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Introduction

There are many types of water pollutants that affect the surface and groundwater of the Cannon River watershed. For the purposes of this watershed strategy we have chosen to focus on those for which we have documented impairments, occur throughout the watershed and are ones that the people who live and work in the watershed have some control over. The Clean Water Act requires states to adopt water quality standards to protect waters from pollution. These standards define how much of a pollutant can be in a water and still allow it to meet designated uses such as drinking water, fishing, swimming, irrigation or industrial purposes.

The pollutants we are focusing on in this document include: sediment, excess nutrients (phosphorus), *E. coli* bacteria, and pesticides. The designated uses most often include aquatic life and aquatic recreation. Figure 8 shows the streams and lakes that are impaired for these pollutants.

One pollutant that is also an issue is mercury. The sources of mercury are not located in the Cannon River Watershed but do affect our waters all the same. Per the MPCA website (Statewide Mercury Total Maximum Daily Load), "Atmospheric deposition of mercury is uniform across the state and supplies more than 99.5% of the mercury getting into fish. Agency research has demonstrated that 70% of current mercury deposition in Minnesota comes from human sources and 30% from natural sources such as volcanoes. About 90% of the deposition in the state comes from outside the state." A statewide Mercury TMDL was approved by EPA in 2007. Sources of mercury include: coal-fired electric generation, industrial, institutional and commercial boilers, taconite processing/mining, use and disposal of products with mercury and other lesser sources. With regard to the lake impairments for mercury, human consumption of fish with mercury in their tissues is the concern. The Minnesota Department of Health (MDH) provides a Fish Consumption Advisory to provide the public with guidelines for consumption of fish from over 1,000 lakes and streams where the fish have been tested for contaminants to include mercury.

In addition to pollutants there are also conditions which stress the aquatic life in our waters. Three potential stressors include: drainage and hydrologic modification, thermal changes, and aquatic invasive species.

To better understand these issues, the input of experts in these fields was solicited and they have contributed the following narratives to give more information about these pollutants and potential stressors.

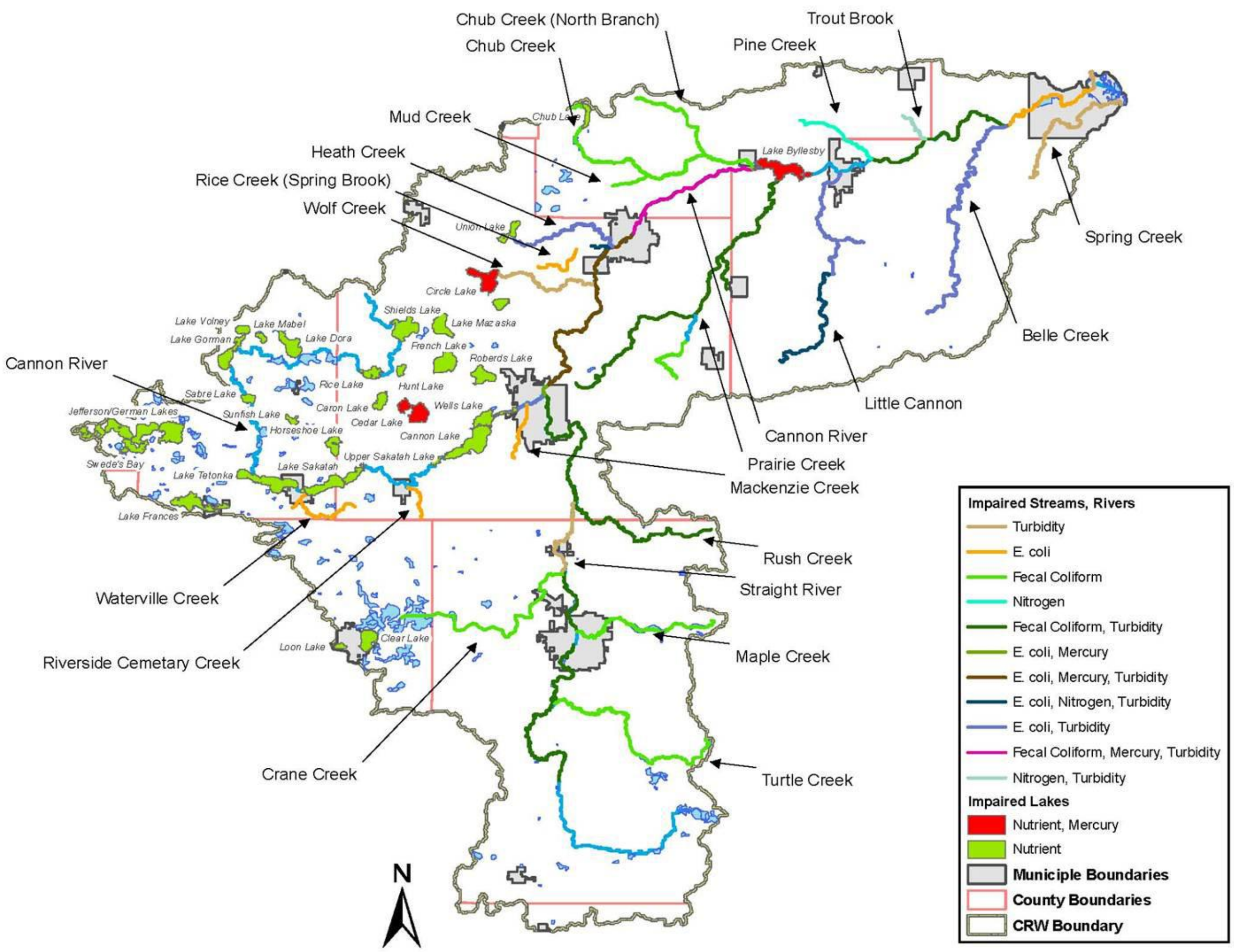

Figure 8. Draft 2010 303(d) map for the Cannon River watershed. This figure shows impaired waters in the Cannon River watershed.

Sediment by Dr. David Mulla, Department of Soil Water and Climate, University of Minnesota

Portions of the Cannon River are impaired for sediment. Sediment pollution produces turbid waters, with diminished light penetration. This turbidity, along with sediment deposited in the river channel can have adverse impacts on aquatic life. It is important to reduce the sediment loads carried by the Cannon River to protect aquatic life and enhance recreational opportunities.

Sediment carried by the Cannon River arises from several sources. These include upland erosion of agricultural fields, erosion from construction sites, headcutting in ravines and gullies, streambank erosion, and mass wasting of river banks. The relative magnitude of sediment generated from each of these sources in the Cannon River is currently not well understood.

Upland erosion is defined as sheet and rill erosion produced by the action of water. It can occur on agricultural, residential or construction sites. When raindrops strike unprotected soil, they generate forces that are strong enough to detach soil particles and break apart soil aggregates. Usually only a small fraction (10% or less) of upland erosion is delivered to stream channels, either by direct runoff or by entering surface tile inlets. The remainder is deposited on flat landscapes downslope of the eroding area. Upland erosion in agricultural sites can be controlled through Best Management Practices such as conservation tillage, perennial cropping, riparian filter strips, and cover crops. At residential and construction sites it can be controlled by vegetative cover, silt fences, and straw bales.

Headcutting in ravines and gullies occurs in areas where runoff or tile discharge is focused into a concave topographic area with a steep slope gradient. Ravines and gullies are deep and wide enough to prevent vehicles from driving across them, in contrast to rills which can easily be crossed by vehicles. Erosion from ravines and gullies can be controlled by reducing the energy of water discharged into them, by stabilizing the banks, or by installing drop or conveyance structures to control the destabilizing forces of water.

Streambank erosion is the failure of low channel banks caused by a variety of factors. Channel banks in this case are lower than bankfull height of the stream, allowing a depositional area to be formed behind the streambank during high stream discharge. The factors affecting streambank erosion include the power of flowing water that undercuts the banks and pore water pressure effects that reduce shear strengths of consolidated bank materials until failure occurs. Another factor is trampling of streambanks by grazing animals. Streambank erosion delivers sediment directly into the stream channel. However, not all of the delivered sediment is transported as suspended sediment. Materials coarser than fine sands are generally transported as bedload, and are redeposited in sand bars downstream. In streambanks that are derived from glacial till parent materials, the fraction of fine sediment that is easily suspended may be only 50% or so of the eroded material. Streambank erosion can be controlled by reducing the power of flowing water at the toe of the streambank or increasing the resistance of the bank to erosion. Four general approaches for doing this include setbacks and exclusions, bioengineering practices, structural enhancements, and clearing the channel of snags and downed trees.

Mass wasting from stream bluffs may also be an important source of sediment in isolated areas. The mechanisms of mass wasting are similar to those involved in streambank erosion. The difference is that in mass wasting from bluffs, the bankfull height of the stream is much lower than the height of bluffs. As a result, there is no depositional area behind the stream bluff during times of high stream discharge. Methods to control mass wasting from stream bluffs are poorly understood. It is generally agreed that exclusions and bioengineering practices have little effect on bluff erosion. Structural practices may be effective, although they are very costly.

The production and transport of sediment sources is controlled by a variety of factors. These include precipitation (snow and rain) and its impact on runoff and stream hydrology, landscape topography (landform shapes and slopes), soil characteristics (texture, structure), geologic parent material, land cover and land management practices.

Precipitation is the primary driver of upland and construction erosion. If the intensity of rain is greater than the infiltration capacity of soil, runoff is generated. Runoff can transport detached soil particles downslope. This process leads to sheet and rill erosion. Runoff can also occur by melting of snow. If the rate of melting is rapid, and the snow is deep, significant amounts of runoff can be generated by snowmelt. In general, this is not as significant a source of upland sediment as intense rainstorms. However, both snowmelt runoff and intense rainstorms can generate enough river discharge to destabilize stream banks and produce either stream bank erosion or mass wasting of river channel bluffs.

Landscape topography is also an important factor in sediment pollution. Steep landscapes with a high runoff potential are more prone to runoff than flat landscapes. Much of the area in the Cannon River watershed west and south of Faribault is steeply rolling topography with a high runoff potential. This area has a slope steepness that varies between 6 to 12%. An area near the mouth of the Cannon River (south of Red Wing) is also very steep, with slopes ranging from 6 to 45%.   Between these two regions, landscapes are flatter, with slopes ranging from 0 to 2% or from 2 to 6%.

Excess nutrients by Steve Heiskary, MPCA

Excess nutrients are a major source of water pollution in the Cannon River Watershed and the Nation's waters as a whole. Phosphorus (P) and nitrogen (N) are the two nutrients of primary concern in the eutrophication of lakes and rivers. While both P and N are needed to allow for algal and rooted plant growth and overall support of a healthy ecosystem; excess amounts lead to severe and frequent blooms of undesirable algae and overabundant plant growth. In turn, this can impair recreational uses like swimming, wading, boating and fishing. It can also directly impact the types and quantity of fish and other aquatic life in lakes and rivers; whereby extremely nutrient-rich systems are often dominated by rough fish and other pollution tolerant forms in contrast to various sport fish and less tolerant forms.

At a national level USEPA has promoted the development of nutrient water quality standards that seek to reduce the amount of P and N that enters the Nation's waters. While both P and N are important, research at the state and national level indicate that P is the nutrient primarily responsible for the eutrophication (nutrient enrichment) of lakes and rivers and has been the primary focus of nutrient standards development. Minnesota has been actively developing eutrophication standards for lakes and rivers. In 2008 lake eutrophication criteria were formally adopted into Minnesota's water quality standards. These ecoregion-based standards (Table 2) provide a basis for assessing the health of Minnesota's lakes and are the primary basis for Minnesota's 303(d) "Impaired Waters" assessment; whereby lakes that do not meet the standards are deemed impaired and then prioritized for development of a Total Maximum Daily Load (TMDL) Study. Alternately the standards also provide a basis for identifying lakes that meet standards and where every effort should be made to ensure that water quality is protected.

More recently MPCA has drafted river eutrophication criteria that are in the process of being brought into Minnesota's water quality standards. These criteria are regionally-based as well and were developed to ensure that aquatic life (fish and invertebrate communities) uses are fully supported in Minnesota's streams and rivers. This rulemaking is currently in process and river eutrophication standards adoption is anticipated for completion by 2012. Table 3 provides draft criteria current as of November 2010.

Excess P arises from both point (e.g. wastewater discharges) and nonpoint (e.g. runoff from cultivated land or urban landscapes) sources. P contributions to Minnesota surface waters by point and nonpoint sources are known to vary, both geographically and over time, in response to annual variations in weather and climate. Nonpoint sources of phosphorus tend to comprise a larger fraction of the aggregate P load to Minnesota surface waters during relatively wet periods, while point sources become increasingly important during dry conditions.

Table 2

Minnesota's Lake Eutrophication Criteria. Criteria are defined by ecoregion for specific lake types and uses (official use classification noted). TP and chlorophyll-a should remain below these concentrations and Secchi should be not less than this value to ensure that the specific use is maintained.

Ecoregion – lake type (use classification[1])	**TP** µg/L	**Chl-a** µg/L	**Secchi** meters
Northern Lakes and Forests – Designated Lake trout (Class 2A)	12	3	4.8
Northern Lakes and Forests – Designated Stream trout (Class 2B)	20	6	2.5
Northern Lakes and Forests – Aquatic Rec. Use (Class 2B)	30	9	2.0
Central Hardwood Forest – Designated Stream trout (Class 2B)	20	6	2.5
Central Hardwood Forest – Aquatic Rec. Use – Deep (Class 2B)	40	14	1.4
Central Hardwood Forest – Aquatic Rec. Use – Shallow (Class 2B)	60	20	1.0
Western Cornbelt Plains & Northern Glaciated Plains – Aquatic Rec. Use – Deep (Class 2B)	65	22	0.9
Western Cornbelt Plains & Northern Glaciated Plains – Aquatic Rec. Use – Shallow (Class 2B)	90	30	0.7

[1] Aquatic life and recreation use class as defined in Minn. R. 7050.0140, subp. 3 and Minn. R. 7050.0222 (Minnesota Rules Chapter 7050 2007). Class 2A is used for waters supporting a cold water fishery and refers specifically to lakes that support natural populations of lake trout. Stream trout refers to all other designated (managed) trout lakes. Class 2B is designation for waters supporting cool or warm water fishery and is the default classification for the majority of Minnesota's lakes.

Table 3

Draft River Eutrophication Criteria by River Nutrient Region for Minnesota

	Nutrient	**Stressor**		
Region	**TP** µg/L	**Chl-a** µg/L	**DO flux** mg/L	**BOD_5** mg/L
North	**55**	**<10**	**≤4.0**	**≤1.5**
Central	**100**	**<20**	**≤4.5**	**≤2.0**
South	**150**	**<40**	**≤5.0**	**<3.5**

Barr (2004) provide statewide and basin-specific summaries of the sources of P to Minnesota surface waters. While these are not specific to the Cannon River Watershed the general message conveyed by these estimates would be applicable. In this work they provide estimates for low, medium and high flow conditions.

Further details may be found in: Barr Engineering. 2004. Detailed Assessment of Phosphorus Sources to Minnesota Watersheds. A report prepared for MPCA. This report may be accessed at: http://www.pca.state.mn.us/index.php/about-mpca/legislative-issues/legislative-reports/detailed-assessment-of-phosphorus-sources-to-minnesota-watersheds-2004-legislative-report.html?menuid=&redirect=1

What does this all mean for the lakes and rivers of the Cannon River Watershed?
The Cannon River drains an area of 1,460 square miles and represents a transition from the North Central Hardwoods Forests (NCHF) ecoregion to the northwest and Western Corn Belt Plains (WCBP) ecoregion to the south. A mosaic of landuses are present in the watershed ranging from a mixture of forested and open lands, including numerous lakes and wetlands, in the northwest to the predominately agricultural lands to the south. Though this portion of the watershed contains many lakes, most are quite eutrophic. The 2010 Draft 303(d) Impaired Waters list includes 34 lake listings for excess nutrients (Figure 7). Work-to-date, on watershed studies in support of eventual TMDLs for these lakes, indicates that large reductions in P must be made in order to meet water quality standards and as is the case for surface waters statewide, nonpoint sources represent the majority of the P loading to the lakes under average to high flow conditions.

Byllesby Reservoir, a reservoir on the main-stem of the Cannon, has been the subject of an extensive TMDL study and indications are that very large reductions in both point and nonpoint sources will be required to ensure that water quality standards for P will be met. As a part of the TMDL study site specific TP, chlorophyll-a and Secchi criteria were developed for the reservoir and these criteria are undergoing review at USEPA. Once adopted the criteria will provide the basis for calculating final load reductions needed to meet the TMDL.

Although the river eutrophication criteria have not been formally adopted into Minnesota's water quality standards draft assessments based on current observed P for the Upper and Lower Cannon and the Straight Rivers suggest that these major tributaries of the Cannon River watershed are likely to exceed standards. This implies there will be need for a watershed-wide TMDL to address sources of excess nutrients to the Cannon to ensure that aquatic life and aquatic recreational uses as met – consistent with the Clean Water Act. Thus, much work lies ahead as CRWP and its partners continue to address nutrient over-enrichment in the Cannon River Watershed.

E.coli Bacteria by Tiffany Schauls, MPCA

E. coli in water is an indicator that other harmful pathogens may exist. Although most strains are harmless and live in the intestines of healthy humans and animals, the strain "E. coli O157:H7" produces a powerful toxin and can cause severe illness. If E. coli impairments are identified, the affected use is aquatic recreation. Aquatic recreation, formerly referred to as "swimmable use", is a use support classification that considers not only swimming, but wading, aesthetics, and other aquatic uses. In addition, high levels of bacteria in water are positively related to common aquatic life stressors such as: sediment (suspended and embedded), temperature, nutrients and pesticides. Some chemicals and pathogens occur naturally, but their abundance may be influenced by other human stressors such as land use and land cover (e.g., paved surfaces, forestry, and irrigation practices, which can influence runoff patterns) or by natural stressors such as weather and climate.

A new E.coli water quality standard became effective in Minnesota Water Quality Rule Ch 7050 on March 17, 2008, and was subsequently approved by USEPA on May 23, 2008. Future aquatic recreation assessments, starting with the 2010 assessments and delisting reviews, will be done using only E.coli data. This change from a fecal coliform to E. coli standard has been made because of the variability in the E.coli/fecal coliform statistical relationship and to emphasize the message that current and future monitoring for aquatic recreation use support should be based on the newly adopted E.coli water quality standard.

The E. coli standard is a geometric mean of not less than five samples collected in one month. Many monitoring programs rarely sample more than once per month, so it was decided that given the low variability by month, that multiple years of data for the same month, could be used for assessment. Generally speaking, the standard for E. coli is 126 organisms/100 mL of water with no more than 10% exceeding the maximum of 1260 organisms/100 mL (with the exception of Class 7 waters). This standard applies from April 1-October 31st. The E. coli standard is fairly basic and clear-cut when compared to aquatic life impairments, which are much more complex.

Bacteria sources in the Cannon River watershed are most likely from multiple sources such as: straight pipe septic systems/ISTS/unsewered communities, urban stormwater, and feedlots/manure application. These issues are widespread in the Cannon River watershed.

Bacteria survival appears to be shortened by exposure to sunlight. It is possible that Byllesby Reservoir, as well as other lakes and wetlands in the upper Cannon Watershed, function to reduce downstream bacteria loading.

A study of the Straight River watershed divided sources into continuous (failing individual sewage treatment systems, unsewered communities, industrial and institutional sources, wastewater treatment facilities) and weather-driven (feedlot runoff, manured fields, urban stormwater catagories). The study hypothesized that when precipitation and stream flows are high, the influence of continuous sources is overshadowed by weather-driven sources, which generate extremely high fecal coliform concentrations. However, during drought, low-flow conditions continuous sources can generate high concentrations of fecal coliform, the study indicated. Besides precipitation and flow, factors such as temperature, livestock management practices, wildlife activity, fecal deposit age, and channel and bank storage also affect bacterial concentrations in runoff (Baxter-Potter and Gilliland, 1988).

Research is underway in Minnesota and elsewhere in the United States on the use of DNA "fingerprinting" techniques to identify the source of *E. coli* bacteria. The goal of this work is an affordable method to determine if the *E. coli* bacteria in surface waters originated from humans or from animals. If this tool can be perfected, it will be very valuable in helping to direct *E. coli* contamination reduction efforts where they will be most effective.

The approved Lower Mississippi River Basin Fecal Coliform TMDL addresses these impairments, and the subsequent implementation plan discusses source reduction strategies, some of which are already in place in the watershed. Numerous projects and millions of dollars have been put to work in southeast Minnesota in the past ten years to address this pollutant. Much of the efforts at fecal coliform reduction have been focused on feedlot fixes, helping unsewered and under sewered communities install safe, functioning wastewater treatment, manure management, grazing management, installation of buffers and other conservation practices. Progress has been made in this area but more work is still to be done.

Pesticides by Joseph Zachmann and Dave Tollefson, Minnesota Department of Agriculture

A pesticide is any substance or mixture of substances intended for preventing, destroying, repelling, or lessening the damage of any pest and may be a chemical substance or a biological agent. Many homeowners, public facilities and institutions, industries and farmers periodically utilize the legal application of pesticides as part of efforts to manage particular pest problems.

Many agricultural producers use pesticides (most commonly herbicides, insecticides and fungicides) to protect crops and increase yields. Homeowners and municipalities use pesticides to manage pests around homes and in lawns, gardens and parkland. Lake managers and lakeshore owners might use aquatic pesticides to control aquatic plants or other aquatic organisms that are causing nuisance conditions or that have an impact on valuable aquatic habitats. Public health officials may request the use of pesticides to control or prevent disease outbreaks.

Some pesticides can leach through soil to groundwater or impact surface water in wastewater or due to losses from fields, impervious surfaces, lawns, turf and roadside ditch maintenance. As such, there is concern that pesticides might be stressors to aquatic plants and animals. Pesticides of potential concern in the Cannon River watershed are likely to be the herbicides and insecticides used to control unwanted weeds and insect pests in residential, industrial, public and agricultural settings.

The potential impact of a pesticide on water quality is partly determined by its physical and chemical characteristics, the properties of the soil or water body to which it is applied, rates and methods of application, and weather patterns. A pesticide may move from its application site by leaching below the soil surface or by movement with sediment or water in surface runoff. Both routes of movement have the potential to adversely affect water quality.

Pesticides may directly access groundwater when spilled or used near naturally-occurring sink holes, and poorly sealed or abandoned wells. These sites provide direct conduits for the transport of water and pesticides to groundwater. Contamination by the less direct route of leaching through the soil profile may occur in areas of concentrated pesticide handling, such as mixing and loading facilities and disposal sites. Certain pesticides may leach to groundwater or runoff to surface water in Minnesota under conditions of normal use.

The Minnesota Department of Agriculture (MDA) monitors both ground and surface water for pesticides across Minnesota. The MDA works with the MPCA and the Minnesota Department of Health to evaluate all pesticide detections in state water resources. The MDA uses a network of nested monitoring wells, naturally occurring springs, and domestic wells to monitor for commonly used pesticides in Minnesota's groundwater. MDA has completed extensive surface water monitoring in Minnesota for pesticides. MDA targets watersheds where pesticides are used, and collects samples in May and June during periods of storm driven run-off. These periods represent the highest likelihood of pesticide detection in Minnesota. MDA uses a tiered approach that increases monitoring efforts at locations with pesticide detections in the past. All sites are monitored for a minimum of three years. In addition to monitoring rivers and streams, MDA monitors lakes, wet precipitation, and agriculture drainage tile.

When pesticides are commonly found in groundwater, they can be placed in common detection status by the Commissioner of Agriculture. Currently, there are five "common detection pesticides": acetochlor, alachlor, atrazine, metolachlor and metribuzin (all corn herbicides). For surface water, the MDA also determines if a pesticide, based on detection frequency and concentration, is a "surface water pesticide of concern." Atrazine, and one associated degradate, de-ethyl atrazine, is detected in several monitored streams throughout southeastern Minnesota. There are only two water quality impairments in Minnesota for a currently registered pesticide: The Le Sueur River and the Beauford Ditch (tributary to the Le Sueur River) were listed by the MPCA as impaired waters for acetochlor based on concentrations observed in 2005, but not since then.

The MDA has published, promoted and is evaluating Best Management Practices for all groundwater common detection pesticides and all surface water pesticides of concern.

MDA conducts both ground and surface water monitoring in the Cannon River Watershed. For the latest information and results, visit www.mda.state.mn.us/monitoring for annual workplans and data reports.

Drainage and Hydrologic Modification by Joel Peterson, PE, Assistant Professor, University of Wisconsin – River Falls

Artificial subsurface drainage, commonly called tile drainage, and modification of surface drainage patterns to support tile drainage are frequently cited as causes of flooding and water quality problems. While these modifications have altered the timing and magnitude of flows and have impacts on the quality of downstream receiving waters, the impacts are often difficult to attribute solely to tile drainage since land use changes often accompany hydrologic modification.

Artificial drainage (subsurface and surface) represents a significant hydrologic alteration to the landscape resulting in changes to the timing and magnitude of flows and has impacted the water quality of receiving waters. Changes to the hydrologic regime in receiving waters have affected ecosystem health.

Tile drainage is used in poorly drained areas to increase crop production. Drainage generally permits earlier and more timely field operations for equipment, allows soils to warm faster and permits greater aeration for seedling development. In general, surface drainage ditches provide an outlet for subsurface drainage by conveying water to receiving bodies of water.

It is difficult to discuss the impact of tile drainage on hydrology without also discussing land use. Historically, much of the Cannon River watershed was covered by prairie or oak savannah in the southern and eastern part of the watershed and hardwoods in the western and central portions of the watershed. Much of the watershed, and of the state, has been converted to agricultural use. Thus, any discussion regarding the effects of drainage must consider the change in land use over the last century or more.

In general, drainage tends to reduce the volume of runoff from an individual rain event, given the same land use. Tile drainage removes gravitational water from the soil profile, so the soil is able to absorb more water during subsequent rain events. Conversely, an undrained soil will have a higher water content and will have less ability to absorb or store more water during a rain event, which causes an increase in runoff volume. This behavior is known as the 'sponge' effect of tile drainage.

While tile drainage generally decreases the volume of runoff from an individual rain event, research indicates that tile drainage tends to increase the water yield from a given area by about 10% (Blann et al., 2009). Water yield can be considered the amount of water leaving a watershed that can be measured using traditional stream gauging techniques. Water yield includes surface runoff, tile drainage water, the groundwater contribution to stream flow, and any other flow (interflow, return flow) that exits the watershed via stream or ditch. The increase in water yield is thought to affect erosion and sediment transport in receiving waters by changing the hydraulic shear force that causes erosion and changes sediment transport conditions.

The impacts of artificial drainage on flooding are not well defined. Channelization, or increased surface drainage, typically increases peak flows at the field scale by decreasing the time of concentration and removing surface storage (Robinson and Rycroft, 1999). The effects of subsurface drainage on peak flows at the field scale are variable, depending on climate and soil conditions. At watershed and larger scales, precipitation event characteristics (rainfall intensity, duration) and basin geometry and topography may become more important that the effects subsurface drainage on peak flow (Robinson and Rycroft, 1999).

Drainage ditches also convey sediment to receiving waters, through in-stream processes and sediment originating from field sources. Kelley and Nater (2000) reported a 12-fold increase in sediment load from the MN river basin, a highly agricultural region with extensive subsurface drainage, over historic levels. Surface inlets to tile systems, used to drain depressional topography, provide a direct pathway for sediment and nutrients in surface runoff to enter drainage ditches (Oolman and Wilson, 2003).

Nutrient and sediment exports have broad implications in MN and elsewhere for Total Maximum Daily Load (TMDL) allocations and addressing large-scale water quality issues like hypoxia, particularly in the Gulf of Mexico (Rabalais et al., 2001; 2010) and accelerated eutrophication in Lake Winnipeg, Canada (Pip, 2006). Nitrogen export from the Mississippi River basin has increased an estimated 2- to 7-fold over the last century (Blann et al., 2009). Agricultural regions with extensive subsurface drainage, growing corn and soybeans, are shown to exhibit the greatest N fluxes (2-100 kg/ha/yr) versus non-drained agricultural land with N losses of 1-50 kg/ha/yr.

The cumulative effect of hydrologic and water quality changes is exhibited in ecosystem health. Perhaps the most noticeable effect of drainage is the direct elimination of wetland and riparian habitats (Blann et al., 2009). According to Dahl (1990), more than 50% of these wetland acres have been lost since the time of European settlement. Drainage impacts are most profound on small, seasonally inundated wetlands.

Changing hydrologic conditions affect stream characteristics like channel width, depth, pool and riffle sequence, channel sediment size distribution, and other related characteristics. Modification of these channel characteristics represents a change in habitat that is a major threat to aquatic biodiversity (Blann et al., 2009).

There is renewed emphasis to investigate methods to mitigate the detrimental effects of hydrologic alteration on the environment. These include 'right sizing' or modifying the drainage coefficient to balance impacts and return, using woodchip bioreactors (Greenan et al., 2009) to reduce nitrate concentrations, and using a two-stage ditch design (Powell et al., 2007) to more closely mimic natural stream function.

Thermal pollution by Brian Nerbonne, DNR

Why is it important?
Aquatic organisms have different preferences for water temperature. Some species such as trout prefer cold water, and can survive only in spring-fed streams that remain cold throughout the summer. Warm-water fish species such as largemouth bass and channel catfish prefer the warmest water temperatures found in Minnesota. Other species such as walleye and smallmouth bass are cool-water fish, preferring moderate temperatures for their optimal growth. Various species of aquatic insects that form an important part of the aquatic food web also have similar variation in temperature preference. Water temperature is one of the key factors that determine what species live in a stream.

Temperature affects aquatic organisms in two primary ways: 1) effects on dissolved oxygen, and 2) effects on metabolism. The capacity for dissolved oxygen in water is inversely related to temperature; the colder the water, the more oxygen it can hold. For species that require high dissolved oxygen levels such as trout, an increase in temperature can cause stress or even death due to the reduction in oxygen availability. Other types of pollution that lower dissolved oxygen can exacerbate the problem.

The effect on metabolism is caused by fish and aquatic invertebrates being cold-blooded, meaning their metabolism rises and falls with body temperature. The preferred temperature of a species is where the intake of energy is greatest relative to energy expended. As temperature increases beyond the optimal temperature, the difference shrinks until at some point the organism is expending more energy than it can take in. If this occurs regularly or for long periods of time, growth and reproduction are compromised and can eventually lead to starvation. If temperature is increased beyond an extreme threshold for even a short period, the metabolic oxygen demand may be higher than intake and the organism may die.

When the temperature conditions are changed, the suite of species present will also change. There are numerous trout streams in the Cannon River Watershed, including Rice Creek (Spring Brook), Pine Creek, Trout Brook, the Little Cannon River and Spring Creek. These systems are most sensitive to thermal pollution, and all are currently impacted to some degree by either agricultural or urban land uses. Cool-water species such as walleye, smallmouth bass, and northern pike are all important fisheries on the Cannon River and some tributaries. Although not as sensitive as trout streams, cool-water species may see declines if thermal pollution is widespread.

What causes thermal pollution?
Water temperature reflects recent average air temperature, but many factors can cause it to be warmer or cooler than that average. Direct sunlight can warm the water during the daytime, making shading of a water body an important factor in how warm the water gets, and how much temperature fluctuates between day and night. The source of water feeding the stream also has a big effect on temperature. Surface runoff reflects air temperature, but it can be even warmer if it flows across unshaded surfaces such as bare soil or asphalt. Groundwater from springs is considerably cooler, reflecting the mean annual air temperature which in Minnesota is around 50˚ F. Streams that receive a greater amount of their flow from groundwater are therefore cooler.

The difference in temperature between surface runoff and groundwater means that geology and land use have a big effect on stream temperature. Areas where precipitation more easily soaks into the ground (such as the limestone bedrock underlying the Lower Lobe of the Cannon River watershed) tend to have more groundwater-fed streams that contain cold or cool-water organisms. Land uses that reduce the amount of surface runoff (e.g. prairie and forests) create streams with cooler water temperatures than in areas with more surface runoff such as row-crop agriculture or developed urban areas.

How can thermal pollution be prevented?
We have little influence over the bigger drivers such as geology or air temperature, although human-induced climate change will certainly have effects on water temperature. What can be done locally is to encourage land-use practices that prevent the unnatural warming of water bodies. A riparian buffer that provides shading and soaks runoff back into the ground can help to keep a stream cool. In agricultural settings, practices that reduce runoff such as conservation tillage, contour farming, and growing perennial crops are beneficial. In urban areas, the amount of impervious surfaces (e.g. roads, rooftops, and parking lots) should be minimized through thoughtful design of developments. The runoff from impervious surfaces should be directed to pervious areas where it can soak back into the ground, such as to raingardens or areas of natural vegetation rather than piped directly to the stream via a storm sewer. Routing runoff through ponds can also cause warming, because warm surface water is pushed out of the pond by incoming runoff. Infiltration and conservation design practices are incorporated into “low impact development”, a suite of techniques growing in popularity as a way to mitigate many of the negative effects on water resources caused by urban development.

Invasive Species by Joe Eisterhold, DNR

Invasive species have been dramatically proliferating globally since the accessibility of human travel in the late 19th century; human activities are increasing the spread of non-indigenous plants and animals. Invasive species have the potential to cause serious problems in Minnesota. Within the Cannon River Watershed non-native species are a threat to the state’s natural resources and local economies.

The best economical investment is to try and keep non-native species from entering any state and watershed in the first place. Once an invasive species has entered a lake or river the cost to manage that nuisance can become very costly. After an invasive species has become well established then an overall expectation to accept that it may be their indefinitely ultimately makes the issue of invasive species hard to accept for anyone that is involved.

Current Invasive Species

Many invasive species such as Eurasian watermilfoil, purple loosestrife, zebra mussels, spiny waterfleas, curly-leaf pondweed, flowering rush, numerous terrestrial invasive plants, and other aquatic nuisances are present in Minnesota. Within the Cannon River Watershed the two main aquatic invasive species are Eurasian watermilfoil and curly-leaf pondweed. These two plants are similar in that they alter ecosystem regimes but manage to do it in different ways. Eurasian watermilfoil starts growing in the early spring while curly-leaf pondweed starts to grow in late fall into the next summer. Both invasive plants can cover large areas and choke out native vegetation resulting in large monocultures of the invasive species. Eurasian watermilfoil reproduces mainly through vegetative rhizomes under the sediment and curly-leaf pondweed spreads through the production of turions. Turions are vegetative buds that grow off the stem and are released to the water column, some float some will sink to the bottom. These vegetative buds are shaped similar to a corkscrew and are hard like a pine cone. Another invasive species that has been recorded in the area is flowering rush. This emergent plant has not spread to nuisance levels but is a concern because it has the potential to become a problem in shallow areas. Little research has been conducted on how to manage this plant. New research is underway as to how this plant grows and to find out any weaknesses it may have to obtain information to better manage this plant.

Invasive species for the future

New invaders that are not in the Cannon River Watershed but should be on the radar include: Asian carp, spiny waterfleas, hydrilla, brazillian waterweed, zebra mussels and faucet snails. Numerous invasive plants and animals are bordering Minnesota but have not been reported to date because of the ongoing efforts that numerous state and federal agencies undertake to prevent invasive species from entering. Nurseries, gardening stores, and pet shops have been vectors of invasive species as well as boaters and improvements have been made to reduce the possibilities that new invasives will be introduced. Invasive species are a difficult challenge because of the management restraints and new ones are approaching rapidly especially in a world with extreme human activity.

Management

The Minnesota DNR has put a large emphasis on prevention and some tools that are being used are watercraft inspections at public water accesses and public awareness events. The various public awareness approaches have been used across the state which has heightened public awareness of the importance of cleaning, draining, and drying one’s boat: public service announcements, billboards, brochures, information kiosks, and many others.

Objectives for Minnesota to manage invasive species include:

1. Enforce and adopt new laws, regulations, and policies to prevent the spread of invasive species.
2. Educate the public of the threat that invasive species could have on the environment and explain how crucial it is to stop the spread.
3. Monitor for existing and new infestations to discern pathways and attempt containment where applicable. Attempt to manage known infestations if control measures meet realistic expectations.

References

Blann, K.L., Anderson, J.L., Sands, G.R., & Vondracek, B. (2009). Effects of agricultural drainage on aquatic ecosystem: a review. *Critical Reviews in Environmental Science and Technology, 39* (11), 909-1001.

Dahl, T.E. (1990). Wetland losses in the United States, 1780’s to 1980’s. U.S. Fish and Wildlife Service, Washington D.C.

Greenan, C.M., Moorman, T.B. , Parkin, T.B., Kaspar, T.C., & Jaynes, D.B. (2009). Denitrification in wood chip bioreactors at different water flows. *Journal of Environmental Quality, 38*, 1664-1671.

Kelley, D.W. & Nater, E.A. (2000). Historical sediment flux from three watersheds into Lake Pepin, Minnesota, USA. *Journal of Environmental Quality*, *29*, 561-568.

Oolman, B.E., & Wilson, B.N. (2003). Sediment control practices for surface tile inlets. *Applied Engineering in Agriculture*, *19* (2), 161-169.

Pip, E. (2006). Littoral mollusk communities and water quality in southern Lake Winnipeg, Manitoba, Canada. *Biodiversity and Conservation*, *15*, 3637-3652.

Powell, G.E., Ward, A.D. , Mecklenburg, D.E. , & Jayakaran, A.D. (2007). Two-stage channel systems: Part 1, a practical approach for sizing agricultural ditches. *Journal of Soil and Water Conservation*, *62* (4), 277-286.

Rabalais, N.N., Turner, R.E., & Wiseman, W.J. (2001). Hypoxia in the Gulf of Mexico. *Journal of Environmental Quality*, *30*, 320-329.

Rabalais, N.N., Diaz, R.J., Levin, L.A., Turner, R.E., Gilbert, D., & Zhang, J. (2010). Dynamics and distribution of natural and human-caused hypoxia. *Biogeosciences*, *7*, 585-619.

Robinson, M., & Rycroft, D.W. (1999). The impact of drainage on streamflow. *Agronomy Monograph*, *38*, 767-800.