Total Maximum Daily Load Evaluation Of Turbidity Impairments In the Lower Cannon River

For Submission to:
Minnesota Pollution Control Agency

Submitted by:
Cannon River Watershed Partnership
8997 Eaves Avenue
Northfield, Minnesota 55057

June 26, 2006
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TABLE OF CONTENTS

List of Figures

List of Tables

Appendices

EXECUTIVE SUMMARY

In utilizing and conserving the natural resources of the nation, the one characteristic more essential than any other is foresight.
--Theodore Roosevelt *1907*

The Clean Water Act, Section 303(d), requires that states publish, every two years, a list of waters that do not meet water quality standards and do not support their designated uses. These waters are then considered to be "impaired". Once a water body is placed on the impaired waters list, a Total Maximum Daily Load (TMDL) must be developed. The TMDL provides a calculation of the maximum amount of a pollutant that a water body can receive and still meet water quality standards (MPCA, 2005). It is the sum of the individual wasteload allocations (WLAs) for point sources, load allocations (LAs) for nonpoint sources and natural background, plus a margin of safety (MOS). TMDLs can be expressed in terms of mass per time, toxicity, or other appropriate measures that relate to a state's water quality standard (USEPA, 1999).

Sediment is considered to be the major pollutant of waters in the United States (Waters, 1995). Excess sediment entering streams and rivers results in increases in turbidity (cloudiness). In Minnesota, the turbidity standard for Class 2B waters is 25 Nephelometric Turbidity Units (NTU). Turbidity is one of several indicators used to assess whether a water body is attaining the aquatic life designated use as established in Minnesota Rules, 7050.0222, subpart 4:

The quality of Class 2B surface waters shall be such as to permit the propagation and maintenance of a healthy community of cool or warm water sport or commercial fish and associated aquatic life, and their habitats. These waters shall be suitable for aquatic recreation of all kinds, including bathing, for which the waters may be usable.

The entire Lower Cannon River is classified as a Class 2B water.

The Cannon River, HUC boundary in Rice Lake Bottoms to Vermillion Slough/Mississippi River, AUID 07040001-511, was placed on the 303 (d) impaired waters list for aquatic life in 1996 based on turbidity data collected by the Minnesota Pollution Control Agency (MPCA) near the mouth of the Cannon River. The Cannon River, Pine Creek to Belle Creek, AUID 07040002-502, was added to the 303(d) list in 2004 based on turbidity data collected by the Cannon River Watershed Partnership (CRWP) and Metropolitan Council. These reaches are referred to as the "confluence reach" and the "Pine-Belle reach" respectively.

The 2004 report by Barr Engineering, "Phase I Report for Lower Mississippi River Basin Regional Sediment Data Evaluation Project," noted that "stream pollution due to sediment inputs and altered hydrology results in degraded stream channels, a loss of recreational opportunities, and decreased economic activity which results from activities such as fishing, canoeing, and tubing". This general conclusion applies to the Lower Cannon River watershed.

The Lower Cannon River Total Maximum Daily Load (TMDL) Turbidity Project began with a collection and assessment of existing turbidity and sediment data in the watershed. During this data mining process, project partners and volunteers collected more information by means of field measurements and observations. Interested citizens began monitoring sites on the Little Cannon River and on Belle Creek in 1999, well before the project began. The TMDL utilizes data collected by these and other citizen stream monitors. Public participation in the TMDL formally began at the first Steering Committee meeting on June 6, 2003. Following two years of field work, the technical committee began meeting in July, 2005. Discussions focused on the data to be used, modeling and results, aquatic biology, erosion potential, sources of sediment, and the determination of load allocations.

As part of the TMDL load allocation process a source inventory was developed. Potential sources of sediment to the Lower Cannon river include: National Pollutant Discharge Elimination System (NPDES) permit holders – municipal waste water treatment plants and industrial facilities, as well as nonpoint sources – natural background, agriculture activities, aggregate mining, unpaved roads, stream bank and stream bed erosion, and stormwater. The point sources in the watershed could contribute up to approximately 4.7 tons/day of sediment to the river based on their current permit limits. Nonpoint sources may contribute as much as 2,000 tons/day during high flow conditions.

The combination of flow and pollutant concentration defines pollutant loading. Loading capacity is defined by the combination of flow and a concentration-based water quality standard or target. It is the pollutant load that a river can carry and still be in attainment of the pollutants water quality standard or target. The TSS target value "equivalent" to the 25 NTU water quality standard for this project is 44 mg/l, as defined in Figure 6. Figure 12 is the product of the Cannon River at Welch flow duration curve and the 44 mg/l TSS target value. The result is a load duration curve that describes the loading capacity of the Cannon River at Welch in tons/day TSS. Based on the 1991-2004 flow record, the capacity ranges from just over 381 tons/day for the mid-point of the high flow zone, to just over 29 tons/day for the low flow zone.

Because the TSS concentration is fixed at 44 mg/l, loading capacities vary only as a function of flow. As such, flow variability is also the appropriate basis for setting margins of safety (MOS). The margin of safety of each zone is the difference between the mid-point of the zone and the lower flow side of the zone. Thus, the margin of safety protects against TSS loading when there is less dilution potential in the river. Table 6 provides the wasteload allocations, load allocations, and margin of safety for the two impaired reaches addressed in this report.

In order to meet the 44 mg/l TSS concentration significant reductions of sediment contributed from nonpoint sources will need to occur. It is estimated that during high flow conditions, reductions from current loads of 50-80% will be needed. For this to occur a group effort will be needed by a variety of partners including: the Minnesota Pollution Control Agency, Soil & Water Conservation Districts, the Natural Resource Conservation Service, county Water Planners, University of Minnesota Extension Service, the Minnesota Department of Natural Resources, the Cannon River Watershed Partnership, local governments, land owners and operators, and citizens. Some important implementation actions will include erosion control through conservation tillage, conservation easement programs such as CRP, rotational grazing, cover cropping, and water and sediment retention structures. Education of government officials, citizens, land owners and operators, as well as their willingness to change some practices, will be critical to sediment reduction. On-going water quality monitoring will also be needed to determine if changes are occurring and if the changes are successful.

Improvements in the water quality of the Lower Cannon River will not be instantaneous or easy. However, through the contributions of all of those who live, work and play in the watershed it can be done. Everyone doing a little accomplishes a lot.

1.0: Background Information & Watershed Assessment

The Cannon River Watershed includes approximately 941,000 acres (~1470 square miles) of primarily agricultural landscape covering portions of eight counties in southeast and south-central Minnesota (Figure 1). Because it is a relatively large watershed, the following subwatershed lobes are often referenced: Straight River Watershed (the largest tributary to the Cannon River), Upper Cannon River Watershed (headwaters and lakes region), Middle Cannon River Watershed, and the Lower Cannon River Watershed (includes Cannon River from Byllesby Reservoir Dam to its mouth at the Mississippi River in Red Wing.

1.1 Lower Cannon River Watershed (LCRW) Background

A major, but not exclusive, focus of this report is on the Lower Cannon River Watershed (Figure 2). The Lower Cannon has a drainage area of 207,645 acres, which is approximately 22% of the entire Cannon River watershed. The Lower Cannon contains five named and several small unnamed subwatersheds (Table 1). The Little Cannon River joins the Cannon River in the city of Cannon Falls; downstream are the confluences of Pine Creek and Trout Brook. The next major tributary is Belle Creek. The Cannon River meets the Mississippi River in Red Wing, near the Wisconsin-Minnesota border. More detailed information on the Little Cannon River, Belle Creek, Pine Creek and Trout Brook subwatersheds is found below and in Appendix F.

United States Geologic Survey (USGS) GAP program land cover data obtained from the Minnesota Department of Natural Resources (DNR) suggest that approximately 60% of the LCRW is agricultural crop land, while about 12% is upland forest (Table 2). Most of the forest and wetland acreage is south of the Cannon River, in the Little Cannon and Belle Creek watersheds – these areas include more steep slopes that are difficult to cultivate. While both are The trout stream watersheds of Pine Creek and Trout Brook to the north are more dominated by agricultural land.

The city of Cannon Falls lies at the top of the LCRW, just downstream of the Byllesby Reservoir dam. The dam is owned and operated by North American Hydro, a private entity that uses the flow of the Cannon River to generate electricity. The Byllesby Reservoir provides somewhat of a "reset point" with respect to water quality, in that a portion of the sediment and other material that enters the reservoir settles out or is utilized internally and does not leave. The dam is monitored and controlled by North American Hydro.

It must be noted that while Spring Creek is considered a part of the Lower Cannon watershed, and is described in this report, it actually joins the Cannon River downstream of the two impaired river reaches. As such, it does not contribute to the turbidity impairments and is not considered in the TMDL calculations. Furthermore, while Spring Creek likely has turbidity issues and contributes turbidity to the Cannon River, it will not be a focus of watershed improvement practices based directly on this TMDL study. Nevertheless, it may be entirely appropriate to address turbidity issues in Spring Creek via other efforts.

Figure 1 – Cannon River Watershed and Major Subwatersheds

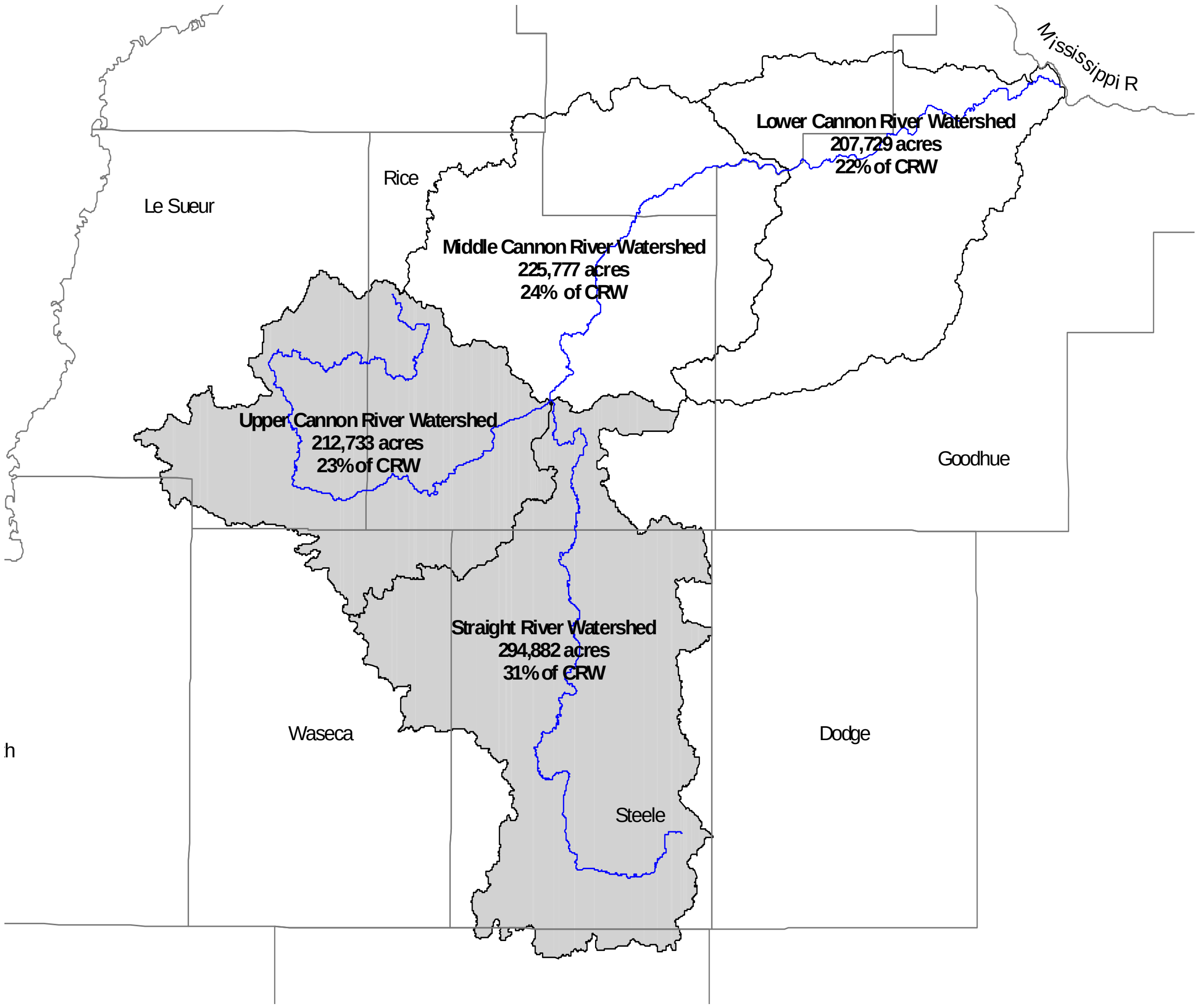

Table 1 - Subwatersheds of the LCRW

Subwatershed	Acres	Percent of watershed	Note
Little Cannon River	60,988	29%	Designated trout stream
Belle Creek	50,353	24%	
Trout Brook	17,860	9%	Designated trout stream
Spring Creek	17,327	8%	Designated trout stream
Pine Creek	14,742	7%	Designated trout stream
Unnamed watersheds	46,375	22%	
LCRW Total	207,645		

Subwatershed Descriptions

Little Cannon River

The Little Cannon River is primarily in Goodhue County, with a small portion in Rice County. It is the largest subwatershed in the Lower Cannon River watershed. The city of Nerstrand (population 234)[1] is in the headwaters area, the town of Sogn (population 20) is in the center and the city of Cannon Falls (population 3973) is at the mouth of the river where it empties into the Cannon River at river mile 25. Other than these three areas the remainder of the watershed is made up of primarily agricultural, pasture land, and forest. The watershed drains approximately 96 square miles. Channel slopes range from 52.8 (f/mile) on Butler Creek to 13.1 (f/mile) on a portion of the Little Cannon (Sanocki, 1999). Maximum elevation is about1200 feet and the minimum is about 820 feet. The upper portions of the river located in T110, R18, Sections 1, 10, 11, 12, 15 and T111, R18, Sections 13, 34, 25, and 36 is designated as Class 2A water (trout streams) per Minnesota Rules 7050.0470.

Belle Creek

The entire Belle Creek drainage lies in Goodhue County and includes no incorporated cities – only small communities such as Vasa, Belle Creek and White Rock. The watershed includes ~ 850 acres (1.7%) of public land (State of MN and MN DNR) in the bottom third of the watershed. It enters the Cannon River at river mile 11 about a mile downstream from the village of Welch. This watershed drains about 75 square miles and has one of the steepest gradients of all of the Cannon River tributaries at about 14 feet per mile. It is a 4th order stream and is primarily agricultural in the headwaters and forest from the midsection down to the mouth

There are several impoundments in the headwaters which were built from 1976 - 1983 to help control the flow during periods of heavy precipitation. Prior to the installation of these structures, the sediment load at the Belle Creek outlet was estimated at approximately 44,000 tons annually (Major, 1974). It was further estimated that the structures would help to reduce sediment loading by approximately 3,000 tons annually. No monitoring has been conducted sufficient to verify the estimated sediment load or assess whether reductions occurred.

Citizen stream monitors collect data on transparency, temperature, stream stage, and appearance of streams throughout the watershed. Mrs. BJ Norman is a long time monitor of Belle Creek. In a letter to CRWP in 2005 Mrs. Norman writes:

> *Belle is always changing. This year (2005) I witnessed particularly the "slumping" off of great chunks of soft bank down stream. Belle wanders quite a bit through the soft sediments of the valleys. Seems that once it starts it will "rapidly' chew away at one bank and build back up on the opposite bank.*

These observations corroborate the findings of Peterson regarding the landscape in this subwatershed. The topography varies and results in flooding and soil deposition in the valley bottoms and soil erosion and fast runoff in the steeply sloped uplands (Peterson, 1965).

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[1] Population estimates for 2005 from State Demographers Office, Minnesota Department of Administration (http://www.demography.state.mn.us/estimates.html)

Trout Brook

Nearly all of the Trout Brook drainage lies in Dakota County. It flows through the Miesville Ravine Park and joins the Cannon River at the Dakota-Goodhue County line. The Trout Brook watershed includes two cities: New Trier (population 120) in the western lobe and Miesville (population 171) in the northeastern lobe.

Only 8.8 miles are defined as perennial stream and are primarily spring fed. Trout Brook can be a "flashy stream" when snowmelt or rain on the upper portions of the sub-watershed cause the water to rise quickly and become turbid. "Total suspended solid concentrations in Trout Brook are disturbing" (NCRWMO,2003).

In its 1999 survey, the MN DNR called the Miesville branch "Trout Brook" and the New Trier branch "Tributary to Trout Brook". The trout stream designation extends from the mouth of the stream, past the confluence of these two branches ~0.8 miles up the New Trier branch only. The entire length of the designated stretch includes well-forested flood plains and vegetative cover on the stream banks. However, the North Cannon River Watershed Management Organization 2003 Management Plan noted shifting sands in the streambed that have resulted in a significant absence of deep holes, and consequently, less cover for fish species.

Spring Creek

Spring Creek is the second smallest of the subwatersheds. It is located in the eastern most portion of the watershed in Goodhue County and ends in the City of Red Wing (population 16,358). This watershed drains approximately 27 square miles with a channel slope of 24 f/mile (Sanocki, 1999). Maximum elevation ~ 1078 feet and minimum is ~700 feet. Land use is primarily agricultural (70%) and pasture/range land (29%). The Richard J. Dorer Memorial Hardwood State Forest extends into this subwatershed.

Pine Creek

Most of the Pine Creek drainage lies in Dakota County (~90%) while the remainder of the acreage is in Goodhue County. The majority of the watershed lies in three townships: Hampton, Douglas, and Cannon Falls. Pine Creek joins the Cannon River approximately 0.7 stream miles downstream of the Goodhue County 17 Bridge.

During the dry season, the stream flow is made up mostly of ground water and its temperature is quite cool and the water is very clear. Turbidity levels are generally below the state standards (10 NTU for Class 2A waters), however during rainfall events samples have been taken that exceed the standards (NCRWMO,2003).

Pine Creek is divided into two separate classes according to Minnesota Rules Chapter 7050. Upstream of Hwy 52, the creek is classified as "2C", which "shall permit the propagation and maintenance of a healthy community of indigenous fish and association aquatic life, and their habitats, and shall be suitable for boating and other forms of aquatic recreation. Below Hwy 52 Pine Creek is a State designated trout stream and classified as "2A" in Chapter 7050. Here the creek "shall be such as to permit the propagation and maintenance of a healthy community of cold water sport or commercial fish and associated aquatic life, and their habitats, and shall be suitable for aquatic recreation of all kinds, including bathing (swimming) (NCRWMO, 2003).

Figure 2 – Lower Cannon River Watershed

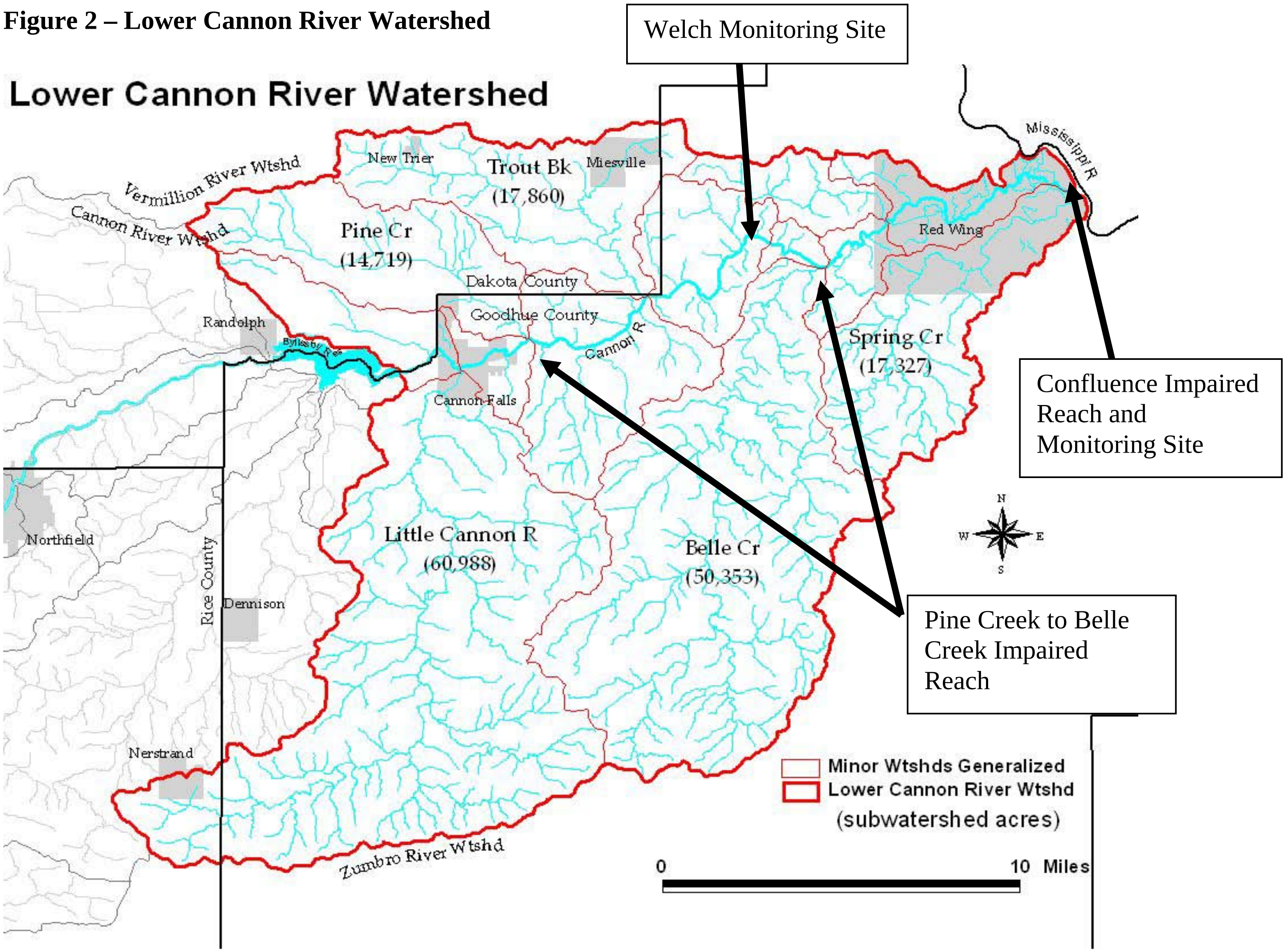


Figure 3 – Lower Cannon River Watershed GAP Land Use

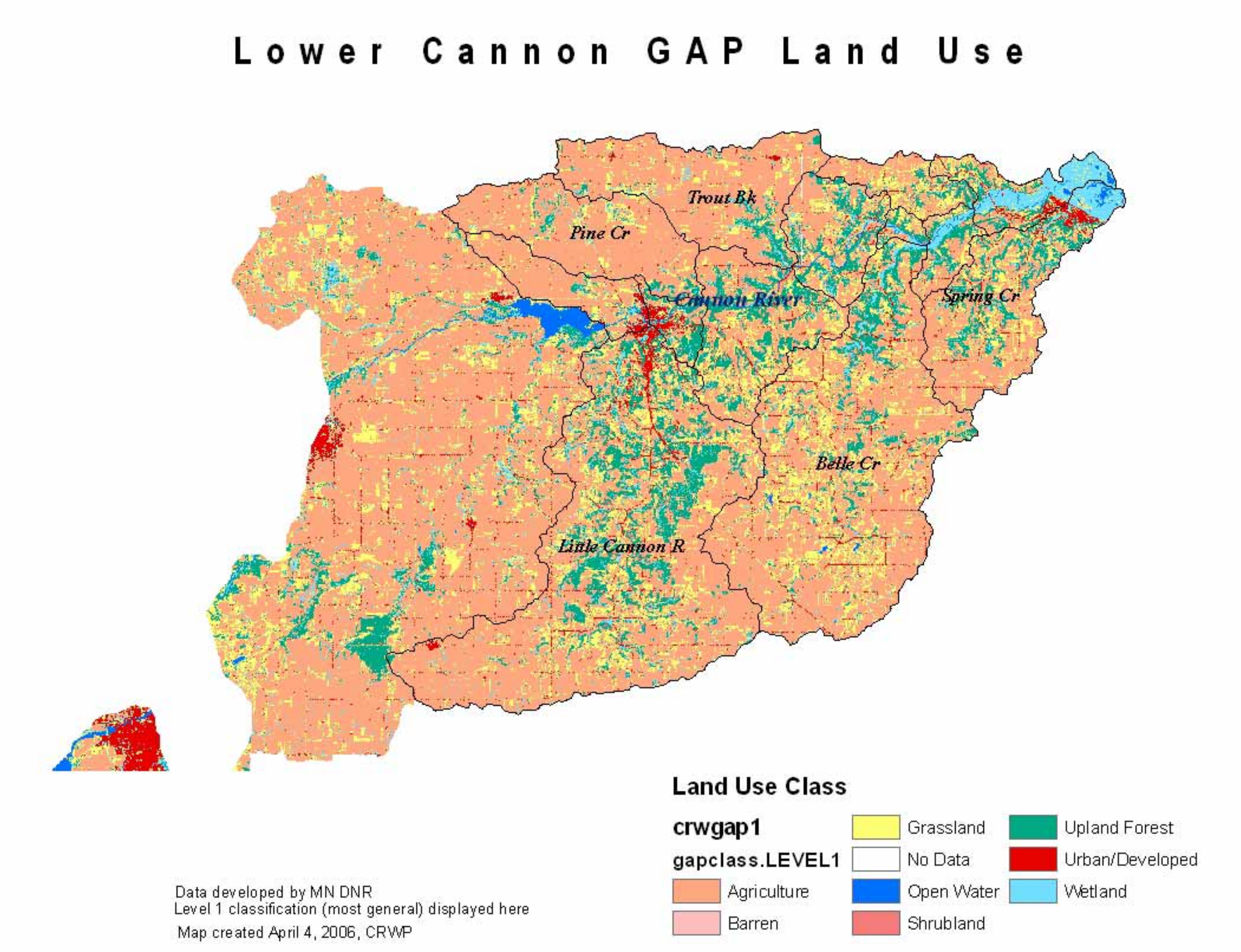


Table 2 – GAP Land Use – Categories and Percents of Use

GAP land use Category Level 1	Percent	GAP land use Category Level 2	Percent	GAP land use Category Level 3	Percent
Agriculture	59.41	Herbaceous/Field Crops	59.41	Row Crops	53.09
Grassland	18.00	Broad-Leaved Deciduous	11.84	Old Fields	11.06
Upland Forest	12.28	Old Field	11.06	Forage Crops (Alfalfa/Pasture/Hay)	6.32
Wetland	5.37	Lowland Forest	4.34	Red Oak	4.86
Urban/Developed	3.04	Cool Season Grassland	4.14	Cool Season Grassland	4.14
Shrubland	1.45	Grassland	2.80	Grassland	2.80
Open Water	0.42	Transportation	2.13	Maple/Basswood	2.42
Barren	0.01	Upland Broadleaf Deciduous Shrub	1.45	Transportation	2.13
No Data	0.00	Lowland Shrub	1.03	Oak	1.70
Total	99.98	Low Intensity (Urban)	0.46	Upland Broadleaf Deciduous Shrub	1.45
		High Intensity (Urban)	0.45	Mixed/Other Broad-Leaved Deciduous	1.31
		Open Water	0.42	Lowland Broad-Leaved Deciduous Shrub	1.22
		Coniferous	0.22	Boxelder	1.17
		Mixed Deciduous/Coniferous	0.22	Cottonwood	1.08
		Mixed Barren	0.01	Bur Oak	0.96
		No Data	0.00	Silver Maple	0.69
		Total	99.98	Low Intensity (Urban)	0.46
				High Intensity (Urban)	0.45
				Emergent/Wet Meadow	0.43
				Open Water	0.42
				Broad-Leaved Sedge-Grass	0.30
				Sedge	0.26
				Basswood	0.17
				Low Mixed/Other Deciduous	0.15
				Sugar Maple	0.15
				White Oak	0.15
				Red/White Pine-Deciduous	0.14
				Aspen	0.12
				Red Cedar-Deciduous	0.08
				Red Pine	0.08
				Red Cedar	0.06
				Floating Aquatic	0.04
				Jack Pine	0.04
				White Pine	0.04
				Willow	0.02
				Black Ash	0.01
				Mixed Barren	0.01
				No Data	0.00
				White Spruce	0.00
				Total	99.98

Soils

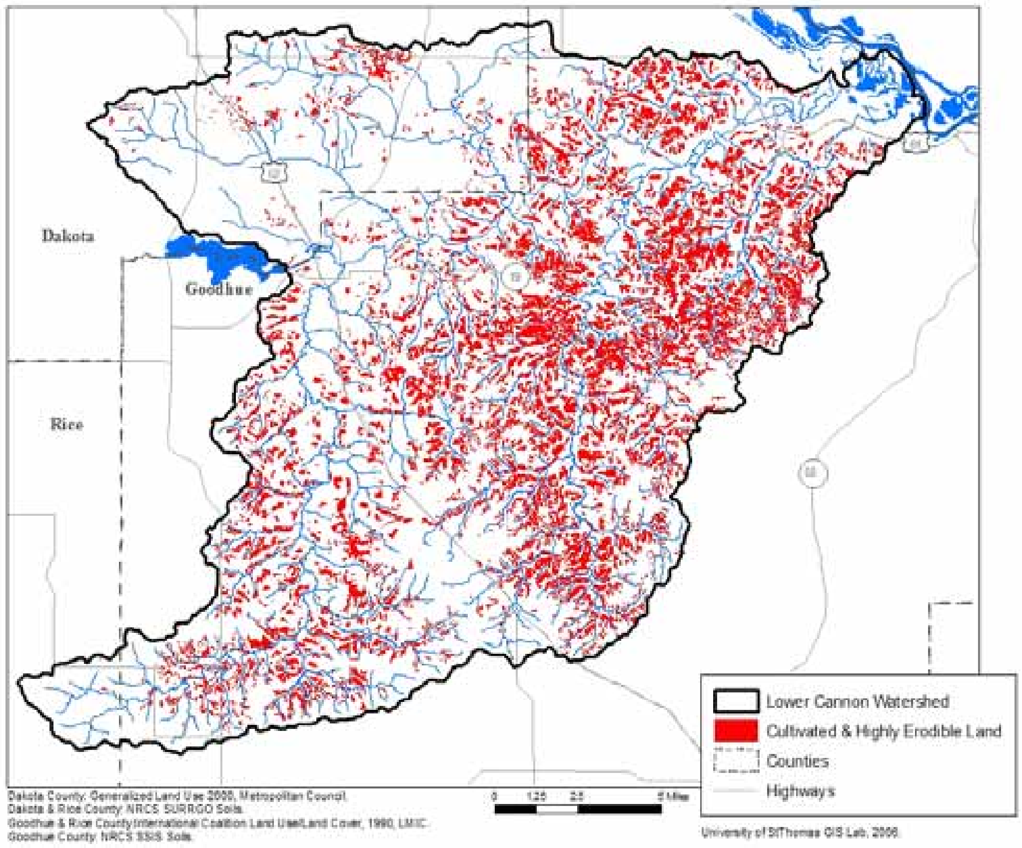
All of the soils in the Lower Cannon River Watershed are formed in areas that were formerly covered with glacial parent materials. Some areas may have been eroded to bedrock and some areas have soils formed in sandy and gravelly glacial stream sediment. Those are less of a sediment problem and will be discussed later.

Most of the soils in Goodhue County developed in windblown silt (loess) deposited at the margin of the last ice sheet. The soil associations formed in loess are Seaton and Mt. Carroll-Garwin-Port Byron. The loess is typically 5 to 15' thick and thickens eastward. Silt-rich soil and parent material is non-cohesive and erodes easily. This is why much of the land in this part of the watershed is classified as highly erodible, especially where the loess lies on steep slopes (Figure 4). Historically, when this part of the state was cleared for farming, much of the loess was eroded from the highest places and re-deposited into the valleys. There is the potential for this historically eroded material to be stored locally in tributary flood plains and to contribute to suspended sediment loads. This has not been quantified.

The windblown silt overlies loam- to clay-loam glacial till from older glaciations in most areas. The till forms a noticeable contrast in density and if the loess has eroded away completely, the farmer is aware of it. The glacial tills are heavier, clayier and slower to accept water than the loess. They may be referred to as gumbo, gray clay, old gray till or even hardpan. They are less susceptible to erosion because of the cohesiveness of the clay except where disaggregated. The steepest slopes in the watershed will have a combination of material that has moved down the slope (colluvium) since glaciation and especially in modern times including loess, till and bedrock. The soil associations formed in loess over glacial till, including these colluvial slopes are Racine-Ostrander –Maxfield; Seaton-Racine-Marlean; Timula-Frontenac; and Seaton-Frontenac-Chaseburg.

The soils that contribute the least sediment in the Lower Cannon River Watershed are those derived from glacial- stream-sediment and bedrock parent materials. These soils associations include Estherville-Waukegan-Alluvial and Marsh-McPaul-Radford. The glacial streams were low-relief and broad with a sandy and gravelly substrate and flowed from west to east, originating near I-35. They form the wide, flat areas through northern Greenvale, Waterford, Sciota and southern Randolph townships in Dakota County (out of the lower Cannon River Watershed) and just enter the lower Cannon River Watershed in northwestern Cannon Falls Township. Because of the low slopes and coarse material, less sediment is shed. East of Cannon Falls, the Cannon River is confined to an incised bedrock channel. The river is continually adjusting its gradient to the Mississippi River and steps or "nick points" in the channel that may be locally controlled by bedrock or gravel lags gradually move upstream. In-channel sources of suspended sediment will be localized in areas where the nick points are actively moving. Historically eroded sediment deposited in the main channel can also be re-eroded in this way.

Figure 4 – Erosion Potential and Cultivated Land in the Lower Cannon River Watershed



Biological Monitoring

Sediment and high turbidity affect the biological communities of streams in a variety of way such as:

(1) Increased turbidity reduces the ability of organisms to visually locate food. This is important for predatory fish
(2) Loss of spawning habitat especially in trout waters, as gravel substrate which is required for spawning, is easily covered by sediment.
(3) Sedimentation affects the distribution of fish and macroinvertebrate species because each species possesses different levels of tolerance. This results in an unbalanced biological community.
(4) Sedimentation leads to less riffle, pool, run habitat types, which support the greatest species diversity. (Allan, 1995).

Benthic macroivertebrates are used in many stream water quality assessment studies. The animal species that inhabit a particular section of stream are indicators of present and past physical, chemical, and biological conditions (Zischke, 1996). Sediment affects macroinvertebrates by filling in the areas used for habitat (Waters, 1995).

The Cannon River Watershed Partnership in collaboration with staff from St. Olaf College (Professor James Zischke and student interns), the U.S. EPA, and a local teacher conducted a study from 1994 – 1996 entitled *Baseline Assessment of Water Quality In Streams of the Cannon River Watershed.* The primary objective of this study was to assess the status of benthic macroinvertebrate communities in streams of the Cannon River basin. Results indicated that streams in the Cannon River Basin were in relatively healthy condition based on the measurements taken during the study. The overall impact of pollution, from mainly nonpoint sources, was measured as slight to moderate. The report also suggested that an important factor influencing stream health in the future would be land use. Habitat assessment scores (of all sample sites in the project) were lowest at sites where land use was unfenced pasture. High end scores were noted in areas that were in their natural condition with wide riparian zones (greater than 25 meters).

A summary of the macroinvertebrate and habitat assessment data for the Lower Cannon River basin sites from 1996 can be found in Appendix A.

Fish

The Minnesota DNR provided a list of Cannon River fish species compiled from sampling conducted from the 1970's – 2005 (see Appendix B). These data show the following numbers of fish species: Faribault – Northfield = 46, Northfield – Byllesby = 49, Byllesby Dam – Mouth of Cannon = 64. According to the DNR, this listing represents a good level of diversity with approximately 14 of the species found being game fish. Species diversity decreases from downstream to upstream and is likely due to migration barriers created by artificial dams at Lake Byllesby and in Northfield. At mile 35 (upstream from the town of Randolph) the DNR found an Ozark Minnow, which is a Minnesota species of special concern. Fish are affected by sediment through the loss of rearing habitat and reproductive success (Waters, 1995). While sediment deposition in the impoundments created by the Byllesby and Northfield dams have resulted in the direct loss of fish habitat diversity, DNR Fisheries have not quantified habitat degradation caused by sedimentation in lotic sections of the Cannon River. (Schmidt, personal communication, 5/8/06).

Mussels

Davis (1988) suggests that instability of the Cannon River bed causes increases in sediment (in excess of the natural rate) that are burying the habitats of mussels (Davis, 1988). During 1987 a field study by Davis found 1,344 live mussels that represented 15 species. One finding that was considered to be of special importance was live Actinonais ellipsiformis that was first recorded in Minnesota in 1983 but only as dead shell. There have been no federally endangered species of mussels found in this portion of the Cannon River (Swift, personal communication, 1/11/06).

1.2 Total Maximum Daily Load (TMDL) Definition and Information

The Clean Water Act, Section 303(d), requires that states publish, every two years, a list of waters that do not meet water quality standards and do not support their designated uses. These waters are then considered to be "impaired". Once a water body is placed on the impaired waters list, a Total Maximum Daily Load (TMDL) must be developed. The TMDL provides a calculation of the maximum amount of a pollutant that a water body can receive and still meet water quality standards (MPCA, 2005). It is the sum of the individual wasteload allocations (WLAs) for point sources, load allocations (LAs) for nonpoint sources and natural background, plus a margin of safety (MOS). TMDLs can be expressed in terms of mass per time, toxicity, or other appropriate measures that relate to a state's water quality standard (USEPA, 1999).

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Turbidity is a measure of the opacity of a substance; the degree to which light is scattered or absorbed by a fluid (USEPA, 1999). In rivers and streams, turbidity is often caused by sediment that is suspended in the water. The sediment enters the water from the land or from the stream bed or banks. While erosion is a natural process, it can be accelerated by human activities. In addition to impacts on water quality, upland soil erosion impacts the long-term sustainability of crop production (USDA, 2004). Streambed and streambank erosion is often a function of changing and unstable hydrologic processes in a watershed. These can range from changing precipitation patterns, to increases in water runoff cause by urbanization or shifting agricultural practices. In addition to sediment, turbidity is also influenced by the algae that exists to a greater or lesser extent in all aquatic environments. This study will suggest that the overall impacts of algae on turbidity in the Lower Cannon River is minor.

As discussed in the USEPA Protocol for Developing Sediment TMDLs, "The general goal of sediment TMDL analyses is to protect designated uses by characterizing existing and desired watershed condition, evaluating the degree of impairment to the existing (and future) conditions, and identifying land management and restoration actions needed to attain desired conditions." (USEPA, 1999).

1.3 Potential Pollutant Source Assessment and Inventory

The following discussion makes some distinction between sources located in the Lower Cannon watershed area and those located in the remainder of the entire Cannon River watershed (the area upstream of Lake Byllesby). This distinction is useful in that sources located in the Lower Cannon area have a disproportionate impact on turbidity in the impaired river reaches. The remainder of the watershed, however, does contribute at least some turbidity to the impaired reaches.

<u>Point Sources</u>

National Pollutant Discharge Elimination System (NPDES) permits are issued by the Minnesota Pollution Control Agency (MPCA) under a delegation agreement from the U.S. Environmental Protection Agency (USEPA). These permits are issued to a range of facilities or industries, most, but not all, of which, have point source discharges. The permits define the conditions that a facility must meet in order to discharge wastewater to surface or groundwater (MPCA, 2002). Effluent limits are set on pollutant discharges based on water quality standards and the receiving water's designated use (MPCA, 2002). The effluent limit most relevant to this TMDL report is for total suspended solids (TSS).

NPDES Municipal and Industrial Permit Holders
Facilities that process primarily wastewater from domestic sanitary sewer sources (sewage) are considered municipal facilities. These include city or sanitary district treatment facilities, wayside rest areas, national or state parks, mobile home parks, and resorts (MPCA Permits web page, 2006). The City of Nerstrand and the City of Cannon Falls municipal wastewater treatment plants are the two municipal facilities permitted in the Lower Cannon River watershed. In the Cannon River watershed upstream of the Byllesby Reservoir, wastewater treatment plants include the cities of : Dennison, Ellendale, Elysian, Faribault, Kilkenny, Lonsdale, Medford, Morristown, Nerstrand, Northfield, Owatonna, Waterville and the Straight River Rest Area operated by the Minnesota Department of Transportation. A summary of these discharge permits is included in Appendix C.

Industrial process wastewater is wastewater which, during manufacturing or processing, comes into direct contact with (or is left over from production of) a raw material, intermediate product, finished product, byproduct or waste product (MPCA Permit web page, 2006). There are three industrial NPDES permit holders in the Lower Cannon River watershed; however none of them have a TSS limit. In the past, Minnesota Malting of Cannon Falls, did have an industrial NPDES permit with a TSS limit but this facility is no longer in business as of the writing of this report. In the Cannon River watershed upstream of the Byllesby Reservoir, Industrial NPDES permit holders include: Faribault Foods, Genova Minnesota Inc., Lakeside Foods, Inc., DNR Waterville State Fish Hatchery, Milestone Materials – Spinler Plant, Owatonna Construction Co/Sites SD001&002, Southern Minnesota Construction/Owatonna, and The Turkey Store – Faribault. A summary of these permits is found in Appendix C.

Stormwater
Urban and suburban stormwater runoff, both from developing and built-out areas, carries sediment loads that can match or exceed agricultural runoff This runoff also contributes to channel instability and streambank erosion (Barr, 2004). Dakota and Goodhue Counties have both seen reductions in the amount of wetlands and pervious land cover and thus increases in stormwater runoff rates. Even in watersheds with a relatively low percentage (10-20%) of impervious surface, major stream degradation can occur (Goodhue, 2005). Pollutants from stormwater runoff can include pesticides, fertilizer, oil, metals, pathogens, salt, sediment, litter and other debris (MPCA web page, 2006). The MPCA has three categories for stormwater permits: Municipal, Construction, and Industrial.

- *Municipal* - In 1987 the Clean Water Act was amended to include provisions for a two-phase program to address stormwater runoff. In March of 2003 the second phase of the program began. Phase II includes permitting and regulation of smaller construction sites, municipalities with Municipal Separate Storm Sewer Systems (MS4s) and industrial facilities. Per Minnesota Rules 7090, MS4 communities outside of urbanized areas with a population of at least 10,000 must apply for a permit as well as cities and townships with a population of at least 5,000 and discharging or the potential to discharge to valuable or polluted waters (MPCA web page, 2006). The regulated entities must develop Stormwater Pollution Prevention Plans (SWPPPs) to document the "best management practices" they will put into place at their sites to minimize pollution (MPCA, 2005).

In the Lower Cannon River watershed approximately 3% of the land use is urban/developed. The city of Red Wing (population 16,116), located at the mouth of the Cannon River, is the only municipality that is required to obtain a permit under the MS4 regulations. However, the city of Red Wing discharges most of its municipal storm water to the Mississippi River rather than the Cannon River. There are a few culverts from the hilly area of the city that discharge to the Cannon River (Strusse, personal communication, April 2006). For the entire Cannon River watershed the cities of Faribault, Northfield, Owatonna, and Waseca are required to apply for MS4 permits. As part of the permit requirements, these municipalities are required to develop and implement a Stormwater Pollution Prevention Plan (SWPPP).

- *Construction Permits* - The MPCA issues construction permits for any construction activities disturbing:
    - One acre or more of soil.
    - Less than one acre of soil if that activity is part of a "larger common plan of development or sale" that is greater than one acre.
    - Less than one acre of soil, but the MPCA determines that the activity poses a risk to water resources.

  US EPA estimates a soil loss of 20 to 150 tons per acre per year from stormwater runoff at construction sites (MPCA Stormwater web page, 2006). Construction sites vary widely in the number of acres they disturb. In the past 6 years there have been 51 construction permits issued in the Lower Cannon River watershed and 329 in the Cannon River watershed. The sites in the Lower Cannon watershed range from 1.1 to 117 acres disturbed. A summary of these permits and acres is found in Appendix C.

- *Industrial* - Industrial sites may contribute to stormwater pollution when the water comes in contact with pollutants such as toxic metals, oil, grease, de-icing salts, and other chemicals from rooftops, roads, parking lots, and from activities such as storage and material handling. There are 11 categories of industrial activities required to apply for NPDES permits for stormwater or certify a condition of no exposure. Examples of exposed materials that would require a facility to apply for an industrial stormwater permit include: fuels, solvents, stockpiled sand, wood dust, gravel, metal and a variety of other materials. As part of the permit requirements, the facilities are required to develop and implement a Stormwater Pollution Prevention Plan (SWPPP). The SWPPP uses Best Management Practices (BMPs) designed to eliminate or minimize stormwater contact with significant materials that may result in polluted stormwater discharges from the industrial site (MPCA, Industrial Stormwater webpage, 2006).

There are 5 facilities with Industrial Stormwater Permits in the Lower Cannon River Watershed and 51 facilities in the entire Cannon River Watershed. All facilities in the Lower Cannon River Watershed are upstream of the section from Pine Creek to Belle Creek (4 in Cannon Falls and 1 in Welch). A summary of these facilities is found in Appendix C.

Nonpoint Sources

Natural Erosion
Erosion is the process of moving materials on the surface of the earth from one place to another. The vehicle for much, but not all, of this movement is water. In the past, water transport systems stored more water on the land and distributed eroded sediment more broadly (Waters, 1995). When a system is in its natural state, the sediment that enters the stream is usually modest in amount and is distributed throughout the channel (MPCA, 2005).

Trimble and Lund (1982) describe the four possible fates of material eroded from uplands:

1. The material can remain in-situ or be redistributed in the uplands as colluvium. Colluvium is eroded material that has moved from its point of origin to some point down gradient and is in some form of storage and not in an active stream channel situation. An example would be soil materials eroded from a soybean field and repositioned at a down gradient fence row.
2. The material can be transported to an active stream channel and become an alluvial (transported by a stream or river) deposit in the floodplain;
3. The material can be transported to an active stream channel and become an alluvial deposit within the stream channel; or
4. Eroded materials from whatever source may be transported out of the watershed or basin (sediment yield).

Of the sediment that is transported or yielded to an active perennial stream channel, a portion of those sediments are suspended under different conditions and may be measured by turbidity or TSS analysis of a water column sample. In some cases, however, delivery to a stream channel may take years or perhaps decades.

Cultural erosion/sedimentation sources
Accelerated erosion results in the loss of the productive top layer of soil faster than new soil can be developed. Food production is affected by accelerated erosion as well as the waters that receive the excess sediment (Muckel, 2004). The Barr engineering report (2004) for the Lower Mississippi River Basin found that "the TSS and turbidity observations associated with greater than 50% of the flow indicate that surface-runoff processes, in addition to channel or in-stream processes (e.g. streambank erosion), represent important contributions to the observed TSS and turbidity"(Barr, 2004).

Sediment-related turbidity sources typically fall into one of the following categories:

- Agriculture is likely a primary source of sediment in the watershed. Approximately 60% of land use in the LCRW is agricultural row crops. Soil loss is due in part to these areas being left without vegetative cover for the portions of the year between crop harvest and the emergence of the subsequent year's crop. Slope length and steepness can exacerbate soil erosion problems. Agricultural best management practices (BMP's) such as reduced tillage, terracing, etc. can reduce soil erosion dramatically. Such BMP's, however, are not universally utilized.

- Aggregate/mining operations can be an important source of sediment as the disturbed land is often left without any vegetative cover (Waters, 1995). Such facilities may also release sediment as a result of material processing activities, although this is often controlled by NPDES permits. Figure 5 shows the locations of MN DOT- identified actual or potential aggregate sites in the Lower Cannon River Watershed.

- Livestock grazing can cause erosion by leaving overgrazed land without vegetative cover. The problem may be more serious if overgrazing occurs along streams or waterways, as eroded material is transported to the water more easily. Roughly 18% of the land use in the LCRW is grassland, a portion of which is pastured..

- Unpaved roads contribute sediment directly from their surfaces or indirectly through increased volume or velocity of runoff. Gravel roads are only slightly more pervious that asphalt or concrete roads.

- In-stream sources (e.g. stream banks & bed) result in an increase in stream channel instability and accelerated sediment yield causing a decrease in water quality. The two processes mainly responsible for this are: (1) fluvial entrainment of bank material by high discharges, and (2) mechanical failure of the bank, allowing material to slump to the basal area, where normal discharges can entrain the added sediment into the stream flow (Waters, 1995). The slope of the bank, amount of moisture in the soil, and the cohesiveness of the material all have a role in bank failure (Waters, 1995). A substantial portion of the sediment derived from banks and beds may have originally come from upland soil eroded years or decades earlier and deposited in riparian areas.

Figure 5 – MN DOT Aggregate Sources

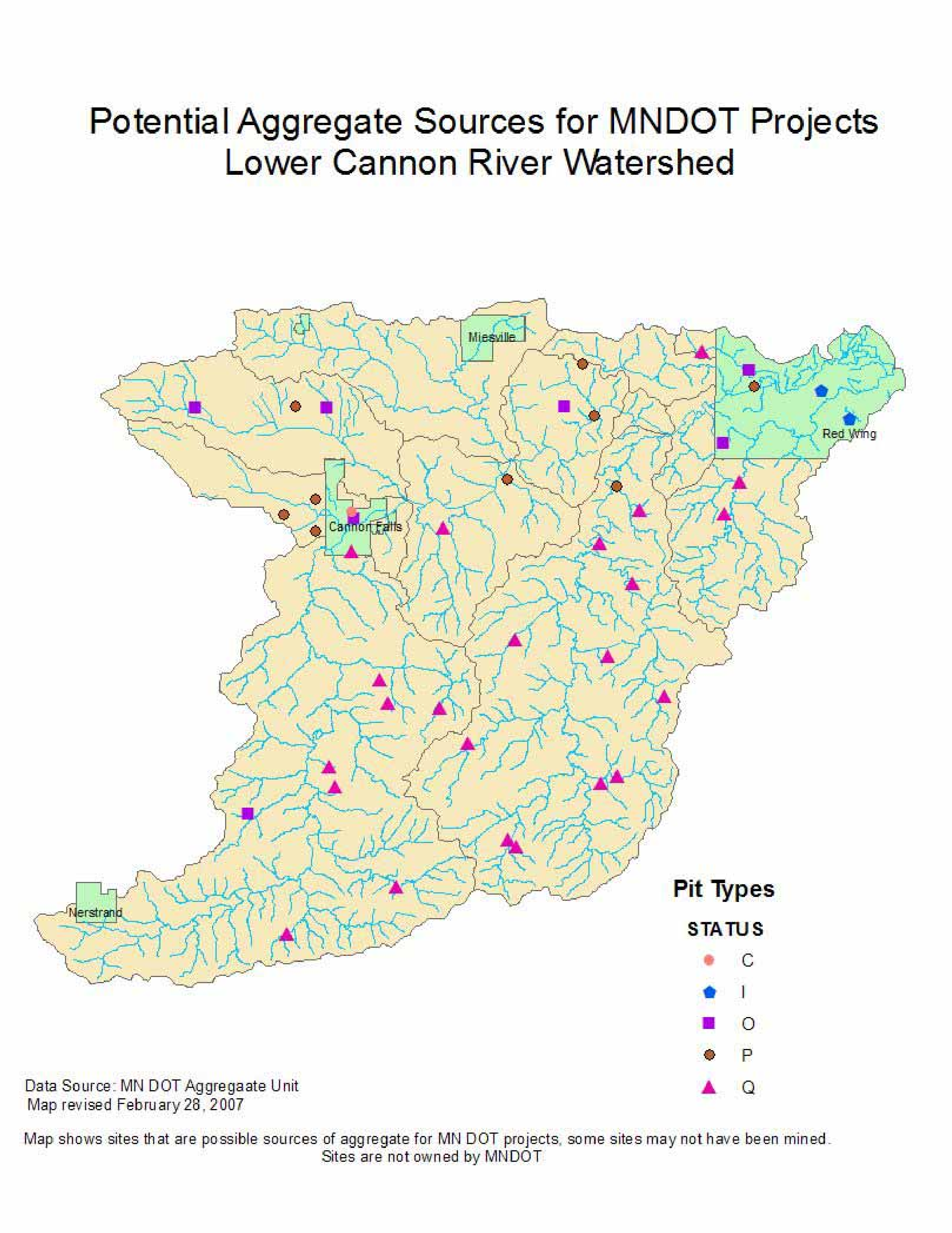


Figure 5 – Pit Type and Status Descriptions

P - Aggregate Pit (Prospected): Indicates a pit that has been prospected and/or leased by Mn/DOT. A "P" classification does not necessarily imply that the source is actually producing aggregate at the present time. In fact, it may only indicate an aggregate deposit that was at one time leased by Mn/DOT and that the Aggregate Unit has tested, but from which no material has ever been excavated.

O - Aggregate Pit (Other): Indicates a location that, while assigned a number, has never been drilled and sampled by the Aggregate Unit.

I - Inactive Aggregate Source: Indicates a source that is either depleted or at least unavailable for future use. (If future circumstances make such sources available, the status may be changed).

Q - Rock Quarry: Indicates a bedrock quarry. Rock type depends on area geology, but most are limestone/dolostone and are located in Southeastern Minnesota. All quarries in Minnesota are privately owned.

C - Commercial Aggregate: Indicates an identified commerical source of aggregate onproperty that has never been prospected (unless otherwise specified) by Mn/DOT, but that has been assigned a source number in order to facilitate tracking of test results when the source is used on Mn/DOT or county projects. These sources are often used for concrete aggregate.

2.0 TMDL DEVELOPMENT AND DETERMINATION OF ALLOCATIONS

2.1 TMDL Description

A TMDL for a waterbody that is impaired as a result of excessive loading of a particular pollutant can be described by the following equation.

$$\textbf{TMDL} = \textbf{LC} = \Sigma\textbf{WLA} + \Sigma\textbf{LA} + \textbf{MOS}$$

Where:

LC = loading capacity, or the greatest pollutant load a waterbody can receive without violating water quality standards;

WLA = wasteload allocation; the portion of the TMDL allocated to existing or future point sources of the relevant pollutant;

LA = load allocation, or the portion of the TMDL allocated to existing or future nonpoint sources of the relevant pollutant. The load allocation may also encompass "natural background" contributions; and

MOS = margin of safety, or an accounting of uncertainty about the relationship between pollutant loads and receiving water quality. The margin of safety can be provided implicitly through analytical assumptions or explicitly by reserving a portion of loading capacity (USEPA, 1999)

Per Code of Federal Regulations (40CFR 130.2(1)) TMDLs can be expressed in terms of mass per time, toxicity or other appropriate measures. For the two Lower Cannon River impaired reaches addressed in this report, the TMDLs are expressed in tons/day of total suspended solids (TSS). Subsequent sections provide support for the use of this expression for turbidity-impaired waters.

2.2 Impact of Lake Byllesby on TMDL

As described in the background section, the Cannon River watershed is often divided into four major subwatersheds; the Straight River, Upper Cannon, Middle Cannon, and Lower Cannon. The Lower Cannon is the area downstream of Lake Byllesby, which is formed by a large hydroelectric dam just west of the City of Cannon Falls. The Lower Cannon subwatershed area (not including Spring Creek) is approximately 20% of the 1,470 square miles that make up the entire Cannon River watershed.

The two impaired river reaches addressed in this report are part of the Lower Cannon. An initial premise of this project was that Lake Byllesby serves as a "reset point" for the Cannon River. The idea is that the Byllesby reservoir traps and retains much of the sediment that may be coming from the Straight, Upper, and Middle watersheds. Consequently, turbidity is reduced just downstream of the reservoir, and increases again mainly as a function of sources in the Lower Cannon watershed. While substantial amounts of sediment are being retained in Lake Byllesby, it is probably an oversimplification to describe it as a reset point. Under certain conditions (i.e. high flows), large amounts of sediment are transported through the reservoir into the Lower Cannon. The precise amounts are not well known. Lake Byllesby also impacts flow in the Lower Cannon, although to a lesser degree than sediment. Unlike sediment, virtually all water entering Lake Byllesby eventually moves downstream, even though there is some temporary storage that varies due to a number of factors. The exact nature of this storage is not completely understood.

Given the uncertainty about the influence of Lake Byllesby on sediment and flow dynamics in the Lower Cannon, the decision was made not to explicitly account for these effects on the TMDLs and associated allocations. The implication of this decision is that, in the TMDLs and allocations, turbidity sources upstream of Lake Byllesby are treated the same as those downstream. At the same time, it is clearly the case that pollutant sources downstream of Lake Byllesby will have a more immediate impact on turbidity in the Lower Cannon. As such, efforts to reduce or eliminate sources of turbidity should be focused on the Lower Cannon and it's tributaries of the Little Cannon River, Trout Brook, Pine Creek, and Belle Creek.

2.3 Data used for Impairment Assessment

The two Lower Cannon River reaches included in this report are on the 303(d) impaired waters list due to violations of the turbidity component of Minnesota's water quality standards. They were added to the impaired waters list at different times based on different turbidity data sets. The short (0.5 miles) reach (Cannon River, HUC boundary in Rice Lake Bottoms to Vermillion Slough/Mississippi River, AUID 07040001-511) at the confluence with the Vermillion and Mississippi rivers was listed in 1996 based on water monitoring conducted by the MPCA from 1990-1992 at a site 0.1 miles upstream of the confluence with the Vermillion/Mississippi rivers. Twenty-four water samples were collected over these three years; 6 samples (25%) exceeded the 25 NTU water quality standard. The threshold for 303(d) listing is 10% of samples. The 11.29 mile reach from Pine Creek to Belle Creek (Cannon River, Pine Creek to Belle Creek, AUID 07040002-502) was listed in 2004 based on water monitoring conducted at Welch by the Metropolitan Council Environmental Services Department (MCES) and MPCA from 1995-2002. Sixty-nine samples were collected over these eight years; 12 samples (17%) exceeded the 25 NTU water quality standard. Some of the MCES samples were obtained by compositing a number of individual samples collected over single storm events. Due to changes in assessment methodology, these samples were excluded from the 2006 preliminary assessment. Considering only MCES "grab sample" data, there were still 6 exceedances out of 34 samples. As such, this reach remains on the 2006 303(d) impaired waters list.

Since the time of the listings, substantial additional turbidity and related total suspended solids (TSS) data has been collected on both of the reaches. The bulk of the additional data for the confluence reach is from the USGS Long-Term Resource Monitoring Program (LTRMP). The additional data for the Pine-Belle reach was collected by the MPCA, MCES, and CRWP. A summary of turbidity data collected at both reaches from 1995-2004 is presented in Table 3. The 20% exceedance value for the confluence reach clearly supports on-going impairment. The 9% exceedance value for the Pine-Belle reach falls just below the threshold for impairment status. The MPCA believes that the lower exceedance percentage for the Pine-Belle reach is at least partially due to differences in sampling design and methodology, and that the reach should still be considered impaired. As such, the decision was made to proceed with TMDL development.

Table 3 – Turbidity Data Summary

AUID	**07040001-511**	**07040002-502**
Reach	**Confluence**	**Pine-Belle**
Time Period	**1/4/95-11/10/04**	**10/26/95-10/14/04**
N	176	123
# exceedance	36	11
% exceedance	20%	9%
Minimum (NTU)	2	1
Median (NTU)	12	5.5
Mean (NTU)	36	14
Maximum (NTU)	1740	424

2.4 Data used for Current Condition Analysis and TMDL Determination

Beyond assessment verification, the additional data collected since the original impairment listings also provide a more robust basis for establishing the current condition of the Lower Cannon River relative to turbidity. For the purposes of this report, “current condition” is defined by turbidity and TSS data collected over the 10-year time period 1995-2004. This time period allows for adequate consideration of normal weather and climate-related annual and inter-annual water quality variability, while excluding data collected prior to 1995 when watershed conditions may have been substantially different than the present. For example, there were periods prior to 1995 when the amount of Conservation Reserve Program (CRP) land in the watershed was much different than in recent years. As a consequence, turbidity in the Lower Cannon River may have been different than at present.

As previously discussed, the 303(d) assessment process for the reaches covered in this report involved a simple comparison of individual water sample test results against the 25 NTU water quality standard. The reaches were listed as impaired because more than 10% of individual observations exceeded the standard. In this process, there is no direct use of streamflow (flow) data, or TSS loading estimates derived from flow data. In the TMDL determination and allocation process, however, the use of flow data is critical. The combination of flow and pollutant concentration defines pollutant loading. Flow data for this project was obtained from the USGS gage site on the Cannon River at Welch, two river miles upstream of the confluence with Belle Creek. This site has been in place since 1909, although it was not in operation from 1972-1990. For this project, 1991-2004 flow data was used to estimate loading capacities and current loads for both of the impaired reaches. The rationale for using only the more recent (1991-2004) flow data instead of the entire period of record parallels the rationale for analyzing only more recent turbidity and TSS data as described above. In the case of flow data, however, the recent 30-year (1975-2004) flow record would have been analyzed if it were available. This 30-year period is a typical duration for defining climate “normals.” As noted, however, the gage site was not in operation from 1972-1990. Summaries of these data are found in Appendix D.

Although Belle Creek and a few small unnamed tributaries from the north enter the Lower Cannon River between the two impaired reaches, the contributing watershed area increases by only about 7% relative to the entire Cannon River watershed. The small increase in drainage area suggests a relatively small increase in flow between the two reaches. In the TMDL calculations, flows were adjusted to account for the differences between the contributing watershed area at Welch and the contributing area for the impaired reaches (Table 5) by using a drainage area to flow ratio.

2.5 Relationship between Turbidity and Total Suspended Solids

Turbidity is a measure of opacity, or the degree to which light is scattered or absorbed by water. Turbidity is typically expressed in nephelometric turbidity units (NTU's). Total suspended solids (TSS) is a closely related mass-based measure of water quality, generally expressed as milligrams per liter (mg/l). Light scatter and absorption is strongly influenced by solid material suspended in the water column – hence the close relationship between turbidity and TSS.

Although the purpose of this report is to create a basis for achieving the 25 NTU turbidity water quality standard, the TMDL and its component parts are expressed as TSS load. Using this mass-based expression offers a couple of distinct advantages. First, many point sources that are addressed in this report, are assigned TSS effluent limits as part of their permits. These limits often include both concentrations (mg/l), and loads (kg/day) that fit well with the TMDL equation presented earlier. Secondly, in the Cannon River watershed, the most significant nonpoint source (including natural background) contributors to turbidity are related to upland, streambank, and stream channel soil erosion and sediment delivery processes. Soil erosion and sediment delivery are commonly expressed in terms of annual or daily mass loads (tons/year or tons/day). In this respect, the wasteload and load allocations, and any point or nonpoint source load reductions that may be necessary to meet the allocations, will be expressed in terms that permit-holders, agricultural professionals, and the construction/development industry can understand and implement.

Figure 6 shows the relationship between TSS and turbidity for the water samples collected by the MPCA, LTRMP, and CRWP. Although some additional TSS and turbidity data from the MCES were used to define TSS loads, only the LTRMP and MPCA data was used to define the TSS-turbidity relationship. The reasoning behind this decision relates to the variety of methods and instruments used to measure turbidity. In particular, monitoring work on the Mississippi River has indicated that MCES methods tend to produce lower turbidity values overall than methods used by the MPCA or USGS. Methods for TSS analysis, on the other hand, are more consistent and result in more comparable data.

Based on the regression depicted in Figure 6, 44 mg/l is the TSS "equivalent" of the 25 NTU water quality standard. It is possible that a regression relationship can be overly influenced by a few values – in this case the handful of very high turbidity and TSS values. As a check for this, the relationship was run using only values with turbidity less than 100 NTU's (Figure 7). The 25 NTU "equivalent" was 47 mg/l TSS. In turbidity TMDL protocol guidance currently being developed by the MPCA, a proposal is made that only NTU values less than or equal to 40 be used in developing equivalency relationships (Greg Johnson, personal communication). This regression, while not shown, produced an equivalent value of 48 mg/l TSS (n = 200; r-squared = 0.67). Considering how close these three equivalency values are, it was decided to use 44 mg/l for loading capacity determinations as it is slightly more conservative, in the sense of being protective of water quality.

Figure 6 – Turbidity/TSS relationship (1995-2004 MPCA, LTRMP, and CRWP data); note log scale to account for range of data

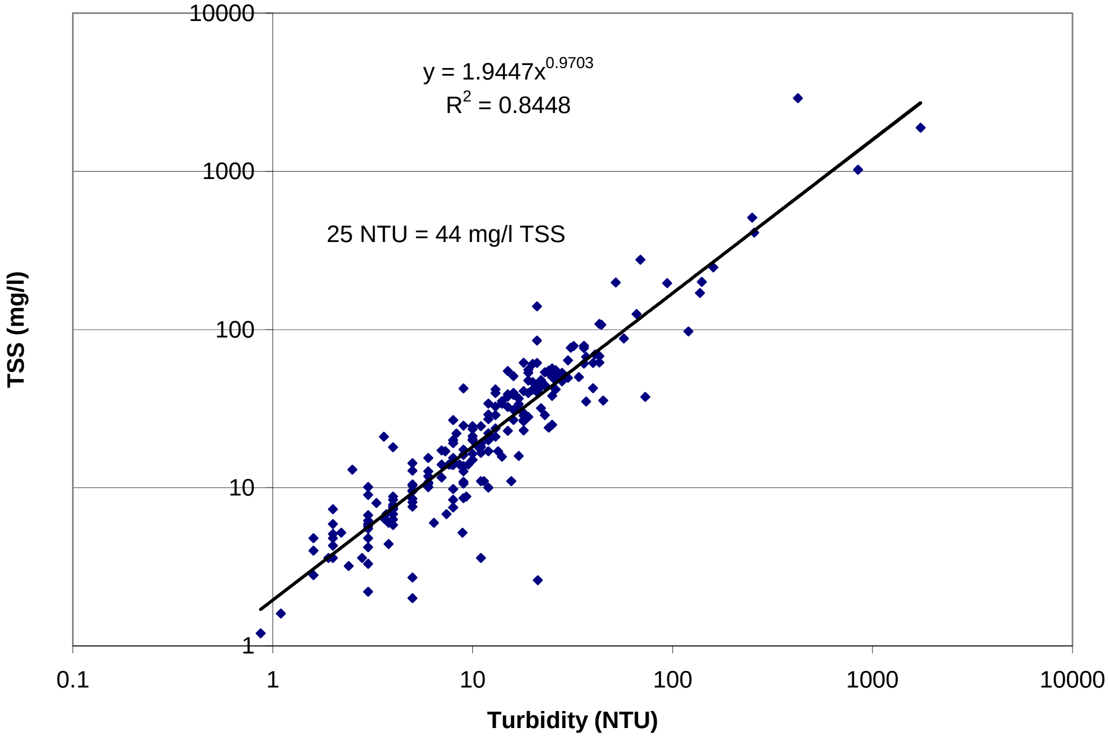
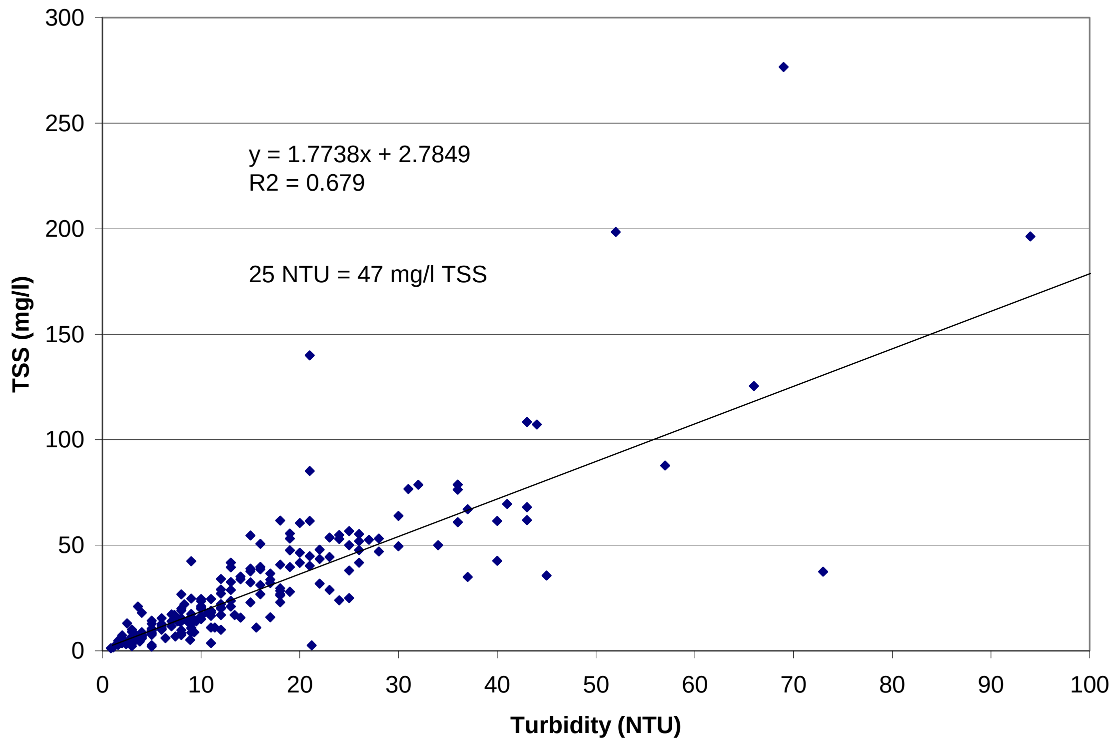


Figure 7 - Turbidity/TSS Relationship for Turbidity Values < 100 NTU (1995-2004 MPCA, LTRMP, and CRWP data)



2.6 Analysis of Total Suspended Solids Differences Between the Impaired Reaches

As previously noted, a simple "% exceedance" analysis of either the original turbidity listing data or the larger 1995-2004 data set, reveals some apparent differences between the two reaches. Reasons for these differences include the years in which the data was collected, and the conditions in a given year under which water samples were collected (Figures 8 and 9). It is particularly worth noting that no sampling was conducted at Welch during 1997 or 1998, both relatively high flow years. In general, the LTRMP sampling near the mouth appears to have better overall coverage of seasons, years, and varying flow conditions. There also appear to be differences in the river moving from the upstream to downstream reach that are not attributable to sampling differences. Statistical analysis indicates that while there is no significant difference in the flows during which samples were collected (t-test; $p = 0.41$), the confluence site exhibits significantly higher TSS concentrations (Wilcoxon rank-sum test; $p < 0.01$). As noted, Belle Creek and some small unnamed tributaries enter the Cannon between the two impaired reaches. At the scale of the entire Cannon River watershed, where the contributing area increases by only 7% between the two reaches, the importance of these tributaries appears to be less than when considered in the context of the Lower Cannon subwatershed only, where they account for nearly 40% of the area. Given this percentage, and TSS differences, it appears likely that Belle Creek and the unnamed tributaries are a major influence on TSS and turbidity in the confluence reach. Table 4 and the box and whisker plot (figure 10) summarize the TSS data set.

Figure 8 – 1995-2004 Mean Daily Flow (Welch) and Water Samples Collected at Welch by MPCA, CRWP, and MCES

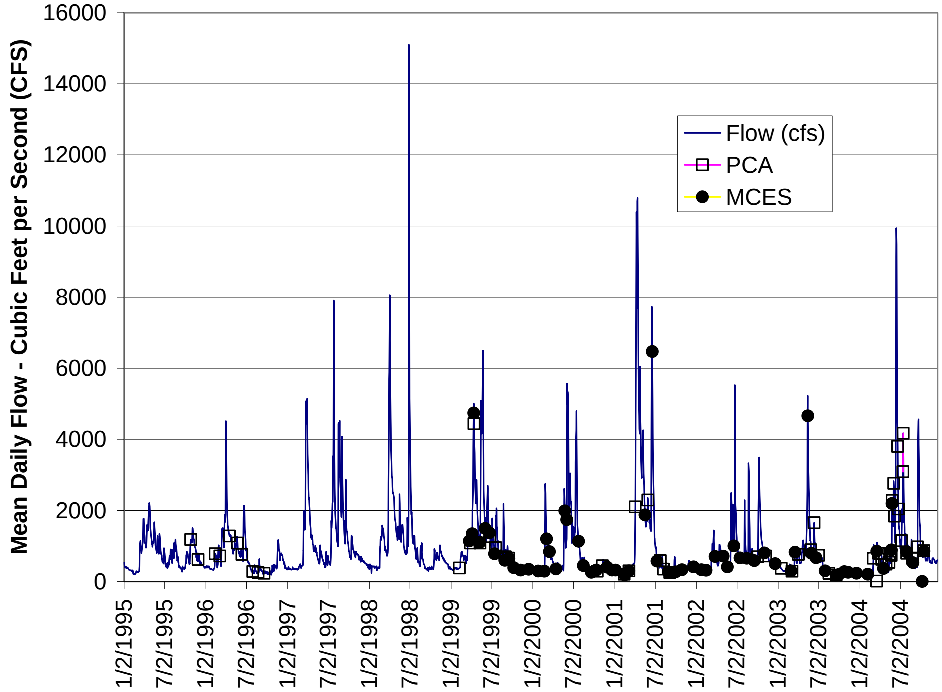


Figure 9 – 1995-2004 Mean Daily Flow (Welch) and Water Samples Collected at Confluence through LTRMP Program

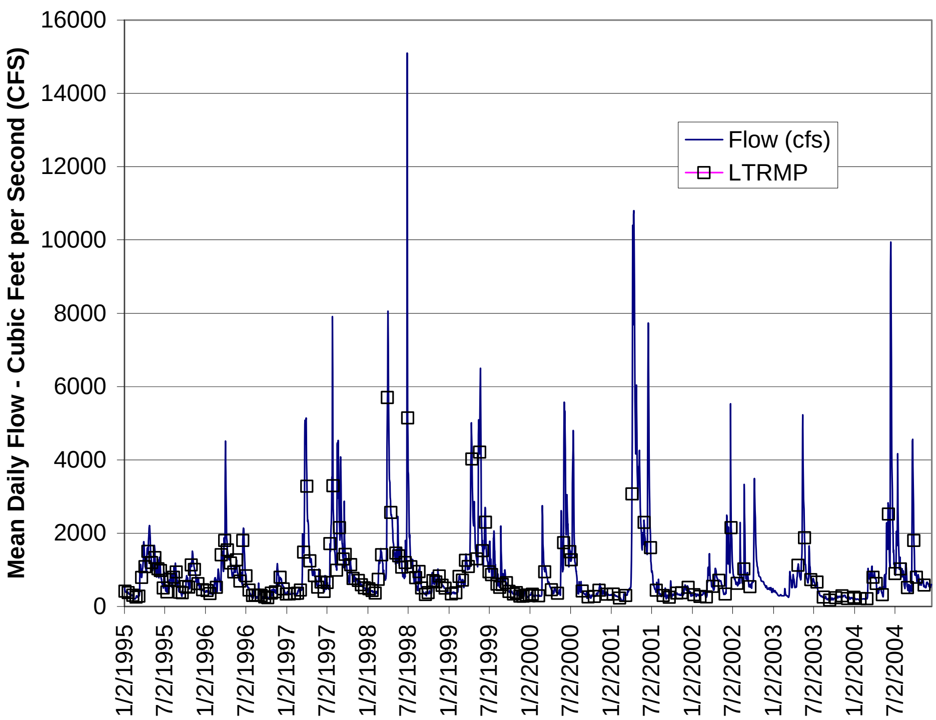
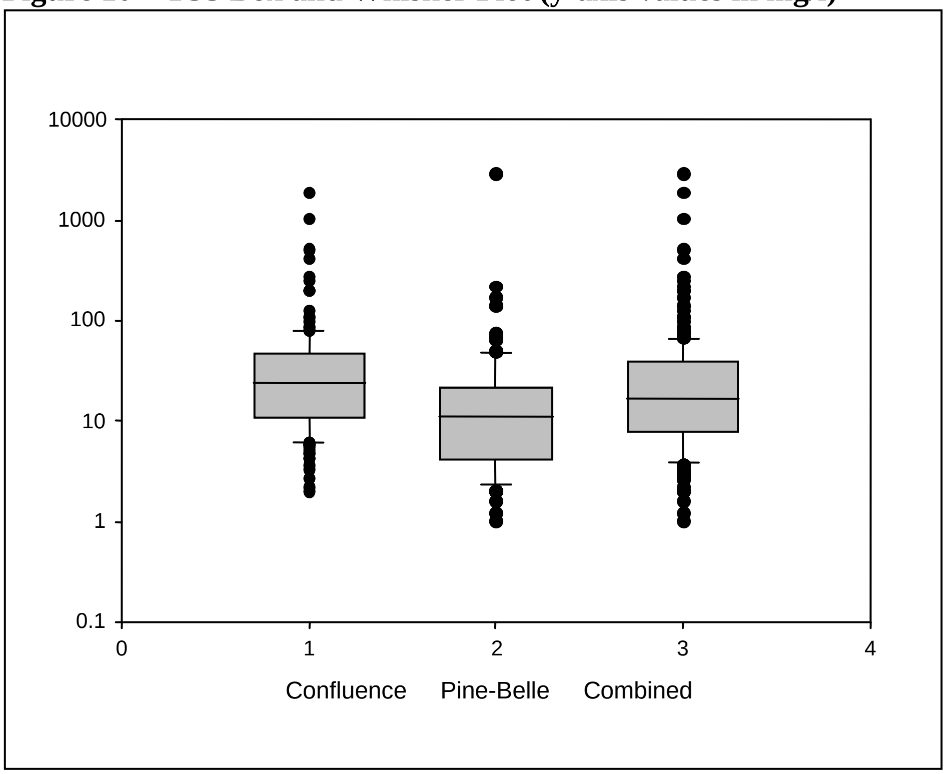


Table 4 – TSS Data Summary

AUID	**07040001-511**	**07040002-502**
Reach	**Confluence**	**Pine-Belle**
Sample Location and Source	**samples taken from boat at confluence through LTRMP**	**Samples taken at Welch by MCES, MPCA, and CRWP**
Time Period	**1/4/95-11/10/04**	**10/26/95-10/14/04**
N	170	115
# exceedance	na	na
% exceedance	na	na
Minimum (mg/l)	2	1
Median (mg/l)	25	11
Mean (mg/l)	57	45
Maximum (mg/l)	1889	2900

Figure 10 – TSS Box and Whisker Plot (y-axis values in mg/l)

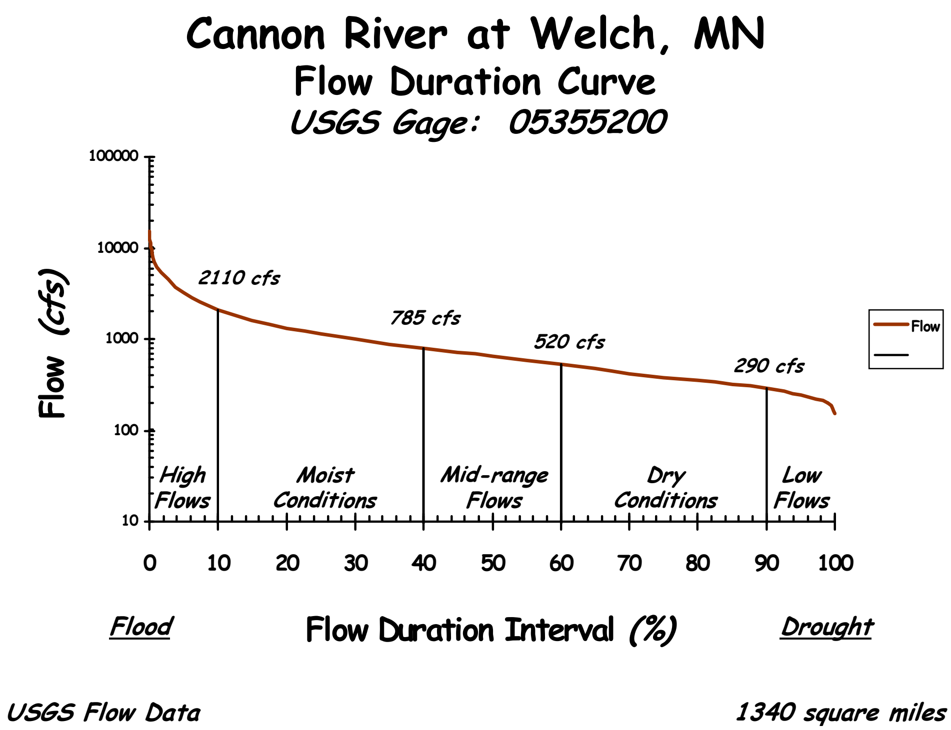


2.7 Load Duration Analysis

Load duration analysis as described by Cleland (2002) was used to integrate flow and TSS data, and to provide graphical displays, loading capacity and margin of safety values for the actual TMDL, and estimates of load reductions necessary for attainment of the turbidity water quality standard.

Figure 11 is a flow duration curve developed from the 1991-2004 gage data from the USGS site at Welch. The curved line that goes from upper left to lower right on the graph relates mean daily flow values to the percent of time those values have been met or exceeded. For example, a flow of 2,110 cfs is met or exceeded only 10% of the time based on the 1991-2004 record; such flows are classified as "high." At the other end of the curve, a flow of 290 cfs is exceeded 90% of the time. Flows less than 290 cfs are classified as "low." The other flow zones are "moist conditions" (10 - 40%), "mid-range flows" (40 - 60%), and "dry conditions" (60 - 90%). The ranges and break points for the zones are somewhat arbitrary, although the mid-point percentiles of each zone are commonly used in statistics (i.e. 50th percentile = median; 75th percentile = upper quartile, etc.)

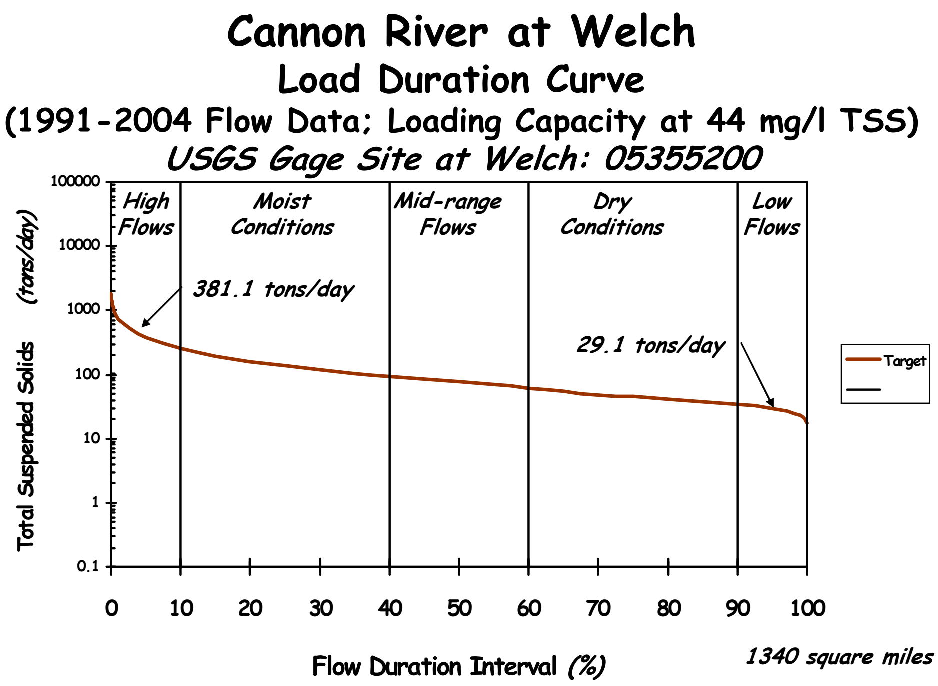
Figure 11 – Flow Duration Curve (Cannon River at Welch)



The combination of flow and pollutant concentration defines pollutant loading. Loading capacity is defined by the combination of flow and a concentration-based water quality standard or target. It is the pollutant load that a river can carry and still be in attainment of the pollutant's water quality standard or target. The TSS target value "equivalent" to the 25 NTU water quality standard is 44 mg/l, as defined in Section 2.5. Figure 12 is the product of the Cannon River at

Welch flow duration curve (Figure 11) and the 44 mg TSS/l target value. The result is a load duration curve that describes the loading capacity of the Cannon River at Welch in tons of TSS/day. Based on the 1991-2004 flow record, the capacity ranges from just over 381 tons/day for the high flow zone, to just over 29 tons/day for the low flow zone.

Figure 12 – Loading Capacity Curve (Cannon River at Welch)



2.8 TMDL Loading Capacities and Margins of Safety by Flow Zone

Because the TSS concentration is fixed at 44 mg/l, loading capacities vary only as a function of flow. As such, flow variability is the appropriate basis for setting margins of safety (MOS). As summarized in table 5, the loading capacity for each flow zone is set at the mid-point of the zone. The margin of safety for each zone is then calculated as the difference between the mid-point of the zone and the right-hand (lower flow) side of the zone (see example in Figure 13). Thus, the margin of safety protects against TSS loading when there is less capacity in the river due to lower flows. Loading capacity minus margin of safety equals the TSS load available for allocation to point (WLA) and nonpoint (LA) sources. Loading capacity, margin of safety, and allocation values are shown for Welch, and for the two impaired reaches as adjusted for their contributing drainage area. The drainage area at Welch is 1340 square miles; 1345 square miles at the downstream end of the Pine Creek to Belle Creek reach; and 1443 square miles at the confluence with the Vermillion/Mississippi River. The adjustment for the Pine-Belle reach was negligible; a factor of 1.08 was used for the Confluence reach.

Figure 13 – Loading Capacity Curve with MOS Depicted for Moist Conditions

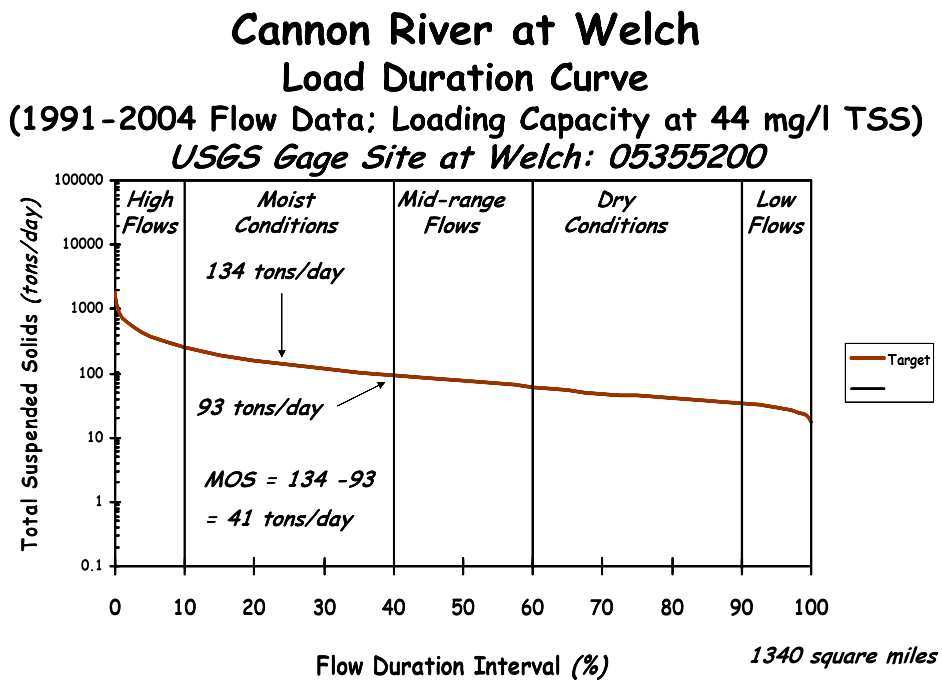


Table 5 – Loading Capacity for Each Flow Zone

Watershed Areas (square miles) Welch = 1340 Confluence = 1443 Pine-Belle Reach = 1345		Flow Zone				
		High Flows	**Moist Conditions**	**Mid-Range Flows**	**Dry Conditions**	**Low Flows**
		values expressed as tons/day TSS				
Welch	**Capacity**	381	134	75	45	29
	MOS	131	41	14	11	11
	Allocation	250	93	62	34	18
Confluence 07040001-511 adj. factor = 1.08	**Capacity**	412	144	81	49	31
	MOS	142	44	15	12	12
	Allocation	270	100	67	37	19
Pine-Belle 07040002-502 adj. factor = 1.0	**Capacity**	381	134	75	45	29
	MOS	131	41	14	11	11
	Allocation	250	93	62	34	18

2.9 Wasteload and Load Allocations

Table 6 presents the wasteload and load allocations for the two impaired reaches covered in this report. Table 7 shows the same values expressed as a percentage of the total daily loading capacity. The process for calculating the allocations was as follows:

WASTELOAD ALLOCATION

- The sum of permitted TSS loads (plus an additional 50% to account for any potential growth/expansion impacts) from all wastewater treatment and industrial facilities with numeric discharge limits for TSS was assigned to that portion of the wasteload allocation for the two impaired reaches.
- The allocation for the remaining wasteload sources (MS4, construction, and industrial stormwater) was determined based on the estimated percentage of land in the impaired reach watersheds affected by these uses. The land area estimates, which consider potential conditions 20 years into the future, are 5% for MS4 communities, 1% for construction stormwater sites, and 0.5% for industrial stormwater sites. There is an equitable nature to this approach in that it provides the same area-based (i.e. per acre) allocation to both urban/industrial stormwater sources and rural/agricultural sources.

LOAD ALLOCATION

- The load allocation includes nonpoint sources that are not subject to NPDES permit requirements, as well as "natural background" sources. As described previously, these include sources of TSS such as soil erosion from cropland, sediment-laden runoff from communities not covered by NPDES permits, and streambed and streambank erosion resulting from human-induced hydrologic changes and disturbance of stream channels and riparian areas. Natural background sources of TSS would include generally low levels of soil erosion from both stream channels and upland areas. The load allocation expressed in tables 6 and 7 is simply the loading capacity that remains after wasteload allocation and margin of safety have been subtracted.
- Ideally, the load allocation could be broken down into distinctsub-categories such as natural background, cropland erosion, streambed and streambank erosion, gully formation, etc. Or, it could be broken down by subwatershed (e.g. Little Cannon River, etc.). However, current understanding of the different source and subwatershed contributions to turbidity in the Cannon River watershed is not sufficient for such numerical breakdowns. Nevertheless, the water quality and watershed analysis completed in this study, combined with other literature, is sufficient to allow for a qualitative discussion of the importance of different sources (Section 3.3) and subwatersheds (Appendix F).

Table 6 – Total Daily Loading Capacities, Wasteload and Load Allocations (expressed as tons/day TSS)

Watershed Areas (square miles): Welch = 1340 Confluence = 1443 Pine-Belle Reach = 1345	Flow Zone				
	High Flows	**Moist Conditions**	**Mid-Range Flows**	**Dry Conditions**	**Low Flows**
	values expressed as tons TSS/day				
Cannon River, HUC boundary in Rice Lk Bottoms to Vermillion Slough/ Mississippi R (AUID: 07040001-511) – referred to in report as Confluence reach					
Total Daily Loading Capacity	412	144	81	49	31
Wasteload Allocation					
Wastewater Treatment and Industrial Facilities with Numeric Discharge Limits for TSS	7.0	7.0	7.0	7.0	7.0
MS4 Communities	13.1	4.7	3.0	1.5	0.6
Construction Stormwater (NPDES)	2.6	0.9	0.6	0.3	0.1
Industrial Stormwater (NPDES)	1.3	0.5	0.3	0.2	0.1
Wasteload Allocation Total	24.1	13.1	10.9	9.0	7.8
Load Allocation	246	87	56	28	11
MOS	142	44	15	12	12
Cannon River, Pine Creek to Belle Creek (AUID: 07040002-502)					
Total Daily Loading Capacity	381	134	75	45	29
Wasteload Allocation					
Wastewater Treatment and Industrial Facilities with Numeric Discharge Limits for TSS	7.0	7.0	7.0	7.0	7.0
MS4 Communities	12.1	4.3	2.7	1.4	0.5
Construction Stormwater (NPDES)	2.4	0.9	0.5	0.3	0.1
Industrial Stormwater (NPDES)	1.2	0.4	0.3	0.1	0.1
Wasteload Allocation Total	22.8	12.6	10.5	8.8	7.7
Load Allocation	227	80	51	26	10
MOS	131	41	14	11	11

Assumptions for stormwater wasteload allocations:

- MS4 communities will comprise 5% of the land area of the respective impaired reach watershed areas
- Construction stormwater sites will comprise 1% of the land area of the respective impaired reach watersheds
- Industrial stormwater sites will comprise 0.5% of the land area of the respective impaired reach watersheds

Table 7 – Total Daily Loading Capacities, Wasteload and Load Allocations (expressed as percentage of total daily loading capacity)

Watershed Areas (square miles): Welch = 1340 Confluence = 1443 Pine-Belle Reach = 1345	**Flow Zone**				
	High Flows	**Moist Conditions**	**Mid-Range Flows**	**Dry Conditions**	**Low Flows**
	values expressed as percentage of total daily loading capacity				
Cannon River, HUC boundary in Rice Lk Bottoms to Vermillion Slough/ Mississippi R (AUID: 07040001-511) – referred to in report as Confluence reach					
Total Daily Loading Capacity	100%	100%	100%	100%	100%
Wasteload Allocation					
Wastewater Treatment and Industrial Facilities with Numeric Discharge Limits for TSS	1.7%	4.8%	8.6%	14.4%	22.3%
MS4 Communities	3.2%	3.2%	3.7%	3.1%	1.9%
Construction Stormwater (NPDES)	0.6%	0.6%	0.7%	0.6%	0.4%
Industrial Stormwater (NPDES)	0.3%	0.3%	0.4%	0.3%	0.2%
Wasteload Allocation Total	5.8%	9.0%	13.4%	18.4%	24.8%
Load Allocation	59.7%	60.4%	68.3%	57.8%	36.4%
MOS	34.5%	30.5%	18.3%	23.8%	38.8%
Cannon River, Pine Creek to Belle Creek (AUID: 07040002-511)					
Total Daily Loading Capacity	100%	100%	100%	100%	100%
Wasteload Allocation					
Wastewater Treatment and Industrial Facilities with Numeric Discharge Limits for TSS	1.8%	5.2%	9.3%	15.6%	24.1%
MS4 Communities	3.2%	3.2%	3.6%	3.0%	1.9%
Construction Stormwater (NPDES)	0.6%	0.6%	0.7%	0.6%	0.4%
Industrial Stormwater (NPDES)	0.3%	0.3%	0.4%	0.3%	0.2%
Wasteload Allocation Total	6.0%	9.4%	14.0%	19.5%	26.5%
Load Allocation	59.5%	60.1%	67.7%	56.7%	34.7%
MOS	34.5%	30.5%	18.3%	23.8%	38.8%

Assumptions for stormwater wasteload allocations:

- MS4 communities will comprise 5% of the land area of the respective impaired reach watershed areas
- Construction stormwater sites will comprise 1% of the land area of the respective impaired reach watersheds
- Industrial stormwater sites will comprise 0.5% of the land area of the respective impaired reach watersheds

2.10 Critical Conditions and Seasonality

Critical conditions based on needed TSS load reductions clearly occur during higher flows, whenever they occur. Seasonally, the April-June time period, which is characterized by convective thunderstorm activity and heavy rainfall, combined with a lack of developed crop canopy, appears to account for a disproportionate portion of turbidity standard violations. Further discussion of the impact of flow and seasonality is contained in section 3.1-3.3.

2.11 Impacts of Growth and Watershed Changes on Allocations

<u>Point Sources with Numeric TSS limits</u>
Current discharge limits for wastewater treatment and industrial facilities are typically 45-65 mg/l TSS. Discharge flows at existing facilities may increase over time, and new permits may be sought. Given that the TSS equivalent of the 25 NTU turbidity water quality standard established in the report is 44 mg/l, new or expanded discharges will have no significant impact on the Lower Cannon provided discharge limits are met. This is because increased discharge flows add to the overall loading capacity of the system. Furthermore, under the lower flow conditions when such discharges would have their greatest impact, the current permitted cumulative TSS mass from all of the point sources (4.7 tons/day) only accounts for 15-16% of the total TSS loading capacity of the two impaired reaches. Despite these factors, the wasteload allocation was set at 50% above current permitted TSS loading, to 7 tons TSS/day.

<u>Municipal Separate Storm Sewer Systems</u>
Urbanization has the potential to directly or indirectly increase TSS loading to the Cannon River. The indirect increases come if development adds to the rate and volume of water runoff, thus creating the potential for stream bed and bank erosion. Expansion of the current MS4 communities (Owatonna, Faribault, Northfield, and Waseca) in the Cannon River watershed is likely to take place over the next 20 years. The wasteload allocation for these communities has been set to account for this. If an even greater expansion of these communities occurs and an increase in the wasteload allocation is necessary, the nonpoint source load allocation will need to be reduced proportionately. This makes sense, and is equitable, because expansion of urban areas effectively reduces the amount of agricultural and other land which may contribute TSS to the Lower Cannon. It should not be taken as a given that the MS4 wasteload allocation will absolutely need to increase. Lower impact development and aggressive stormwater management using such practices as infiltration might allow a community to grow with little or no added water quality impact.

<u>Agricultural Practices</u>
As discussed above, the nonpoint source load allocation could be reduced over time proportional to the loss of agricultural land to urbanization or suburbanization. While an increase in the amount of land devoted to agricultural uses in the watershed seems unlikely, there could be a continued shift from pasture and hay land to row cropping. Such a change has the potential to increase TSS loading to the Lower Cannon. A response of providing more loading capacity, however, may not be appropriate. Rather, an expectation of holding soil loss and sedimentation rates at least to that of the pasture or hay land would seem more appropriate.

<u>3.0 TSS LOADING, NECESSARY LOAD REDUCTIONS, AND DISCUSSION OF SOURCES</u>

The material presented in this section represents an attempt to provide a general sense of the magnitude, timing, and sources of TSS load reductions necessary for substantial water quality improvement in the Lower Cannon River. The reduction magnitudes are based on statistical expressions of loads for different flow zones and time periods. Although they do not represent the TSS reductions necessary to attain the 25 NTU standard on a daily year-round basis, they do approximate the reductions necessary to drop the Lower Cannon River below the 10% exceedance threshold for impairment listing. In theory, this would result in the river being de-listed and no longer considered impaired.

3.1 TSS Loading

Paired with flow data from the USGS site at Welch, each of the 285 TSS values obtained on the Lower Cannon River from 1995-2004 allow the estimation of a daily TSS load. In figures 14 and 15, the daily loads are plotted along with the loading capacity curve shown previously in Figure 12. All points that fall above the curve represent exceedances of the loading capacity (i.e. violations of the turbidity standard). It is clear that most exceedances, including some very severe ones, occur during mid-range to high flow.

Figure 14 – Cannon River near Mouth – Daily TSS Loads with Loading Capacity

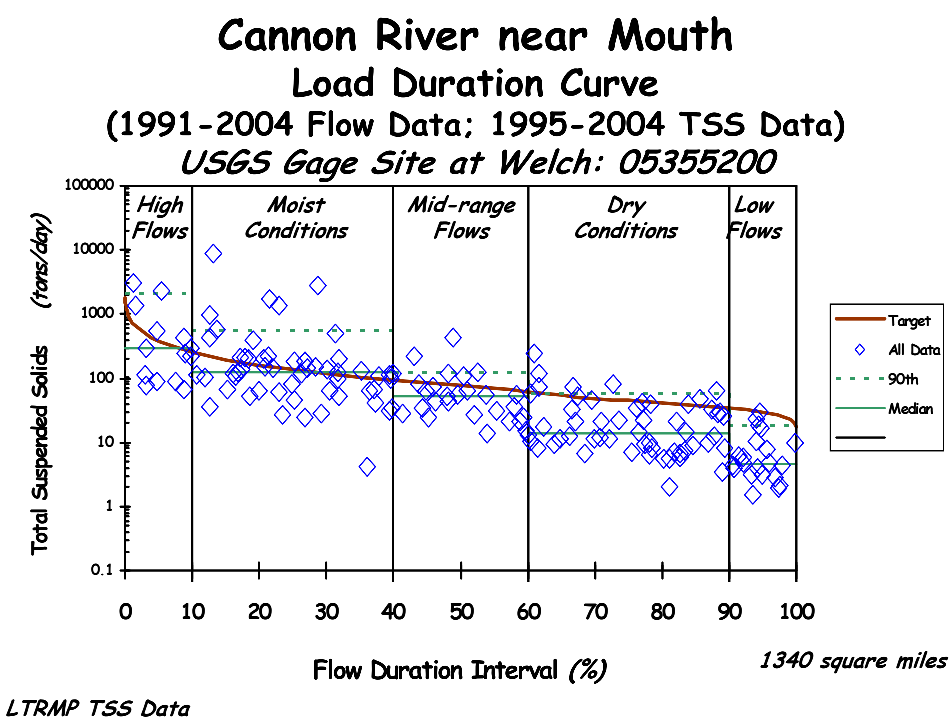
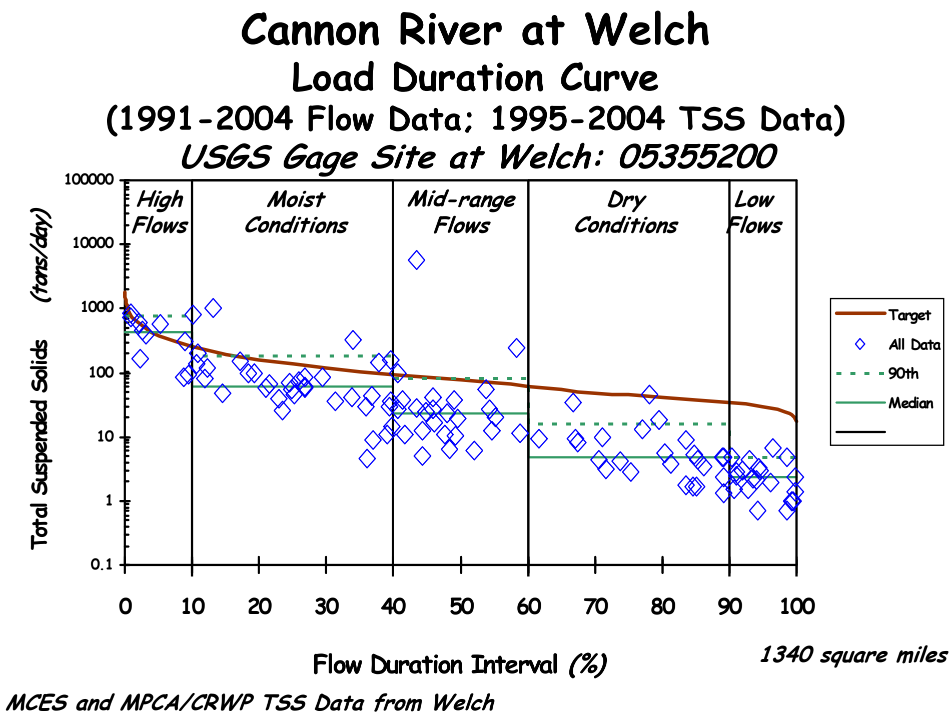


Figure 15 – Cannon River at Welch – Daily TSS Loads with Loading Capacity



3.2 Necessary Load Reductions

Table 8 compares the 90th percentile TSS load for each of the flow zones to the loading capacity at the mid-point of the flow zone. The difference between these two sets of numbers produces the estimated percent reduction in TSS load that will be necessary for the Lower Cannon to be removed from the impaired waters list (i.e. fewer than 10% of samples exceed 25 NTU). These reductions should not be confused with the target of the wasteload and load allocations, which is to meet the 25 NTU standard on all days. Nevertheless, the reduction percentages do describe a scenario under which the Lower Cannon would no longer be considered impaired. It must be noted that these percent reduction figures may only roughly correspond to certain potential source reductions. For example, a 25 % reduction in soil erosion from cropland or construction sites may or may not produce a directly corresponding reduction of instream TSS loads. Many variables, which can be quite difficult to measure and understand, influence such relationships.

Table 8 – Comparison of 90th percentile daily load to capacity at the mid-point of the zone

• capacity is mid-point for flow zone • current load is 90th percentile value for flow zone		Flow Zone				
		High Flows	**Moist Conditions**	**Mid-Range Flows**	**Dry Conditions**	**Low Flows**
		values expressed as tons/day TSS				
Confluence 07040001-511	**Capacity**	411	145	81	49	31
	Current Load	2264	591	132	61	20
	% Red. Needed	82%	76%	39%	20%	0%
Pine-Belle 07040002-502	**Capacity**	381	134	75	45	29
	Current Load	748	183	81	16	5
	% Red. Needed	49%	27%	8%	0%	0%

As noted previously, TSS data from grab samples collected by MCES at Welch were used to estimate TSS loading. The MCES monitoring program at Welch also includes automated sampling of storm events; the results of which are also used to estimate TSS loading. Table 9 compares these estimates, which have been made since 2000, to those derived from the 1995-2004 load duration analysis. A range of percent reductions based on the MCES loads are also presented. The nearly 5-fold range in annual TSS load (38,197 in 2003; 174,095 in 2001) between 2000 and 2004 is worth noting. The percent reductions ranges, derived in a manner different from those shown in Table 8, also show substantial year-to-year variability. They also provide a slightly different sense of the magnitude of TSS reduction that may be necessary for the Lower Cannon to be removed from the impaired waters list.

Table 9 - Comparisons of TSS Loading Estimates from Metropolitan Council Environmental Services to Daily Loading Capacities and Estimates Derived from Flow Duration Analysis (comparisons for Welch location)

MCES			Duration Analysis (1995-2004)	
Year	Annual TSS Load (tons)	Average Daily TSS load (tons/day)	Daily Loading Capacity (tons/day) 25th-75th pct. flows	Percent Reductions from MCES Estimates to Meet Daily Loading Capacities
2000	90971	249.2	45-134	46-82%
2001	174095	477.0	45-134	72-91%
2002	67267	184.3	45-134	27-76%
2003	38197	104.6	45-134	0-57%
2004	114662	314.1	45-134	57-86%
2000-2004		265.9	45-134	50-83%

3.3 Discussion of External and Internal TSS Sources

In Section 1.3, TSS and turbidity sources were discussed in terms of being either point sources or nonpoint sources. Most point and nonpoint sources are typically considered external (or upland) in that they are located outside of a waterway, stream, or river, yet contribute TSS and turbidity to the waterway in some manner. Internal sources typically encompass processes that occur within the channel (i.e. the bed and banks) or the floodplain of a waterway, stream, or river. Such processes include channel and floodplain erosion or scour, and bank slumping. Internal processes can also include the growth and decay of algae and other plant material in the channel or in the water column.

Based on the relationship between flow and load discussed in the previous sections, water is clearly the overall driver of both internal and external sources of TSS and turbidity in the Lower Cannon River. The greater the water runoff over the land, and in the small channels and streams of the watershed, the greater the load of TSS carried into the Cannon River. The same runoff increases flow in the Cannon River itself, causing the mobilization of streambank and streambed sediments.

Figures 14 and 15, and Table 8 clearly show that the greatest TSS loads in the Lower Cannon occur during higher flow periods. These loads are not simply a function of higher flows, however. They are the product of both higher flow and the higher TSS concentrations that generally occur during periods of higher flow. Higher flows contribute directly to higher TSS concentrations through sheer stress on stream bank and bed material. And, the watershed runoff that leads to higher flows may also be generating upland soil erosion and sediment transport to the river. Many factors complicate these relationships.

Figures 16 and 17 help describe Lower Cannon River TSS dynamics in two ways. First, estimated daily TSS loads that occurred during the months April-June are flagged with the "+" symbol. Two conditions converge in these months that have the potential to strongly influence TSS loads – convective thunderstorm activity and heavy rainfall combined with a lack of crop canopy to protect the soil. The higher daily TSS loads associated with the April-June time period is particularly apparent at the Pine-Belle reach. The second dynamic relates to TSS loads that are particularly influenced by "stormflow" – these are flagged with a red diamond. A hydrograph separation program (Sloto and Crouse, 1996) was used with the USGS Welch gage data to estimate days on which > 50% of the flow in the Lower Cannon is stormflow, or flow made up primarily of relatively rapid surface runoff and soil erosion from the watershed. High flows can occur independently of a predominance of rapid surface runoff and soil erosion from the watershed; these may be snowmelt periods, or times when more runoff is moving through the soil profile rather than as surface runoff. Water movement through the soil profile might occur with light to moderate but steady precipitation over several days rather than during or after a heavy thunderstorm. It is clear from the figure that while higher daily TSS loads are associated with higher flow, they are even more associated with the > 50% stormflow samples. This suggests that while streambank erosion and channel scour is likely a significant source of TSS in the Lower Cannon, it is probably not the dominant source. If it were, one would expect to see high TSS loads associated with all higher flows, not just those associated with higher stormflow percentages.

Table 10 is an attempt to quantify some of the dynamics described in the previous paragraph. Median and 90th percentile values for daily TSS loads are shown for all the data at each impaired reach site, and for scenarios that the “> 50% stormflow” samples and the April-June samples. The differences between the values derived from the complete data set and those from the two scenarios provide some quantification of external and internal sources of TSS, and of the effect of vegetative cover on the landscape. External (watershed) sources of TSS may be limited directly or indirectly by vegetative cover on the landscape. Vegetation protects soils from the erosive force of raindrops. Through plant evapotranspiration processes, the moisture holding capacity of soils are increased, thus limiting runoff. And if soil erosion occurs, vegetation can filter out sediment before it enters waterways.

The second row of values in Table 10 for each impaired reach is the estimated daily TSS load if the “>50% stormflow” samples are removed from the duration curve analysis. The third row is the percent of the TSS load represented by this removal. These percentages could be interpreted as an upper estimate of the percentage of the TSS load contributed by instream processes, as opposed to external processes. In-stream processes in this case include streambank erosion, re-suspension of streambed material, and algae production. The percentages range from 40-86% for the two reaches. As mentioned, these should be interpreted as upper estimates because some of the “<50% stormflow” samples used in the second row calculations could represent some TSS carried in watershed runoff. It is also important to reiterate that in-stream processes such as stream channel erosion are ultimately driven by external factors.

The fourth and fifth rows for each impaired reach in Table 10 show the results of removing from duration curve analysis all samples collected during the pre crop canopy months of April-June. In an agricultural setting, the crop canopy may mimic natural vegetative cover. The median and 90th percentile values for daily TSS loads for the two impaired reaches decrease by 21-81%. This supports a potentially large beneficial effect of perennial vegetative cover in the Lower Cannon watershed, especially on more steeply sloped land. In areas of gentler slopes, adequate crop residue can provide a similar beneficial effect. As noted earlier, the effects appears greatest for the Pine-Belle reach. This may suggest the importance of perennial vegetation, cover crops, and crop residue in the Little Cannon, Pine Creek, and Trout Brook watersheds.

Perspectives on potential upland soil erosion and sediment delivery

The 2000-2004 annual TSS loading rate estimates for the Cannon River at Welch (Table 9) range from 38,000 to 174,000 tons per year. Assuming that 50% of these loads come from internal sources, this suggests a potential of 19,000-87,000 tons per year from upland sources. Considering only the portion of the Cannon River watershed downstream of the Lake Byllesby dam, there is approximately 72,000 acres of crop land that drains to the Cannon River at Welch. If that crop land had an average soil erosion rate of 5 tons/acre per year, between 5 and 25 percent of the eroded material would need to be delivered to the Cannon River on an annual basis to account for the 19,000-87,000 tons of annual sediment loading.

Soil erosion from land undergoing development (i.e. construction sites) is typically much greater than that on agricultural land. Assuming 10 active 25-acre construction sites with soil erosion rates of 50 tons/acre per year, and 25% sediment delivery, these sites would contribute 3125 tons per year of sediment load to the Cannon River. This represents between 4 and 16% of the 19,000-87,000 tons of annual sediment loading.

In the case of either of the "example" upland sediment sources describes above, both soil erosion rate and sediment delivery rate impact the actual sediment load that reaches the Cannon River. Soil erosion rates for different types and soils, slopes, and land uses are generally well understood. Tools such as the Universal Soil Loss Equation (USLE) and Revised Universal Soil Loss Equation (RUSLE) have been used for many years to model soil erosion. Sediment delivery, on the other hand, is significantly more difficult to understand and model. In addition to proximity to a water body, sediment delivery is affected by very small-scale factors such as the presence, absence, and location of vegetative buffers and fence rows, and conveyances such as tile intakes, gullies, and intermittent streams.

Efforts to reduce upland sediment loading to water bodies must focus both on soil erosion control and the reduction of sediment delivery.

Figure 16 – Cannon River Near Mouth (Confluence Reach) – Load Duration Curve showing seasonality and stormflows

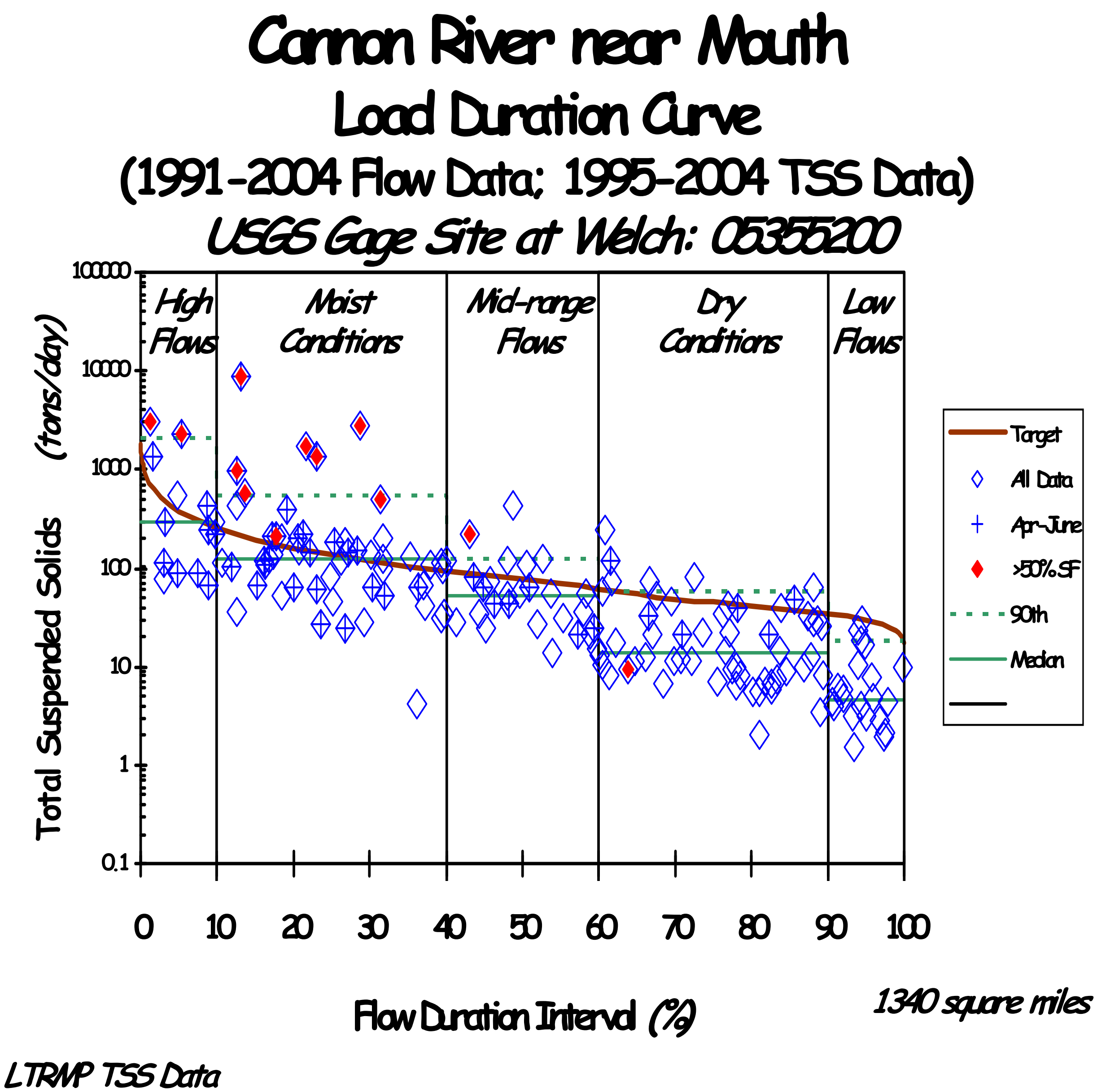


Figure 17 – Cannon River at Welch (Pine-Belle Reach) – Load Duration Curve showing seasonality and stormflows

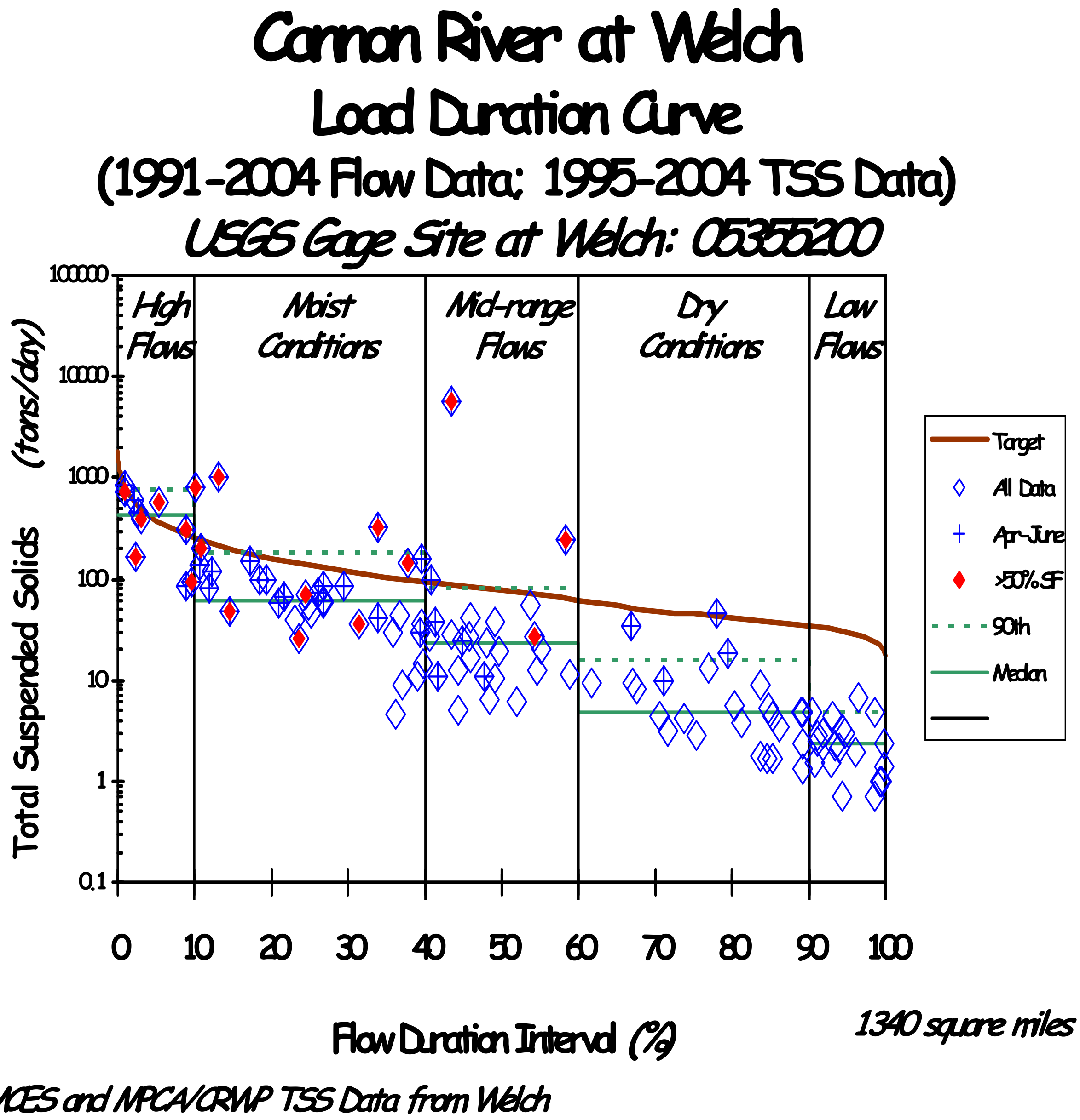
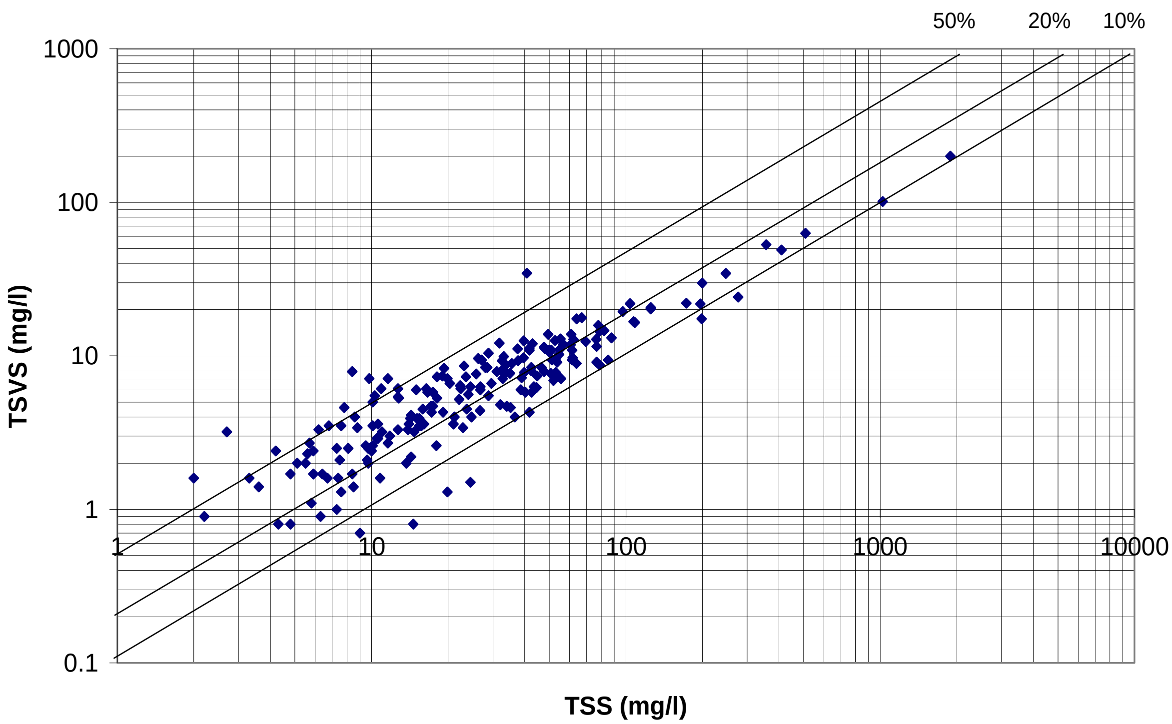


Table 10 - Lower Cannon Stormflow and Crop Canopy Effects on TSS Loading

		50^{th} percentile (median)	90^{th} percentile
Confluence 07040001-511	**All Data (tons/day TSS)**	47	266
	Stormflow samples removed (tons/day TSS)	40	202
	Percent of current load not associated with stormflow samples	86%	76%
	Pre-crop canopy (April-June) samples removed (tons/day TSS)	31	211
	Effect of April-June sample removal	21% reduction	34% reduction
Pine-Belle 07040002-502	**All Data (tons/day TSS)**	19	227
	Stormflow samples removed (tons/day TSS)	11	90
	Percent of current load not associated with stormflow samples	57%	40%
	Pre-crop canopy (April-June) samples removed (tons/day TSS)	6	44
	Effect of April-June sample removal	68% reduction	81% reduction

It is often assumed that TSS in river and streams is made primarily of inorganic clay, silt and sand soil particles. In the Lower Cannon River, however, the organic material portions of the TSS (total suspended volatile solids or TSVS), ranges from around 10 to 50% (Figure 18). The highest percentages tend to occur when TSS values are low, and decline as TSS increases. While some organic material is washed into the river along with inorganic material, or is directly deposited streambank vegetation, some of the TSVS is living or dead phytoplankton (algae) produced in the river itself. This phytoplankton may grow in the water column and be free floating, or grow on streambed surfaces such as rocks and woody material. Phytoplankton in a given section of river may be transported from upstream areas, or dislodged from streambed surfaces during periods of increase flow. Hypereutrophic Byllesby Reservoir is a source of algal material to the Lower Cannon River.

Figure 18 – Relationship Between Total Suspended Volatile Solids and Total Suspended Solids (1993-2004 Lower Cannon LTRMP Data) – diagonal lines represent percent TSVS.



While there is clearly a substantial amount of TSVS in the Lower Cannon River, and some of this material is algae, it is less clear what impact the algae may have on turbidity. It is important to develop some understanding of this as actions to reduce turbidity caused by algae would likely differ from those applied to control inorganic suspended solids.

A few chlorophyll-a observations were available for the Welch and Confluence monitoring stations on the Lower Cannon. Chlorophyll-a is a pigment used to measure the concentration of algal material in lakes and streams. Figure 19 shows only a very slight positive relationship between chlorophyll-a and turbidity for seven observations with chlorophyll-a concentrations ranging from 0-80 ug/l. The 80 ug/l value, which is a very high chlorophyll-a value, is associated with a turbidity of around 37 NTU. In Figure 20, the same turbidity values are plotted against total suspended non-volatile solids (TSNVS) – inorganic material. The relationship is much stronger and it can be seen that the 37 NTU value is associated with a TSNVS of around 50 mg/l; which based on previously outlined relationships, would be sufficient to produce at least 25 NTU. This would indicate that the TSNVS is probably the dominant influence, but that very high algae levels may contribute to turbidity. Figure 21 and 22 show the same analysis repeated for seven observations at Welch (note scale differences), and show similar results.

Further support for the limited effect of chlorophyll-a on turbidity comes from the Lower Mississippi River Basin Sediment Data Evaluation Project (Barr Engineer, 2004) which concluded that "chlorophyll-a does not significantly influence turbidity readings and TSS concentrations, based on the overall dataset." Additionally, the Lower Vermillion Watershed Turbidity TMDL Project – Phase I Report (Tetra Tech, Inc., 2004) suggested that algal growth is a secondary influence on turbidity, but that a reduction of 20 ug/l in chlorophyll- a would only reduce turbidity by 2.4 NTU. Given the nature of the Lower Vermillion (i.e. a low-velocity system in the Mississippi River floodplain), the potential for algal production would seem even greater than for the Lower Cannon. Finally, it is important to note that violations of the turbidity standard in the Lower Cannon tend to occur during periods of higher flow. Favorable conditions for algae growth, however, tend to be during lower flow periods.

Given what would appear to be the relatively minor impact of algae on turbidity in the Lower Cannon River, no attempt is made in this report to explicitly account for this relationship, or allocate loading based on potential algae production. It is understood, however, that any effort to control TSS load will also control algae by limiting sediment-associated phosphorus that is ultimately the cause of algal growth in most aquatic systems.

Figure 19 – Cannon River at Confluence Turbidity and Chlorophyll-a (7 LTRMP observations; 1999-2004)

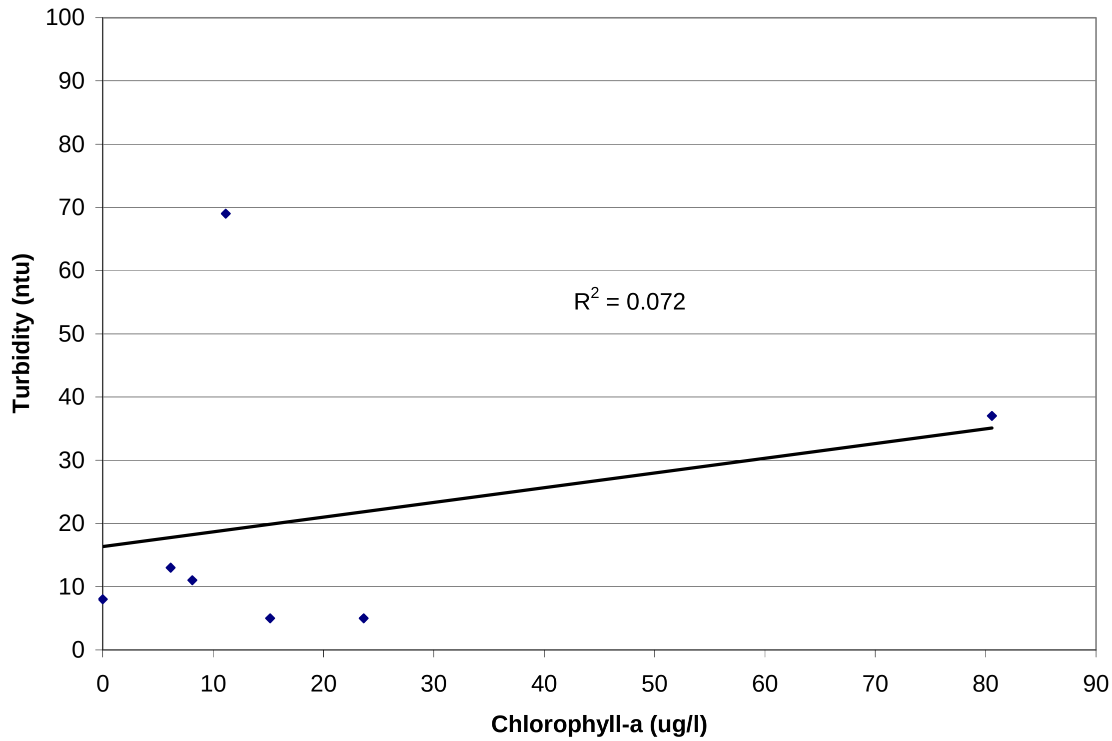


Figure 20 – Cannon River at Confluence Turbidity and Total Suspended Non-Volatile Solids (7 LTRMP observations; 1999-2004)

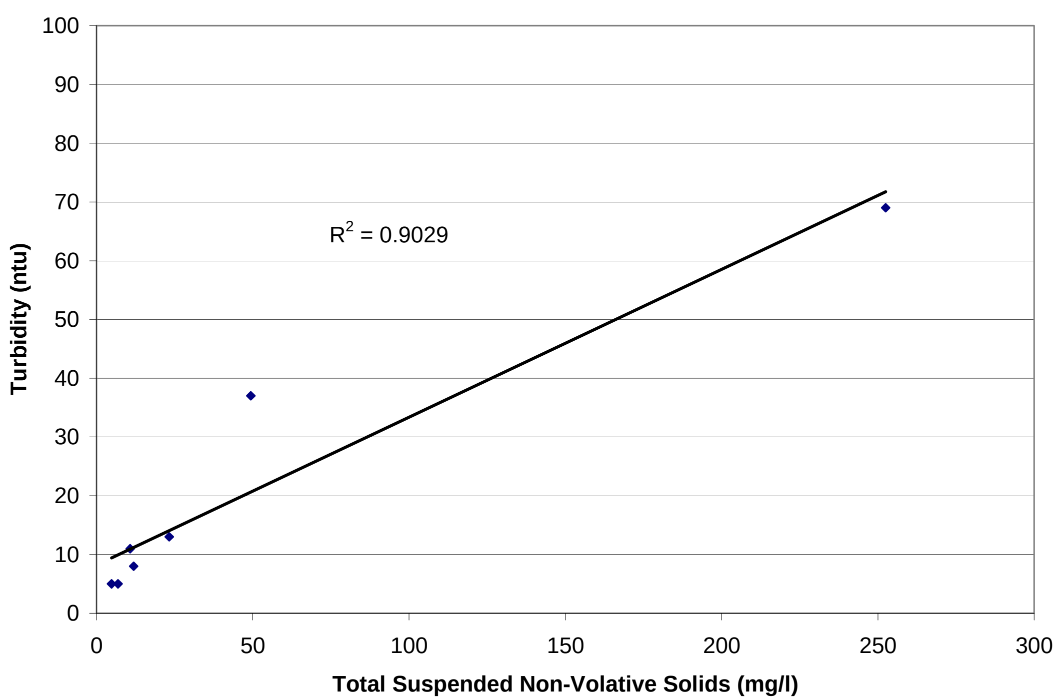


Figure 21 – Cannon River at Welch Turbidity and Chlorophyll-a (7 CRWP observations; Summer 2004)

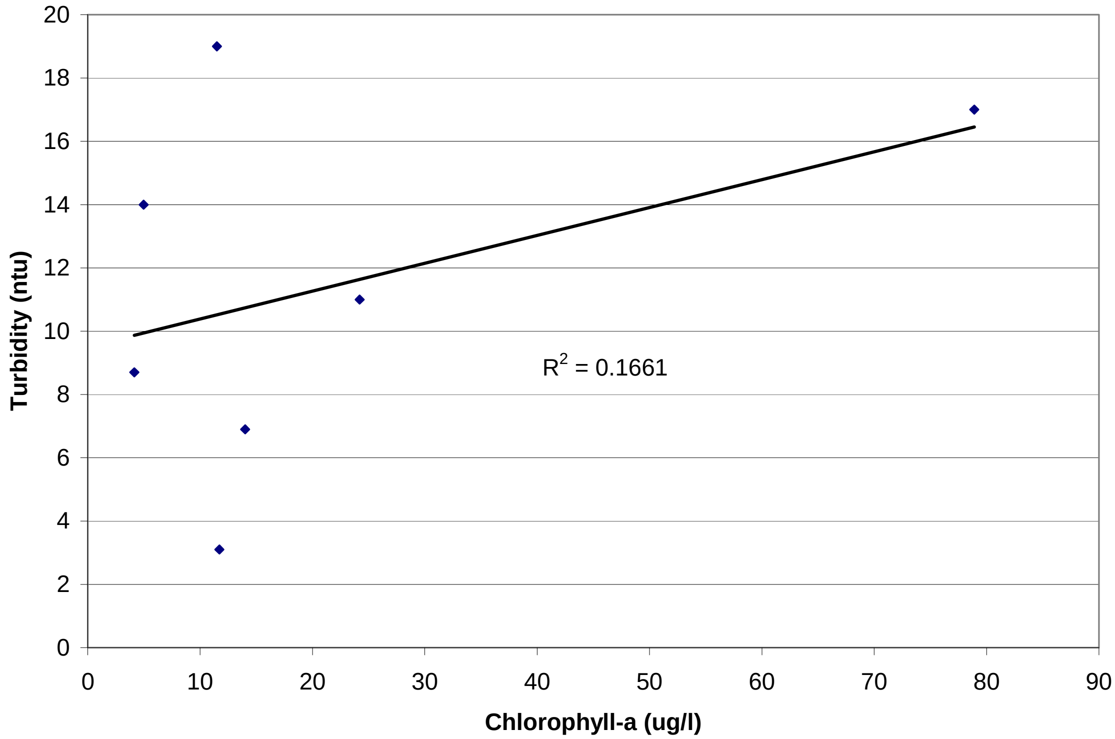
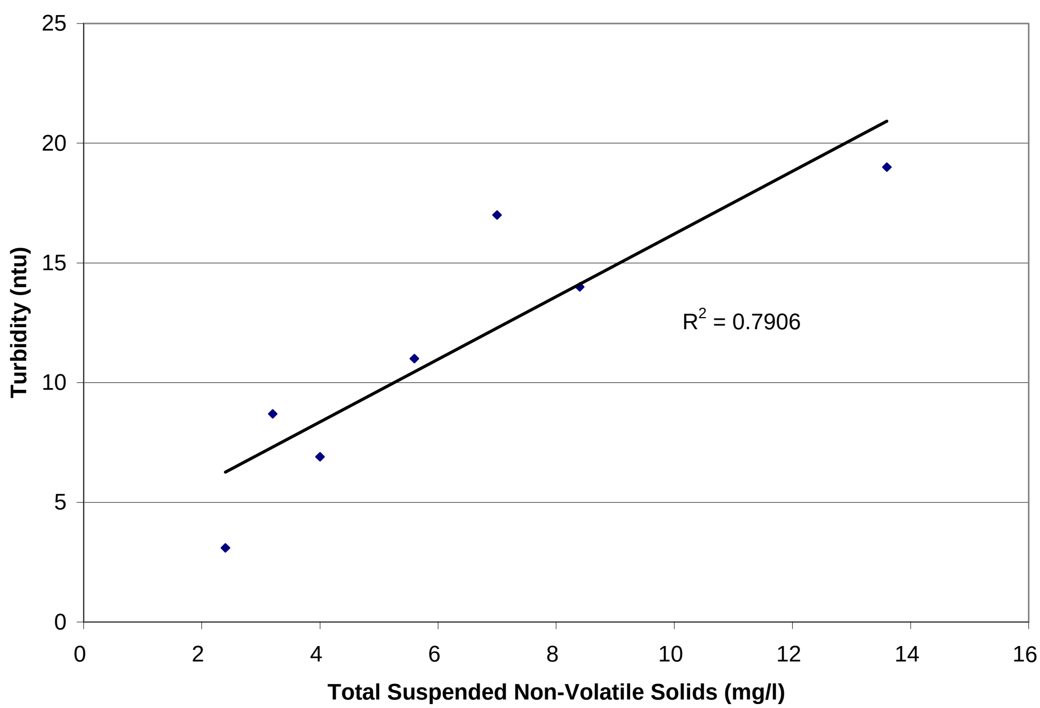


Figure 22 – Cannon River at Welch Turbidity and Total Suspended Non-Volatile Solids (7 CRWP observations; Summer 2004)



In project technical committee meetings, there seemed to be some consensus that watershed runoff and the resulting streamflow are the key drivers for the turbidity impairment in the Lower Cannon River. These discussions led to questions about whether there are trends in flow, due either to watershed changes, climate patterns, or both. Figures 23 and 24 show long-term streamflow at Welch expressed in four different ways: average annual; maximum annual; average May flow; and average September flow. With the exception of maximum annual flow, where no clear trend is apparent, the other three measures have increased by factors of two to three over the past century. These increases are apparent even if one “factors out” the very dry years of the 1930’s. Regardless of the cause of these increases in flow, they reveal an important factor affecting turbidity in the Lower Cannon River, and highlight the challenges to reducing this turbidity. First, they reflect more runoff from the land. Even with good erosion and sediment control practices in place, more runoff generally means more TSS loading. Soil conservation practices developed in earlier times may not be adequate for current runoff patterns. The second challenge is in the area of stream channel stability. As long as flows are trending upward, the channel of the Lower Cannon and its tributaries will be in a state of instability as they try to adjust to the higher flows. This adjustment occurs in the form of channel widening (bank erosion) and downcutting (streambed erosion) that contributes TSS and turbidity and will continue until flows stabilize. The ultimate measure of success for reduced turbidity in the Lower Cannon River may be a flat or downward trend in streamflow at Welch.

Figure 23 – Average Annual (boxes; upward trending line) and Maximum Annual (triangles; flatter line) Flow at Welch

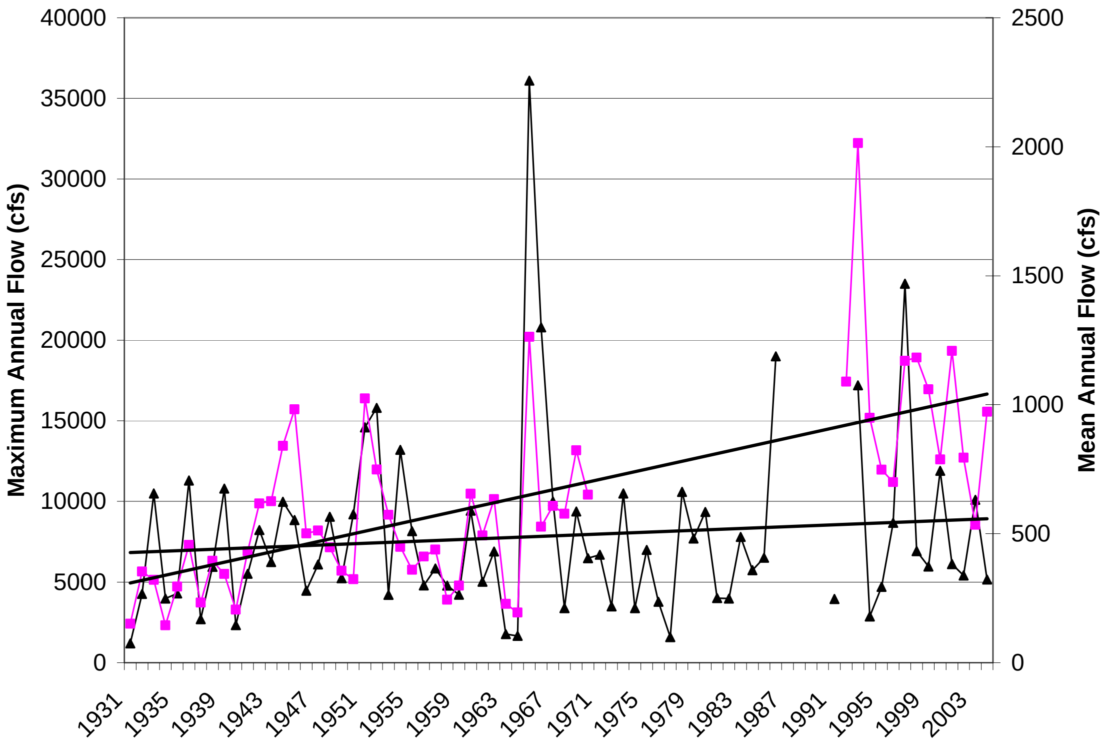
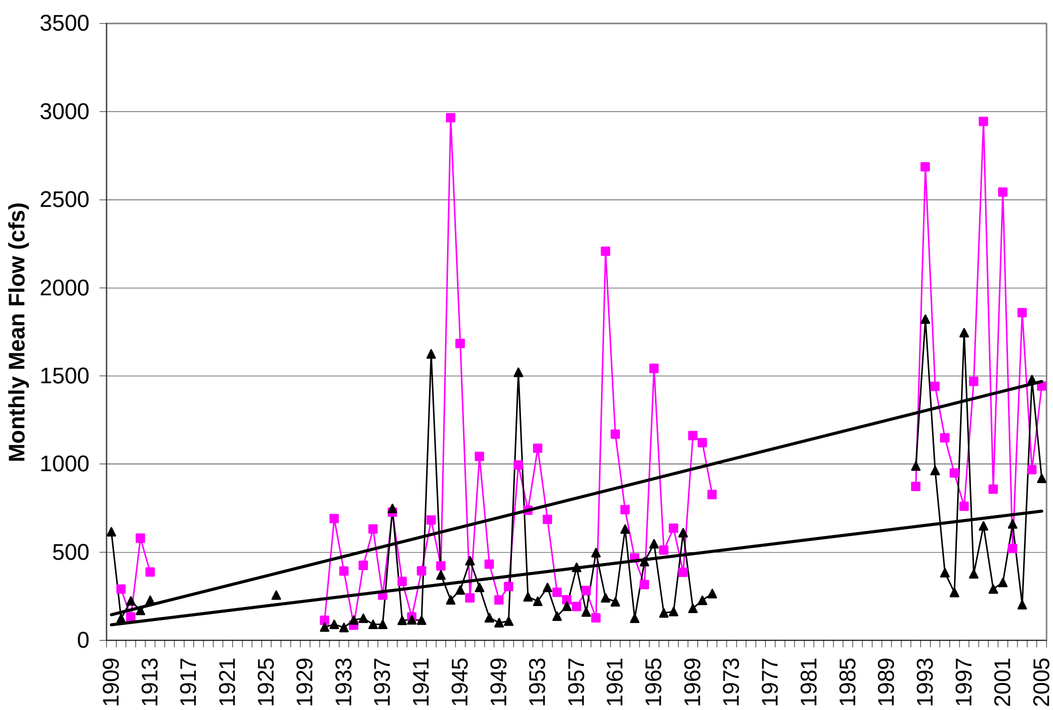


Figure 24 – Average May (boxes; upper line) and September (triangles; lower line) Flow at Welch



4.0 PUBLIC PARTICIPATION RECORD

4.1 Direct Participation

Interested citizens began monitoring sites on the Little Cannon River and on Belle Creek in 1999, well before the project began. The TMDL utilizes data collected by these and other citizen stream monitors. Public participation in the TMDL formally began at the first Steering Committee meeting on June 6, 2003.

Three types of meetings were held:

1) Steering (or advisory) committee meetings, for which broad representation was sought.
2) Technical committee meetings, primarily involving those who modeled and calculated loads and load allocations.
3) A public meeting, which was advertised to the CRWP membership, and to the public media.

Table 11 illustrates citizen, state and county agency, and other entities' participation in meetings. In addition to these meetings, Lee Ganske, Carrie Jennings and Justin Watkins contributed sections to this TMDL document.

4.2 Education and Outreach

Cannon River Watershed Partnership has made information about this TMDL available to its members beginning in the November, 2003 edition of its newsletter, Watershed Watcher. Mailed to over 1000 members and interested parties, updates on this TMDL have been reported ten times. In the February, 2006 newsletter, an article explaining the Impaired Waters list, and its relationship to the TMDL process was published.

At the first meeting of the Steering Committee in June, 2003, MPCA staff presented an overview of TMDL structure and program elements. In July, 2005, CRWP staff created a table display to communicate the definition, purposes, and processes of a TMDL study. This display has been utilized at the Cannon River Festival in August, 2005, at the public meeting for this TMDL held in red Wing on August 17, 2005, and at presentations for implementation of a different TMDL (the Lower Mississippi River Basin Fecal Coliform Bacteria TMDL).

The public meeting held in Red Wing in August, 2005, was publicized with press releases in the Cannon Falls and Red Wing newspapers, postcard and electronic mailings to CRWP members and contacts, and through flyers posted at public locations in the affected townships. The agenda included a project update and outlook, a presentation by Hugh Valiant, DNR Fisheries, and an overview of the turbidity impairment by Greg Wilson, of Barr Engineering, Inc.

Two additional pubic meetings were held (June 14 and October 26, 2006) that included review and discussion of drafts of the Lower Cannon TMDL report.

Table 11 – Participant Roles

	Agency or Entity Represented	6/6/2003	2/26/2004	6/8/2004	7/20/2005	8/17/2005	11/15/2005	1/11/2006	5/9/2006
	(Steering, Technical, or Public Meeting)	Steering	Steering	Steering	Technical	Public	Technical	Technical	Steering
State or County Agencies									
	MN Pollution Control Agency (MPCA)	*	*	*	*	*	*	*	*
	MPCA/ CRWP Citizen Stream Monitoring Program	*		*		*			
	Dakota County Parks Department		*	*					
	Dakota County Soil and Water Conservation District	*	*	*	*	*			
	Goodhue County Soil and Water Conservation District		*				*		
	Twin Cities Metropolitan Area Council							*	
	MN Dept of Agriculture	*							
	MN Geologic Survey						*		
	MN DNR Fisheries	*				*			
	MN DNR Waters	*	*	*					
	University of Minnesota Extension Service						*		
Local and Private Entities									
	Cannon River Watershed Partnership (CRWP)	*	*	*	*	*	*	*	*
	Cannon Falls Beacon (newspaper)	*							
	Cannon Valley Trail Joint Powers Board								
	Citizen At Large			*		*			
	North Cannon Watershed Management Organization	*	*	*					
	St. Olaf College	*					*	*	

Please note: More than one member from an agency may have attended.

5.0 GENERAL IMPLEMENTAION STRATEGIES

Within one year of approval of this TMDL by EPA, an expanded and more detailed implementation plan will be developed. It is unlikely that during that process all sources of turbidity will be precisely defined. However, we believe that implementation can proceed, even as more research is being done. In general terms, increased streambank and bed erosion is caused by factors that accelerate, or increase the volume of water runoff from a watershed. There is substantial overlap between these factors and general upland (non-streambank and bed) soil erosion and sediment delivery potential. The removal of forest cover from a steeply-sloped hillside will likely increase both water runoff and soil erosion potential; so will the conversion of perennial vegetation to annual crops and the installation of systems that speed up the drainage of agricultural and urban land. Efforts to address these issues can be expanded immediately. On the other hand, large-scale initiatives to expand structural repairs to eroding stream channels or ravine head-cuts should probably be delayed until more information is available.

5.1 Activities

For many years we have known that in order to reduce sediment in streams the most important thing we can do is control erosion and contain runoff in cultivated areas (USDA, 1976). In addition, streambank erosion could be reduced by keeping cattle and other animals from over-grazing streambanks. The contributions of sediment from urban stormwater grow each day as we develop more land and create greater amounts of impervious surface for rain and snow to wash off carrying sediment along with it. Reducing the amount of sediment in streams will not be a quick process. As noted in the MN DNR Healthy Rivers CD:

"After a century or more of erosion from farmland and other sources, some stream reaches will require decades or more to move and redeposit accumulated sediment"

This is all the more reason to begin working on sediment loading reduction right away. Some of the priority management mechanisms will include:

<u>Erosion control</u>
Erosion control has been and will continue to be an ongoing effort in the entire Cannon River Watershed. To better understand the volume and mechanisms by which sediment is reaching the streams continued research to develop a sediment budget for the watershed would be useful. The county Soil & Water Conservation district, the Natural Resource Conservation Service, University of Minnesota Extension Service, and many others will play an important role in education, implementation, and financing projects to control erosion and thereby decrease the level of sediment in the streams and rivers. Methods that have been used in the past and proven successful in doing this are: conservation tillage, placing land into conservation reserve programs, implementing rotational grazing, the use of continuous crop cover, and water retention projects. More detail on these methods follows.

- Conservation Tillage:

  Conservation tillage is the practice of maintaining crop cover on the land as a means of reducing soil erosion. If it is managed properly, the reduction in soil erosion can be up to two-thirds (Randall, et. al., 2002). The following are examples of some types of conservation tillage (Randall et. al., 2002).

Ridge Till:
Tillage is limited to that performed by the planter (ridge leveling) and one or two in-season cultivations (ridge building). Preformed ridges provide a drier and warmer seedbed at planting. Adequate levels of crop residue remain after planting.

Strip-Till:
Strips about 4" to 6" wide and 7" to 8" deep matched to the row-spacing of the planter are prepared in the fall with mole fertilizer knives or anhydrous knives mounted on a tool bar. Fertilizer P and K can be injected directly into the strip at the time of strip tillage. Corn is planted into the tilled “residue free” strip without any secondary spring tillage.

No-Till (the planter performs all seedbed preparation):
Starter fertilizer placement and cleaning residue from the rows usually are done with the planter, but may be performed separately, sometimes in combination with fertilizer injected into a strip or band.

Conservation tillage can be promoted through a variety of methods such as:

1. Holding “field day” trials to show producers the results of various methods.
2. Individual meetings of producers and Soil & Water Conservation District or Extension service staff to discuss the best options for a particular land area.
3. Incentive payments to producers who enroll land in these practices such as those offered by the American Farmland Trust Best Management Practices Challenge.
4. Development and sales of equipment designed for conservation tillage practices.

- Conservation Reserve/Landscape Buffers
  The following conservation programs are examples of options in which landowners and operators in the Lower Cannon river watershed may choose to enroll their land. All of these programs focus on the removal of land from production in order to reduce soil erosion and improve water quality.

Conservation Reserve Program (CRP)
The USDA Farm Service Agency (FSA) Conservation Reserve Program (CRP) is a voluntary program available to agricultural producers to help them safeguard environmentally sensitive land. Producers enrolled in CRP plant long term, resource covering covers to improve the quality of water, control soil erosion, and enhance wildlife habitat. In return, FSA provides participants with rental payments and cost share assistance. Environmentally desirable land devoted to certain conservation practices may be enrolled in CRP at any time under continuous sign-up.

Continuous sign-up contracts are 10 to 15 years in duration. The land must be eligible and suitable for any of the following conservation practices: riparian buffers, wildlife habitat buffers, wetland buffers, filter strips, wetland restoration,

grass waterways, shelterbelts, living snow fences, contour grass strips, salt tolerant vegetation, and shallow water areas for wildlife.
(FSA website, http://www.fsa.usda.gov/pas/publications/facts/html/crpcont03.htm, accessed 5/23/06).

Re-invest in Minnesota (RIM)Reserve Program
The Reinvest in Minnesota (RIM) Reserve Program is managed by the Minnesota Board of Water and Soil Resources. RIM is designed to protect and improve water quality and reduce soil erosion through the planning of permanent vegetation and restoration of previously drained wetlands. Landowners are paid a percentage of the assessed value of their land to voluntarily enroll it in a conservation easement. Eligible land types include wetland restoration areas, riparian agricultural lands, marginal cropland, pastured hillsides, and sensitive groundwater areas. Once land is enrolled conservation practices are put in place such as native grass plantings, tree plantings, and wetland restoration. The contracts are for 45 years or permanent (MNBWSR, April 2005)

Conservation Reserve Enhancement Program-Minnesota II (CREP-II)
The Conservation Reserve Enhancement Program (CREP) – Minnesota II is a federal-state natural resource conservation program that works to meet state environmental objectives and to protect environmentally sensitive land on 120,000 acres in parts of Northwest, Southeast, and Southwestern Minnesota. CREP II combines the certain practices from the FSA Conservation Reserve Program and the Minnesota Re-invest in Minnesota (RIM) program.

Under the CREP, participants receive financial incentives for both the CRP and RIM contracts for removing cropland from agricultural production and converting the land to native grasses, trees, and other native vegetation. CRP contracts are for 14-15 years and RIM easements are for 45 years or are permanent (an exception is contour grass strips in Southeast Minnesota, which is restricted to 14- to15-year CRP contracts. The Lower Mississippi Watershed, which includes the Cannon River Watershed, is one of the targeted areas for CREP II enrollment. (FSA website, http://www.fsa.usda.gov/pas/publications/facts/html/crepmn05.htm, accessed 5/23/06).

- Rotational Grazing (Kevin Blanchet, personal communication 5/26/06)

Rotational grazing is a forage-based livestock production system that relies on controlling the movement of livestock to maximize the forage and land resources. With rotational grazing, only one portion of the pasture is grazed at a time while the remainder of the pasture is allowed to rest. This is accomplished by subdividing the pasture into smaller areas, called paddocks, and by moving livestock from one paddock to another based on the supply of forage in the paddock. By resting grazed paddocks, forage plants will have faster regrowth and more vigor as a result of having more leaf area to intercept light and deeper root systems for improved nutrient and water uptake. In contrast, continuously grazed pastures have lower long-term forage production because this grazing system ends up having inadequate leaf cover, shallow root systems and poor plant vigor.

Rotational grazed pastures have several environmental advantages to tilled land or to continuously grazed pastures: they dramatically decrease soil erosion potential, require minimal pesticides and fertilizers, and decrease the amount of nutrient runoff. Grazing management that encourages tall, vigorous growing vegetation will result in higher water infiltration into the soil, thus reducing the water, soil and nutrient runoff losses. If streams cut through pasture land, good grazing management practices are needed to prevent soil erosion and protect water quality. When grazing along streams, rotational grazing can be used as a tool to manage livestock activity for maintaining healthy stream bank vegetative cover while controlling unwanted plant species.

- Cover Crops
  Cover crops are used to protect soil from erosion during times when row crops are not established. These cover crops include rye, oats, barley and alfalfa. The cover crop then helps to keep the soil in place and also provides a source of forage and nutrients. Late summer aerial seeding of rye into a corn crop was successful in 2005 in the Zumbro River watershed in southeastern Minnesota. Cattle were then able to use this rye for grazing.

- Sediment budget
  Development of a sediment budget would help to give a more complete picture of the situation (B. Thompson, personal communication, May 9, 2006). Figure 25 (taken from the Proceedings of the Seventh Federal Interagency Sedimentation Conference 2001, Reno, Nevada), illustrates the sedimentation process. In the Upper Midwest region, sediment budgets have been developed for several watersheds. These include the Coon Creek Watershed in southwestern Wisconsin, the Whitewater River Watershed of southeastern Minnesota, and the Nemadji River Basin of northern Minnesota and Wisconsin. The results of these projects demonstrate the need to acknowledge sediment sources, sinks and yields – all occurring over a longer timeframe than we typically deal with as we assess streams for water column turbidity and/or suspended sediment parameters (B. Thompson, personal communication, May 9, 2006). If soil erosion is improving in the watershed we may not see an improvement downstream for years to come as the soil is trapped in these sinks. Alternatively, we may also not see worsening of erosion conditions as the sediment is not necessarily reaching the streams for us to measure. It is important to review erosion rates and make visual observations as well as monitor for transparency and suspended sediment to get a complete picture of what is occurring.

Figure 25 - Sedimentation Process

Proceedings of the Seventh Federal Interagency Sedimentation Conference, March 25 to 29, 2001, Reno, Nevada

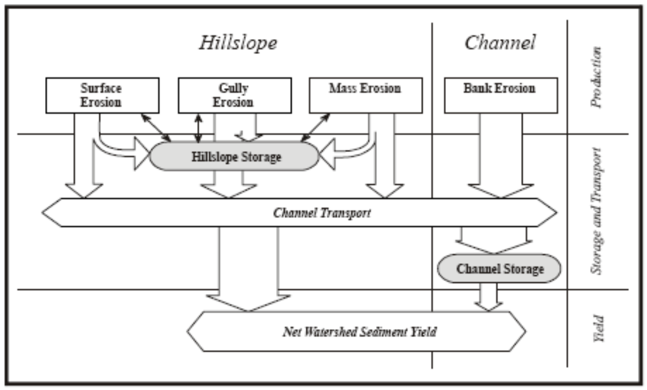


Figure 1 Sedimentation process (after USEPA, 1999).

- Water retention projects can be used to reduce peak flows and spread the flow out over longer time periods. In 1998, severe storms in the area produced very heavy flows in the headwater areas of the Little Cannon River and Belle Creek. Both of these streams are of similar size, however there are water retention structures in the upper sections of Belle Creek. An NRCS employee noted that there was much more damage in the Little Cannon watershed as opposed to Belle Creek as a result of reductions in flooding due to the retention structures (T. Steger, personal communication, May 24, 2006). Water retention practices can range from larger in-channel structures to smaller scale practices such as road culvert downsizing, interception of tile flows, and wetland restorations. Larger in-channel structures, while providing flow stabilization and sedimentation benefits, may also have negative impacts such as increasing stream temperatures or blocking the free movement of aquatic life.

<u>Urban Stormwater management</u>
There are no cities in the Lower Cannon River watershed which are required to obtain MS4 permits for stormwater. (Red Wing, which is required to have a permit, discharges stormwater primarily to the Mississippi River). However, the communities can and will be encouraged to implement BMPs with measurable goals and to conduct effectiveness monitoring. Educational efforts will also be conducted to inform residents about stormwater pollution. In the remainder of the Cannon River Watershed, the Cites of Northfield, Faribault, Owatonna, and Waseca will all be required to apply for MS4 permits which include BMP implementation and education. Active enforcement of MS4 permit requirements and vigorous application of the required Storm Water Pollution Prevention Plans (SWPPPs) will be critical.

<u>Point Sources</u>
Municipal and Industrial NPDES permit holders are given discharge limits for TSS as part of their permit. The wasteload allocations assigned to these facilities are based up their current permit limits. Provided the facilities stay within their limits, no reduction activities will be required.

5.2 Monitoring and research plan

An important step in the implementation process will be ongoing monitoring of flow, turbidity, TSS, and transparency in the streams and river to determine if the conditions are changing and determine the effectiveness of reduction strategies. Partners in this process will include: citizen stream monitors, CRWP staff, the MPCA, the Dakota and Goodhue SWCDs, the MN DNR, and the USGS. Funding for monitoring is a critical issue that needs to be addressed.

Key monitoring requirements and objectives include:

- **Ensure that monitoring is well integrated with the report *Minnesota's Water Quality Monitoring Strategy 2004-2014* (MPCA, 2004).**
- **Maintaining the existing flow and water quality monitoring stations and water sampling regimes at Welch and at the confluence with the Mississippi River.**
- **Establishing a new monitoring station in conjunction with one or both of the MDNR floodwarning sites on the Little Cannon River.**
- **Develop a watershed model for the Little Cannon River watershed to help assess the effectiveness of BMP application at the watershed scale.**
- **Ensure that all implementation activities, whether they occur through local, state, or federal programs, or other means, are tracked using a reporting database such as the BWSR E-link system. This will be crucial for gauging general implementation progress, developing realistic inputs to the Little Cannon watershed model, and allowing extrapolation of model results to other areas of the larger Cannon River watershed.**
- **Continue to promote and expand citizen stream monitoring in the Cannon River watershed.**
- **Coordinate with the Minnesota Department of Agriculture , the University of Minnesota, farm organizations, and others to conduct research on soil erosion and sediment delivery processes and the effectiveness of particular BMPs. Apply results of sediment "fingerprinting" and other research that will be completed through the Lake Pepin TMDL project.**
- **Maintain all monitoring activities for a period of no less than 10 years, and preferably on a permanent basis.**

5.3 Responsible parties

Implementation of the actions listed above will require a collaborative effort by many organizations and individuals if we hope at achieve a reduction in sediment loading in the Lower Cannon River watershed. Table 12 provides a listing of potential partners and actions they could undertake.

Table 12 – Implementation Plan Partners

Partners	**Action**					
	Funding	Monitoring	Education	Conservation Practices	Data Analysis	Land Use Planning
MPCA	X	X	X		X	
Goodhue County SWCD	X		X	X		
Goodhue County Water Planner		X	X			X
Dakota County SWCD	X	X	X	X		
Dakota County Water Planner		X	X			X
CRWP		X	X	X	X	
NCRWMO	X		X	X		
Belle Creek Watershed District	X			X		X
MN DNR	X	X	X			
Extension Service			X	X		X
USGS		X				
Local governments	X		X			X
Land Owners		X		X		X
Other Citizens		X		X		X

6.0 REASONABLE ASSURANCE OF IMPLEMENTATION

The following should be considered as reasonable assurance that implementation will occur and result in sediment load reductions in the reaches of the Cannon River to meet their designated uses.

- The technical committee had broad representation from government, academia, citizens, and agricultural experts. Input was sought from a variety of groups to assure the most complete document possible.
- Representatives from Dakota and Goodhue SWCDs, the North Cannon River WMO, the Belle Creek Watershed District, NRCS, University of Minnesota Extension, and the Cannon River Watershed Partnership will continue to be actively involved in assisting land owners and operators to implementing erosion control activities.
- Local water plans address erosion control as a key priority for current and future projects.
- Local, state and federal funds are available to pay for conservation easements on sensitive lands.
- Monitoring and research will be conducted to track progress and suggest adjustment in the implementation approach.
- There is local interest from citizens to “clean up” the Cannon River to improve recreational suitability.
- The MPCA and local entities have active construction, urban, and industrial stormwater management programs.
- Continued funding for TMDL implementation and water quality monitoring through the state Clean Water Legacy Act appears promising.

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Appendix A - Macroinvertebrate Summary and Habitat Assessment on Lower Cannon River sites from *Baseline Assessment of Water Quality in Streams of the Cannon River Watershed*, 1996

Location	QHEI	ICI				Richness				Diversity				Equitability			
		June	July	Avg	Impact	June	July	Ave	Impact	June	July	Ave	Impact	June	July	Ave	Impact
Lower Cannon Mainstem Average	63.0	36	33	34	Slt	25	22	23.4	Slt	3.2	2.2	2.7	Slt	0.57	0.33	0.45	Mod
Lower Cannon Tributaries Average	72.1	35	34	34	Slt	23	21	21.9	Slt	3.3	2.8	3.1	Non	0.65	0.55	0.60	Slt

Data taken from Table 2: Cannon River monitoring sites in June and July and the average of the two 1996 data samples.
Impact Codes - -- Non=Non-impacted Slt = Slight Impact Mod = Moderately Impacted Sev = Severely Impacted

Lower Cannon Mainstem includes sample sites at: Lower Cannon at Hwy 61, Lower Cannon at Randolph, Lower Cannon at Hwy 3 Dundas and Lower Cannon at Faribault.

Lower Cannon Tributaries include sample sites at: Belle Creek Near Welch, Pine Creek Near Cannon Falls, Little Cannon at Oxford Mill, Prairie Creek Near Randolph, Chub Creek at Randolph, Heath Creek at Sechler Park, Wolf Creek at Rice Cty 8.

From text of report:
Qualitative Habitat Evaluation Index (QHEI) is a physical habitat index designed to provide an empirical, quantified evaluation of the streams habitat quality. The score was computed by adding the components of seven metrics to obtain the metric scores (total maximum score 100). The QHEI provided a means of comparing the habitat of each of the sampling sites to one another. However, it should be noted that on many occasions, stream characteristics at the immediate sampling site varied greatly from the characteristics only a short distance up or down stream. Varying land management practices by each owner of property adjacent to the stream resulted in a wide range of scores especially in the riparian zone and instream cover metrics. The lowest QHEI scores (of all sample sites in the project) were both sites where landuse was unfenced pasture. In general the highest scores were at sites where there was a wide (greater than 25 meters) riparian zone that was left in a natural condition unaffected by human activity.

Invertebrate Community Index (ICI) was developed by the Ohio EPA as a modification of the IBI for fish. It consists of ten structural and functional community metrics with four scoring categories to reflect the following levels of biological community conditions: 6 exceptional, 4 good, 2 fair, and 0 poor

Richness is simply the total number of taxa in a community. Streams with more than 25 taxa are generally regarded as non-impacted while communities with less than 10 taxa are considered severely impacted.

Diversity indicates the relative importance of each species collected, not merely the relationship between the total numbers of species and individuals. Values for unpolluted streams are generally between 3 and 4, and for polluted streams were generally less than 1.

Equitability (e) values will range between 0 and 1 for most samples. EPA data indicates that streams in the southeastern United States unaffected by oxygen-demanding wastes generally have “e” values of 0.6 to 0.8 and never below 0.5, and even slightly impacted streams have “e” values below 0.5 and generally range from 0.0 to 0.3.

Appendix B: MDNR Fisheries Data: Cannon River Fish Species List provided by Al Schmidt, MDNR Fisheries; Trout Brook and Tributary Data from MPCA Environmental Data Access System

Species	Mouth - Byllseby Dam	Byllesby - Northfield	Northfield - Faribault
Brook Trout	X		
Brown trout	X		
Bowfin	X		
Mooneye	X		
Longnose gar	X		
Northern pike	X	X	X
Muskellunge	X	X	
Central stoneroller	X	X	X
Gizzard shad	X		
Burbot	X		
Common carp	X	X	X
Carpsucker sp.	X	X	X
Creek chub	X	X	X
Hornyhead chub		X	X
Speckled chub	X		
Silver chub	X		
Spottail shiner	X	X	
Common shiner	X	X	X
Spotfin shiner	X	X	X
Emarald shiner	X		
Mimic shiner	X		
Rosyface shiner		X	X
Bigmouth shiner	X	X	X
River shiner	X	X	X
Golden shiner	X	X	
Sand shiner	X	X	X
Ozark minnow		X	
Bluntnose minnow	X	X	X
Fathead minnow	X	X	X
Brassy minnow	X	X	X
Bullhead minnow	X		
Pearl dace	X		
Blacknose dace	X	X	X
Longnose dace	X	X	X
Quillback	X	X	X
White sucker	X	X	X
Northern hogsucker	X	X	X
Smallmouth buffalo	X		
Bigmouth buffalo	X	X	X
Greater redhorse		X	X
Silver redhorse	X		
Golden redhorse	X	X	X
Shorthead redhorse	X	X	X
Yellow bullhead		X	X
Black bullhead	X	X	X
Channel catfish	X	X	X
Tadpole madtom			X
Stonecat	X	X	
Flathead catfish	X		
White bass	X	X	X
Green sunfish	X	X	X
Pumpkinseed	X	X	X
Bluegill	X	X	X
Orangespotted sunfish			X
Hybrid sunfish	X	X	X
Rock bass	X	X	X
Largemouth bass	X	X	X
Smallmouth bass	X	X	X
White crappie	X	X	X
Black crappie	X	X	X
Mud darter	X		
Blackside darter	X	X	X
Slenderhead darter	X		
Fantail darter	X	X	X
River darter	X		
Johnny darter	X	X	X
Yellow perch	X	X	X
Logperch	X	X	X
Sauger	X		
Walleye	X	X	X
Freshwater drum	X	X	X

Biological Station Information

Photo not available

Lat/Lon: 44.5652/-92.8336
Datum: NAD83
County: Dakota

Stream Name	TRIBUTARY TO TROUT BROOK	
Waterbody Name	tributary to Trout Brook	
Collecting Organization	MINNESOTA DEPT OF NAT RES	
Station ID	99LM004	
Hydrologic Unit Code (HUC)	07040002	
Assessment Unit		
Period of Record	1999 through 1999	
Predominant substrate		
Mean Depth (cm)		
Mean Width (meters)		
Drainage Area (square miles)	10.1	
Land Use	Agricultural	57.0 %
	Forest	7.3 %
	Range	35.5 %
	Urban	0.2 %
	Water	0.0 %
	Wetland	0.0 %
	Other	0.0 %

Projects Associated with this Station

Project	Purpose

Metro Surveys	Monitoring sites established to characterize Twin Cities Metro Area streams.

Site Index of Biological Integrity (IBI)

Category	IBI/Rating
Fish IBI	Not Calculated
Fish Rating	
Invertebrate IBI	No Visit
Invertebrate Rating	

Chemical Data

Date	27-JUN-99
Water Temperature (°C)	12
Conductivity (µmhos/cm)	475
Field Turbidity (NTU)	.73
Dissolved Oxygen (mg/L)	9.5
pH	7.65
Flow (m^3/sec)	
Nitrogen (mg/L)	
Total Phosphorus (mg/L)	
Total Suspended Solids (mg/L)	
Ammonia (mg/L)	

Fish Found at this Site

Species	Count	Min. Length (mm)	Max. Length (mm)
Brook Stickleback	9	31	41
Brook Trout	5	76	209

Fish Attributes

Attribute	Value
DELT (abnormalities)</A< td>	0
Darter species</A< td>	0
Exotic species</A< td>	0
Fish per 100 m</A< td>	8
Game fish species</A< td>	1
Piscivore species</A< td>	1
Pollution intolerant species</A< td>	1
Pollution tolerant	1

species</A< td>	
Special concern species</A< td>	0
Total species</A< td>	2

Invertebrates Found at Site

Common Name

Sorry, there was no data collected this year.

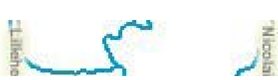
Invertebrate Attributes

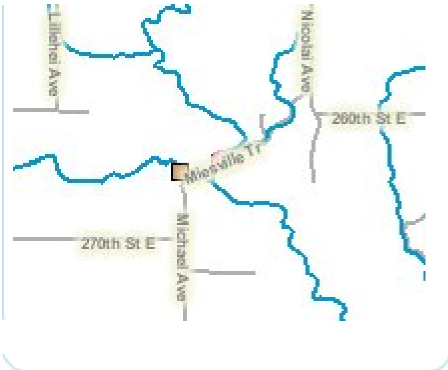
Attribute	Value
Sorry, there was no data collected this year.	

Biological Station Information

Photo not available

Stream Name	TROUT BROOK
Waterbody Name	Trout Brook
Collecting Organization	MINNESOTA DEPT OF NAT RES
Station ID	99LM005
Hydrologic Unit Code (HUC)	07040002
Assessment Unit	
Period of Record	1999 through 1999





Lat/Lon: 44.5664/-92.8275
Datum: NAD83
County: Dakota

Predominant substrate		
Mean Depth (cm)		
Mean Width (meters)		
Drainage Area (square miles)	10.1	
Land Use	Agricultural	57.0 %
	Forest	7.4 %
	Range	35.5 %
	Urban	0.2 %
	Water	0.0 %
	Wetland	0.0 %
	Other	0.0 %

Projects Associated with this Station

Project	Purpose
Metro Surveys	Monitoring sites established to characterize Twin Cities Metro Area streams.

Site Index of Biological Integrity (IBI)

Category	IBI/Rating
Fish IBI	Not Calculated
Fish Rating	
Invertebrate IBI	No Visit
Invertebrate Rating	

Chemical Data

Date	27-JUN-99
Water Temperature (°C)	12
Conductivity (µmhos/cm)	460
Field Turbidity (NTU)	1.04
Dissolved Oxygen (mg/L)	8.1
pH	6.92
Flow (m^3/sec)	
Nitrogen (mg/L)	
Total Phosphorus (mg/L)	
Total Suspended	

Solids (mg/L)	
Ammonia (mg/L)	

Fish Found at this Site

Species	Count	Min. Length (mm)	Max. Length (mm)
Brook Stickleback	6	42	64
Brook Trout	70	65	226

Fish Attributes

Attribute	Value
DELT (abnormalities)</A< td>	1
Darter species</A< td>	0
Exotic species</A< td>	0
Fish per 100 m</A< td>	46.6
Game fish species</A< td>	1
Piscivore species</A< td>	1
Pollution intolerant species</A< td>	1
Pollution tolerant species</A< td>	1
Special concern species</A< td>	0
Total species</A< td>	2

Invertebrates Found at Site

Common Name

Sorry, there was no data collected this year.

Invertebrate Attributes

Attribute	Value
Sorry, there was no data collected this year.	

Minnesota Pollution Control Agency, 520 Lafayette Road, St. Paul, MN 55155-4194
Phone: 651-296-6300, 800-657-3864; 24-hour emergency number: 651-649-5451 or 800-422-0798; TTY: 651-282-5332, TTY 24-hour emergency number: 651-297-5353 or 800-627-3529

Appendix C: NPDES Permit Holders

NPDES Permit Holders in the Cannon River Watershed; Facility Design Flows and TSS Mass Limits Shown Where Applicable

name	preferred_id	facility_design_flow (mgd)	pcs_parameter_name	
Cannon Falls WWTP	MN0022993	0.92		
			Solids, Total Suspended (TSS)	89 kg/day
Dennison WWTP	MN0022195	0.029		
			Solids, Total Suspended (TSS)	64 kg/day
Ellendale WWTP	MN0041564	0.1003		
			Solids, Total Suspended (TSS)	313 kg/day
Elysian WWTP	MN0041114	0.13		
			Solids, Total Suspended (TSS)	336 kg/day
Faribault Foods - Faribault Division	MN0050491	0.068		
Faribault WWTP	MN0030121	7		
			Solids, Total Suspended (TSS)	1191 kg/day
Genova Minnesota Inc	MN0046957	0.12		
Kilkenny WWTP	MNG580084	0.0228		
			Solids, Total Suspended (TSS)	78 kg/day
Lakeside Foods Inc - Owatonna Plant	MN0001571			
			Solids, Total Suspended (TSS)	96 kg/day
Lonsdale WWTP	MN0031241	0.2418		
			Solids, Total Suspended (TSS)	104 kg/day
			Solids, Total Suspended (TSS)	100 kg/day
			Solids, Total Suspended (TSS)	117 kg/day
MDNR Waterville State Fish Hatchery	MNG640122			
MNDOT Straight River Rest Area	MN0049514	0.0093		
			Solids, Total Suspended (TSS)	21 kg/day
Medford WWTP	MN0024112	0.09	Solids, Total Suspended (TSS)	
				15 kg/day
Milestone Materials - Spinler Pit	MN0063045			
Minnesota Malting Co	MN0001481	1		
			Solids, Total Suspended (TSS)	104.3 kg/day
Morristown WWTP	MN0025895	0.21		
			Solids, Total Suspended (TSS)	36 kg/day
Nerstrand WWTP	MN0065668	0.042	Solids, Total Suspended (TSS)	7.14 kg/day
Northfield WWTP	MN0024368	5.2		
			Solids, Total Suspended (TSS)	578 kg/day
Owatonna Construction Co/Sites SD001&002	MN0067792	0		
Owatonna WWTP	MN0051284	5		
			Solids, Total Suspended (TSS)	851 kg/day
Southern Minnesota Construction/Owatonna	MN0041394	0.6		
The Turkey Store - Faribault	MN0002500	0.072		
Waterville WWTP	MN0025208	0.271		
			Solids, Total Suspended (TSS)	46.1 kg/day
Aggregate Industries Inc -Multiple Sites	MNG490073			
All Flex Inc	MNG120024	0.0012		
Bergquist Co - Cannon Falls	MNG120003			
Bituminous Materials Inc - Faribault	MNG490004			
Cannon Equipment Midwest	MNG120053	0.047		
CenterPoint Energy Minnegasco Waterville	MN0063967	0.4		
Emerson Network Power Connectivity Solut	MNG120007	0.027		
Eureka Sand & Gravel Inc - Eureka Pit	MNG490077			
Faribault Energy Park	MNG255083			
Gemini Inc - Pretreatment	MNG120057			
Hope Creamery	MN0001317	0.017		
Koch - Wood River Pipeline	MN0064700			
Lake Volney Estates WWTP	MN0067776	0.011993		
Lazy U Mobile Home Park	MN0041106	0.0218		
MDNR Nerstrand State Park	MN0046558	0.001		
Mercury Minnesota Inc	MNG120047			
Multek Flexible Circuits - Pretreatment	MNP055484	0.18		
Multek Flexible Circuits Inc - NCC	MNG255031	0.163		
Owatonna Construction Co	MNG490064			
Plainview Milk Products Coop	MNG250044			
Telamco Inc	MNG255064			
Tri-County Aggregate Inc	MNG490176			
Viracon	MNG255078	0.175		
Witte Brothers Inc	MNG490156	0		
Wondra Pit	MNG490130			

Industrial Stormwater Permit Holders in the Cannon River Watershed

preferred_id	name	site_addr	site_city	county_name
A00013960	Amesbury Group Inc - SW	105 Washington St	Cannon Falls, MN 55009	Goodhue
A00000406	Cemstone Products - Cannon Falls - SW	2133 County Road 29	Cannon Falls, MN 55009	Goodhue
164129355	Hancock Concrete - Cannon Falls - SW	RR 3	Cannon Falls, MN 55009	Goodhue
060470317	Archer Daniels Midland - Red Wing - SW	118 Main St	Red Wing, MN 55066	Goodhue
A00013540	Cemstone Frotenac Site 2 - SW	33305 Highway 61 Blvd	Red Wing, MN 55066	Goodhue
A00000412	Cemstone Products - Red Wing - SW	27592 Highway 61 Blvd	Red Wing, MN 55066	Goodhue
A00010120	Goodhue Co/Red Wing Mixed Mun SW Land	1521 Bench St	Red Wing, MN 55066	Goodhue
009771304	Laidlaw Transit Inc 7003 - Red Wing - SW	714 Bench St	Red Wing, MN 55066	Goodhue
051692614	Monson Trucking Inc - Red Wing - SW	27319 Highway 61 Blvd	Red Wing, MN 55066	Goodhue
A00000517	NSP/Xcel Energy Red Wing Rdf Ldfl - SW	Bench St & Featherstone Rd	Red Wing, MN 55066	Goodhue
A00007502	NSP/Xcel Energy Red Wing Steam Plant -SW	801 5th St E	Red Wing, MN 55066	Goodhue
089489181	Neufeldt Industrial Services Inc - SW	211 Pioneer Rd	Red Wing, MN 550663921	Goodhue
193139417	Ole Miss Marina - SW	Baypoint Park	Red Wing, MN 55066	Goodhue
061441465	Riviera Cabinets - SW	3860 Vermillion St	Red Wing, MN 55066	Goodhue
006161723	SB Foot Tanning Co - SW	805 Bench St	Red Wing, MN 55066	Goodhue
A00002177	St Paul Terminals dba SPT's Metal Ex-SW	1220 Brick Ave	Red Wing, MN 55066	Goodhue
A00005620	UPS - Red Wing - SW	880 Bench St	Red Wing, MN 55066	Goodhue
147584304	USG Interiors - Red Wing - SW	27384 Highway 61 Blvd	Red Wing, MN 55066	Goodhue
A00007501	NSP/Xcel Energy Praire Island Plant - SW	1717 Wakonade Dr E	Welch, MN 55089	Goodhue
188563753	Sustane Corp - Natural Fertillizer - SW	310 Holiday Ave E	Cannon Falls, MN 55009	Goodhue
A00000956	Viking Auto Salvage - SW	26548 Chippendale Ave	Northfield, MN 55057	Dakota
059668566	Fessel Pallet Recycling - SW	RR 2	Waterville, MN 560969802	Le Sueur
A00000822	ABC Bus Companies Inc - SW	1506 30th St NW	Faribault, MN 55021	Rice
A00005580	BH Heselton Demolition Landfill - SW	Highway 60 E	Faribault, MN 55021	Rice
A00011442	Bonger/Met Con Construction Demolition	18100 Cagger Trl	Faribault, MN 55021	Rice
A00000416	Cemstone Products - Northfield - SW	1501 Riverview Ln	Northfield, MN 55057	Rice
A00001018	Distributor Bulk Plant/Kucera - SW	1128 3rd Ave NW	Faribault, MN 550213720	Rice
A00005160	FMC FoodTech Inc - SW	1700 Cannon Rd	Northfield, MN 55057	Rice
A00000903	Faribault Municipal Airport - SW	3401 Highway 21 W	Faribault, MN 55021	Rice
A00000904	Faribault Municipal Public Works - SW	28 State Ave	Faribault, MN 550214330	Rice
022789861	Harley's Auto Salvage - SW	510 20th St NW	Faribault, MN 55021	Rice
A00016380	Jennie-O Turkey Store - Faribault Plant SW	1116 NW 4th Ave	Faribault, MN 55021	Rice
A00001188	Johnson Auto Salvage - SW	3300 150th St E	Faribault, MN 55021	Rice
A00000569	Kelly Auto Parts - SW	1814 7th St NW	Faribault, MN 55021	Rice
A00008041	Lonsdale Painting/Trimcote	104 Demann Ct	Dundas, MN 55019	Rice
A00002620	Malt-O-Meal Co - SW	701 5th St W	Northfield, MN 55057	Rice
083463570	McDonough Truck Line - SW	3115 Industrial Dr	Faribault, MN 550211700	Rice
preferred_id	**name**	**site_addr**	**site_city**	**county_name**
A00002365	McQuay International/Faribault - SW	300 24th St NW	Faribault, MN 55021	Rice
A00009820	Rice County Landfill - SW	3800 145th St E	Dundas, MN 55019	Rice
A00013480	Shafer Contracting Co Inc Pelant Pit-SW	1780 - 30th St W	Webster, MN 55088	Rice
A00013461	Shafer Contracting Inc Streefland Pit - SW	3200 Bagley	Webster, MN 55088	Rice
A00011363	Tupper Demolition Landfill - SW	12330 Cabot Ave	Dundas, MN 55019	Rice
A00005609	UPS - Faribault Center - SW	1820 6th St NW	Faribault, MN 55021	Rice
A00006240	Viratec Thin Films Inc - SW	2150 Airport Dr	Faribault, MN 550217798	Rice
A00000759	Waste Management Inc - Northfield - SW	1510 Highway 3 S	Northfield, MN 55057	Rice
060469657	AMPI - Owatonna - SW	3100 Parkway Dr / Box 7F	Owatonna, MN 55060	Steele
022954556	Blount Inc - SW	3249 County Road 45 S	Owatonna, MN 55060	Steele
A00000967	Conway Central Express - XOW - SW	1020 28th Ave NW	Owatonna, MN 55060	Steele
047243035	Fabricated Wood Products Inc - SW	6150 Frontage Rd W	Medford, MN 55049	Steele
A00008301	FedEx Freight East Inc - Owatonna - SW	1060 26th Place NW	Owatonna, MN 55060	Steele
A00008540	Ferro Graphics Inc - SW	2424 Highway 14 W	Owatonna, MN 55060	Steele
006158612	Gandy Co - SW	528 Gandrud Rd	Owatonna, MN 55060	Steele
A00005220	McQuay International/Owatonna - SW	1001 21st Ave NW	Owatonna, MN 55060	Steele
092788421	Misgen Auto Parts - SW	12880 SW 72nd Ave	Ellendale, MN 560262184	Steele
161926381	Owatonna Construction Co - SW	5145 51st St SW	Owatonna, MN 55060	Steele
022984165	Owatonna Metal Recycling Inc - SW	1210 Industrial Rd	Owatonna, MN 55060	Steele
A00000868	Owatonna Municipal Airport - SW	3800 W Frontage Rd	Owatonna, MN 55060	Steele
A00005619	UPS - Owatonna Center - SW	3350 Park Dr	Owatonna, MN 55060	Steele
A00006780	Viracon Inc - SW	800 Park Dr	Owatonna, MN 55060	Steele
A00005562	Waste Management Inc - Owatonna - SW	1171 Brady Blvd	Owatonna, MN 55060	Steele
155990120	Clemons Bus Line Inc	1904 N State St	Waseca, MN 560932664	Waseca
A00000886	Corchran Inc - SW	1340 S State St	Waseca, MN 560933925	Waseca
059027078	Design Homes of Minnesota - SW	PO Box 462	Waseca, MN 560930462	Waseca
193131984	Highway 14 Auto Parts - SW	15062 US Highway 14	Waseca, MN 56093	Waseca
A00001104	Kuskies Salvage - SW	8114 415th Ave	Janesville, MN 560481200	Waseca
193195005	Marie's Excavating - SW	40163 State Highway 13	Waseca, MN 56093	Waseca
SWIS00100	Waseca Co SLDF - SW	See location description	Waseca, MN 56093	Waseca

Construction Permits in the Lower Cannon River Watershed

preferred_id	name	city_name	county_name	start	end	Acres Disturbed
C00015313	Fox Hollow - CSW	Miesville	Dakota	5/25/2005 0:00	6/30/2005 0:00	4.37
C00004658	3rd/Water/ Minnesota Streets - CSW	Cannon Falls	Goodhue	8/10/1997 0:00	6/15/1998 0:00	7.2
C00017212	Back Bowl at Welch Village - CSW	Welch	Goodhue	1/2/2006 0:00	12/26/2009 0:00	30
C00010162	Boldon Paper Company CSW	Cannon Falls	Goodhue	6/22/2003 0:00	9/30/2003 0:00	4
C00007814	Briarwood CSW	Red Wing	Goodhue	6/20/2001 0:00	10/1/2002 0:00	80
C00009131	Cannon Bluffs (Residential)	Cannon Falls	Goodhue	9/16/2002 0:00	5/31/2003 0:00	5
C00013302	Cannon Bluffs 2nd - CSW	Cannon Falls	Goodhue	10/8/2004 0:00	6/30/2005 0:00	13.75
C00013702	Cannon River Bluffs - CSW	Red Wing	Goodhue	9/22/2004 0:00	11/30/2006 0:00	40
C00015798	Cannon River Bluffs 2nd - CSW	Red Wing	Goodhue	7/5/2005 0:00	11/30/2005 0:00	17
C00013641	Cannondale Court - CSW	Red Wing	Goodhue	10/1/2004 0:00	10/1/2005 0:00	10
C00015269	Charlson Crest 5th - CSW	Red Wing	Goodhue	6/1/2005 0:00	10/30/2007 0:00	21.7
C00011818	Charlson Crest Water Treatment Facility	Red Wing	Goodhue	4/12/2004 0:00	7/1/2005 0:00	3.5
C00017315	Clay City Industrial Park 5th - CSW	Red Wing	Goodhue	11/28/2005 0:00	5/15/2006 0:00	11.3
C00013514	College Ave 156-MP-04-03U - CSW	Red Wing	Goodhue	9/7/2004 0:00	11/15/2004 0:00	1.5
C00011755	Danforth Place - CSW	Red Wing	Goodhue	4/19/2004 0:00	11/1/2004 0:00	3.5
C00016334	Dave & Tammy Stephani - CSW	Red Wing	Goodhue	8/16/2005 0:00	12/30/2006 0:00	3
C00005826	Fil-Mor Warehouse CSW	Cannon Falls	Goodhue	4/16/1999 0:00	9/1/1999 0:00	6
C00012112	Goodhue-pioneer State Trl Ped Bridge 255	Red Wing	Goodhue	8/1/2004 0:00	12/1/2005 0:00	2.5
C00008617	Hay Creek / Riverfront Trail	Red Wing	Goodhue	5/1/2002 0:00	7/31/2002 0:00	6.1
C00006339	Hi Park Heights 2nd & 4th Replat - CSW	Red Wing	Goodhue	10/1/1999 0:00		10
C00006229	Hi Park Hills Townhouses - CSW	Red Wing	Goodhue	8/1/1999 0:00	8/30/2000 0:00	8.3
C00012581	Lake Beyllesby Park - Goodhue County	Cannon Falls	Goodhue	8/15/2004 0:00	10/30/2004 0:00	2.5
C00012076	Lindell Project - CSW	Cannon Falls	Goodhue	5/1/2004 0:00	5/15/2004 0:00	8
C00012804	McDonalds - Red Wing - CSW	Red Wing	Goodhue	8/20/2004 0:00	11/1/2004 0:00	1.42
C00013010	Menard's - Red Wing - CSW	Red Wing	Goodhue	6/12/2004 0:00	11/15/2005 0:00	25
C00008207	Prairie Island Indian - Upper Island Dev	Welch	Goodhue	8/20/2001 0:00	7/1/2002 0:00	20
C00012776	Prairie Island Security VBS Project	Welch	Goodhue	6/29/2004 0:00	9/1/2004 0:00	2.5
C00017645	Randy Peine Site - CSW	Welch	Goodhue	2/2/2006 0:00	12/30/2006 0:00	2
C00014855	Red Fox Townhomes - CSW	Red Wing	Goodhue	6/1/2005 0:00	10/30/2007 0:00	13.3
C00014260	Red Wing 50 Unit Catered Living Communit	Red Wing	Goodhue	12/9/2004 0:00	9/1/2005 0:00	1.6
C00014656	Red Wing Port Authority - CSW	Red Wing	Goodhue	4/15/2005 0:00	9/17/2005 0:00	30
C00012594	Residential Home/Driveway - CSW	Cannon Falls	Goodhue	6/15/2004 0:00	11/15/2004 0:00	3
C00012504	Ridgeview - CSW	Red Wing	Goodhue	6/7/2004 0:00	6/7/2005 0:00	16.5
C00012691	SAP 156-106-02 & SAP 156-109-06	Red Wing	Goodhue	6/14/2004 0:00	9/30/2004 0:00	6.5
C00017093	SAP 25-600-04 - CSW	Cannon Falls	Goodhue	10/10/2005 0:00	11/10/2006 0:00	8.5
C00014453	SAP 25-601-23 - CSW	Cannon Falls	Goodhue	5/2/2005 0:00	7/2/2006 0:00	72
C00010331	SAP 25-625-03 CSW	Cannon Falls	Goodhue	7/11/2003 0:00	11/30/2003 0:00	16
C00009946	SP 156-121-02 CSW	Red Wing	Goodhue	7/15/2003 0:00	11/1/2003 0:00	4.7
C00011493	SP 25-601-20, SAP 25-601-24 & 25-606-14	Red Wing	Goodhue	5/15/2004 0:00	11/30/2004 0:00	96
C00017129	SP 25-601-21 - CSW	Red Wing	Goodhue	5/10/2006 0:00	9/10/2007 0:00	117
C00011538	SP 25-602-21 CSW	Red Wing	Goodhue	6/1/2004 0:00	9/30/2004 0:00	8
C00009540	SP 2510-30 (TH58) CSW	Red Wing	Goodhue	3/25/2003 0:00	10/17/2004 0:00	85
C00011133	Steam Generator Replacement Site Grading	Welch	Goodhue	11/16/2003 0:00	7/30/2004 0:00	7.4
C00011926	Twin Bluffs Water Treatment Facility	Red Wing	Goodhue	4/26/2004 0:00	9/24/2004 0:00	2.6
C00014585	Two Rivers Condominiums - CSW	Cannon Falls	Goodhue	4/1/2005 0:00	12/30/2006 0:00	2.13
C00006664	Tyler Hills Development Phase II -CSW	Red Wing	Goodhue	9/1/1999 0:00		80
C00016660	Village Coop of Red Wing - CSW	Red Wing	Goodhue	9/1/2005 0:00	9/1/2006 0:00	12.5
C00016973	Villas of Rivers Ridge - CSW	Red Wing	Goodhue	6/1/2005 0:00	10/30/2007 0:00	12.5
C00012706	West 8th Addition - CSW	Cannon Falls	Goodhue	6/23/2004 0:00	8/1/2004 0:00	1.1
C00013394	Westwood 2nd - CSW	Cannon Falls	Goodhue	9/7/2004 0:00	7/15/2005 0:00	6
C00011072	Woodridge Bluffs Development	Cannon Falls	Goodhue	9/10/2003 0:00	9/1/2004 0:00	22
						974.47

Appendix D:

Total Suspended Solids (TSS) and Turbidity Data - Lower Cannon River

Date	Site	Collector	TSS (mg/l)	Turbidity (NTU)
1/4/1995	confluence	LTRMP	10.1	6
1/19/1995	confluence	LTRMP		6
2/9/1995	confluence	LTRMP	15.4	6
2/23/1995	confluence	LTRMP	26.7	8
3/8/1995	confluence	LTRMP	8.1	5
3/20/1995	confluence	LTRMP	16.4	10
4/5/1995	confluence	LTRMP	8.4	8
4/17/1995	confluence	LTRMP	31.1	16
5/4/1995	confluence	LTRMP	19	11
5/19/1995	confluence	LTRMP	18.1	11
6/2/1995	confluence	LTRMP	54.6	15
6/13/1995	confluence	LTRMP	23.7	13
6/26/1995	confluence	LTRMP	85.2	21
7/12/1995	confluence	LTRMP	76.7	31
7/26/1995	confluence	LTRMP		34
8/10/1995	confluence	LTRMP	53.7	23
8/23/1995	confluence	LTRMP	78.7	32
9/7/1995	confluence	LTRMP	21	13
9/20/1995	confluence	LTRMP	22.1	12
10/5/1995	confluence	LTRMP	24.5	11
10/18/1995	confluence	LTRMP	10.6	6
10/30/1995	confluence	LTRMP	15	10
11/13/1995	confluence	LTRMP	10.6	9
11/29/1995	confluence	LTRMP	15.9	17
12/20/1995	confluence	LTRMP	10.1	6
1/9/1996	confluence	LTRMP		4
1/22/1996	confluence	LTRMP		4
2/20/1996	confluence	LTRMP		4
3/13/1996	confluence	LTRMP		150
3/28/1996	confluence	LTRMP	87.8	57
4/9/1996	confluence	LTRMP	28.8	23
4/23/1996	confluence	LTRMP	8.6	9
5/8/1996	confluence	LTRMP	20.4	12
5/20/1996	confluence	LTRMP	63.9	30
6/5/1996	confluence	LTRMP	22.9	15
6/18/1996	confluence	LTRMP	198.4	52
7/2/1996	confluence	LTRMP	29.6	18
7/16/1996	confluence	LTRMP	60.9	36
7/31/1996	confluence	LTRMP	36.6	17
8/12/1996	confluence	LTRMP	40.2	21
8/26/1996	confluence	LTRMP	78.8	36
9/9/1996	confluence	LTRMP	32.1	17
9/24/1996	confluence	LTRMP	14.3	8
10/8/1996	confluence	LTRMP	7.4	4
10/24/1996	confluence	LTRMP	10.1	3
11/12/1996	confluence	LTRMP	10.8	6

12/3/1996	confluence	LTRMP	14.6	8
12/17/1996	confluence	LTRMP	9	3
12/31/1996	confluence	LTRMP	7.3	4
1/14/1997	confluence	LTRMP	2.2	3
2/5/1997	confluence	LTRMP	5.8	4
2/19/1997	confluence	LTRMP	8.5	5
3/4/1997	confluence	LTRMP	18	4
3/18/1997	confluence	LTRMP	34	12
4/2/1997	confluence	LTRMP	10	12
4/16/1997	confluence	LTRMP	42.6	40
5/6/1997	confluence	LTRMP	28	19
5/21/1997	confluence	LTRMP	17.2	7
6/5/1997	confluence	LTRMP	24.7	9
6/19/1997	confluence	LTRMP	19.1	8
7/2/1997	confluence	LTRMP	247.2	160
7/15/1997	confluence	LTRMP	125.4	66
7/29/1997	confluence	LTRMP	61.5	40
8/14/1997	confluence	LTRMP	50.7	16
8/27/1997	confluence	LTRMP	51.9	26
9/12/1997	confluence	LTRMP	43.5	22
9/22/1997	confluence	LTRMP	53.2	28
10/16/1997	confluence	LTRMP	26.8	16
10/27/1997	confluence	LTRMP	13.7	9
11/20/1997	confluence	LTRMP	12.7	6
12/4/1997	confluence	LTRMP	8.8	4
12/17/1997	confluence	LTRMP	5.9	3
1/6/1998	confluence	LTRMP	7.3	2
1/21/1998	confluence	LTRMP	5.9	2
2/4/1998	confluence	LTRMP	6.7	3
2/17/1998	confluence	LTRMP	108.5	43
3/5/1998	confluence	LTRMP	13.9	8
3/30/1998	confluence	LTRMP	199.8	140
4/15/1998	confluence	LTRMP	12.7	9
5/8/1998	confluence	LTRMP	53.2	19
5/21/1998	confluence	LTRMP	107.2	44
6/3/1998	confluence	LTRMP	50	25
6/19/1998	confluence	LTRMP	409.5	256
6/30/1998	confluence	LTRMP	97.3	120
7/14/1998	confluence	LTRMP	61.7	18
8/5/1998	confluence	LTRMP	55.6	19
8/20/1998	confluence	LTRMP	196.3	94
9/1/1998	confluence	LTRMP	53	24
9/18/1998	confluence	LTRMP	44.8	21
9/30/1998	confluence	LTRMP	33.9	14
10/22/1998	confluence	LTRMP	39.7	19
11/4/1998	confluence	LTRMP	28.8	13
11/19/1998	confluence	LTRMP	18.1	11
12/2/1998	confluence	LTRMP	20.3	10
12/16/1998	confluence	LTRMP	12.8	5
1/13/1999	confluence	LTRMP	5.9	3

2/2/1999	confluence	LTRMP	41.8	13
2/17/1999	confluence	LTRMP	47.7	26
3/3/1999	confluence	LTRMP	17.4	9
3/17/1999	confluence	LTRMP	509.2	250
3/30/1999	confluence	LTRMP	39.6	13
4/15/1999	confluence	LTRMP	26.8	18
5/6/1999	confluence	LTRMP	56.7	25
5/20/1999	confluence	LTRMP	9.8	8
6/2/1999	confluence	LTRMP	26.3	18
6/15/1999	confluence	LTRMP	69.6	41
7/1/1999	confluence	LTRMP	47.9	22
7/13/1999	confluence	LTRMP	55.3	26
8/6/1999	confluence	LTRMP	76.4	36
8/18/1999	confluence	LTRMP	41.8	26
8/30/1999	confluence	LTRMP	33.7	17
9/17/1999	confluence	LTRMP	31.8	22
9/29/1999	confluence	LTRMP	10.9	9
10/19/1999	confluence	LTRMP	7.6	5
11/1/1999	confluence	LTRMP	6.8	4
11/17/1999	confluence	LTRMP	6.2	3
12/1/1999	confluence	LTRMP	7.8	4
12/17/1999	confluence	LTRMP	11.6	7
12/29/1999	confluence	LTRMP	10.3	5
1/12/2000	confluence	LTRMP	16.1	9
2/9/2000	confluence	LTRMP	5.5	3
3/8/2000	confluence	LTRMP	38.6	16
4/7/2000	confluence	LTRMP	27.1	12
5/4/2000	confluence	LTRMP	39.8	16
6/1/2000	confluence	LTRMP	1889	1740
6/29/2000	confluence	LTRMP	52.6	27
7/25/2000	confluence	LTRMP	61.5	21
8/24/2000	confluence	LTRMP	40.8	18
9/19/2000	confluence	LTRMP	32.6	13
10/17/2000	confluence	LTRMP	4.2	3
11/17/2000	confluence	LTRMP	7.5	8
12/12/2000	confluence	LTRMP	8.4	4
1/10/2001	confluence	LTRMP	6.3	4
2/8/2001	confluence	LTRMP	4.8	3
3/7/2001	confluence	LTRMP	4.3	2
4/4/2001	confluence	LTRMP	276.6	69
5/29/2001	confluence	LTRMP	11	11
6/27/2001	confluence	LTRMP	15.7	14
7/23/2001	confluence	LTRMP	44.5	23
8/23/2001	confluence	LTRMP	35.2	14
9/19/2001	confluence	LTRMP	24.5	10
10/23/2001	confluence	LTRMP	9.5	5
11/14/2001	confluence	LTRMP	14.3	5
12/13/2001	confluence	LTRMP	9.6	5
1/9/2002	confluence	LTRMP	10.5	5
2/5/2002	confluence	LTRMP	2	5

3/5/2002	confluence	LTRMP	5.7	3
4/3/2002	confluence	LTRMP	14	7
5/1/2002	confluence	LTRMP	32.4	15
5/29/2002	confluence	LTRMP	23.5	10
6/25/2002	confluence	LTRMP	37.5	73
7/22/2002	confluence	LTRMP	61.9	43
8/21/2002	confluence	LTRMP	1023	846
9/18/2002	confluence	LTRMP	38.9	15
4/22/2003	confluence	LTRMP	60.6	20
5/21/2003	confluence	LTRMP	19.9	10
6/18/2003	confluence	LTRMP	41.7	20
7/17/2003	confluence	LTRMP	67.1	37
8/14/2003	confluence	LTRMP	42.4	9
9/11/2003	confluence	LTRMP	21.2	10
10/9/2003	confluence	LTRMP	11.8	6
11/6/2003	confluence	LTRMP	5.1	2
12/2/2003	confluence	LTRMP	3.6	2
12/30/2003	confluence	LTRMP	4.8	2
1/26/2004	confluence	LTRMP	3.3	3
2/26/2004	confluence	LTRMP	7.6	4
3/25/2004	confluence	LTRMP	46.5	20
4/8/2004	confluence	LTRMP	37.7	15
5/6/2004	confluence	LTRMP	54.9	24
6/2/2004	confluence	LTRMP	35.6	45
7/1/2004	confluence	LTRMP	47.6	19
7/26/2004	confluence	LTRMP	28.5	18
8/27/2004	confluence	LTRMP	15.4	8
9/24/2004	confluence	LTRMP	49.5	30
10/6/2004	confluence	LTRMP	16.6	11
11/10/2004	confluence	LTRMP	2.7	5
3/24/99	Welch	met council	18	6.6
4/6/99	Welch	met council		23
4/13/99	Welch	met council	48	18
5/10/99	Welch	met council	25	6.7
6/3/99	Welch	met council	37	12
6/21/99	Welch	met council	27	7
7/15/99	Welch	met council	13	5.1
8/30/99	Welch	met council	35	6.4
9/17/99	Welch	met council	11	5.5
10/8/99	Welch	met council	4	2.1
11/8/99	Welch	met council	6	1.6
12/14/99	Welch	met council	4	1.7
1/26/00	Welch	met council	6	1.6
2/22/00	Welch	met council	2	1.7
3/3/00	Welch	met council	12	7.5
3/16/00	Welch	met council	19	5.5
4/14/00	Welch	met council	19	4.4
5/23/00	Welch	met council	37	15
6/1/00	Welch	met council	218	60
7/24/00	Welch	met council	15	5.6

8/14/00	Welch	met council	8	3.1
9/19/00	Welch	met council	3	1.5
10/11/00	Welch	met council	5	3
11/28/00	Welch	met council	3	1.6
12/20/00	Welch	met council	2	2.3
1/5/01	Welch	met council	2	0.9
2/14/01	Welch	met council	2	1.2
3/6/01	Welch	met council	6	1.4
5/17/01	Welch	met council	16	4.8
6/18/01	Welch	met council	49	28
7/9/01	Welch	met council	13	5.5
8/28/01	Welch	met council	6	3.7
10/1/01	Welch	met council	3	2.3
10/29/01	Welch	met council	10	2
12/20/01	Welch	met council	4	1.7
1/24/02	Welch	met council	2	1.5
2/14/02	Welch	met council	4	1.9
3/25/02	Welch	met council	14	7.5
5/1/02	Welch	met council	13	6
5/20/02	Welch	met council	9	2.6
6/18/02	Welch	met council	31	15
7/15/02	Welch	met council	13	5
8/14/02	Welch	met council	21	10
9/17/02	Welch	met council	8	3.8
11/1/02	Welch	met council	5	2.4
12/19/02	Welch	met council	7	1.5
2/28/03	Welch	met council	3	3
3/18/03	Welch	met council	64	24
5/14/03	Welch	met council	13	4.2
5/30/03	Welch	met council	75	12
6/20/03	Welch	met council	6	1.7
7/30/03	Welch	met council	6	2
9/17/03	Welch	met council	3	2
9/29/03	Welch	met council	2	1.2
10/24/03	Welch	met council	2	1
11/10/03	Welch	met council	1	1.2
12/18/03	Welch	met council	3	1.6
2/6/04	Welch	met council	9	3.6
3/17/04	Welch	met council	13	3.4
4/16/04	Welch	met council	46	9.1
5/21/04	Welch	met council	137	28
5/24/04	Welch	met council	16	4.8
7/28/04	Welch	met council	4	2.9
8/26/04	Welch	met council	8	3.9
10/14/04	Welch	met council	2	2.8
10/26/1995	Welch	PCA, CRWP	8	3.3
11/29/1995	Welch	PCA, CRWP	3.6	1.9
2/13/1996	Welch	PCA, CRWP		1.2
3/4/1996	Welch	PCA, CRWP	6.4	3.6
4/16/1996	Welch	PCA, CRWP	17	7.3

5/22/1996	Welch	PCA, CRWP	21	3.6
6/11/1996	Welch	PCA, CRWP	5.2	2.2
7/30/1996	Welch	PCA, CRWP	4	1.6
8/22/1996	Welch	PCA, CRWP	4.8	1.6
9/18/1996	Welch	PCA, CRWP		1.6
2/8/1999	Welch	PCA, CRWP	2.8	1.6
3/29/1999	Welch	PCA, CRWP	20	8
4/14/1999	Welch	PCA, CRWP	38	25
5/11/1999	Welch	PCA, CRWP	29	12
6/23/1999	Welch	PCA, CRWP	20	12
7/19/1999	Welch	PCA, CRWP	14	9.5
8/31/1999	Welch	PCA, CRWP	22	8.3
9/15/1999	Welch	PCA, CRWP	3.6	11
10/15/2000	Welch	PCA, CRWP	3.6	2.8
11/7/2000	Welch	PCA, CRWP	6.8	3.7
2/13/2001	Welch	PCA, CRWP	1.2	0.87
3/6/2001	Welch	PCA, CRWP	1.6	1.1
4/3/2001	Welch	PCA, CRWP	140	21
5/29/2001	Welch	PCA, CRWP	14	8.6
6/12/2001	Welch	PCA, CRWP	25	
7/24/2001	Welch	PCA, CRWP	17	7.3
8/7/2001	Welch	PCA, CRWP	6	3.8
9/4/2001	Welch	PCA, CRWP	4.4	3.8
10/2/2002	Welch	PCA, CRWP	8.8	9.3
11/6/2002	Welch	PCA, CRWP	2.6	21.2
1/15/2003	Welch	PCA, CRWP	13	2.5
3/5/2003	Welch	PCA, CRWP	3.2	2.4
4/2/2003	Welch	PCA, CRWP	18	10.7
5/28/2003	Welch	PCA, CRWP	17	13.4
6/11/2003	Welch	PCA, CRWP	11	11.4
7/1/2003	Welch	PCA, CRWP	14	7.6
8/17/2003	Welch	PCA, CRWP	11	15.6
9/17/2003	Welch	PCA, CRWP	5.2	8.9
3/1/2004	Welch	CRWP		21
3/16/2004	Welch	CRWP		11
3/25/2004	Welch	PCA, CRWP	17	12
4/2/2004	Welch	PCA, CRWP	14	7.8
4/8/2004	Welch	CRWP		14
4/21/2004	Welch	PCA, CRWP	29	
4/27/2006	Welch	CRWP		17
5/11/2004	Welch	CRWP	170	137
5/17/2004	Welch	PCA, CRWP	47	28
5/20/2004	Welch	PCA, CRWP	2900	424
5/25/2004	Welch	PCA, CRWP	50	34
6/1/2004	Welch	CRWP		42
6/4/2004	Welch	PCA, CRWP	24	24
6/15/2004	Welch	PCA, CRWP	41	
6/18/2004	Welch	CRWP		29
6/22/2004	Welch	PCA, CRWP	25	25
7/6/2004	Welch	PCA, CRWP	23	18

7/12/2004	Welch	PCA, CRWP	68	43
7/13/2004	Welch	PCA, CRWP	35	37
7/29/2004	Welch	PCA, CRWP	6.8	7.4
8/24/2004	Welch	PCA, CRWP	6	6.4
9/15/2004	Welch	CRWP		18
10/13/2004	Welch	CRWP		8.1

Belle Creek Overview: Transparency and Turbidity Data

Introduction

The Belle Creek watershed is a 50,350 acre subwatershed of the lower Cannon River; it accounts for approximately 24% of the basin's 207,645 total acres. The entire Belle Creek drainage lies in Goodhue County, and while it includes sections of nine different townships, most of the acreage is in Belle Creek, Vasa and Leon townships. The Belle Creek watershed includes no incorporated cities—only small communities such as Vasa, Belle Creek and White Rock. The watershed includes ~850 acres (1.7%) of public land (State of MN and MN DNR) in the bottom third of the watershed; the stream joins the Cannon River just after crossing the Cannon Valley Trail (bike and walking route) in one of these publicly-owned polygons [CRWP].

There is no rating curve available for any station on Belle Creek; however, the Cannon River Watershed Partnership (CRWP) recorded stage near the mouth of the stream in 2003 and 2004. The Belle Creek watershed is very similar to that of the Little Cannon River: they are approximately the same size, overlain by similar soils and are situated adjacent to one another as the "twin" lower Cannon River tributaries to the south. It follows that the respective flows of the two streams are very similar. In 2004 the mean daily stage recorded near the mouth of Belle Creek tracked very closely the mean daily flow recorded near the mouth of the Little Cannon River.

Figure 1. Mean Daily Stage Compared to Little Cannon River Mean Daily Flow.

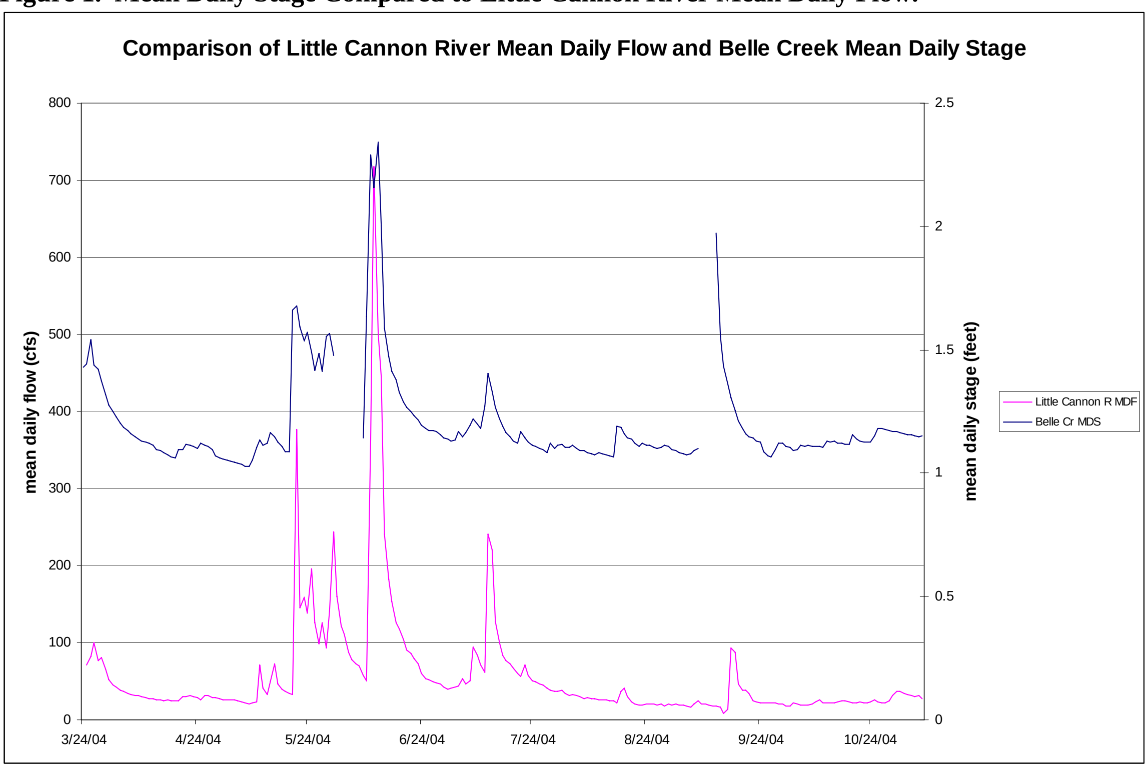
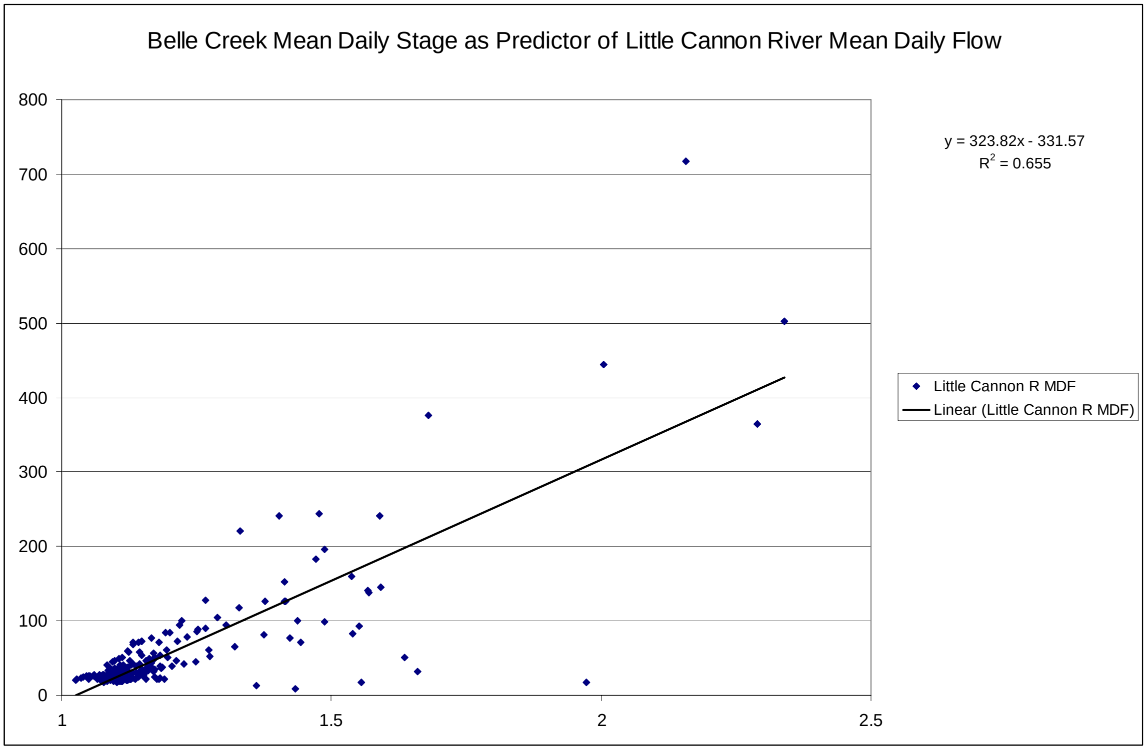


Figure 2. Mean Daily Stage as Predictor of Little Cannon River Mean Daily Flow.



Thus, it can be safely assumed that Belle Creek contributes a volume of water to the lower Cannon River system *approximately* equal to that output by the Little Cannon River.

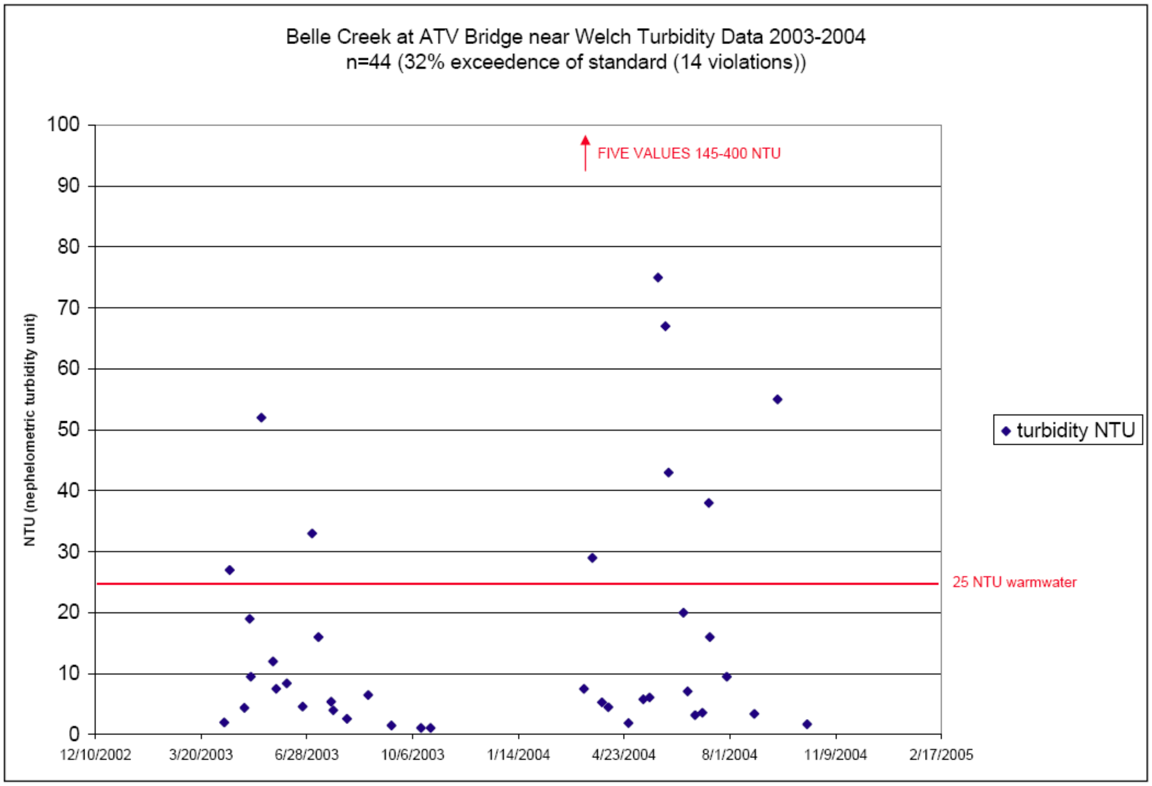
Water Quality Data

There are two active Citizen Stream Monitoring Program (CSMP) participants in the Belle Creek watershed. B-J Norman has monitored a site in the bottommost quarter of the watershed since 1999; Duane Thompson has monitored a site in the bottommost quarter of the watershed and a site near the middle of the watershed since 2003. Both of these volunteers compile a significant record of water quality data each year; they have created the best available dataset for the water body.

In 2003 and 2004 CRWP collected paired turbidity and transparency tube data near the mouth of Belle Creek. There were no CSMP volunteers actively monitoring this particular site during the project period.

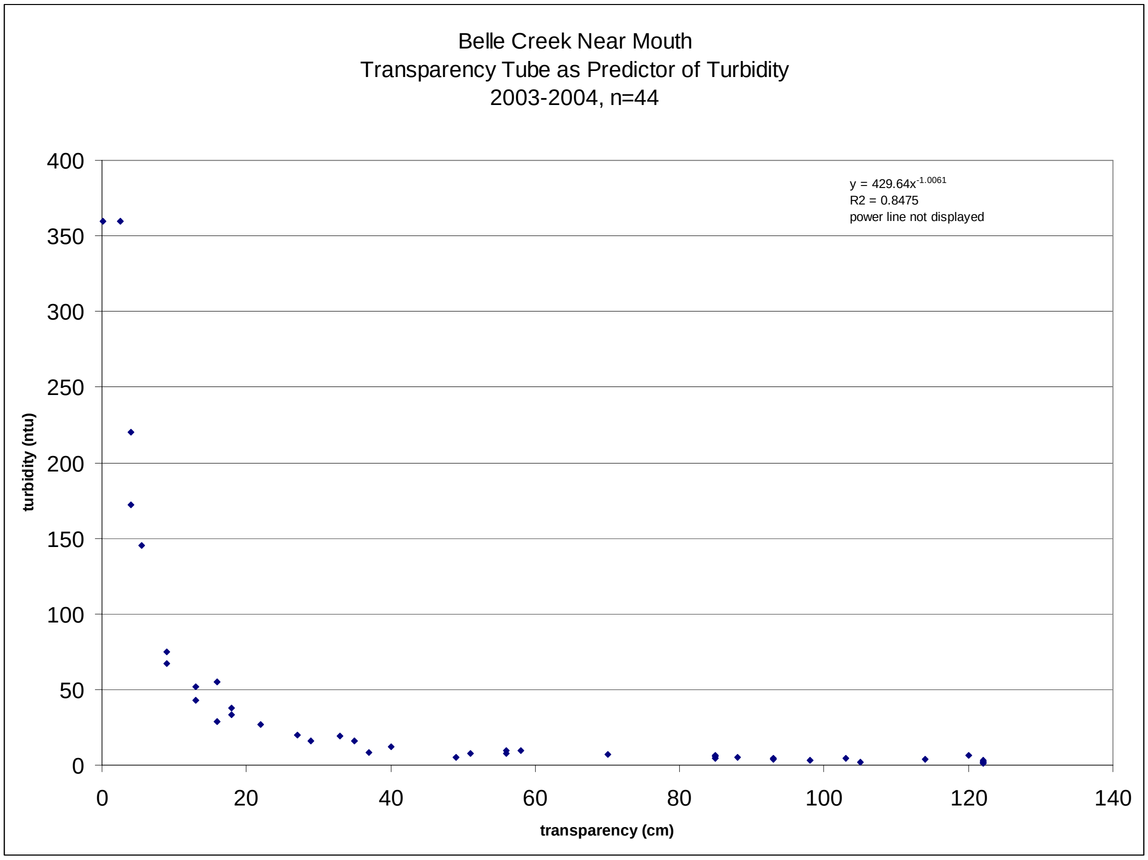
These data together indicate that Belle Creek exhibits numerous exceedences of the turbidity standard (both the warmwater and the coldwater standards) each year. In many cases, these exceedences are intense and prolonged.

Figure 3. Turbidity Data 2003-2004.



The transparency tube is a good predictor of turbidity near the mouth of the creek (the site labeled "ATV Bridge near Welch" is near the mouth of Belle Creek), according to 44 pairs of data collected in 2003 and 2004. A water clarity of approximately 17 centimeters (cm) is equivalent to a turbidity of 25 nephelometric turbidity units (ntu).

Figure 4. Transparency as Predictor of Turbidity.



Additionally, instantaneous stage measured at the CRWP gauging site is a good predictor of water clarity. At approximately 1.35 feet (2004 local datum), transparency drops below 20 cm in most cases. Even as flow recedes, it has been well documented by citizen stream monitors and CRWP staff that clarity often remains low when the water level is greater than 1.35 feet. The following figure documents that in 2004, CSMP data collected near the mouth of Belle Creek included no transparency readings >=20 centimeters recorded at a mean daily stage >=1.35 feet (the first figure depicts transparency and instantaneous stage, the second figure plots transparency in 2004 over the stage record, which consists of mean daily stage values).

Like many systems, the majority of the flow volume that moves through Belle Creek in a given year does so during events – flows that occur at a stage that is greater than 1.35 feet. Thus, it could be suggested that Belle Creek is in violation of the turbidity standard during much of its yearly volumetric loading to the Cannon River.

Figure 5. Instantaneous Stage as Predictor of Transparency Tube.

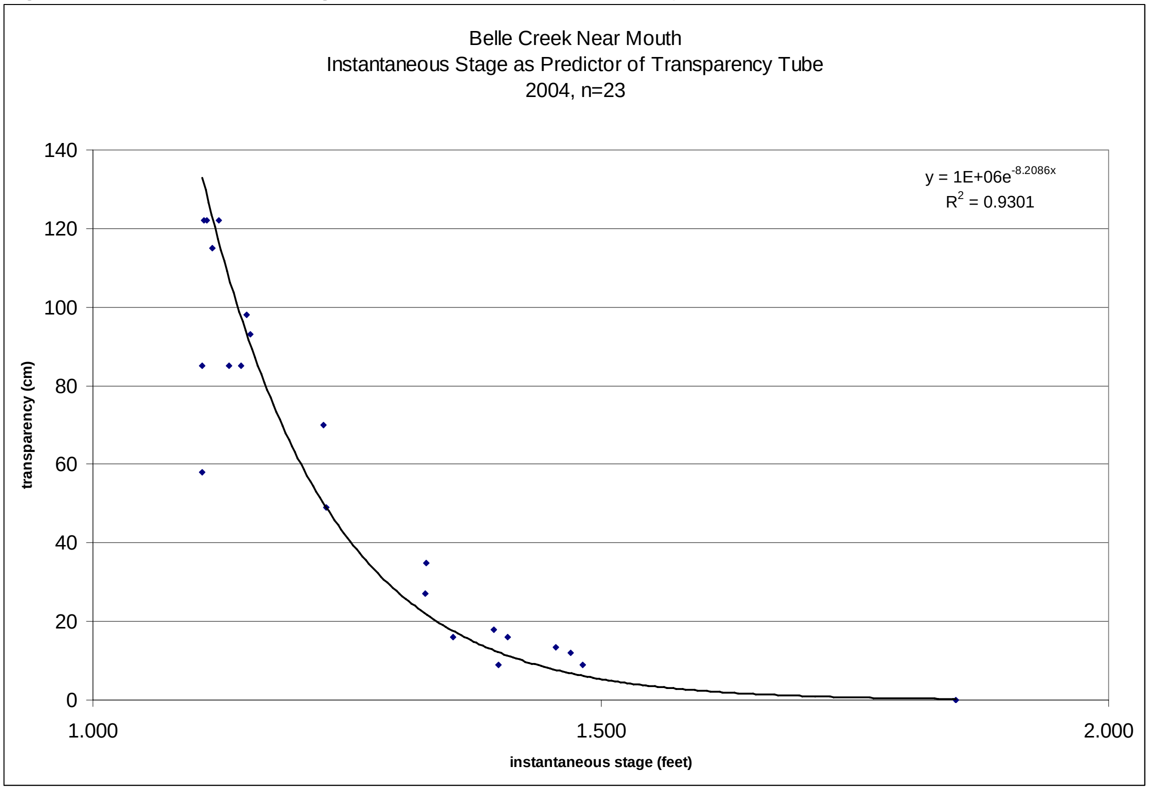
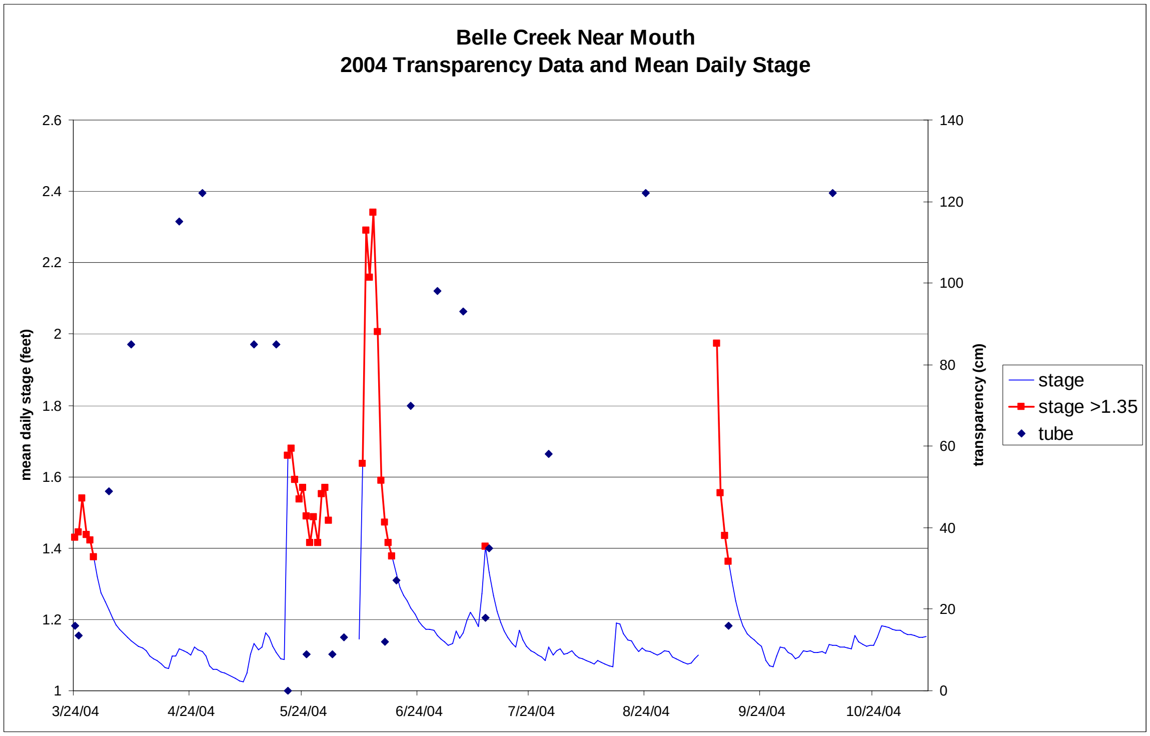


Figure 6. Transparency Tube Data and Mean Daily Stage.



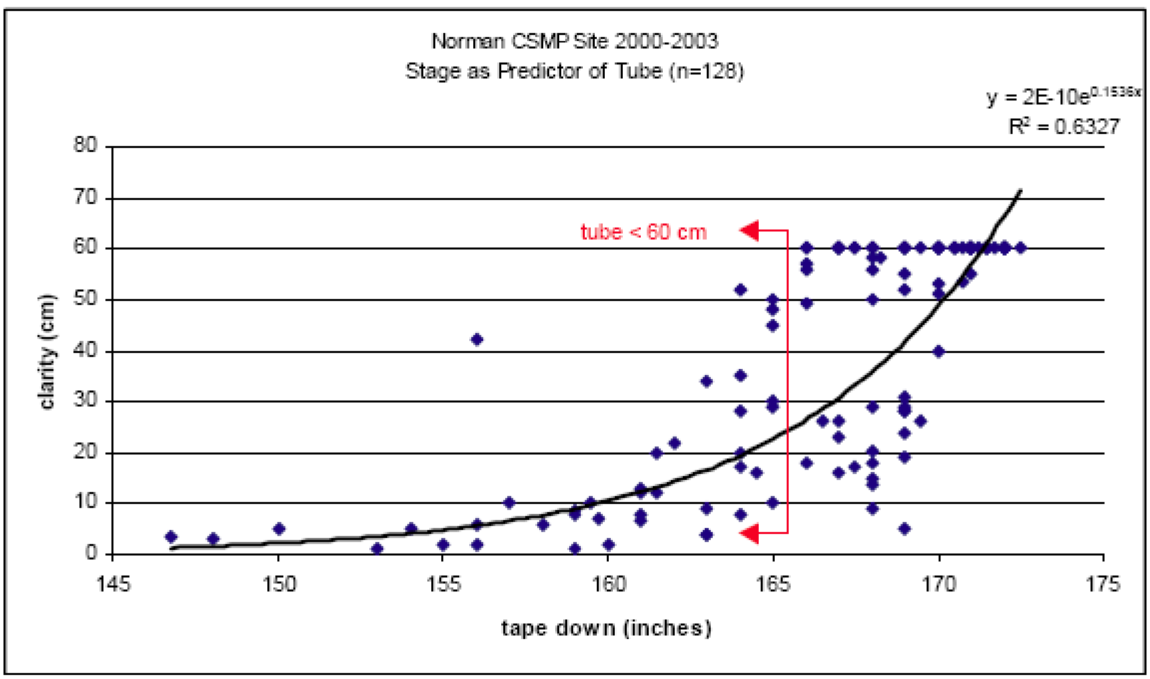
Other CSMP data suggest a similar relationship between stage and clarity. The Cannon River Watershed Partnership wrote the following regarding B-J Norman's long term record at another site near the mouth (in the bottom quarter of the watershed):

Notes Regarding Duration of Turbid Flows

1999 CSMP Data: Norman records no >60 clarity readings from 6/29 to 8/29, and each time she recorded appearance it was "muddy."

According to the extensive set of CSMP data collected by Norman, Belle Creek's clarity (at her site—recall large watershed) appears to be a function of both precipitation and stream stage (unlike Trout Br and Pine Cr, where clarity appears to be strongly related to precipitation, but not to stage). At tape-down (TD) <=165 cm, she never recorded a clarity of >60 cm, and at TD <=160 cm no clarity readings of >10 cm. Her 6/26/01 and 6/28/01 tube readings of 26 cm (both days) followed a week during which no rain fell, and a ten day period during which only 0.27 inches were recorded (her own precipitation records). However, significant precipitation fell June 13-15, and the water level at her site was still relatively high when she recorded those tube readings (TD 166.5 and 167 inches respectively). The limited data recorded at additional sites in 2003 (Thompson CSMP, CRWP at ATV bridge) document a similar correlation between stage and clarity. CRWP Field Book Note, 3/19/03 at White Rock Trail site: "South bank 'chunking' and falling into water even as I monitor—large masses of sediment/soil splashing into creek. Noted this on 3/17/03 as well." TD that day was 184.5 (6.5 inches higher than lowest level recorded that year) and tube was 22 cm [CRWP].

Figure 7. Norman CSMP Data 2000-2003 [CRWP].



General Conclusion

Belle Creek is likely a significant contributor of sediment to the lower Cannon River system. An extensive citizen stream monitoring data set and data collected by CRWP suggest that the stream reacts strongly to rain events, and the effects (turbid flows, usually in violation of the standard) have been observed to be long-lasting in many cases.

Figure 8. Photograph: May 2004 Event Flow.

Data Sources

Citizen Stream Monitoring Program Data: retrieved from the Environmental Protection Agency's STORET database.

Little Cannon River Flow Data: acquired from the Minnesota Department of Natural Resources.

Belle Creek Stage Data: acquired from the Cannon River Watershed Partnership.

Turbidity Data: acquired from Cannon River Watershed Partnership.

Bibliography

Cannon River Watershed Partnership (CRWP). *Belle Creek Folio*, 2004.

Little Cannon River Overview: Transparency and Turbidity Data

Introduction

The Little Cannon River comprises approximately 29% of the lower Cannon River watershed (60,988 of its 207,645 acres). It is the largest of the lower Cannon's tributaries. However, the top of the lower Cannon River watershed is a dam from which flows the Cannon River as it leaves the Byllesby Reservoir. Thus, despite accounting for 29% of the land area, the Little Cannon River typically contributes only 5-15% of the mean daily flow at Welch – a station on the Cannon River downstream of Cannon Falls. Depending on rainfall patterns and event magnitude, the Little Cannon may contribute up to 35-50% of the mean daily flow at Welch, but records suggest that this does not happen often. Flow at Welch usually tracks very closely the flow at the Byllesby Dam.

Figure 1. Mean Daily Flow Compared to Cannon River Mean Daily Flow.

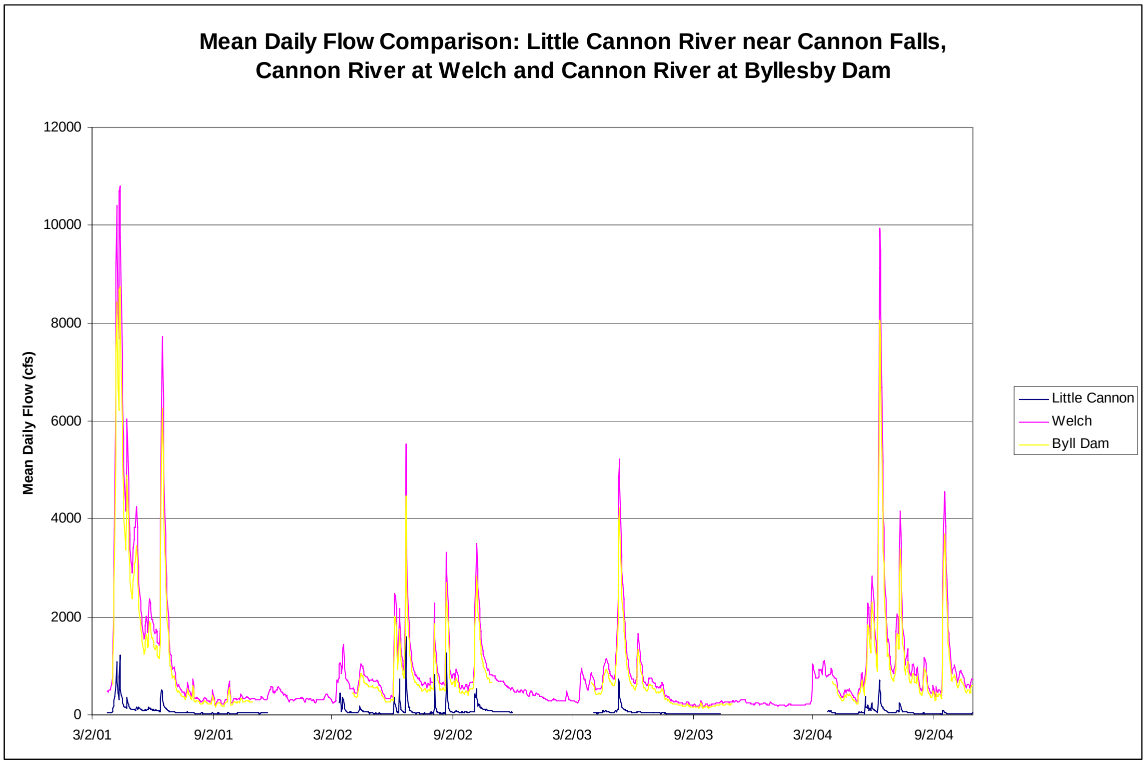
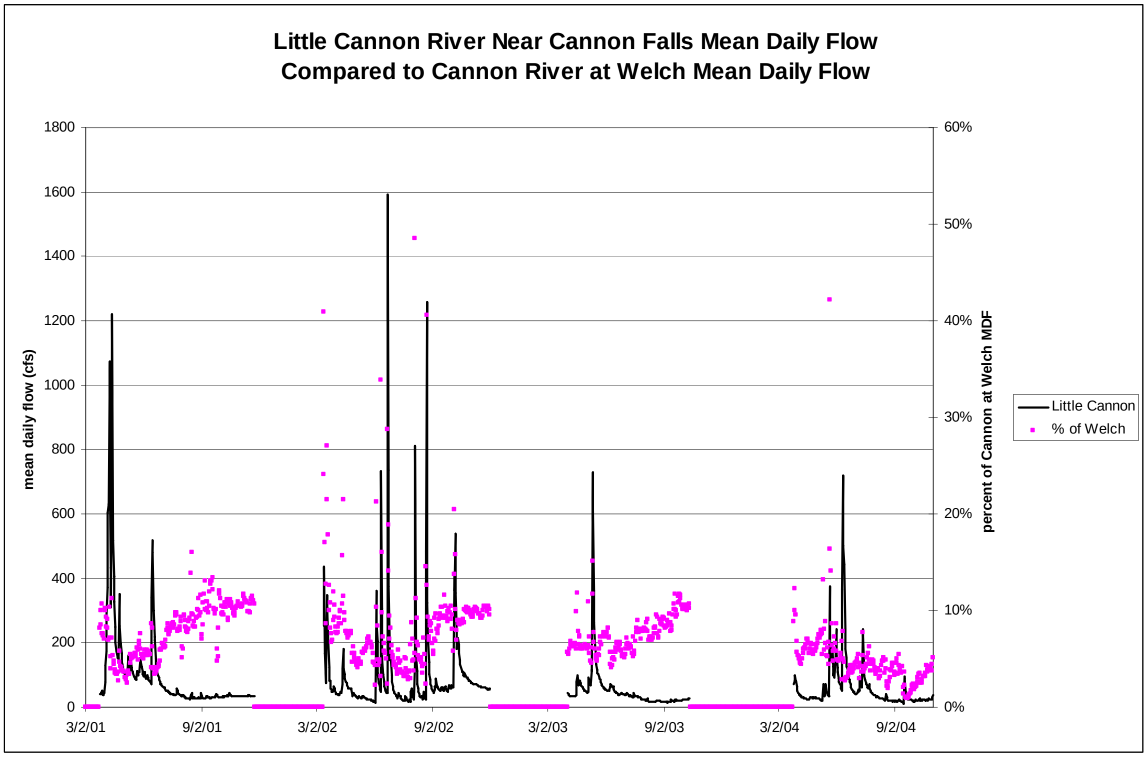


Figure 2. Mean Daily Flow Expressed as Percentage of Cannon River Mean Daily Flow.



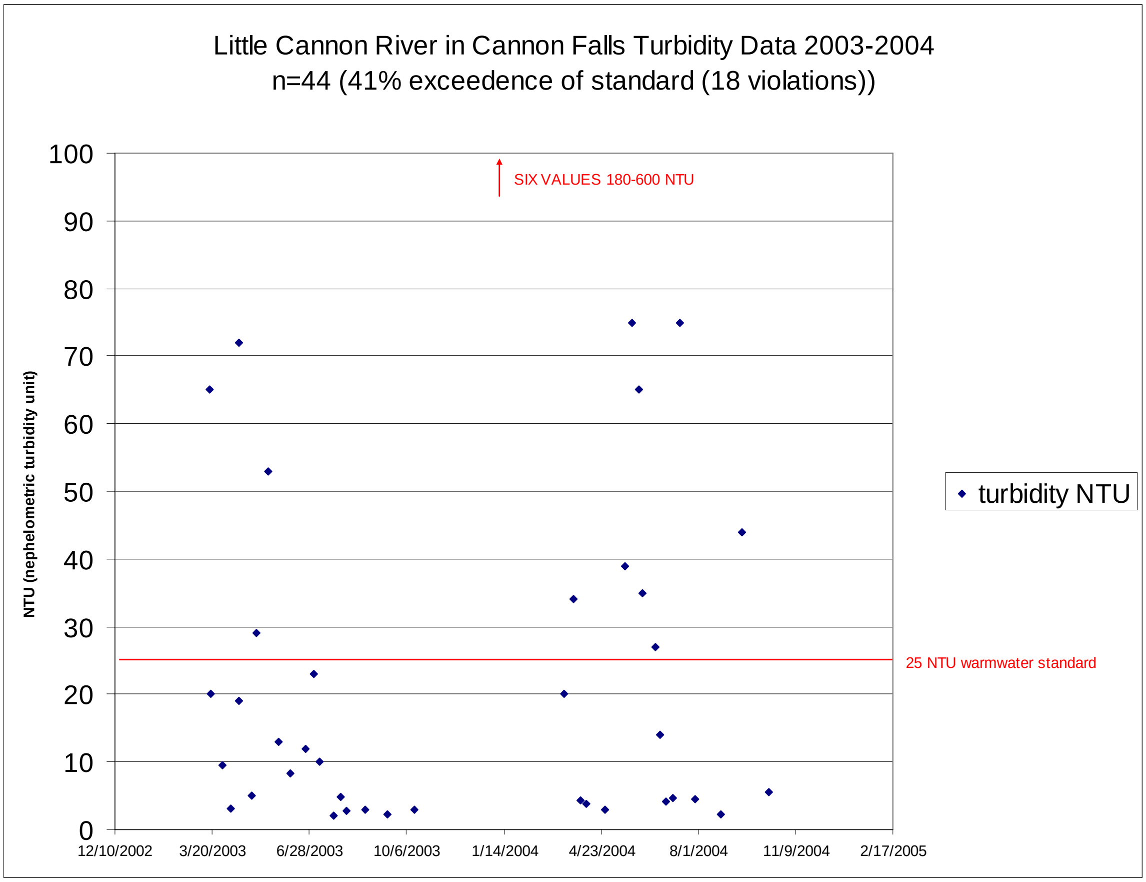
Water Quality Data

There are three active Citizen Stream Monitoring Program (CSMP) participants in the Little Cannon River watershed. Alden McCutchan has monitored a site in the uppermost quarter of the watershed since 1999; Steve Collins and Dick Dalton have both monitored sites in the bottommost quarter of the watershed since 2002. All three of these volunteers compile a significant record of water quality data each year; they have created the best available dataset for the water body.

In 2003 and 2004 the Cannon River Watershed Partnership (CRWP) collected paired turbidity and transparency tube data near the mouth of the Little Cannon River. There were no CSMP volunteers actively monitoring this particular site during the project period.

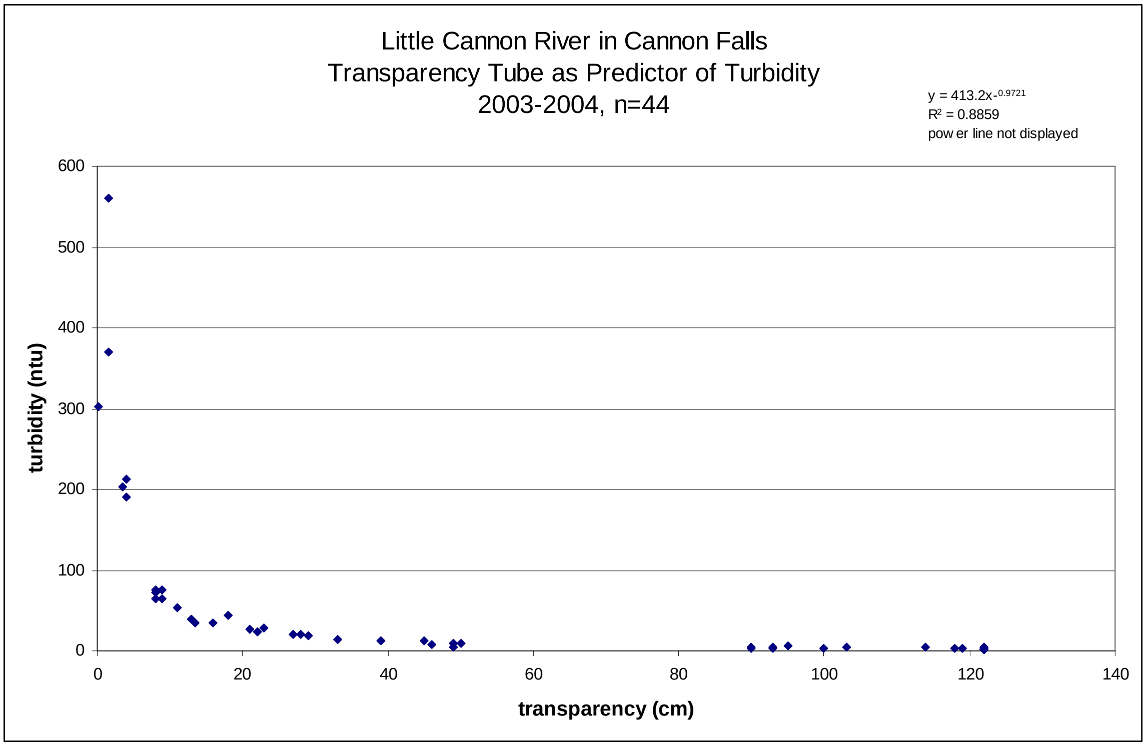
These data together indicate that the Little Cannon River exhibits numerous exceedences of the turbidity standard (both the warmwater and the coldwater standards) each year. In many cases, these exceedences are intense and prolonged.

Figure 3. Turbidity Data 2003-2004.



The transparency tube is a good predictor of turbidity near the mouth of the river, according to 44 pairs of data collected in 2003 and 2004. A water clarity value of approximately 19 centimeters (cm) is equivalent to a turbidity value of 25 nephelometric turbidity units (ntu).

Figure 4. Transparency as Predictor of Turbidity.



Additionally, instantaneous flow measured at the Department of Natural Resources (DNR) gauging site is a fair predictor of water clarity. At approximately 100 cubic feet per second (cfs), transparency drops below 20 cm in most cases. Even as flow recedes, it has been well documented by citizen stream monitors and CRWP staff that clarity often remains low when flow is greater than 100 cfs. The following figure documents that in 2002, CSMP data collected near the mouth of the Little Cannon River included only a single transparency reading >20 cm recorded at a mean daily flow of >100 cfs (the first figure depicts transparency and instantaneous flow, the second figure plots transparency in 2002 over the hydrograph, which consists of mean daily flow values).

Like many systems, the majority of the flow volume that moves through the Little Cannon River in a given year does so during events – flows that occur at a rate that is greater than 100 cfs. Thus, it could be suggested that the Little Cannon River is in violation of the turbidity standard during much of its yearly volumetric loading to the Cannon River.

Figure 5. Instantaneous Flow as Predictor of Transparency Tube.

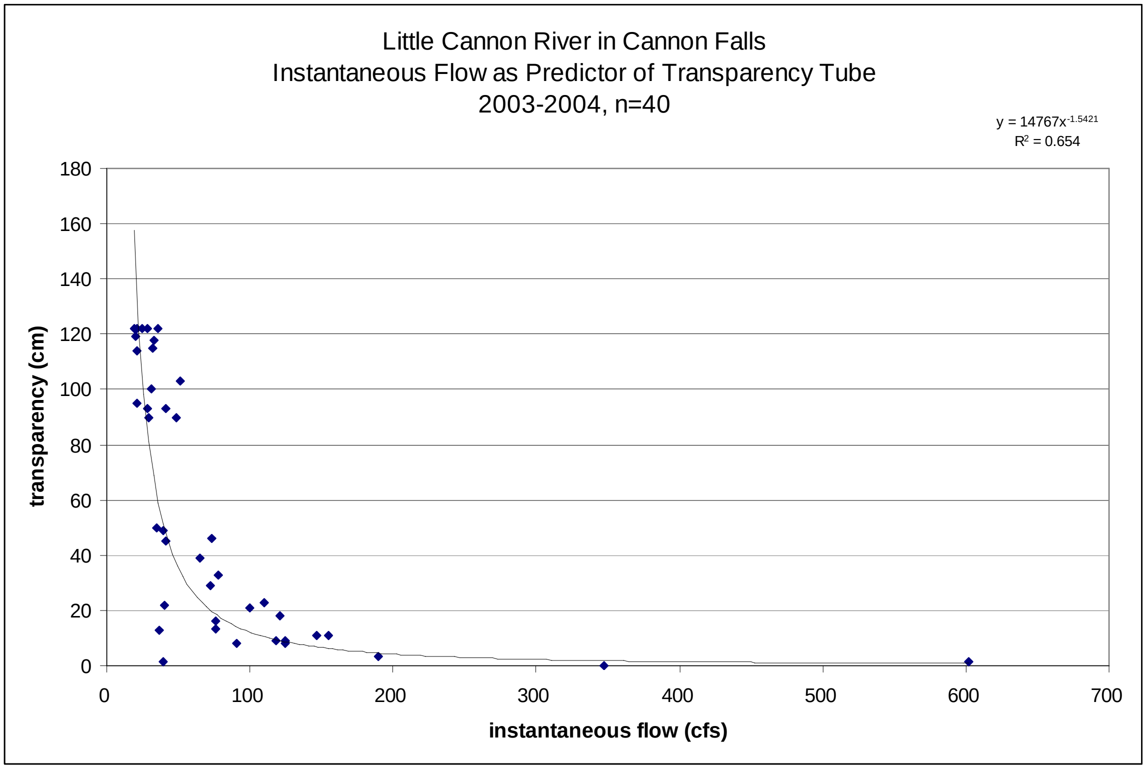
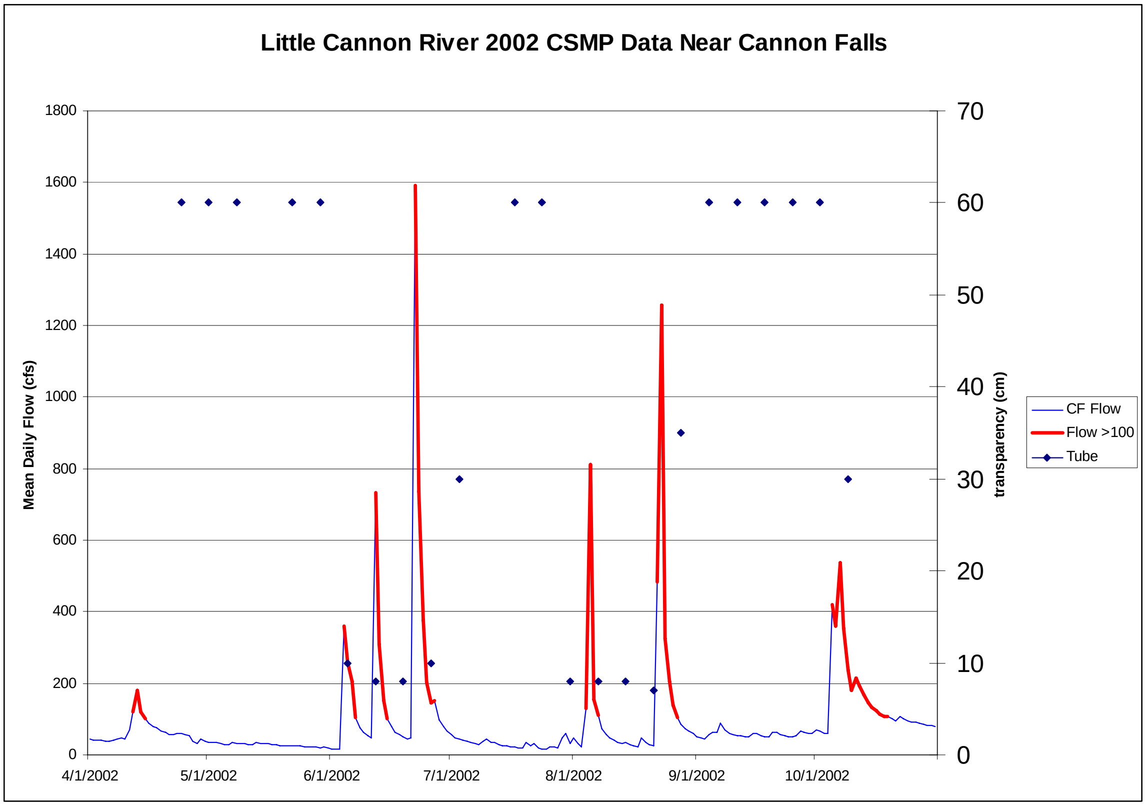
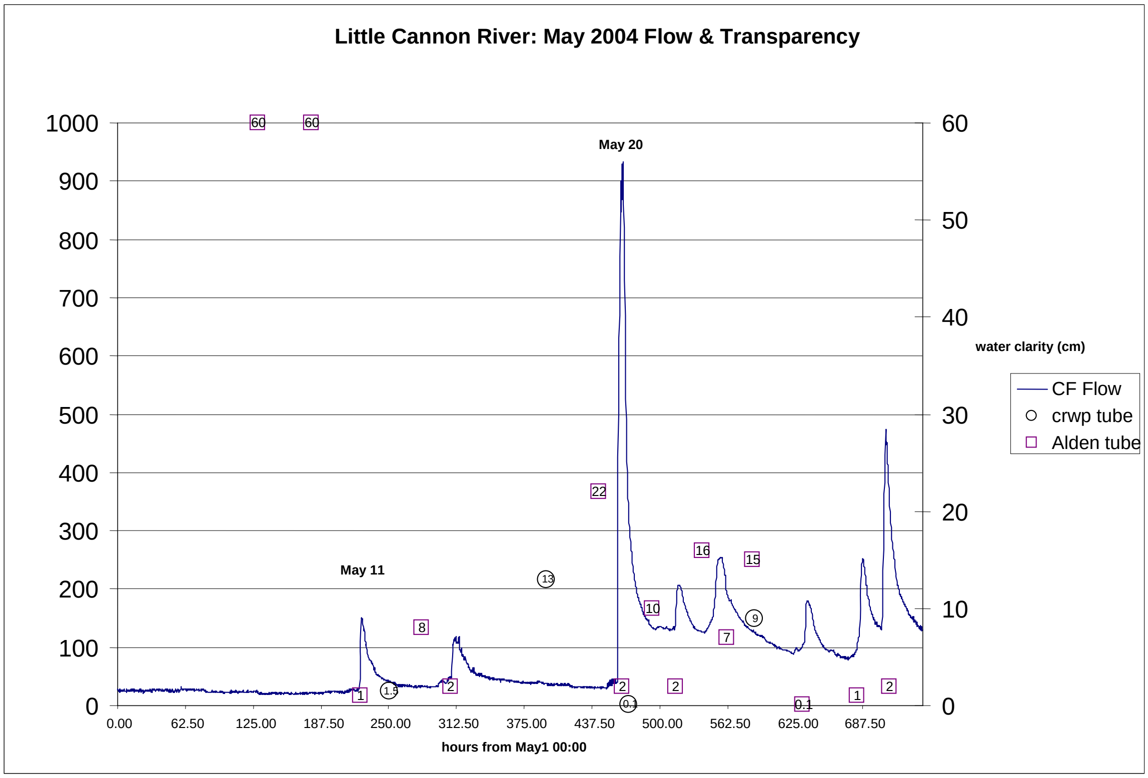


Figure 6. Transparency Tube Data and Mean Daily Flow.



The CSMP data suggest that if several events occur in succession, the result can be prolonged periods of turbid flow, with no return to "clear" conditions between events. For example, in May 2004 the Little Cannon River watershed was subjected to eight rain events that drove the flow near the mouth over 100 cfs. Seventeen tube readings collected at two different sites in the watershed suggest that from May 10th to May 31st the water clarity (at both sites) did not recover to a level much greater than 20-30 cm and for a significant part of that time period it was less than 20 cm. The May 2004 string of events may be somewhat atypical, but a more common occurrence of 2-3 successive rain events appears to have a similar relative effect.

Figure 7. May 2004 Flow and Transparency Summary.



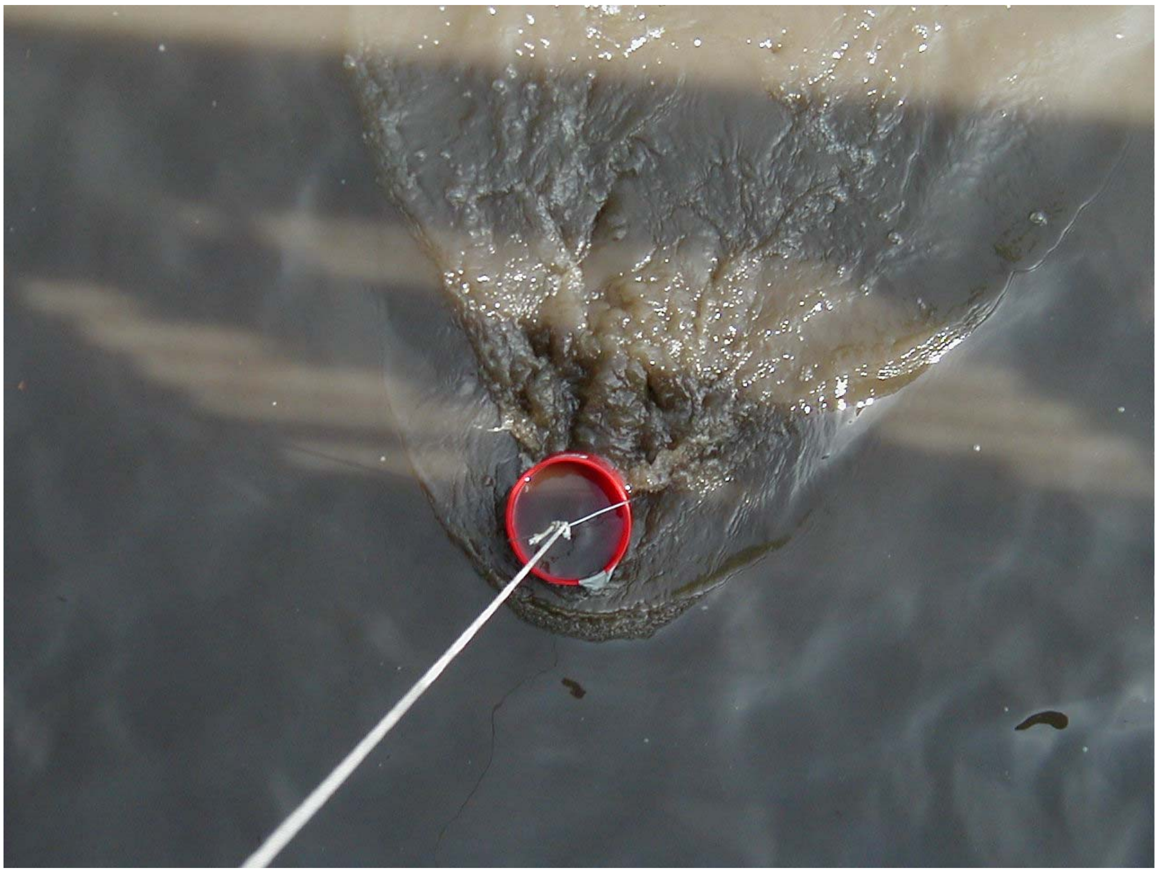
Note: *CF Flow* is instantaneous flow recorded near the mouth; *CRWP tube* is transparency recorded near the mouth; *Alden tube* is transparency recorded far upstream of the mouth in the uppermost third of the watershed.

Figure 8. Photograph: May 2004 Event Flow.

General Conclusion

The Little Cannon River is likely a significant contributor of sediment to the lower Cannon River system. An extensive citizen stream monitoring data set, data collected by CRWP, and flow records provided by MN DNR suggest that the stream reacts strongly to rain events, and the effects (turbid flows, usually in violation of the standard) have been observed to be long-lasting in many cases.

Figure 9. Photograph: May 2004 Event Flow.



Data Sources

Citizen Stream Monitoring Program Data: retrieved from the Environmental Protection Agency's STORET database.

Little Cannon River Flow Data: acquired from the Minnesota Department of Natural Resources.

Cannon River Flow Data (Welch): acquired from the United States Geological Survey.

Cannon River Flow Data (Byllesby Dam): acquired from North American Hydro and processed by the Minnesota Pollution Control Agency.

Turbidity Data: acquired from the Cannon River Watershed Partnership.

Pine Creek Overview: Transparency and Turbidity Data

Introduction

Pine Creek is the smallest named subwatershed of the lower Cannon River: its 14,742 acres account for only 7% of the basin's 207,645 acres. Most of the Pine Creek drainage lies in Dakota County (13,217 acres (~90%)), while the remainder of the acreage is in Goodhue County. The majority of the watershed lies in three townships: Hampton (Dakota County), Douglas (Dakota County) and Cannon Falls (Goodhue). Pine Creek joins the Cannon River approximately 0.7 stream miles downstream of the Goodhue County 17 bridge.

"*The ecological classification for Pine Creek is Class ID (trout waters) from its headwaters downstream to Hwy. 20. This is the stretch that is within Dakota County and within the NCRW. Downstream of Hwy. 20 to its confluence with the Cannon River, it is classified as Class IA trout waters (although this stretch lies outside the WMO boundaries). DNR stream surveys note that the stream above Hwy. 20 was channelized (ditched and straightened) and receives water from numerous tile lines. Habitat in this section of the stream is limited to in-stream vegetation (such as grasses) as there are few well-defined riffles and pools.*

Pine Creek supports a naturally reproducing population of brown trout. Other fish species found in Pine Creek include blacknose and longnose dace, white sucker, and brook stickleback. A Stream Management Plan for Pine Creek was prepared by the DNR in 1998. Management goals include improving trout populations, continuing stream surveys every three years, and restoring the channelized section to a free flowing stream corridor. Pine Creek is divided into two separate use classes according to Minnesota Rules Chapter 7050. Upstream of Hwy. 52, the creek is classified as "2C," which "shall permit the propagation and maintenance of a healthy community of indigenous fish and association aquatic life, and their habitats, and shall be suitable for boating and other forms of aquatic recreation."

Below Hwy. 52, Pine Creek is a State designated trout stream and classified as "2A" in Chapter 7050. Here the creek "shall be such as to permit the propagation and maintenance of a healthy community of cold water sport or commercial fish and associated aquatic life, and their habitats, and shall be suitable for aquatic recreation of all kinds, including bathing (swimming) (NCRWMO)."

While the trout stream designation reaches from the mouth of Pine Creek upstream to Highway 52, the majority of the trout fishing occurs in the two mile stretch from the mouth to Highway 20, with the bottom-most mile usually receiving the most pressure. This Goodhue County segment of the stream includes fairly good vegetative stream-bank cover: a one stream-mile upstream walk from the mouth of the creek would reveal only a few homes, one road-bridge, and virtually no agricultural land (within sight). This stretch of Pine Creek features fairly good riffles, bends and instream woody and rocky habitat for fish and other stream creatures [CRWP].

There is no rating curve available for any station on Pine Creek; however, Dakota County Soil and Water Conservation District (DSWCD) and the Cannon River Watershed Partnership (CRWP) have recorded stage at one or more sites for most years dating back to 2001.

Water Quality Data

There is one active Citizen Stream Monitoring Program (CSMP) participant in the Pine Creek watershed. Bruce Johnson has monitored a site near the mouth of the stream since 2003. The DSWCD has worked with the North Cannon River Watershed Management Organization (NCRWMO) to conduct baseline monitoring at three sites in the Pine Creek watershed. In 2003 and 2004 CRWP collected paired turbidity and tube data near the mouth of Pine Creek.

These data together indicate that Pine Creek exhibits infrequent exceedences of the turbidity standard. There have been very few documented occurrences of prolonged turbid flow in the Pine Creek system. In fact, Pine Creek includes some of the only water in the Cannon River watershed that has been *fully assessed* with respect to turbidity and has not been subsequently listed as an impaired water.

Figure 1. Transparency Tube Data 2001-2004.

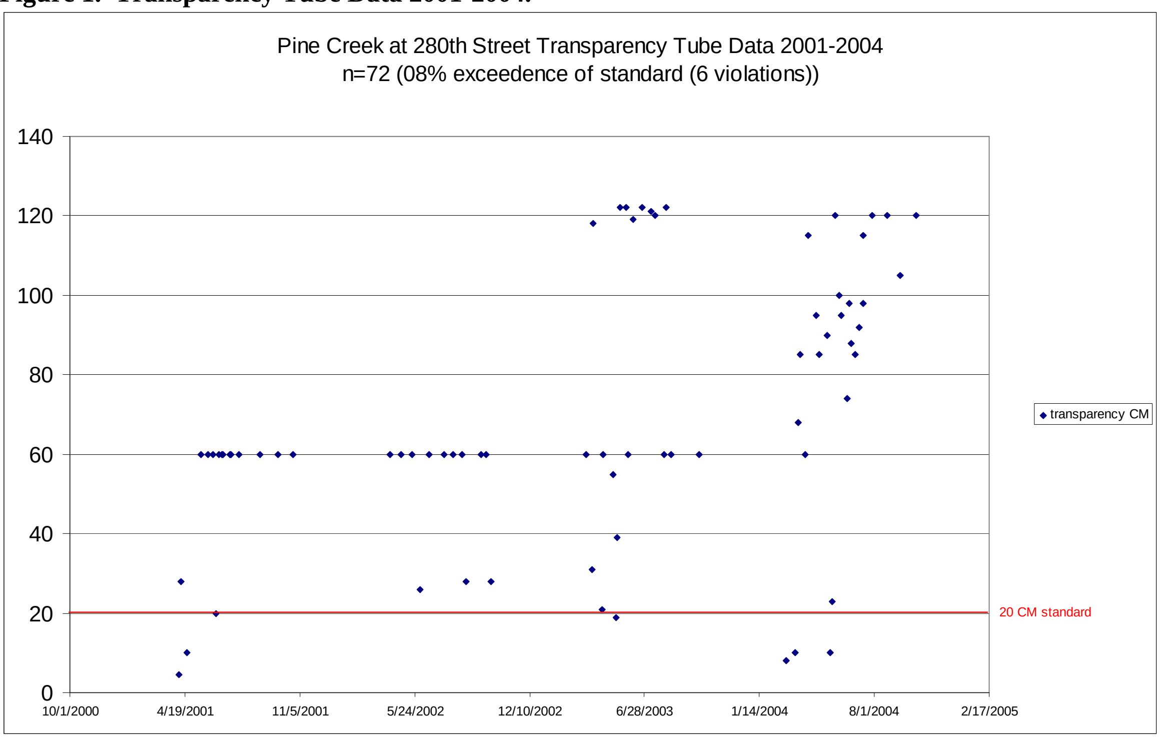
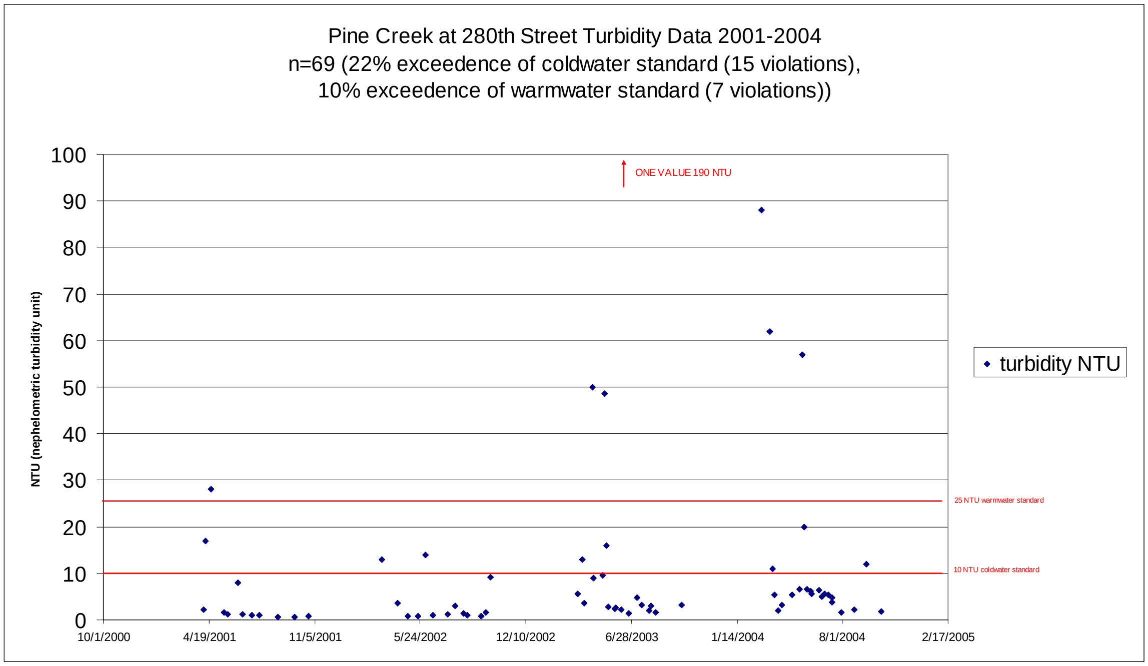
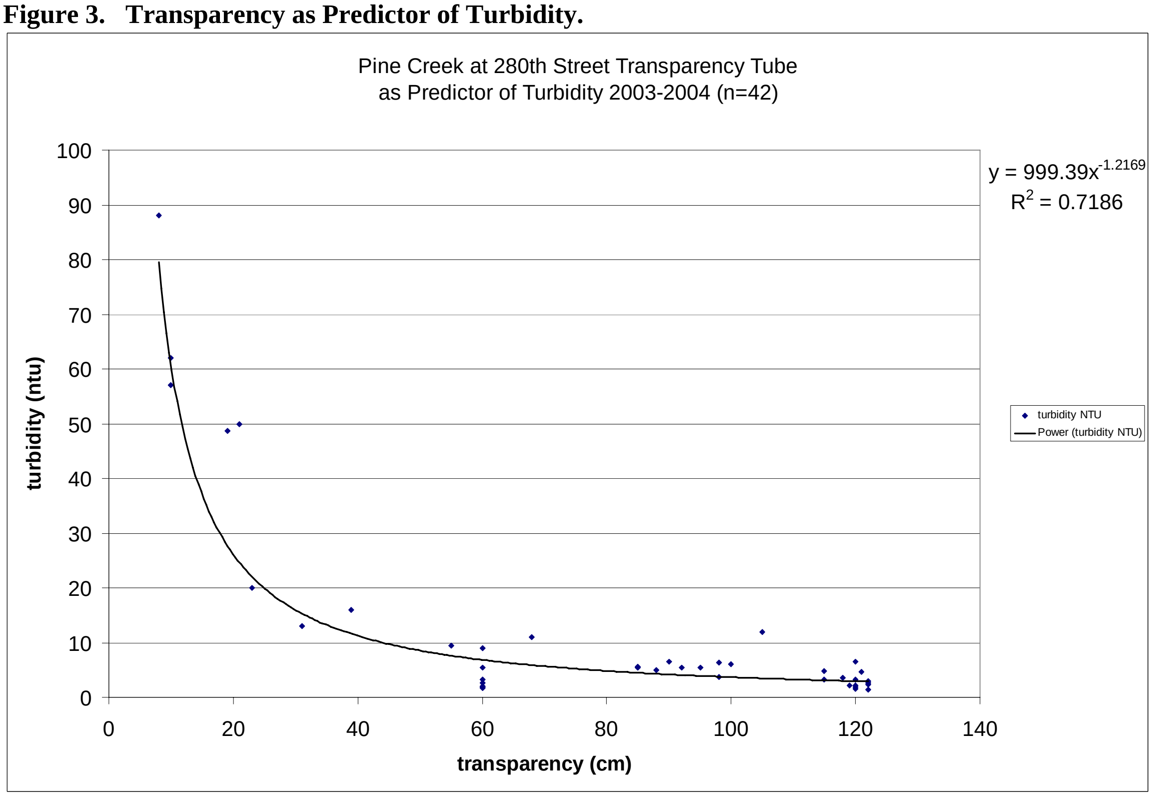


Figure 2. Turbidity Data 2001-2004.



The transparency tube is a good predictor of turbidity near the mouth of the stream, according to 42 pairs of data collected in 2003 and 2004. A water clarity of approximately 21 centimeters is equivalent to a turbidity of 25 ntu.

Figure 3. Transparency as Predictor of Turbidity.



However, mean daily stage measured at the 280th Street gauging site is not a good predictor of water clarity (or turbidity). For most of the 2004 sampling period, clarity was >80 centimeters. Only twice were poor transparency values recorded. Even at higher stages and during periods of increasing stage transparency was still often times relatively good. What is more, a CSMP volunteer (approximately one mile downstream of 280th Street at site 665) recorded transparency values of >60 centimeters on every sampling occasion in 2004 – through all events and all different stages. Thus, there is no well-defined relationship between water level and transparency like that seen at sites on the Little Cannon River and Belle Creek.

Figure 4. Transparency Tube Data and Mean Daily Stage.

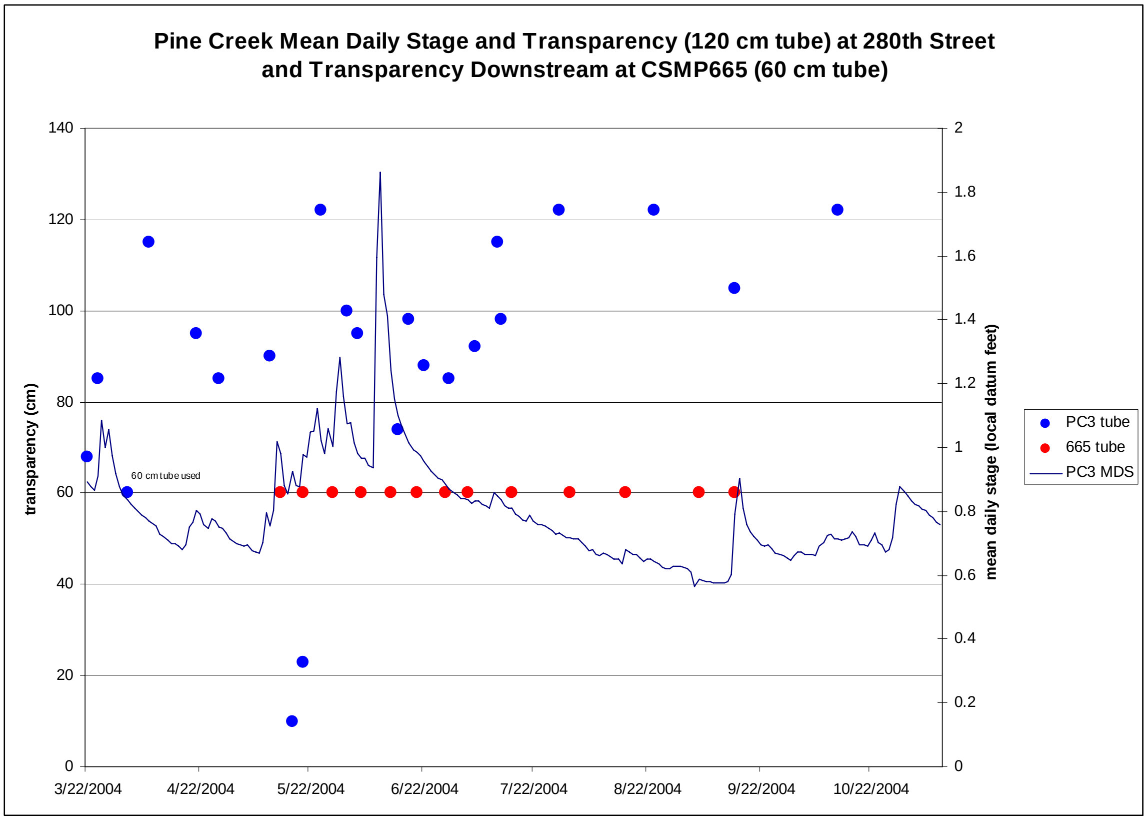
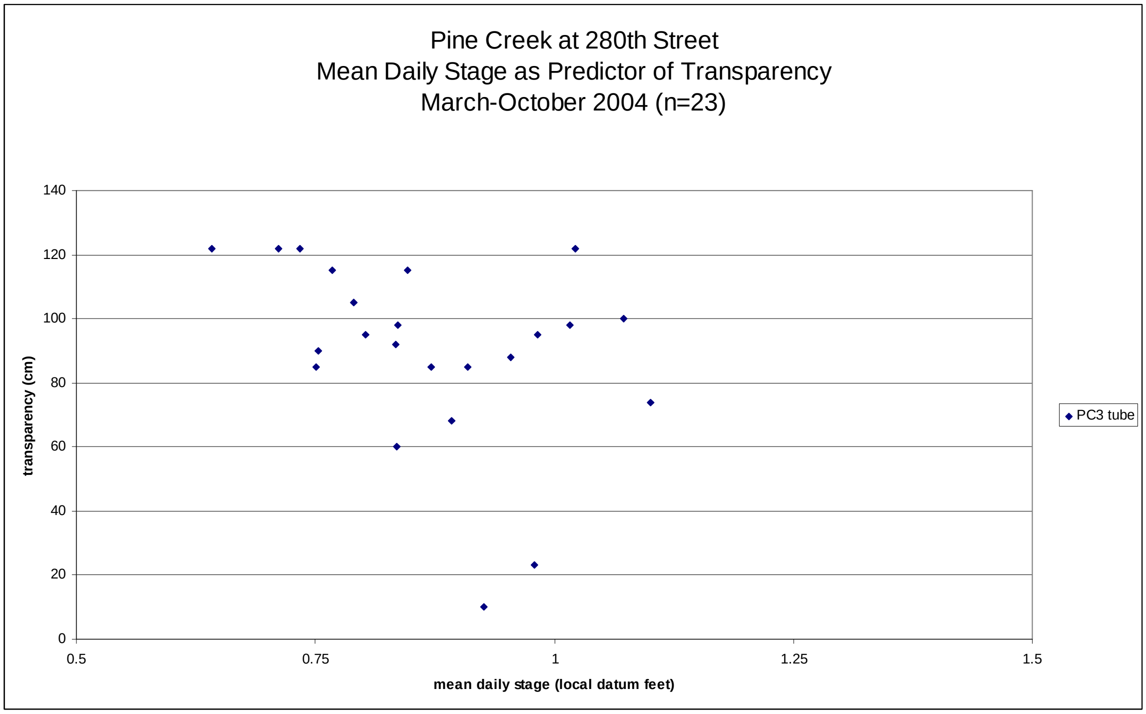


Figure 5. Mean Daily Stage as Predictor of Transparency.



General Conclusion

The basic water quality data – stage, transparency and turbidity – collected in the Pine Creek watershed provide enough information to generally conclude that the stream is likely not a major contributor of sediment to the Cannon River. Particularly relative to other tributaries of the lower Cannon River watershed: event sediment concentrations are muted when compared to those of Trout Brook, and there are few or no prolonged periods of turbid flow like those seen in the Little Cannon River and Belle Creek.

Figure 6. Photograph: Looking Downstream from Monitoring Site at 280th Street.

Figure 7. Photograph: Looking Upstream at Johnson's CSMP Site (665).

Figure 8. Photograph: Typical Terrain Found in Lower Watershed.

Figure 9. Photograph Series: Looking Upstream from Monitoring Site at 280th Street.

Data Sources

Citizen Stream Monitoring Program Data: retrieved from the Environmental Protection Agency's STORET database.

Pine Creek Stage Data: acquired from the Cannon River Watershed Partnership.

Turbidity Data: acquired from Cannon River Watershed Partnership.

Bibliography

North Cannon Watershed Management Organization (NCRWMO). *North Cannon River Watershed Management Organization Plan*, 2003.

Cannon River Watershed Partnership (CRWP). *Pine Creek Folio*, 2004.

Trout Brook Overview: Transparency and Turbidity Data

Introduction

Trout Brook is a 17,860 acre subwatershed of the lower Cannon River: it accounts for approximately 9% of the basin's 207,645 total acres. Nearly all of the Trout Brook drainage lies in Dakota County (17,837 acres (~99.8%)), while 23 acres—a small polygon near the mouth of the brook—is in Goodhue County. The majority of the watershed lies in two townships: Douglas (Dakota County) and Hampton (Dakota County). Trout Brook flows through Miesville Ravine Park and joins the Cannon River near the Dakota— Goodhue County line. The Trout Brook watershed includes two cities: New Trier, in the western lobe (population ~100) and Miesville, in the northeastern lobe (population ~100-150).

"Ecologically, the fish assemblage of Trout Brook is classified by the DNR as Class IA trout waters for its entire length. The stream contains naturally reproducing populations of both brook and brown trout. However, fish habitat in Trout Brook is generally only fair to poor with high amounts of shifting sands in the streambed and few deep pools with suitable cover. Other fish species collected in Trout Brook over the years include the blacknose and longnose dace, brook stickleback, white sucker, and green sunfish (Jester, WMO Plan)*."*

In its 1999 survey, the MN DNR called the Miesville branch "Trout Brook" and the New Trier branch "Tributary to Trout Brook." The trout stream designation extends from the mouth of the stream, past the confluence of these two branches ~0.8 miles up the New Trier branch only. Fishing access is usually by means of County Road 91 or Miesville Ravine Park (these two entry points roughly bracket the designated stretch). The entire length of the designated stretch includes well forested flood plains and vegetative cover on the stream banks. However, as mentioned in the WMO plan, shifting sands in the streambed have resulted in a significant absence of deep holes, and consequently, less cover for fish species [these three paragraphs from CRWP].

There is no rating curve available for any station on Trout Brook; however, Dakota County Soil and Water Conservation District and the Cannon River Watershed Partnership have recorded stage at one or more sites for most years dating back to the late 1990s. Much of the data collected near the mouth of the stream is affected by the backflow of the Cannon River, and is not useful in any analysis of the dynamics of the Trout Brook watershed (the site has since been moved upstream).

Figure 1. Recorded[1] Mean Daily Stage Compared to Cannon River Mean Daily Flow.

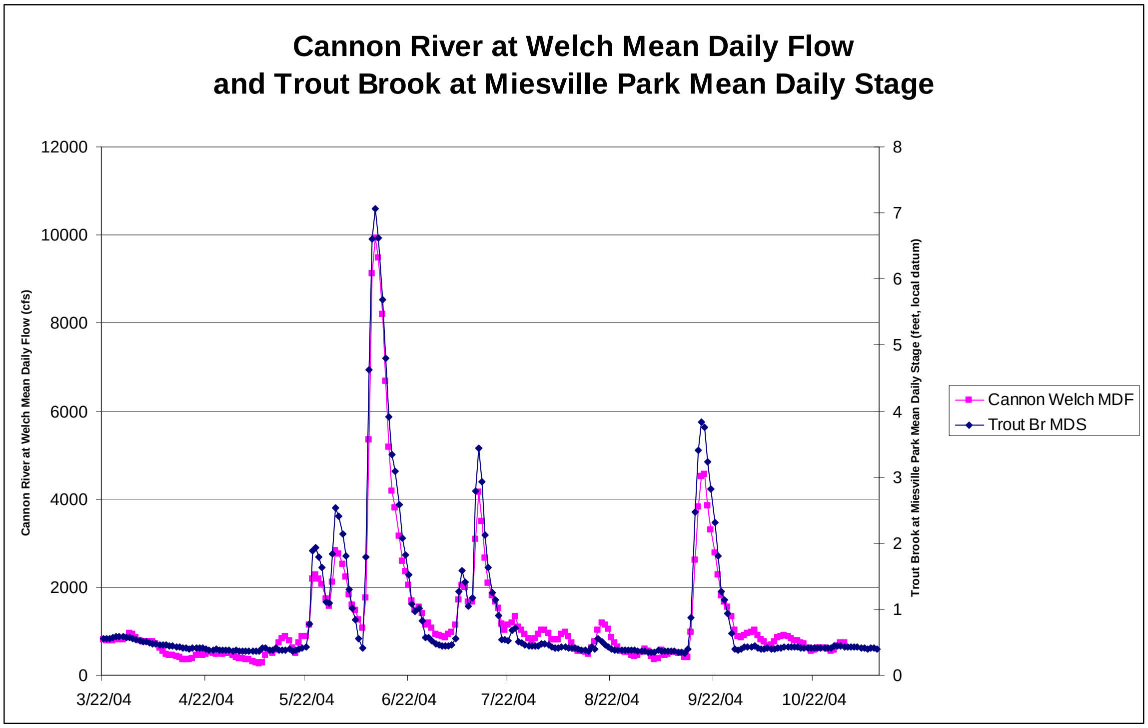
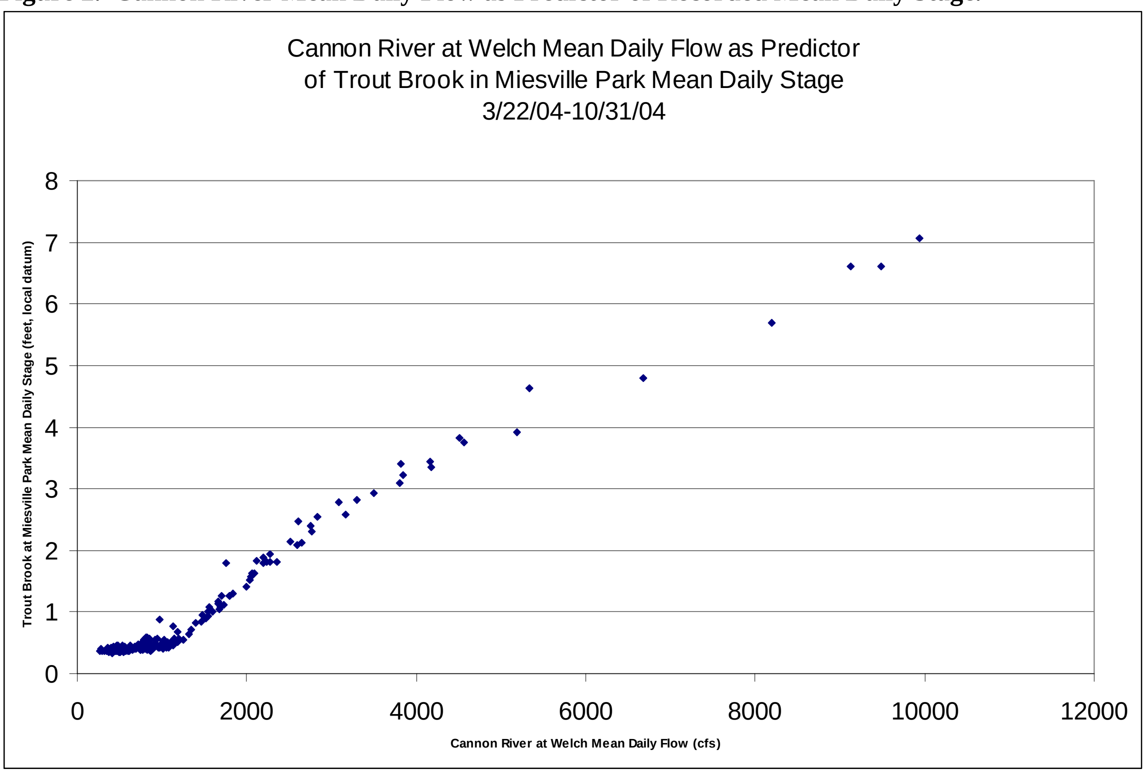


Figure 2. Cannon River Mean Daily Flow as Predictor of Recorded Mean Daily Stage.



[1] This record is not representative Trout Brook's mean daily stage because it was affected by backflow from the Cannon River.

Water Quality Data

There is one active Citizen Stream Monitoring Program (CSMP) participant in the Trout Brook watershed. John Schumacher has monitored a site at the mouth of the watershed since 2002. The Dakota County Soil and Water Conservation District (DSWCD) has worked with the North Cannon River Watershed Management Organization (NCRWMO) to conduct baseline monitoring at three sites in the Trout Brook watershed. Together these data sets provide a fair understanding of the sediment loading yielded to the Cannon River from Trout Brook.

In 2003 and 2004 Cannon River Watershed Partnership collected paired turbidity and tube data near the mouth of Trout Brook. In response to backflow conditions, samples were collected upstream of the established site. Given the flashiness of the system though, the 2003-2004 data covered mainly low flow conditions.

These data together indicate that Trout Brook exhibits numerous exceedences of the turbidity standard (both the warmwater and the coldwater standards) each year. However, there have been no documented occurrences of prolonged turbid flow in the Trout Brook system.

Figure 3. Transparency Tube Data 2001-2004.

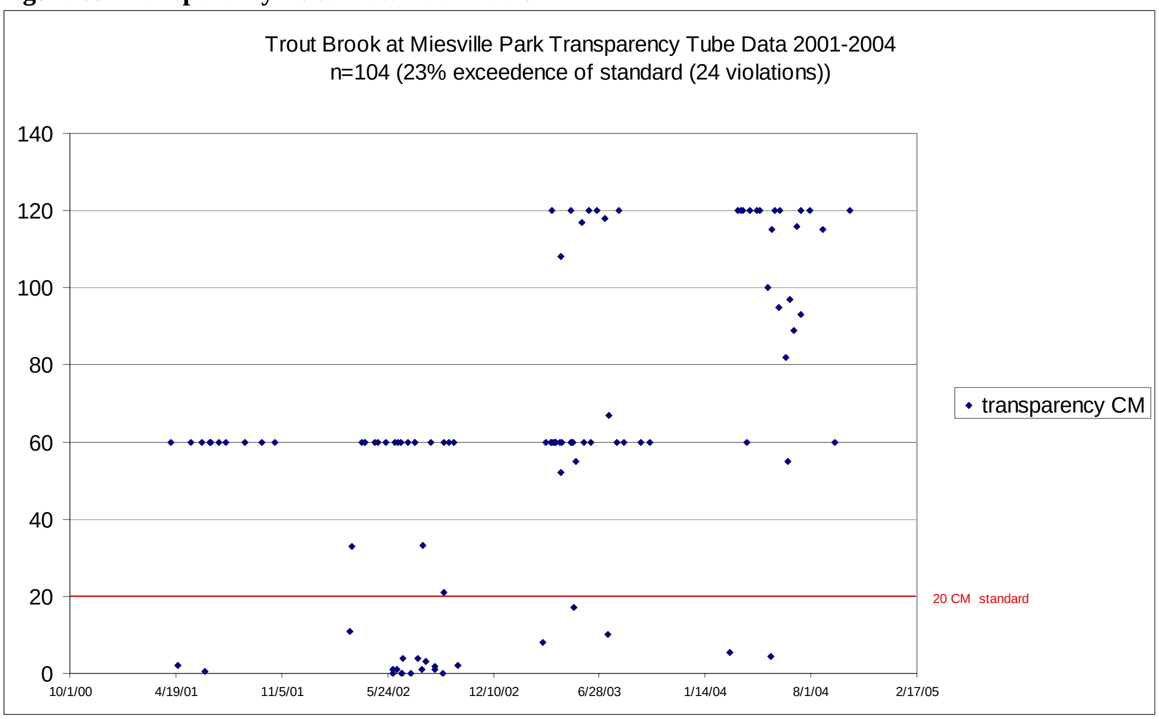
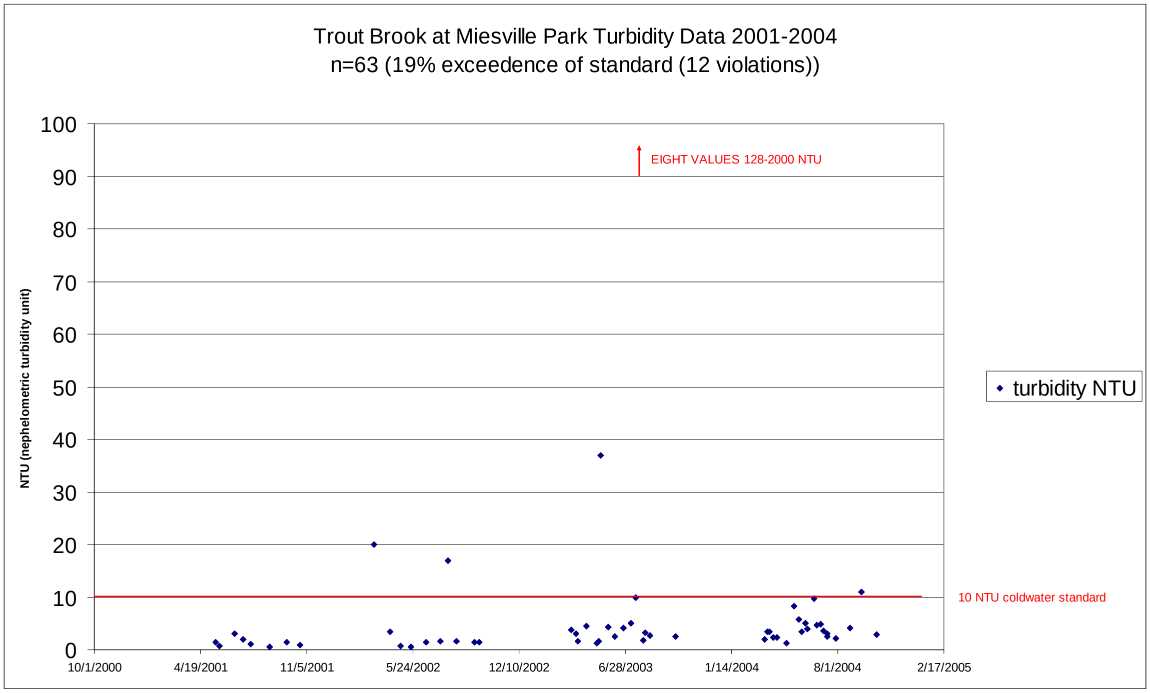


Figure 4. Turbidity Data 2001-2004.



Intensity of turbidity is event-driven, and is greatest when hydrograph slope is steep and positive. Stage is not always an accurate predictor of turbidity, as there were a few recorded instances of low water and high turbidity as well as high water and low turbidity. However, the high turbidity values were usually associated with stage >1.5 feet, and there was only one instance of high turbidity and stage <1.5 feet.

Of 40 turbidity measurements completed at TB3 (site nearest to mouth) in 2001-2003, only 6 exceeded 20 NTU, however—those six data are extremely high, ranging from 250 to 2000 ntu. Similarly, of 24 measurements completed at TB2 in 2001-2002, data collected during/after the same six events exceeded 200 NTU; likewise for TB1: 25 measurements, 4 of which >300 NTU (one suspected bad data point, and one instance of significantly lower turbidity with respect to TB2 and TB3). The greatest turbidity measured at any site was 2000 NTU at TB3 on 6/13/02. Overall, Trout Brook exhibits significantly greater turbidity and TSS measurements with respect to neighboring Pine Creek (during the same events). Note that these two watersheds are contiguous and of similar size.

Tube vs Turbidity

The transparency tube is a good predictor of turbidity at all three Trout Brook sites; however, very few intermediate values have been recorded. The non-event flows produce extremely clear water, while the events leap to drastically turbid situations. For example, at TB3: 32 of the 40 data collected over three years include tube readings of >60 cm and single-digit turbidity readings. There are only two turbidity data >10 ntu and <250 ntu; the remaining six are extreme values of 250-2000 ntu (note scale of graph, and see table to right). Thus, the tube is a good predictor, in that high clarity is paired with low turbidity, and low clarity is paired with very high turbidity, but the middle segment of the *relationship has yet to be verified (North Cannon WMO Plan suggested the stream is extremely flashy). The data at TB1 and TB2 exhibit the same lack of intermediate data* [CRWP].

Figure 5. Duration of Turbid Flows Excerpt [CRWP].

Duration of Turbid Flows

Table at right includes all visits by all data collectors to TB3; column "days since" is number of days since previous visit. In the set of 81 total visits, there are several groups of data that include consecutive days bunched around an event.

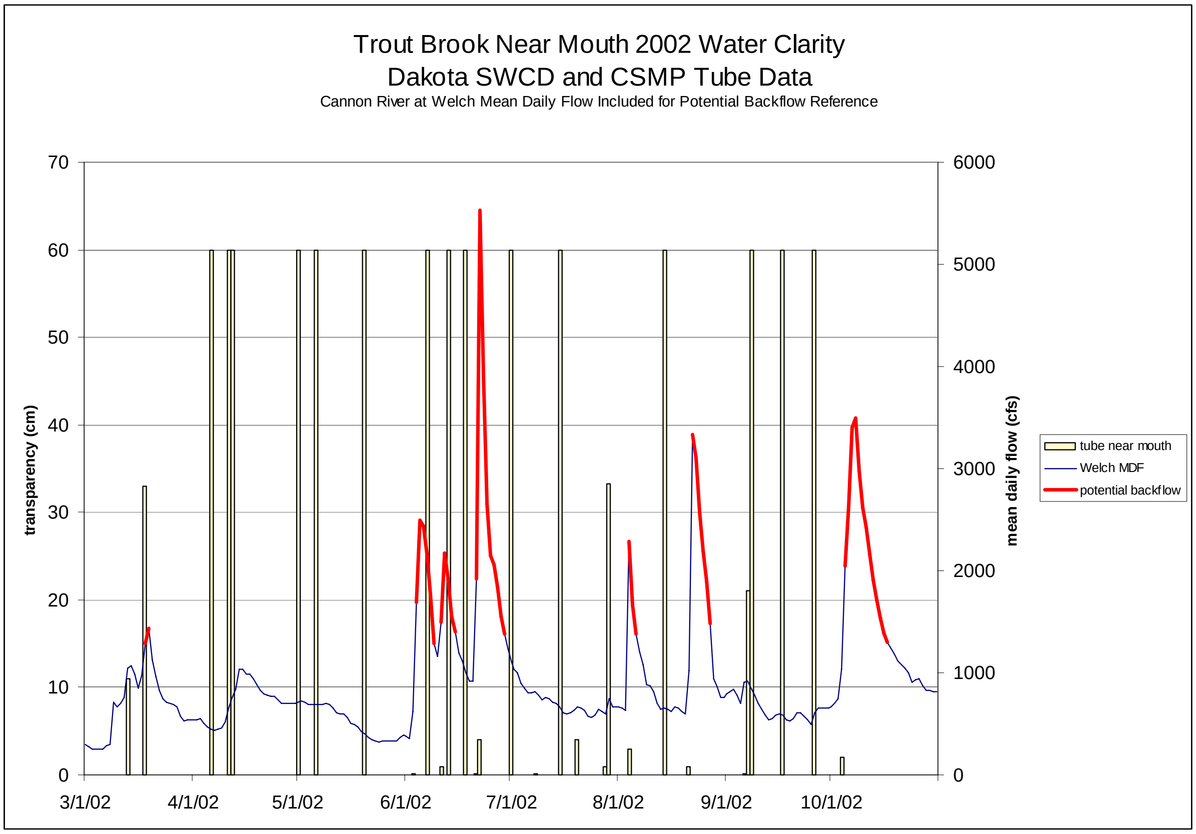
6/3/02-6/7/02: this was an extreme event of ~3 inches of precipitation throughout the watershed—began with ~2 inches on 6/3, followed by ~0.5 inches on both 6/4 and 6/5. DSWCD and Schumacher documented clarity at 0-1 cm on 6/3/02; turbidity was very high. At Schumacher's next visit only four days later, tube was >60 cm.

6/20/02-6/22/03: another extreme event during which ~3 inches fell 6/20-6/21. Three visits by Schumacher on 6/21 all produced 0 cm tube readings, and the DSWCD visit on the same day recorded <1 cm. Schumacher visited the next day and recorded 4 cm; next visit was not until 7/1, when >60 cm was recorded.

9/6/02-9/8/02: good example of stream recovery from an extreme event. Schumacher recorded 2.45 inches of precipitation on 9/6 (fell either latter 9/5 or early 9/6), and a tube of 0 cm on the same day. Approx 27 hours later, clarity had increased to 21 cm (1400, 9/7) and 24 hours after that reading, it had returned to >60 cm (1456, 9/8). These data document a 50-70 hour recovery from an extreme event during which heavy rain drove water clarity to 0 cm.

date	time	days since	tube	turbidity NTU	Collector
4/9/2001	12:00		60		DSWCD
4/23/2001	10:00	14	2	260	DSWCD
5/17/2001		24	60	1.4	DSWCD
5/24/2001	12:00	7		0.8	DSWCD
6/7/2001	14:25	14	60		DSWCD
6/13/2001	9:15	6	0.6	2000	DSWCD
6/22/2001	13:10	9	60	3.1	DSWCD
6/25/2001	13:05	3	60		DSWCD
7/9/2001	11:45	14	60	2	DSWCD
7/23/2001	9:55	14	60	1.1	DSWCD
8/28/2001	10:30	36	60	0.5	DSWCD
9/28/2001	10:25	31	60	1.4	DSWCD
10/24/2001	15:45	26	60	0.9	DSWCD
3/12/2002	**14:45**	**139**		**20**	**DSWCD**
3/13/02	**1300**	**1**	**11**		**Schumacher, J**
3/18/02	1530	5	33		Schumacher, J
4/6/02	1300	19	60		Schumacher, J
4/11/2002	**11:40**	**5**	**60**	**3.4**	**DSWCD**
4/12/02	**1230**	**1**	**60**		**Schumacher, J**
5/1/2002	12:45	19	60	0.8	DSWCD
5/6/02	830	5	60		Schumacher, J
5/20/2002	9:30	14	60	<.05	DSWCD
6/3/02	**1030**	**14**	**0**		**Schumacher, J**
6/3/2002	**10:10**	**0**	**1**	**750**	**DSWCD**
6/7/02	1030	4	60		Schumacher, J
6/11/02	850	4	1		Schumacher, J
6/13/02	1200	2	60		Schumacher, J
6/18/2002	10:15	5	60	1.4	DSWCD
6/21/02	**900**	**3**	**0**		**Schumacher, J**
6/21/02	**1530**	**0**	**0**		**Schumacher, J**
6/21/02	**1800**	**0**	**0**		**Schumacher, J**
6/21/2002	**10:20**	**0**	**< 1.0**	**1100**	**DSWCD**
6/22/02	**1100**	**1**	**4**		**Schumacher, J**
7/1/02		9	60		Schumacher, J
7/8/02	2000	7	0		Schumacher, J
7/15/02	**930**	**7**	**60**		**Schumacher, J**
7/15/2002	**10:05**	**0**	**60**	**1.6**	**DSWCD**
7/20/02	1100	5	4		Schumacher, J
7/28/02	**1915**	**8**	**1**		**Schumacher, J**
7/29/2002	**11:33**	**1**	**33.2**	**17**	**DSWCD**
8/4/02	1900	6	3		Schumacher, J
8/14/2002	10:15	10	60	1.6	DSWCD
8/21/02	1530	7	1		Schumacher, J
8/21/2002	11:42	0	1.8	250	DSWCD
9/6/02	**1100**	**16**	**0**		**Schumacher, J**
9/7/02	**1400**	**1**	**21**		**Schumacher, J**
9/8/02	**1456**	**1**	**60**		**Schumacher, J**
9/17/2002	10:33	9	60	1.5	DSWCD
9/26/2002	10:40	9	60	1.4	DSWCD
10/4/2002	12:15	8	2	310	DSWCD
3/14/2003	1340	161	8		Schumacher, J
3/19/2003	1430	5	60	3.8	Watkins, J
3/28/2003	1330	9	60	3	Watkins, J
3/30/2003	1444	2	60		Schumacher, J
3/31/2003	1255	1	122	1.7	Watkins, J
4/4/2003	1330	4	60		Schumacher, J
4/6/2003	1200	2	60		Schumacher, J
4/8/2003	1900	2	60		Schumacher, J
4/15/2003	1754	7	60		Schumacher, J
4/16/2003	1245	1	108	4.5	Watkins, J
4/17/2003	1200	1	52		Schumacher, J
4/19/2003	1700	2	60		Schumacher, J
5/5/2003	1240	16	122	1.2	Watkins, J
5/5/2003	1900	0	60		Schumacher, J
5/7/2003	1600	2	60		Schumacher, J
5/9/2003	12:45	2	60	1.63	DSWCD
5/14/2003	1815	5	55		Schumacher, J
5/16/2003	1145	2	105	4.5	Watkins, J
5/27/2003	1150	11	117	4.3	Watkins, J
5/30/2003	11:55	3	60		DSWCD
6/9/2003	1130	10	120	2.5	Watkins, J

Figure 6. Transparency Tube Data and Cannon River Mean Daily Flow.



General Conclusion

The data sets available for Trout Brook are not as comprehensive as those recorded in the Little Cannon River and Belle Creek watersheds. There is no flow information, and even the stage data at the site near the mouth of Trout Brook are only somewhat useful given the backflow effect from the Cannon River. Add to that the flashiness of the system and the consequent lack of event samples (and significant lack of "intermediate flow" samples) and it becomes difficult to fully document the behavior of the stream.

However, a general interpretation of the pooled data, consideration of anecdotal information, and examination of photographs collected over the years allows for the following conclusions: (1) Trout Brook is a very flashy system that reacts intensely to major rain events, (2) Many minor and some moderate rain events produce no noticeable effect on the water quality or stage of Trout Brook, (3) Much of the lower stream corridor is forested, with little or no understory; intense gullying on slopes down to the stream channel has been documented and is suspected to be somewhat common in the lower watershed, (4) Trout Brook recovers its water clarity very quickly, even after extreme events and intense turbid flows, (5) Unlike the Little Cannon River and Belle Creek, Trout Brook does not exhibit a strong relationship between stream stage and transparency [see following graph]. When stage is very high, transparency is very low. However, the majority of the recorded water levels are 119-131 inches (tape down); in this range the transparency values are highly variable and do not suggest any sort of regular decrease in clarity as water level rises, but rather form a "column" of values extending up from 0 cm to 60 cm. The following figure does not include any data recorded on days for which the Cannon River's mean daily flow at Welch was >=1250 cfs, so as to eliminate records that may have been affected by backflow.

Figure 7. Stage as Predictor of Transparency Tube.

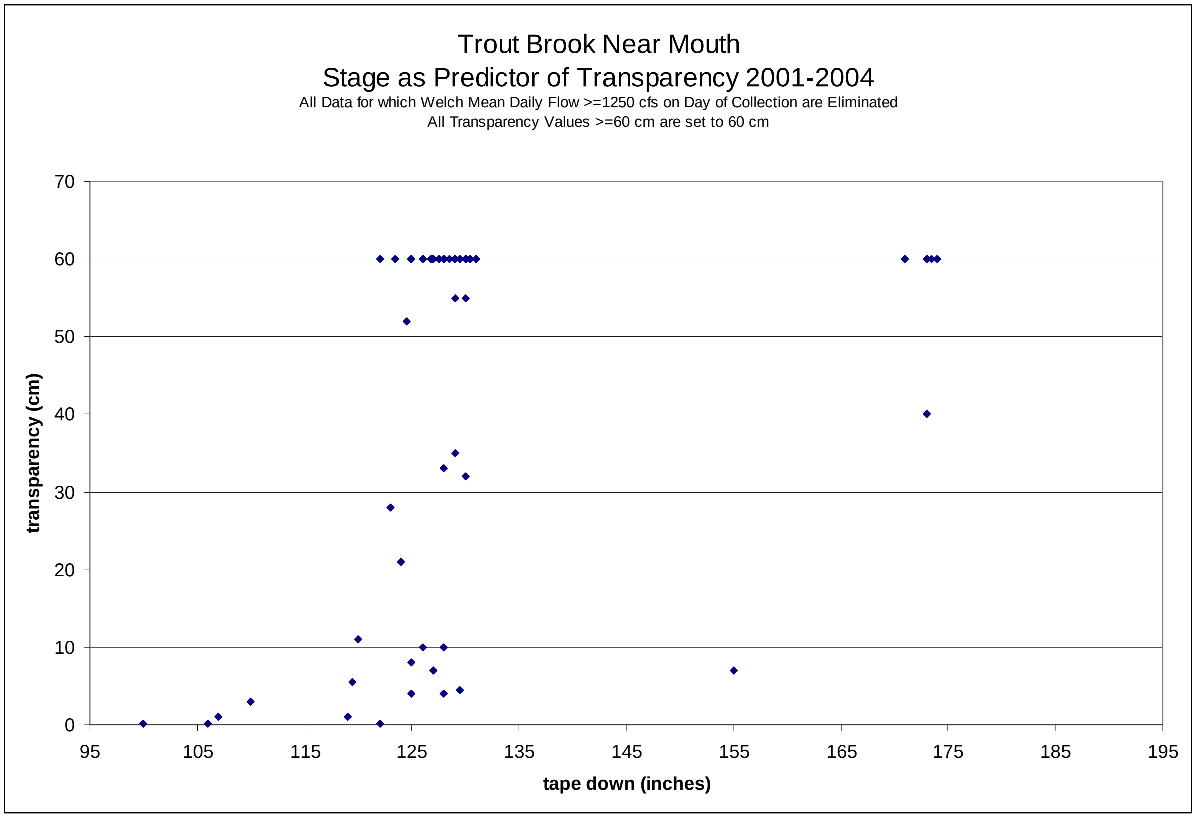


Figure 8. Photograph Series: Looking Upstream from Monitoring Site in Miesville Park.

Figure 9. Photograph Series: Near Mouths of Two Upper Branches at County Road 91.

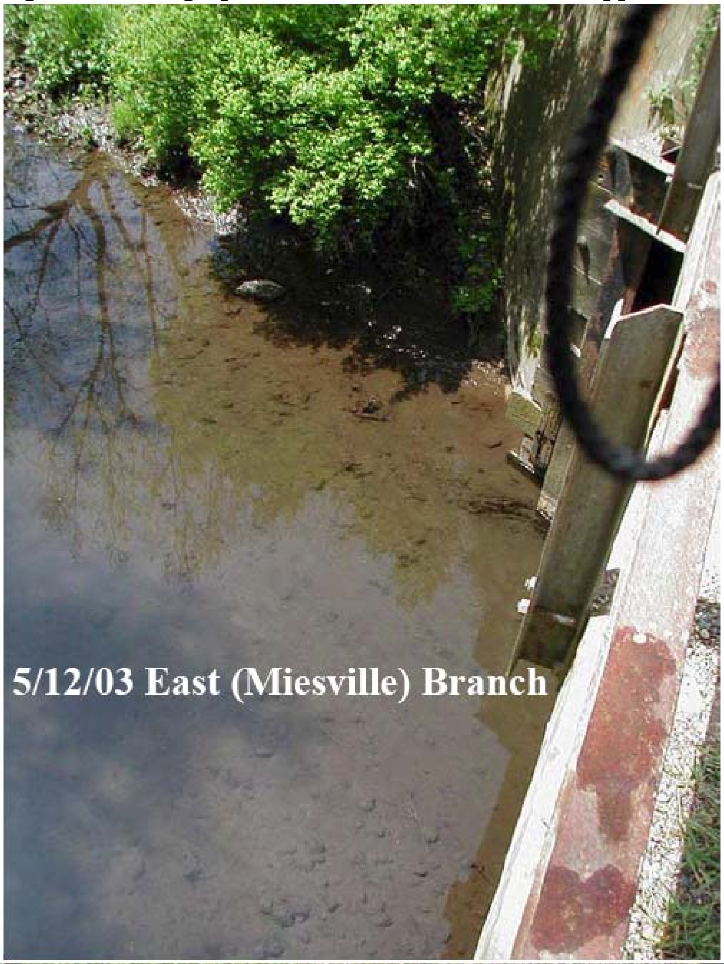


Figure 10. Lower Watershed Gully in Miesville Park (Spring 2004).

Figure 11. Lower Watershed Gully in Miesville Park (Summer 2004).

Data Sources

Citizen Stream Monitoring Program Data: retrieved from the Environmental Protection Agency's STORET database.

Trout Brook Stage Data: acquired from the Cannon River Watershed Partnership.

Turbidity Data: acquired from Cannon River Watershed Partnership.

Bibliography

North Cannon Watershed Management Organization (NCRWMO). *North Cannon River Watershed Management Organization Plan*, 2003.

Cannon River Watershed Partnership (CRWP). *Trout Brook Folio*, 2004.