methods and data quality, and model calibration is provided within this subsection. Additional information on these topics is provided in the Project Work Plan (Appendix B), internal memorandum regarding Quality Assurance and Quality Control (QA/QC) Results (Appendix E), Rating Curve Development (Appendix F), and Hydrograph Development (Appendix G), and the Credit River Hydrology and Total Suspended Solid Modeling report (Appendix C).

Monitoring data was collected over the period of 2008 and 2009 from the Credit River at multiple sites as detailed in the Work Plan (Appendix B). Stream monitoring consisted of rigorous collection of physical and chemical data at three monitoring stations including stream flow, and less intensive collection of data using meters to measure turbidity at multiple sites across the watershed. All of the sites are shown on Figure 3-1. The intensely monitored sites include sites 123, 154, and C68. The other sites were the less intensely monitored synoptic sites.

QA/QC objectives for the data collected are evaluated and discussed as part of several internal memoranda completed over the course of the Project (i.e., QA/QC Results (Appendix E), Rating Curve Development (Appendix F), and Hydrograph Development (Appendix G)). In general, the quality of the data appears to be good.

- Duplicate measurements used to assess <u>precision</u> generally met Data Quality Objectives
- Calibration procedures to insure <u>accuracy</u> were followed
- <u>Completeness</u> assessed as the number of samples and/or monitoring events planned versus the number completed was good, with collection of data completed as planned. The exception was the number of samples which was limited to less than planned by the lack of water and intermittent flow at some sites, and dry conditions over the sampling period.

- Samples collected were representative of the range of flows observed at the sites. However, 2008 was a dry year and was not representative of average annual hydrologic conditions for the area. The Scott WMO therefore added a second year (i.e., 2009) of monitoring at sites 154 and C68 in order to improve representativeness. The Metropolitan Council also continued monitoring at their site in 2009. Rainfall measured at the National Weather Service Station in Chanhassen just north of the Credit River Watershed was 22.4 inches in 2008 and 29.8 inches in 2009. The long term average for the area is about 29 inches.

With respect to the hydrographs it should be noted that large parts of the 2008 hydrographs for sites 154 and C68 are predicted based on a relationship developed between stage at the two sites and the MCES site (site 123) located near the mouth of the river. High water levels in the spring of 2008 and then beaver dam impacts later in the year, affected the ability to install equipment and collect accurate stage levels. This introduces some uncertainty regarding load predictions (Figure 3-8) at the upstream sites. This does not affect model calibration since was completed at the downstream site. For 2009 flows could not be predicted to fill in those parts of the year where stage was not measured at the two sites, because there were problems at the downstream MCES site.

The special monitoring effort for macroinvertebrates was cancelled because of low to no flow at the upstream sites. The Metropolitan Council already monitors at the downstream site and this data is summarized later in this section. Cancellation of this monitoring was also partly due to the fact that conditions of the upstream sites were more representative of wetlands than streams and thus it was thought that stream metrics could not be meaningfully applied to these sites.

Model calibration is covered in Appendix C: Credit River Hydrology and Total Suspended Solid Modeling. Calibration and model development was set up for hydrology and total suspended solids. TSS was used instead of turbidity since it is not possible to express turbidity as a load – a measure of transparency. Instead, a relationship between turbidity and TSS has been developed by the Metropolitan Council (MCES, 2009). Comparison of various calibration statistics and measures indicate that the SWAT model developed for the Credit River Watershed is well calibrated and able to satisfactorily predict hydrology and TSS loads for the watershed.

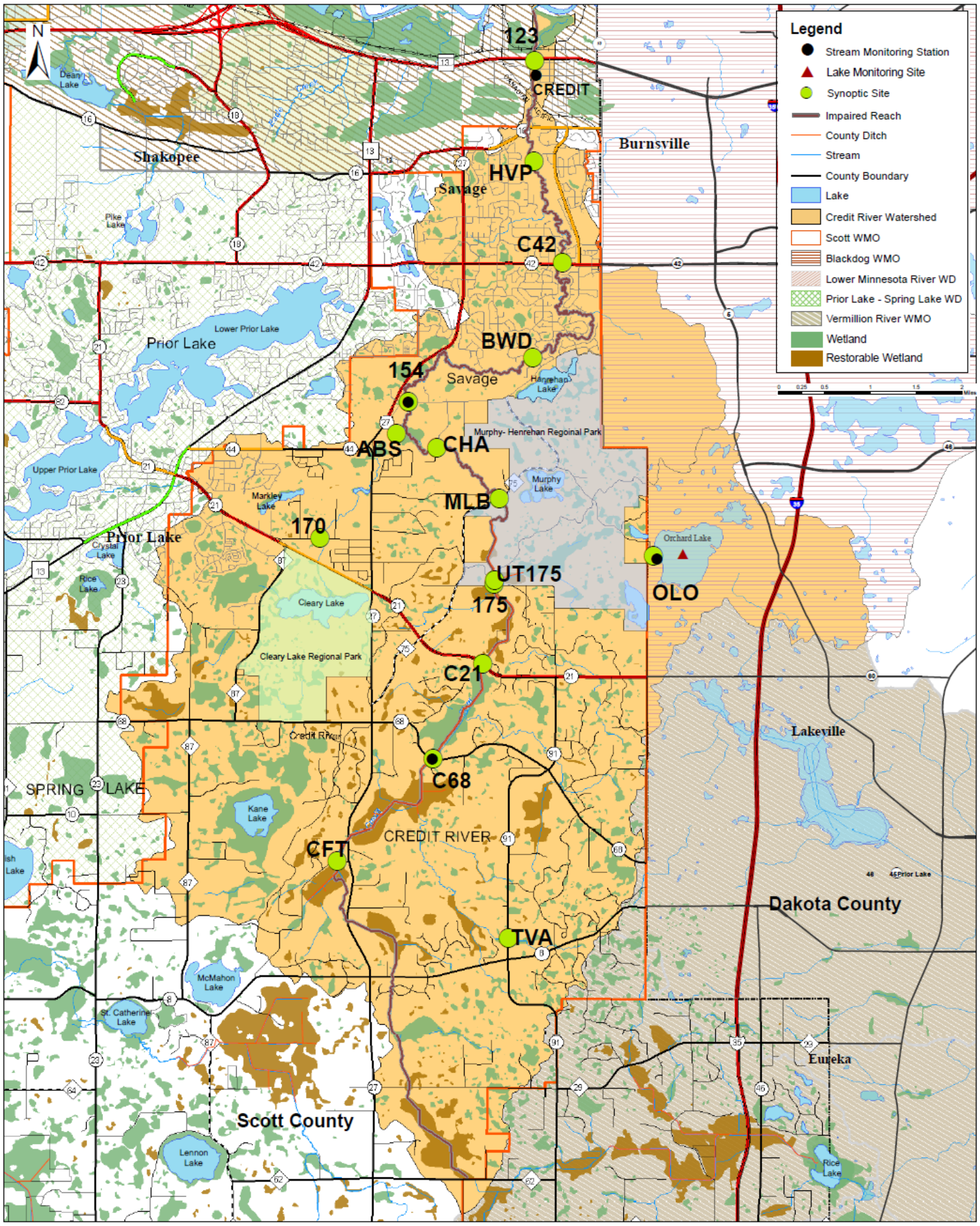

Figure 3-1. Credit River Monitoring Sites

Turbidity and Total Suspended Solids Assessment

This assessment of turbidity focused on evaluating the relationship between turbidity and other sediment related variables, comparison with the standard, documenting spatial and temporal variability, and evaluating sediment sources.

Relationship Between Turbidity and Sediment-Related Variables. The threshold for turbidity impairments, 10% of measurements exceeding a turbidity reading of 25 NTU, is straightforward. The process used to compare data in other units of turbidity and TSS data to the 25 NTU standard requires additional explanation. Figure 3-2 is a graphical representation of the relationship developed between the data sets used for this project. The central link is formed by the laboratory sample analysis, which was deemed most reliable link to the other measurements of turbidity.

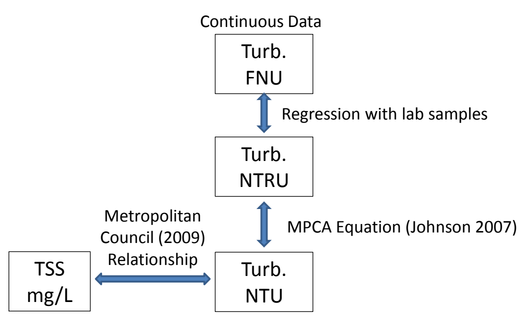

Figure 3-2. Credit River Watershed Turbidity and Sediment-Related Monitoring Data Relationships

Laboratory turbidity (NTRU) and Standard (NTU). Laboratory turbidity readings in NTRU were converted to NTU for analysis of all the laboratory readings. The equation developed by MPCA (Johnson, 2007).

NTRU to NTU equation $NTU = 10^{(-0.0734+0.926*LOG(NTRU))}/1.003635$

Continuous turbidity (FNU) and Laboratory Turbidity (NTRU). Continuous recording field meters used in the study where found to consistently provide higher turbidity readings that the laboratory meter (Figure 3-3). This was also found to be the case with other studies and creeks in the area (Scott WMO, 2010). Therefore, continuous probe results in FNU were first converted to NTRU, and then to NTU. To convert from FNU to NTRU, dates for grab samples evaluated in the lab were matched with same time and date results from the field probe to develop the regression equation in Figure 3-3. Results in NTRU were then converted to NTU using the equation developed by Johnson (2007).

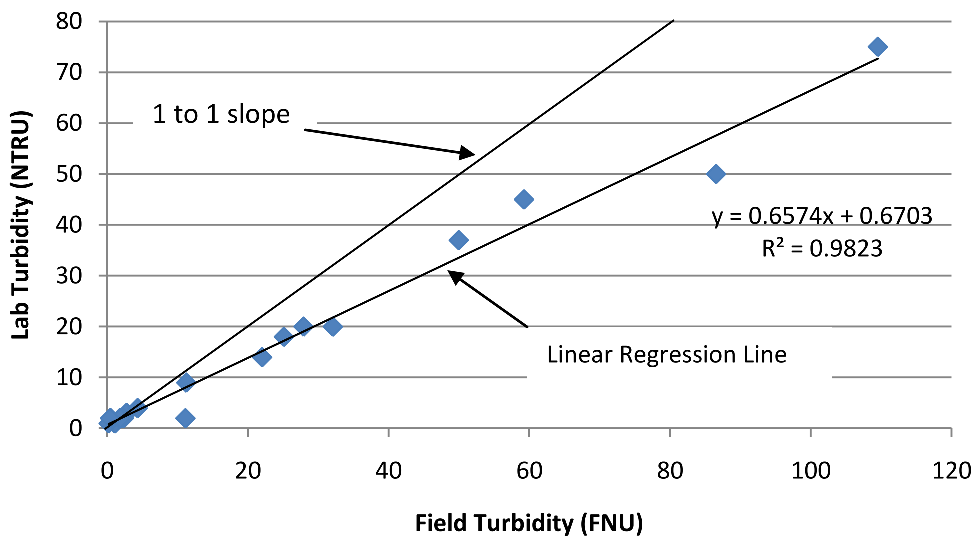

Figure 3-3. Regression between field and laboratory turbidity for the Credit River 0.9 Site (2008 and 2009)

Laboratory Turbidity (NTRU) and Total Suspended Solids (TSS, mg/L). Turbidity and TSS relationships for streams across the metropolitan area were assessed by the Metropolitan Council (2009). For the Credit River they found that 25 NTU was equivalent to 139 mg/L. This relationship is used by this study since the Metropolitan Council's analysis used a longer record of measurements than was captured in the monitoring efforts for this study. The log transformed relationship is fairly strong with a slope of 0.210572, R-Sq of 63.7% and R-Sq (adj) of 63.1%. The equation is: Log10(TSS) = 0.2420 +1.361Log10(Turbidity).

Additional analysis of the relationship between turbidity, total suspended solids, and volatile suspended solids (VSS) was completed to assess whether turbidity is primarily influenced by non-volatile (inorganic) solids, volatile solids or a combination. The question being whether or not algae from lakes in the watershed could be affecting turbidity in the stream, and if so, whether phosphorus, which drives the algae group needs to be part of the modeling effort. To complete this analysis the concentration of non-volatile suspended solids (NVSS) was calculated by subtracting VSS from TSS. The percent NVSS of TSS was then calculated and compared to turbidity readings at the three sites. Model calibration was to the downstream METC 123 site, but the other two sites were also assessed.

Figures 3-4 and 3-5 present the results of the analysis for 2008 and 2009 data, respectively. These results show that:

1. Turbidity readings rarely exceeded the 25 NTU standard
2. When turbidity was higher, NVSS was 75% or more of the TSS

Based on these findings the Technical Advisory Committee for the project felt comfortable proceeding with model development for TSS without simulating phosphorus and algae.

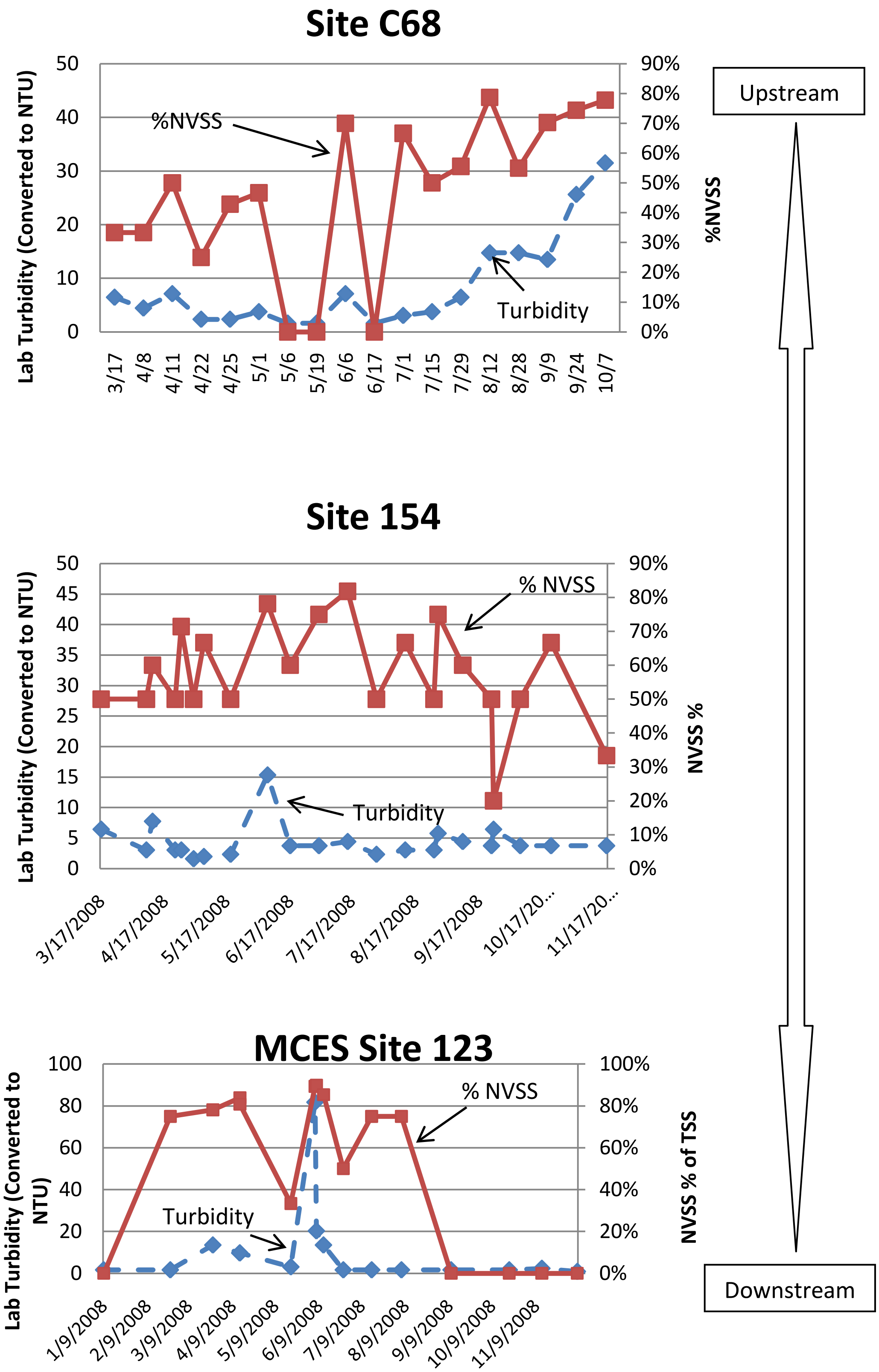

Figure 3-4. Turbidity And Percent NVSS, 2008

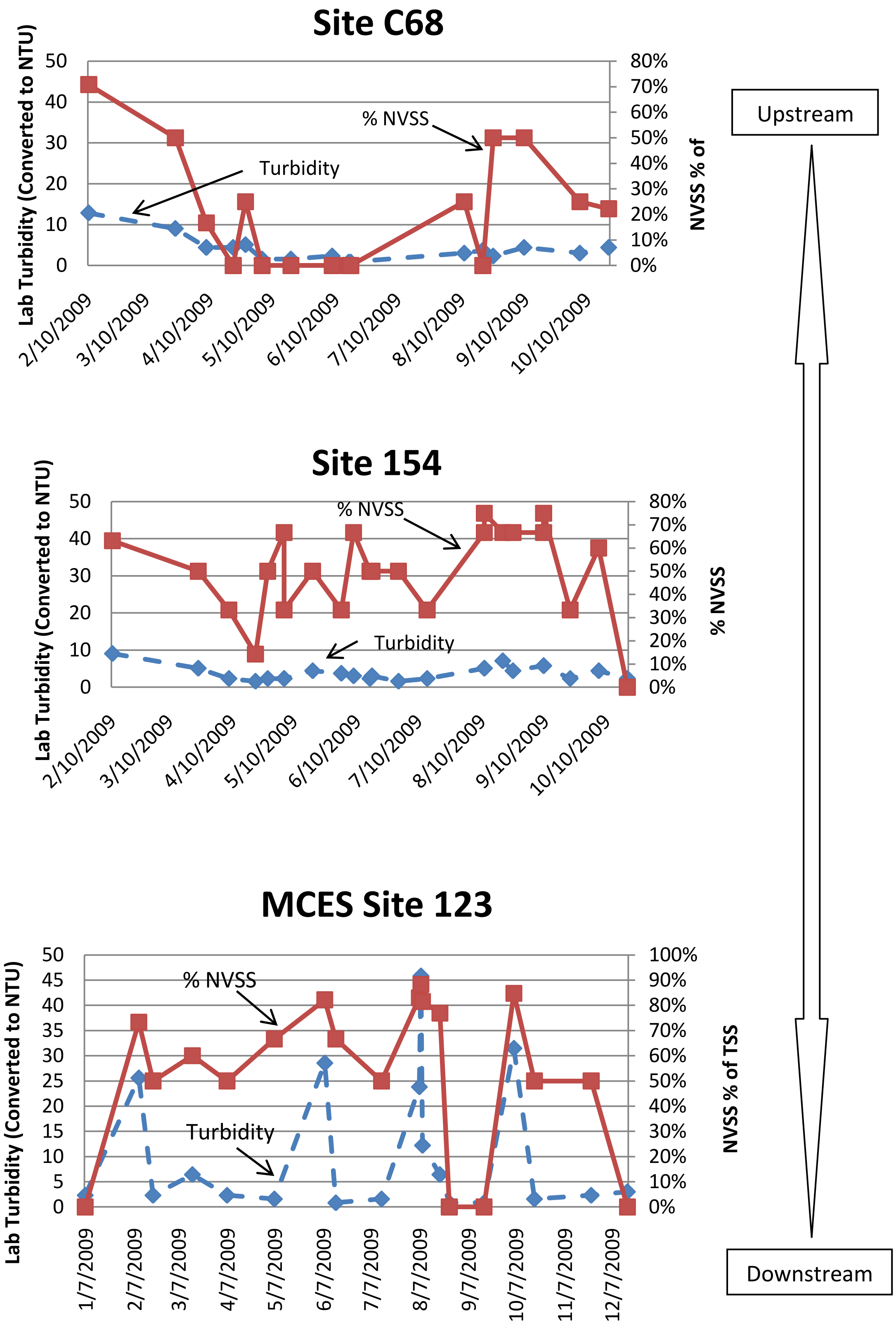

Figure 3-5. Turbidity And Percent NVSS, 2009

Relationship Between Turbidity and Flow. As demonstrated by the Metropolitan Council (2009) that there is a strong relationship between turbidity and TSS in the Credit River. It is also known that sediment and TSS loads vary with flow with higher suspended and bed loads during higher flows. Higher flows have more energy to suspend and move sediment. Since turbidity in the Credit River appears to be related to TSS loads, it is likely that turbidity is also affected by flow. To assess this both continuous field turbidity data and lab turbidity data were compared to flow at the MCES site 123. Figure 3-6 shows the relationship between continuous data for mean daily flow and mean daily turbidity. Figure 3-7 shows a similar relationship between lab turbidity sample results (converted to NTU) and flow. Both graphs show fairly strong relationships between turbidity and flow.

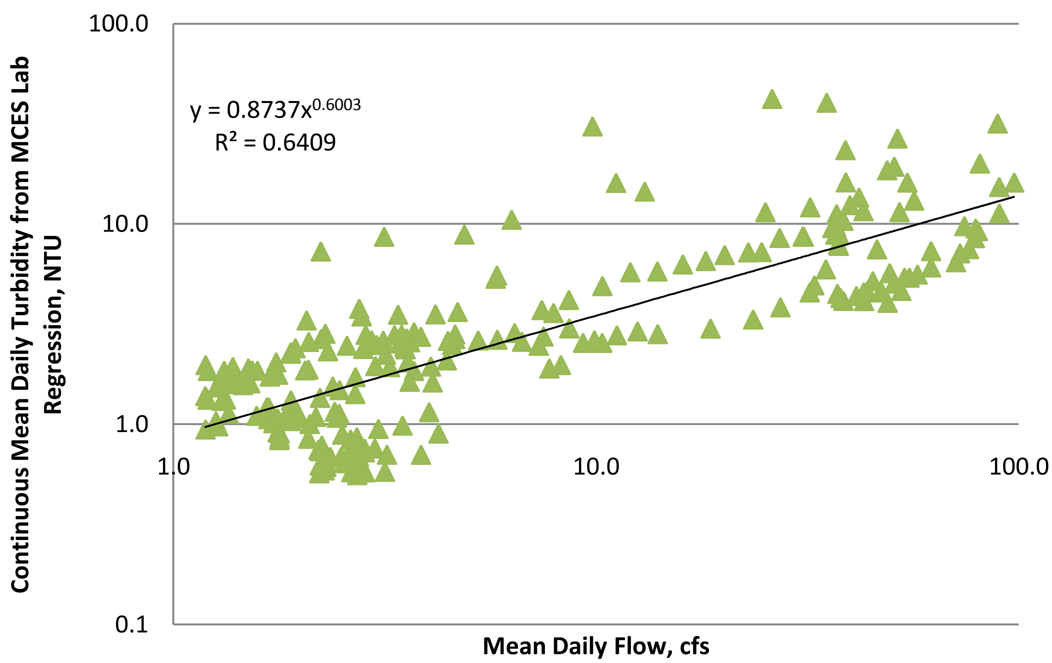

Figure 3-6. **Comparison of continuous mean daily turbidity readings and flow for the Credit River, 2008 -2009, MCES site 123**

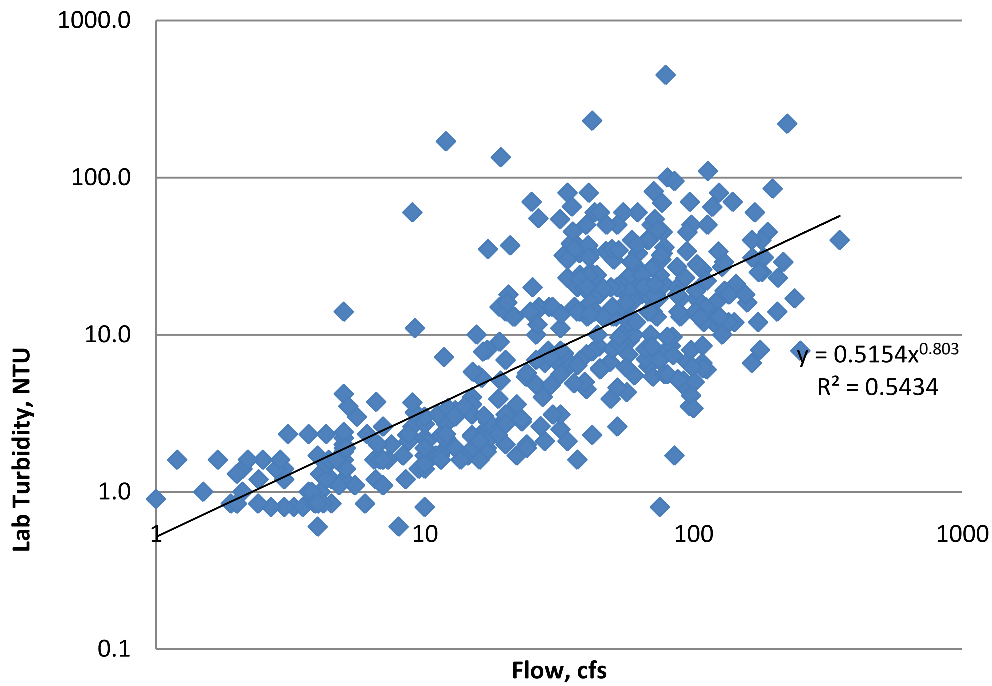

Figure 3-7. Comparison of laboratory turbidity sample analyses and flow from the Credit River, 1993-2008, Metropolitan Council site @ MR 0.6/0.9 (MCES site 123)

Comparison with Standard. As previously discussed, the threshold for turbidity impairment is based on 10% or more of the measurements exceeding a turbidity reading of 25 NTU. The data used for the 2002 original listing came from the MCES monitoring site of river mile 0.6. Analysis of this data shows that the standard was exceeded about 24% of the time. However, more recent continuous turbidity probe data for a two year period of 2008 and 2009 at the MCES site 123 shows that the turbidity level for which 10% of values exceed the standard is 8.3 NTU (Table 3-1) after conversion from FNU units to NTU units; and further that the percent exceedence of the 25 NTU standard is only 1.2%. It has been hypothesized for this data on the Credit River and for other data (Nine Mile Creek; Greg Wilson, 2009) that differences in the results for continuous probe data and Metropolitan Council laboratory sample data could be due to the following:

1. That the more recent continuous probe readings were taken during a drier period where there were lower flows where lower turbidity results typically occur, and since the

continuous data only represents two years, the data may not be as representative of long term conditions as the lab sample data.

2. The analyses using the Metropolitan Council laboratory sample results are biased high since the monitoring program under which the samples were collected was biased toward high flows under which higher turbidity results typically occur.
3. Changes in the watershed characteristics.

These hypotheses are discussed in detail in the Credit River Turbidity Delisting memo (Nelson, 2010) included as part of the MPCA Listing Transparency Document (Appendix A) and summarized below. There is some concern about using all the conversions (i.e., FNU to NTRU and NTRU to NTU). Therefore, the distribution for the continuous data was also calculated without converting. Without the conversion, the 90% percentile (i.e., the 10% exceedence) for field turbidity was 17.1 FTU which is still well below the 25 NTU standard. An analysis was also completed to assess the effects of flow because of questions about whether 2008 and 2009 are representative of long term weather and flow conditions. Rainfall at Chanhassen was 22.4 inches and 29.8, respectively for 2008 and 2009. Average annual rainfall is about 29 inches. Thus, the two year period with the continuous data represents one dry year and one year close to the average.

Table 3-1. Turbidity Distributions

Percentiles	MPCA 2000 NTU	Met Council Continuous 2008 and 2009 NTU*
90^{th}	50.5	8.3
50^{th}	12	2.0
10th	1.7	0.8

*Converted to NTU as described above: Field FNU to Lab NTRU, Lab NTRU to NTU

The analysis of the effects of flow was completed using a relationship developed between flow and laboratory turbidity to all the MCES flow records to evaluate whether the standard would have been exceeded if monitoring had been completed on a continuous basis. In other words, a relationship was developed between flow and laboratory turbidity (see Figure 3-6 above), and then turbidity was predicted for the 90^{th} percentile flow value of the entire 15 year flow record at the MCES monitoring site. Using the equation developed between continuous turbidity and flow for 2008, a value of 8.6 NTU at the 90% flow value for the 15 year flow record, would represent the 10% exceedence value for turbidity. Using the equations developed from lab turbidity and flow, gives turbidity values of 11 NTU and 18.4 NTU for the 90% flow value of the 15 year record, based on the regression and the upper 95% confidence interval, respectively. This analysis confirms that the 25 NTU standard will be meet 90% of the time with 95% confidence, based on long term flow duration characteristics.

Spatial Variability. Spatial variability is discussed as observed from the monitoring data collected over 2008 and 2009 for TSS; and as predicted by the SWAT model for TSS.

Spatial Variability of Monitoring Data. Spatial variability was assessed using the results of the monitoring at the three primary monitoring sites, the synoptic monitoring sites, and data obtained for Orchard and Cleary Lakes.

Table 3-2 presents distributions for TSS at the three primary monitoring sites (sites 123, C68, and 154; see Figure 3-1, page 3-3). At first glance it appears that site 123 has much higher TSS than the other two sites. This may, however, be due to differences in sampling protocol between the sites. The Metropolitan Council collected both composite and grab samples in 2008 while all samples collected at the other sites are grab samples. All samples at all sites collected in 2009 were grab samples. Composite samples are collected to represent the storms and are a mix of a number of small sample volumes collected over the duration of a storm. Since there is a relationship between TSS concentrations and flow, it is expected that composite samples will have a higher concentration than samples collected during non-storm periods. Similarly, "event" grab samples were collected at sites C68 and 154 to ensure that storm flows were represented in the data from these sites. Since composites were collected in 2008, the 2009 results provide the best comparison between sites. The 2009 TSS results at site 123 show much higher TSS concentrations at the high end of the distribution than at the other two sites.

Table 3-2. TSS Distributions

Percentile	Site					
	C68		154		Met Council 123	
	2008	2009	2008	2009	2008	2009
90th	88.2	10.2	13.8	8.8	269	131
50th	8.5	4	4	4	2.5	4
10th	1.9	1	2.3	2	0.5	1
n	18	17	22	23	16	19

The Metropolitan Council calculated TSS loads at the three monitoring sites for 2008 using FLUX (Figure 3-8). These results shows that most of the TSS load originates downstream of site 154. This makes sense as this is where the Credit River cuts through the Minnesota River Valley bluff and picks up grade. These lower watershed areas are also where the Geomorphic Assessment (Appendix D) found the most stream bank instability, the Scott SWCD streambank erosion survey (Scott SWCD, 2006) found the most erosion, and where a couple of eroding ravines were known to exist at the time of the study.

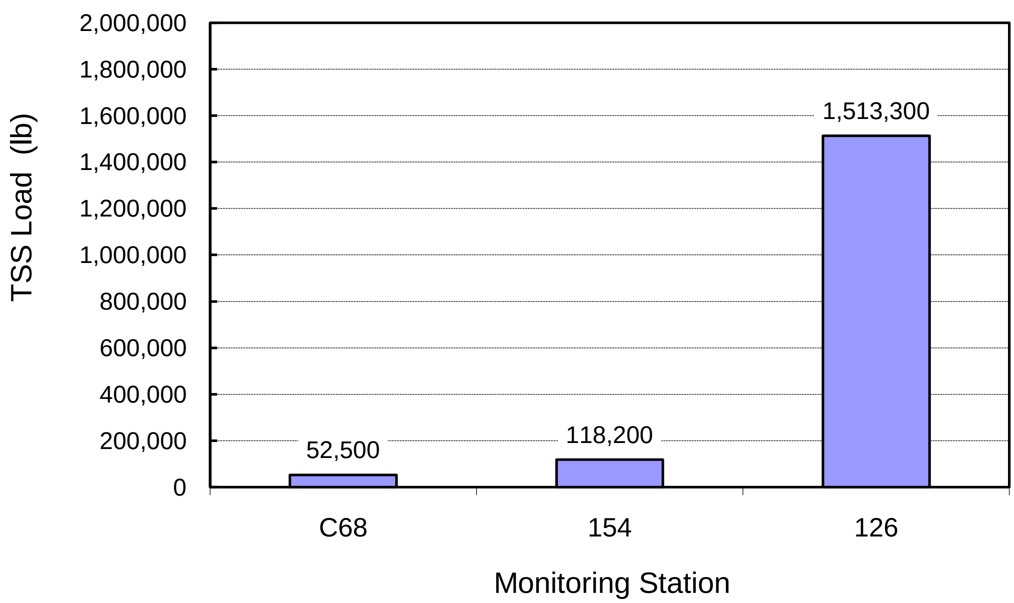

Figure 3-8. Estimated TSS Loads 2008

Results of the synoptic monitoring for field turbidity are presented in Table 3-3. Synoptic monitoring consisted of periodic (seven times) monitoring across the watershed using meters to get a wider distribution of data than at just the three primary sites. Review of the data obtained from the synoptic effort found that the data was not particularly informative, with a couple of exceptions, since there was only one observation that exceeded 25 FNU. The exceptions are that there was no flow out of Cleary and Orchard Lakes for much of the summer and the fall of 2008. This finding is important as it helps to diagnose whether the two lakes could be contributing TSS in the form of algae thereby affecting turbidity readings.

The Metropolitan Council's Lake Water Quality Grade gave Orchard Lake an "A" for 2008-2009, indicating a potential improving water quality trend, given that from 2004-2006 it received a grade of "B" and in earlier years a grade of "C". The 2008 data summary from Met Council's CAMP program (Metropolitan Council, 2009b) shows Orchard Lake's (May through September) mean chlorophyll-a at 10.1 ug/L, transparency at 3.1 meters, and total phosphorus at 22.5 ug/L. The improvement could be due to the City of Lakeville developing the Orchard Lake Management Plan in 2000, which contains recommended projects to meet fisheries goals, improve shoreland habitat, and reduce aquatic plants and nutrients. The study conducted in 1999, included water quality improvement alternatives identified in the diagnostic feasibility study, with the exception of in-lake alum treatment. The City of Lakeville is working toward implementation of all the best management practices identified in the Orchard Lake Management Plan (2000). The basic conclusion is that with the low chlorophyll-a concentrations observed and the lack of discharge, that algae growth in the lake was not significantly contributing to turbidity in the Credit River in 2008. Synoptic data were not collected, but chlorophyll-a concentrations were even lower than in 2008 averaging 3.6 ug/L (Metropolitan Council, 2009b).

Cleary Lake is listed as impaired for excessive nutrients and experiences nuisance algae blooms. These blooms could contribute to turbidity levels downstream. However, the synoptic monitoring completed in 2008 never had any flow. It is therefore concluded that Cleary Lake and areas upstream of the Lake did not contribute turbidity to the River in 2008.

Table 3-3. 2008 Synoptic Monitoring Results for Turbidity (FNU)

Site	Map ID	Date						
Order moving downstream		**8-May**	**4-Jun**	**17-Jul**	**15-Aug**	**11-Sep**	**16-Oct**	**13-Nov**
Unnamed Tributary to Credit River at Vernon Avenue (CSAH 91)	TVA	0	0	43.9			0.3	0
Credit River at Flag Trail	CFT	5.8	8.5	16.5			6.1	0.8
Credit River (CD4) at CSAH 68	C68	0	4	5.4	3.6		16.3	11.2
Credit River (CD4) at CSAH 21	C21	0	0.1	2.6		9.4	1.8	5.6
Credit River (CD4) at 175th ST	175	0	5.7	10.1	8.4	28	13.6	8.7
Unnamed Tributary at trail crossing downstream of 175th	UT175	0	2.6	10.5	16.7	10.5	4.5	9.3
Downstream of Orchard Lake Outlet	OLO	0.4	1.7					
Unnamed tributary downstream of Cleary Lake at 170th Street	170	0						
Credit River at Murphy Lake Boulevard near Murphy Lake	MLB	0	0.8	1			0	0
Credit River at Hampshire Avenue	CHA	0	1.4	17.1	16.1	9.7	0.6	0
Unnamed tributary at Allen Boulevard S	ABS	0	0	0.2	0.1	0	No data	No data
Credit River at 154th Street	154	0	2.9	6.8	2.6	4.5	4.9	2.5
Credit River at Bridgewater Drive Crossing	BWD	0.2	2.8	0.9	2.9	3.9	0.8	0.9
Credit River at CSAH 42 crossing	C42	11	0.4	3.2	1.1	0	0	0
Credit River at 132nd Street W at Hidden Valley Park	HVP	3.8	2.2	1.2	0.1	0.5	0.9	0
Credit River at 123rd Street W	123	6.8	1.9	0	0.1	0	0	0.8

* empty cell indicates no flow

Spatial Variability Assessed by the SWAT Model. The SWAT modeling effort assessed spatial variability as part of developing the model, and predicted spatial variability of TSS sources across the watershed as an output. The following discussion first summarizes the assessment of non-field (i.e, channel, ravine, etc) versus field sediment source distributions used to develop and calibrate the model, and then presents a summary of model predictions. Readers are referred to Appendix: C for the full modeling report produced by the Metropolitan Council.

The model was calibrated to the TSS loads at the MCES site 123, and to field to non-field TSS ratios. The final ratio in the model was 18.5 percent from field erosion and 81.5 percent from non-field erosion. These ratios are consistent with other reported values for the region. Figure 3-9 shows field and non-field erosion ratios for other Lower Minnesota River Watersheds estimated using the isotope fingerprint technique by the Minnesota Science Museum St. Croix Watershed Research Station (MPCA, 2009). The average TSS contribution from field erosion in the other Lower Minnesota River watersheds is 14 percent. Among the studied watersheds using isotope fingerprint technique, Carver Creek and Bevens Creek are two watersheds in close proximity to the Credit River Watershed. The field erosion ratios for these two watersheds are 10 percent and 18 percent respectively.

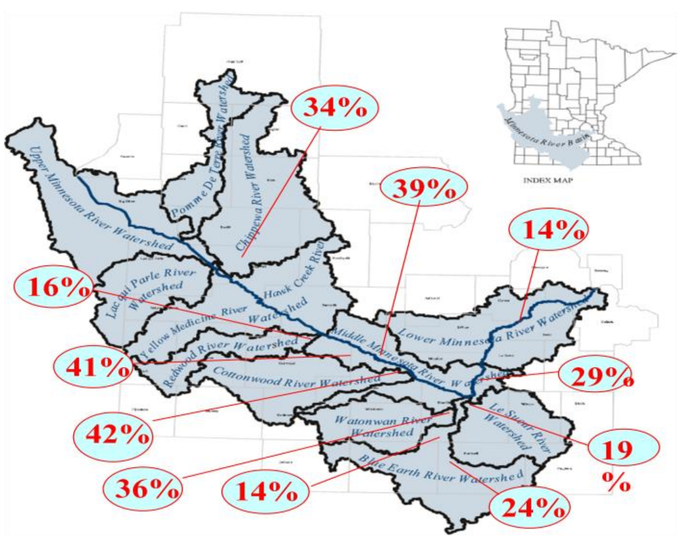

Figure 3-9. Field Erosion Percentages Estimated Using Isotope Fingerprint Techniques for Lower Minnesota River Watersheds (MPCA, 2009)

Figure 3-10 displays the annual surface runoff and total water yield compared to land use predicted by the SWAT model. The total water yield is the total amount of runoff leaving an individual Hydrologic Runoff Units (HRU) and entering the main channels. It includes surface, subsurface, and ground water flows as well as water lost due to evaporation. The results show that urban areas generated the highest surface runoff (6.9 inches), while forest contributed the lowest surface runoff (0.8 inch). Modeled results also show that sand mining had only 0.1 inch of surface runoff but it also had the largest total water yield (18.7 inches), probably due to limited evapotranspiration occurring at the sand mining sites. Wetlands were one of the land covers that yielded relatively large amounts of water; wetlands were simulated as impervious in SWAT with no water removal except for evaporation and seepage.

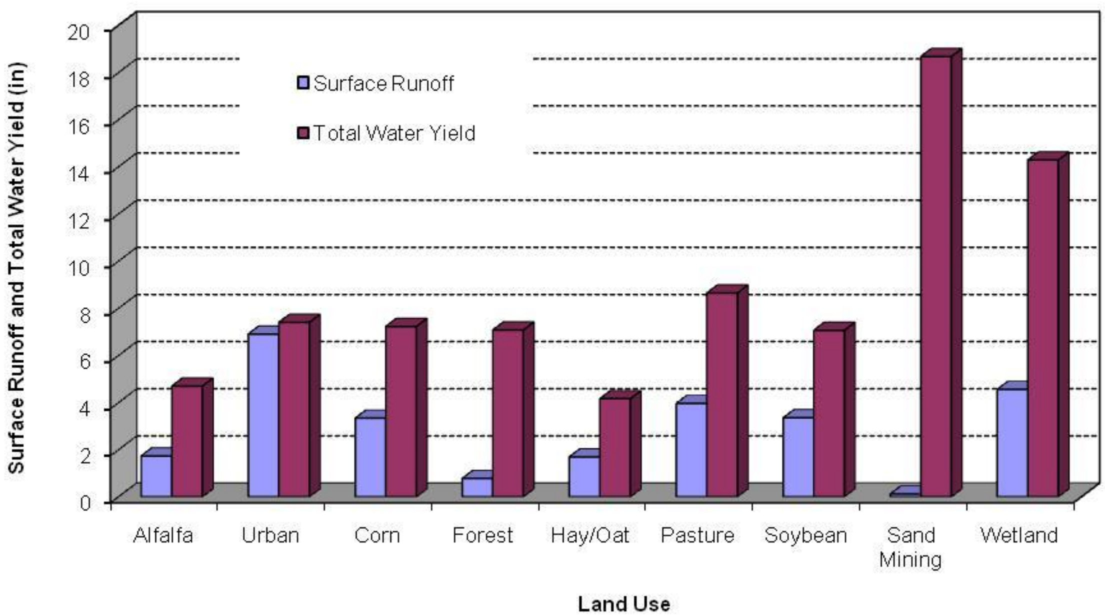

Figure 3-10. Simulated Surface Runoff and Water Yield by Land Use

For TSS yields from land uses, two values were estimated by SWAT for comparison (Figure 3-11): the TSS yield leaving the HRU and the TSS load entering the channel after flowing through impoundments and buffer strips. The two values were significantly different for the Credit River Watershed because the numerous vegetated buffers, wetlands, and ponds in each subbasin effectively remove most of the TSS from the runoff before it enters the channels.

Results show that TSS yields varied across the watershed. For example, agricultural land uses (corn, soybean and alfalfa) had the largest TSS yields leaving the HRUs. However, only a small portion of the TSS yield from agricultural lands entered the Credit River due to removal in buffer strips, wetlands, and ponds. Urban land uses, on other hand, contributed the largest TSS loads to the river, most likely due to having fewer wetlands and buffers than the agricultural areas. TSS loads from the urban land use were simulated to be 57 lb/ac. Forests together with sand mining had the smallest TSS yields and loads to the channels (4.0 and 0.2 lb/ac). Because SWAT simulated the TSS generated from the wetlands without any removal by buffers and impoundments in urban areas, the TSS load entering the channels from wetlands was similar to the HRU yield.

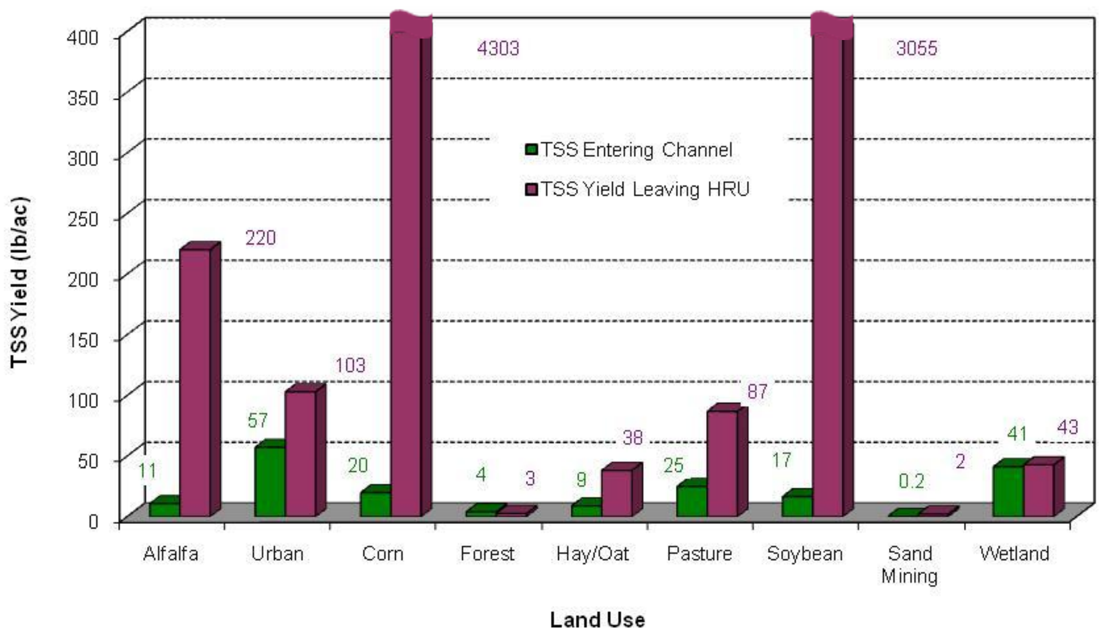

Figure 3-11. Simulated Field Erosion by Land Use

Spatial distribution of the surface runoff volume and TSS load was analyzed with the model to identify the areas that contribute major flow and TSS to Credit River and where BMP implementation for TSS control should be prioritized. Seventy subbasins have been delineated in the watershed based on SWAT, numbered roughly from upstream to downstream (Figure 3-12). Annual average runoff volumes and TSS yields per unit area from each subbasin were analyzed based on the modeled results from 1997 - 2008. To make it comparable to non-field erosion, TSS yields from field erosion were calculated based on the loads entering the channels after flowing through buffers and impoundments.

The results show that average annual surface runoff volumes from upstream subbasins, for example above Subbasin 18, were relatively small, ranging from 2 inches to 4 inches (Figure 3-12). The mostly urban downstream subbasins contributed relatively large amounts of runoff, ranging from 4 inches to 10 inches. The highest runoff was generally found from the urban subbasins (Subbasins 1-10) below the bluff area.

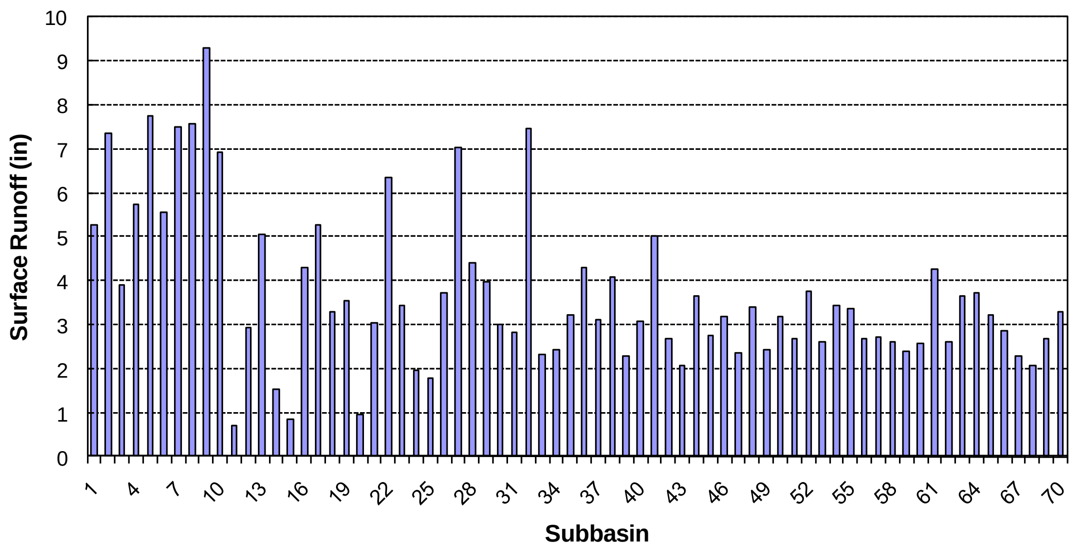

Figure 3-12. Simulated Average Annual Surface Runoff by Subbasin

Figure 3-13 shows the simulated average annual TSS yields of field erosion per unit area by subbasin. The yields ranged from 1 lb/ac (Subbasin 11) to 150 lb/ac (Subbasin 6). The yields from most subbasins were relatively small regardless of subbasin location. Subbasins 3 and 6 were exceptions, contributing extremely high TSS yields (140 lb/ac and 150 lb/ac). The yields were calculated based on the amount of TSS entering the channels, which are influenced by many factors, including land cover, slopes, soil properties, buffer application and impoundment settlement. Any combination of these factors may determine high or low TSS loads from a subbasin.

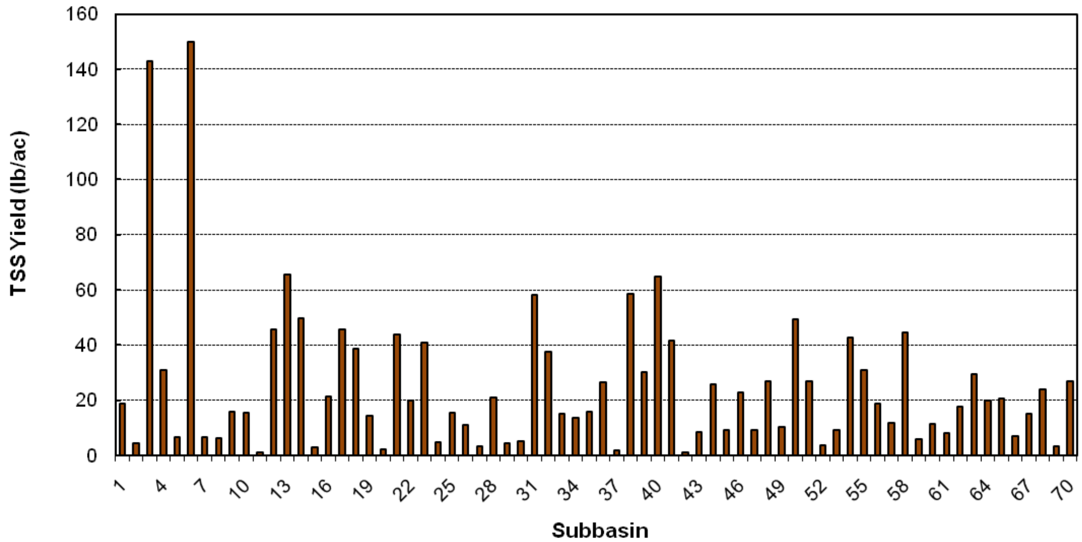

Figure 3-13. Simulated Average Annual TSS Yields by Subbasin

The total TSS load from field and non-field erosion was used to quantify TSS non-point sources in the watershed. The total TSS load is not only dependent on the TSS yield per unit area but also on subbasin area. Figure 3-14 is a spatial distribution map of annual field and non-field TSS loads by subbasin, reflecting the magnitude of field and non-field erosion by subbasin.

Figure 3-15 shows model predicted non-field erosion expressed as a percent of the total TSS load by subbasin. Figures 3-14 and 3-15 show that a large amount of non-field erosion occurs in the downstream subbasin channels below the bluff area, ranging from about 141,100 lb/yr to 315,300 lb/yr and contributing up to 74 percent of the total bank erosion load. Upstream subbasins have either no erosion or low risk for non-field erosion. These upland subbasins contributed only 26 percent of the total bank erosion load. This is consistent with the Scott SWCD (2006) stream bank erosion survey and the Geomorphic Study (Appendix D) which found more active channel process in the downstream reaches of the River. Some of the tributaries discharging to the downstream reaches of the River were also known to be unstable.

When comparing field and non-field erosion, TSS loads from field erosion are relatively insignificant. Non-field erosion from the downstream reaches of the watershed is the primary sources of TSS in the Credit River Watershed.

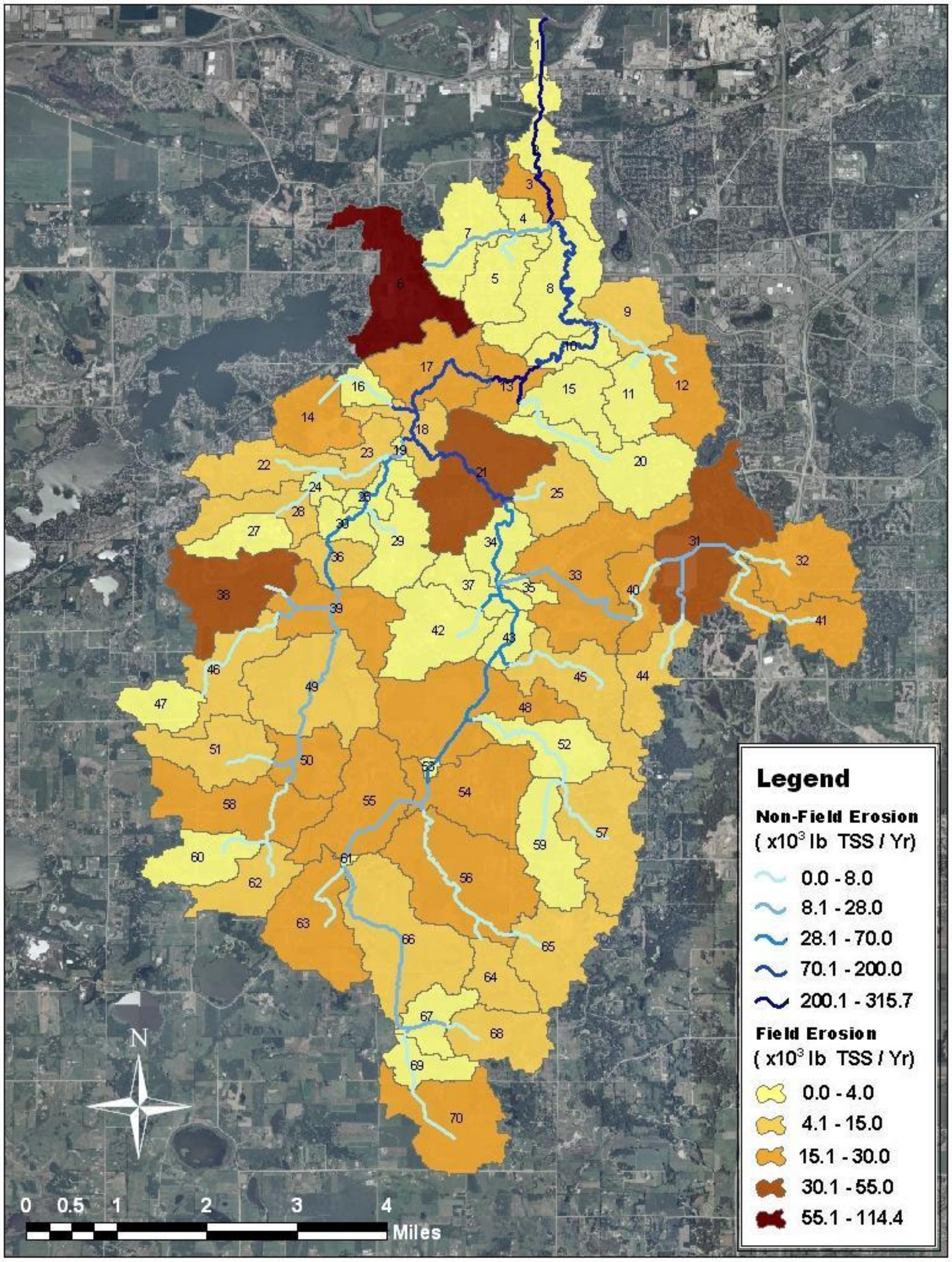

Figure 3-14. Simulated Field and Non-Field TSS Loads by Subbasin for Credit River Watershed

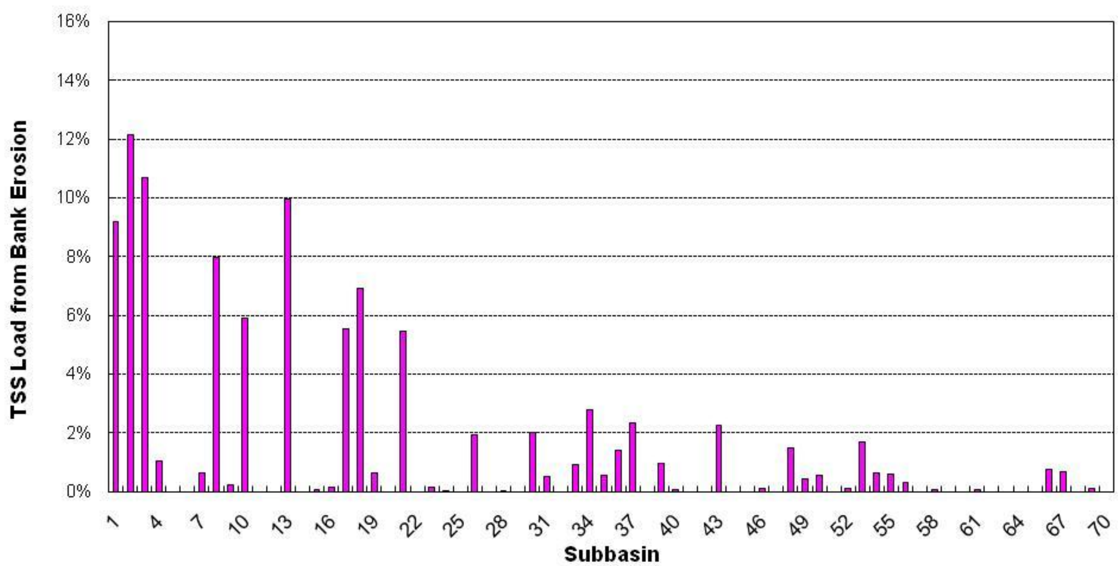

Figure 3-15. Simulated Non-field Erosion Load in Percent by Subbasin

Simulated mass balances of the TSS loads in the Credit River Watershed were analyzed and summarized in a flowchart (Figure 3-16). The TSS loadings from various sinks and sources are distinguished by color. This mass balance shows that field erosion generates the highest TSS export, but that much of that is trapped by buffers, wetlands, and lakes before reaching the river, Non-field (channel) erosion has a much smaller TSS export, but since it is directly linked to the rivers its impact is higher.

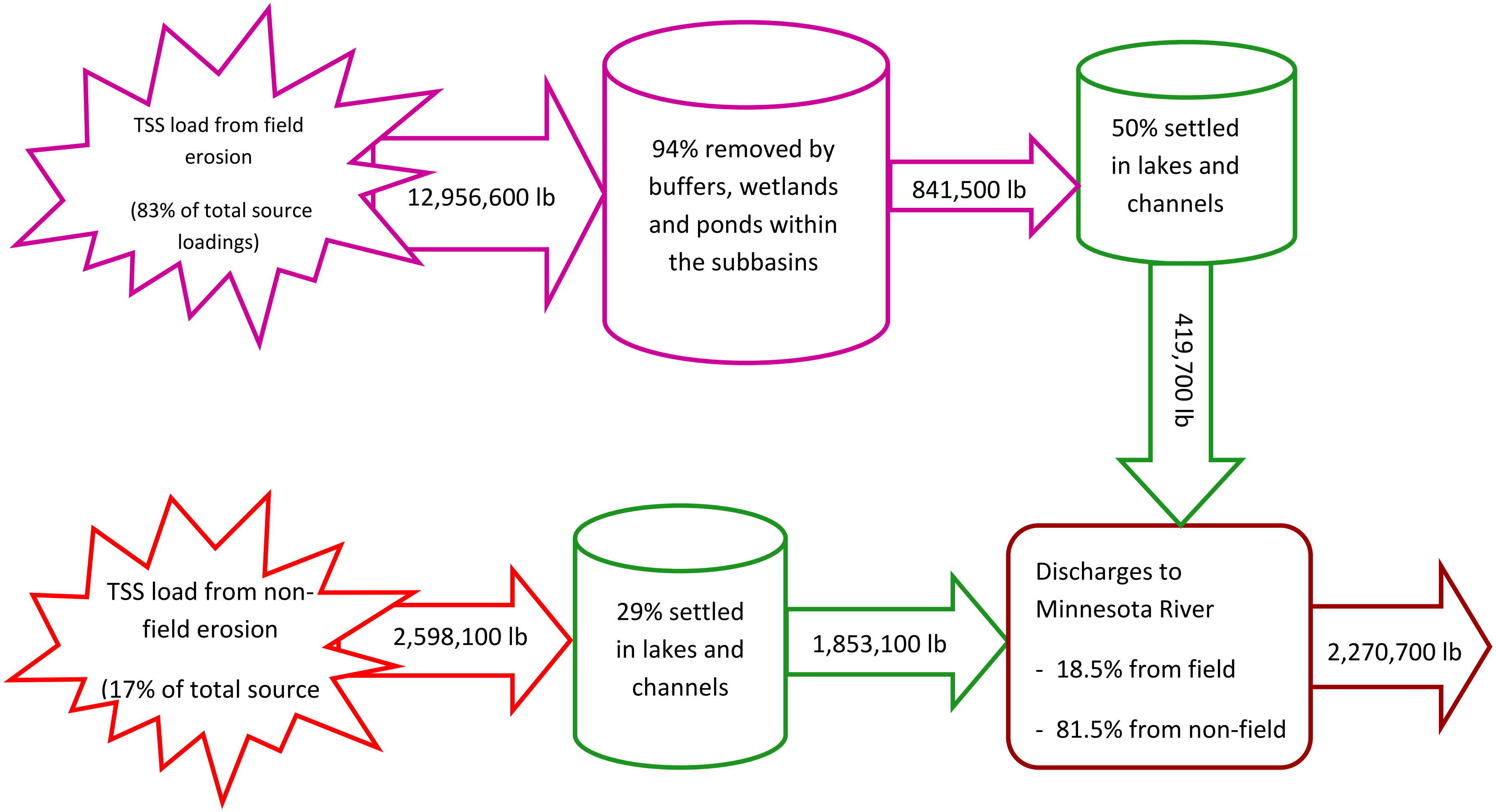

Figure 3-16. Mass Balance of Non-Point TSS Loads in Credit River Watershed

Temporal Variability. Figure 3-17 presents the continuous turbidity readings at the MCES site 123 for 2008 and 2009. This short period of record makes it difficult to identify seasonal patterns. However, since there is a strong relationship between turbidity and flow it is expected that seasonal patterns for turbidity would be similar to that of flow. Figure 3-18 presents the flow data for the MCES outlet site 123 (both when it was at RM0.6 and 0.9) for the entire period of record. This flow data shows a seasonal pattern with higher flows in the spring and early summer.

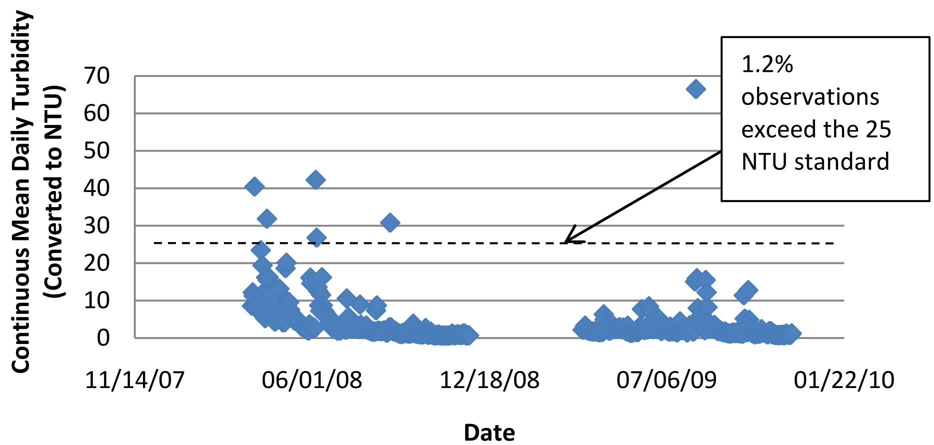

Figure 3-17. Continuous Turbidity Credit River Site 123, 2008 -2009

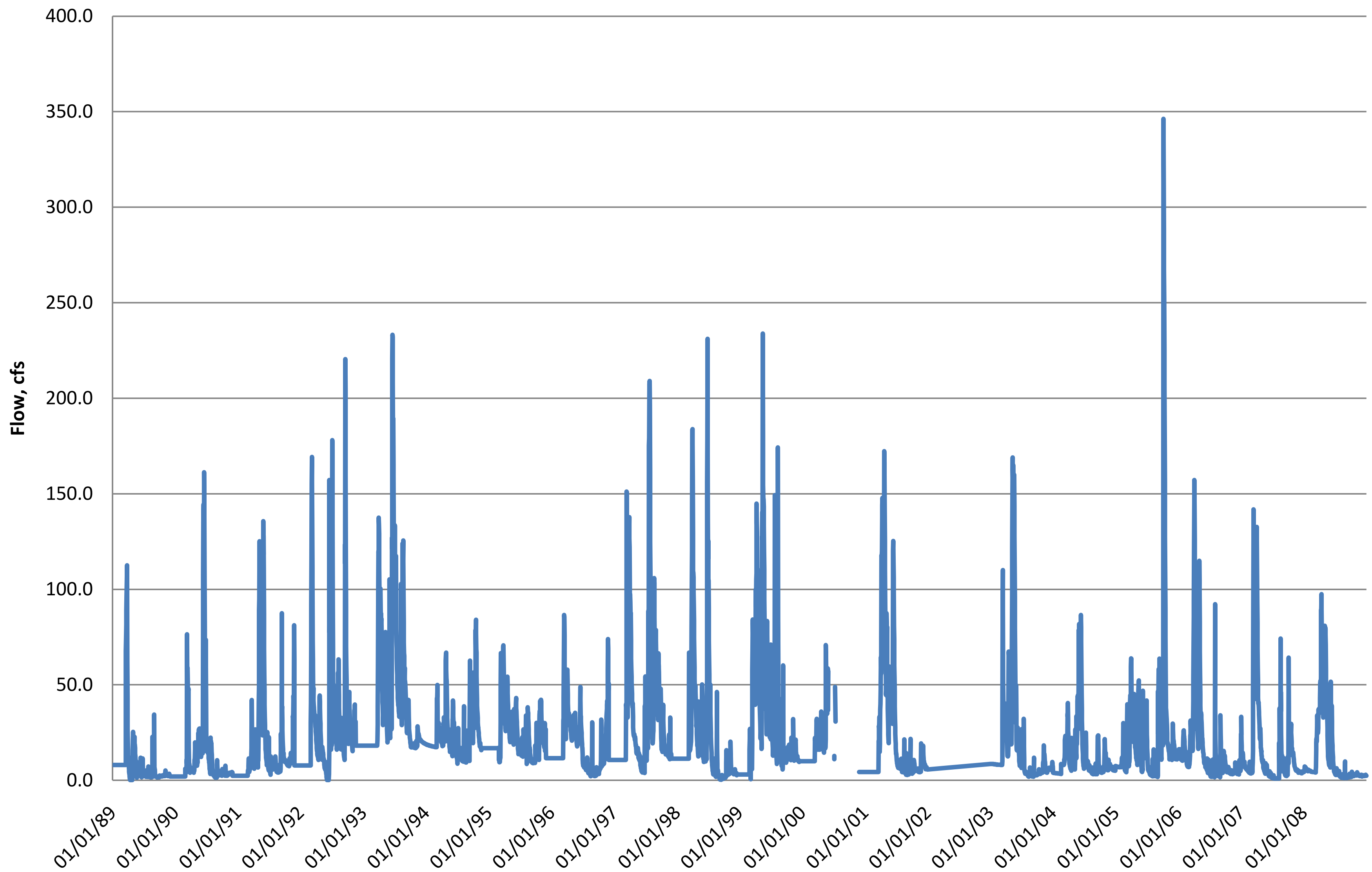

Figure 3-18. Credit River Flows at the Metropolitan Council site 123 (RM0.6/RM0.9)

Macroinvertbrates

Macroinvertebrates are organisms without a backbone (i.e., insects, leaches, etc.). They are frequently used as a means of assessing water quality and the health of aquatic communities. The presence or absence of different species, with different levels of tolerance to pollution, reflects exposure to pollution and other stressors. The Metropolitan Council collected data on macroinvertebrates at the downstream end of the watershed near their monitoring station from 2004 to 2007. This subsection provides a summary of the macroinvertebrate data collected by Metropolitan Council Environmental Services (MCES).

A number of different metrics can be calculated with macroinvertebrate data to get a sense of species diversity, the species present and their tolerance for pollution , etc. Table 3-4 below shows the metrics from 2004 to 2007 for Credit River site CR.9. The Hilsenhoff Biotic Index (HBI) was also calculated by the Metropolitan Council and was forwarded for use in this report. Results of the HBI are discussed separately below.

Interpretation of this type of data generally requires comparison with a regional reference site, and none is known for this area. Consultation with the MPCA regarding a reference site found that the Credit River had the lowest Human Disturbance Scale score for the region, and would qualify as a regional reference site. Thus, results are compared to the results reported by the Metropolitan Council for other metropolitan area streams from 2004 (Metropolitan Council, 2005). Data for other years has not been published. Comparison of the 2004 data shows that the Credit River had the highest number of taxa among the 12 streams assessed, was in the middle with respect to EPT taxa and % EPT, was highest on total Diperta taxa (flies and midges), and in the upper third on % Diptera taxa.

With respect to the Hilsenhoff Biotic Index (HBI) calculated from the 2004 through 2007 data from MCES indicated “very good” water quality in 2005 and 2006, to “good” water quality for 2004 and 2007.

Table 3-4. 2004-2007 Macroinvertebrate Metrics

Year	Total Taxa	Mean Tolerance Value	Total EPT* Taxa	% EPT* Taxa	Total Diptera Taxa	% Diptera Taxa	% Intolerant
2004	49	4.9	8	16	29	59	4
2005	33	4.2	7	21	18	54	5
2006	47	4.5	11	23	19	40	9
2007	36	4.8	10	27	19	53	8
	*EPT = Ephemeroptera, Plecoptera, and Trichoptera (Mayflies, Caddisflies, and Stoneflies)						

Conclusions

Analysis of the data collected showed the following.

1. QA/QC Review
    a. Water quality measurements and sample collection met data quality objectives
    b. Flow measurements met data quality objectives, as assessed by duplicate measurements. However, some uncertainty is introduced in the hydrographs for sites C68 and 154 because portions of the hydrographs had to be predicted using relationships developed between these sites and the Metropolitan Council site 123.
2. Turbidity and TSS
    a. There is a strong relationship between turbidity and TSS with a TSS concentration of 139 mg/L being equivalent to turbidity of 25 NTU.
    b. When turbidity was higher, NVSS was 75% or more of the TSS.
3. Turbidity and the standard
    a. The standard is not exceeded at site 123.
4. Spatial Variability

a. Most of the TSS load originates downstream of site 154. This makes sense as this is where the Credit River cuts through the Minnesota River Valley bluff and picks up grade.
b. Orchard Lake (and areas upstream) do not appear to be contributing significantly to turbidity in the Credit River.
c. Cleary Lake (and areas upstream) do not appear to be contributing significantly to turbidity in the Credit River.
d. Model calibration efforts and isotope studies in the Lower Minnesota River basin suggest that most of the TSS load in the river is from non-field sources. The SWAT model was calibrated to reflect that 18.5 percent of the TSS loads came from field erosion and 81.5 percent was from non-field erosion, consistent with isotope studies in the area.
e. Modeling suggests that the hydrologic load is greatest from urban land uses.
f. Modeling demonstrates that agricultural land uses (corn, soybeans and alfalfa) had the highest TSS export yields, but only a small portion of TSS export yield from field sources impacts the Credit River due to removal in buffers, wetlands, and ponds.
g. Modeling demonstrates that field sources of TSS have export rates 5 to 6 times that of non-field sources (channel or in stream), but much is trapped by buffers, wetlands and ponds such that non-field source directly in or adjacent to the river are the dominant TSS sources.

5. Temporal Variability
   a. There is a seasonal pattern for flow in the Credit River with higher flows occurring in the spring and early summer, and since there are strong relationships between turbidity, TSS, and flow, these seasonal patterns are also true for turbidity and TSS.
6. Macroinvertebrates
   a. Hilsenhoff Biotic Index (HBI) indicates “very good” water quality in 2005 and 2006, to “good” water quality for 2004 and 2007 for the Credit River.
   b. The Credit River qualifies as a reference site for the region due to a low Human Disturbance Scale score.