

Vermillion River Watershed Fecal Coliform Bacteria Study

A Technical Report Supporting the Regional Total
Maximum Daily Load Study



Submitted to the
Minnesota Pollution
Control Agency

May 2004



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I. Executive Summary

1.1 Abstract

The Vermillion River was officially listed as impaired for swimming in 1998 when it was added to the Federal 303(d) list of impaired waters due to high bacteria levels. A Total Maximum Daily Load (TMDL) Study for fecal coliform bacteria in the Vermillion watershed officially began in 1999 with guidance and support from the PCA and project management by the Dakota County Soil and Water Conservation District (SWCD). However, the scope of the Vermillion River TMDL changed after the Regional TMDL Study for Fecal Coliform Bacteria in the Lower Mississippi River Basin in Minnesota was developed by the PCA and accepted by the EPA. Since the Vermillion River watershed is included in the Regional TMDL, the Vermillion River TMDL effort was changed from a formal TMDL to a technical supporting document to the Regional TMDL.

Water monitoring through the Vermillion study found bacteria levels above the standard of 200 organisms/100 ml throughout the watershed from the headwaters to just below the falls in Hastings. Since landuse in the watershed varies from dense urban centers to rural agricultural areas, there is a wide variety of potential bacteria sources including failing individual sewage treatment systems, manure running off fields and feedlots, urban runoff, wildlife, and wastewater treatment plants.

It was recommended by MPCA staff that it was most appropriate to estimate and express source loads in relative categorical terms (low, moderate, high) for the Vermillion River TMDL Study. Therefore all available data including landuse/landcover data, impirical bacteria data, and anecdotal information was reviewed by a large group of stakeholders who assigned relative loadings from different fecal coliform sources. The entire watershed was divided into nine subwatersheds and relative loads were assigned to each (Table 1.1).

Table 1.1 Relative Load in Subwatersheds and Overall Ranking of Sources

Source	Eureka	Middle Creek	South Creek	North Creek	South Branch	Farmington	Empire	Goodwin	Hastings	Overall Ranking ¹
Livestock in water	Low	High	Low	NA	Mod.	Low	Low	Mod.	Low	1.3
Feedlots	Mod.	High	Low	NA	Mod.	NA	Low	Mod.	Mod.	1.4
ISTS	Mod.	Mod.	Low	Low	High	Mod.	High	Mod. - Hi	High	2.2
Manure Appl.	Mod.	High	Mod.	Low	Low	Mod.	Mod.	Mod.	Mod.	1.9
WWTP	Mod.	NA	NA	NA	Low	NA	Low	Lo – Mod	NA	0.6
Urban	Low	Mod.	Mod.	High	Low	Mod.	Low	Low	Low	1.5
Wildlife	Low	Low	Low	Low	Low	Low	Low	Low	Low	1.0

¹ Overall ranking was calculated by taking the average of the scores where NA (not applicable) = 0, low = 1 point, moderate = 2 points, and high = 3 points.

Overall, individual sewage treatment systems (ISTS) were found to be the highest contributor to the fecal contamination in the river. Manure applied to fields, urban runoff, and feedlot runoff contributed the next highest amounts of bacteria, respectively.

Local stakeholder involvement and public outreach was a large component of this study. Efforts to educate stakeholders on the impairment, the study, and the TMDL process were varied and included updating citizens, interested parties, and the Vermillion River Watershed Joint Powers Organization (JPO) on a regular basis. Currently, the JPO is in the middle of developing a comprehensive watershed management plan. Recommendations on implementation strategies are being considered by the JPO for inclusion in the watershed management plan.

1.2 Acknowledgements

The Dakota County Soil and Water Conservation District would like to thank the many people that contributed time and effort towards this study. Without their help and input this study would not have happened! Our thanks goes out to:

Minnesota Pollution Control Agency staff especially Dave Morrison and Lee Ganske for their technical support and expertise; citizen volunteer monitors including Bob Nicholson, Ceil Strauss, Judy Sloan, and Dave and Klaarjte Stegmeier; Prairie Island Indian Community staff, especially Ruth Estes; Dakota County staff; the Dakota County Environmental Education Program, especially Charlotte Shover, for “getting the ball rolling”; and various local stakeholders and technical advisors from several different agencies and local units of government.

II. Background

2.1 Watershed Features

The entire Vermillion River Watershed encompasses 372 square miles and lies at the southern edge of the Twin Cities in Scott, Dakota, and Goodhue Counties, Minnesota (Figure 2.1). The mainstem of the river begins in eastern Scott County and travels northeasterly through Dakota County for 38 miles before falling 90 feet at waterfall in the City of Hastings. From there, the river winds through the “bottoms” for another 20 miles, often co-mingling with the Mississippi River. The actual confluence with the Mississippi River is just north of the City of Red Wing in Goodhue County.

The Upper Vermillion River, from the headwaters to the falls in Hastings, is often referred to as a “prairie river,” slowly meandering through farm fields and past suburban residential lawns. Human pressures and demands on the river are great. For instance, the population of the watershed (in Dakota County) grew 47% in the past decade from an estimated 100,700 residents in 1990 to over 148,000 in 2000. Landuse in the watershed includes rapidly expanding suburban residential areas, commercial and industrial areas, and agriculture including row crops, hobby farms, dairy operations, etc. Most of the active suburban development is taking place in the headwaters and along major tributaries (Figure 2.2).

There are approximately 50 miles of designated trout stream along the mainstem of the Vermillion and many more miles are known to harbor healthy trout populations. Trout need cold, clean water to thrive and reproduce and currently, the Vermillion is providing such habitat.

Recreation in the river includes activities such as canoeing, kayaking, fly-fishing, wading, and swimming. Rambling River Park in Farmington is the site of some wading and swimming by local children in the summer and the Rapids Riders kayaking club often uses the river just below the falls in Hastings, especially during periods of high flow. There is very little public access to the river along most of its length, however, and it is unknown how widely the river is used for contact recreation by riparian landowners.

The Scott County and Dakota County portions of the watershed have been managed since 1984 under the State’s Surface Water Management Act and State Statute 103B. From 1984 to July 2000, the watershed was managed by the Vermillion River Watershed Management Organization (WMO) through a joint powers agreement among 21 member communities. In August 2000, the WMO dissolved and Dakota and Scott Counties took over watershed management responsibilities. Since September 2002, the watershed has been managed by a Joint Powers Organization (JPO) between Scott and Dakota Counties. A three-member Joint Powers Board comprised of two Dakota County Commissioners and one Scott County Commissioner oversees the operations of the JPO. A nine member Planning Commission made up of watershed citizens and local officials advises the JPB. Currently, the Planning Commission and JPB are working on updating their watershed management plan which dates back to 1989. *(For more information on the Vermillion River Watershed Joint Powers Organization, please visit their website at <http://www.co.dakota.mn.us/planning/vermillionjpo/index.htm>.)*

2.2 Water Quality in the Vermillion

While the Vermillion River and some tributaries support healthy trout populations, there are also some water quality problems in the river including high fecal coliform bacteria and nitrogen. These pollutants occur in even higher concentrations during and after runoff events such as rainstorms and snowmelt. In addition, total phosphorus and turbidity increase significantly during runoff events.

Fecal coliform bacteria are indicator organisms, nonpathogenic bacteria that are usually associated with pathogens transmitted by fecal contamination, but which are more easily sampled and measured. They are found in the intestines of warm-blooded animals (including humans) and their existence in a waterbody shows the presence of fecal matter and suggests the likely presence of associated harmful bacteria, viruses and protozoa (giardia, certain *E. coli* strains, cryptosporidium, etc.). The Minnesota State standard for fecal coliform bacteria in surface water is 200 organisms per 100 milliliters (ml) of water as a geometric mean of at least five samples in any calendar month from March 1 to October 31 (MN Rules Chapter 7050). (Minnesota drinking water standards do not allow for any fecal coliform bacteria.) Typically, unimpacted waterbodies contain only trace amounts of fecal coliform (usually less than 10% of the state standard). Bacteria levels higher than the State standard are considered dangerous for human contact.

Fecal coliform contamination in surface water can originate from a variety of sources. These include wastewater treatment plants and other point sources, and non-point sources such as leaking or non-conforming individual sewage treatment systems, runoff from feedlots or fields with land-applied manure, livestock in the waterbodies, pet waste, urban stormwater, and wildlife.

2.3 Evolution of the Vermillion River Bacteria Study

(See Appendix A for the original and revised workplans for the Vermillion River TMDL.)

1998: The Vermillion River from Empire Township to Hastings was added to the Federal Clean Water Act's 303(d) list of impaired waters due to fecal coliform bacteria contamination.

1999: The Dakota County Environmental Education Program and local citizens began monitoring the river more intensely to determine the extent of the pollution and identify possible sources. The Minnesota Pollution Control Agency (PCA) began an official total maximum daily load study for bacteria in the watershed.

2000: The Minnesota Pollution Control Agency (PCA) contracted with the Dakota County Soil and Water Conservation District to complete the Vermillion River TMDL Study for fecal coliform bacteria.

2001: Through a grant from the Legislative Commission on Minnesota Resources, the University of Minnesota began a study of the DNA associated with bacteria in Vermillion River Watershed to help determine pollution sources.

2002: While the Vermillion River TMDL was getting underway, the MPCA was beginning to recognize the widespread nature of fecal coliform pollution in the streams and rivers of southeastern Minnesota. In an effort to address this problem in a comprehensive manner, the MPCA completed the Regional Total Maximum Daily Load Study of Fecal Coliform Bacteria: Impairments in the Lower Mississippi River Basin in Minnesota. This document was submitted to and approved by the U.S. Environmental Protection Agency (EPA), Region 5. Data from the Vermillion River TMDL Study was integral to the completion of the regional study.

2003: The PCA and the Basin Alliance for the Lower Mississippi in Minnesota (BALMM) submitted an Implementation Plan for the Regional TMDL.

III. Methods

3.1 Water Sampling and Analysis

Surface water grab samples were collected by a variety of agency staff and citizen volunteers throughout the Vermillion River watershed during the course of the study; March 1999 – October 2002. Sampling sites were located on small headwater streams, major tributaries, and the mainstem of the Vermillion River (Figure 3.1). Samples were typically grabbed by lowering a clean bucket from a bridge and placing the water in a new container or bag supplied by the laboratory. Some samples were grabbed by placing the container directly in the waterbody. Samples were labeled with time, date, location, and the initials of the person taking the sample and were placed on ice. The sampling bucket was rinsed with distilled water and site water before each sample was taken and it was not used for any other purposes. Samples were delivered to certified laboratories and analysis took place within 24 hours of collection. Field notes taken at the time of each sample included recent weather and stream conditions.

Data from approximately 900 samples collected from 28 different sites by a variety of agencies were used in this study. The vast majority of the monitoring was done by SWCD staff, PCA staff, University of Minnesota staff, and trained, adult citizen volunteers for purposes of this study and the DNA Study. Data from regular monitoring done by the Metropolitan Council at Biscayne Ave., Hwy. 79, and just above the falls in Hastings were also used as well as data collected for the Vermillion River Watershed Joint Powers Organization by the SWCD.

Monitoring for this study was typically done on a weekly basis. Additionally, some runoff events were sampled between regularly scheduled monitoring. In order to extend the monitoring budget to include as many sites as possible, sites were typically sampled for half the monitoring season so that other sites could be sampled during the second half of the season. This also allowed for monitoring at sites with no prior bacteria data rather than continuing to monitor locations that suggested no major impairments. In hindsight, this made some data analysis difficult, especially when attempting to analyze for seasonal differences or to compare sites against each other. Additionally, some sites were sampled for multiple years, while others were sampled for only one year.

Analysis for fecal coliform bacteria was done at four different certified laboratories during the study period. These labs follow approved QA/QC procedures. The following is a list of those labs and the methods they used.

Metropolitan Council Environmental Services, St. Paul, MN
Method: USEPA 600/8-78-017; total fraction sampled; reporting # colonies/100 ml

Minnesota Valley Testing Laboratory, New Ulm, MN
Method: Membrane Filtration; Standard Methods 18th Edition; Method No. 9222D

Prairie Island Indian Community Wastewater Treatment Plant, Red Wing, MN
Method: Membrane Filtration; Standard Methods 19th Edition; Method No. 9222D

Minnesota Department of Health, St. Paul, MN
Method: Membrane Filtration; Standard Methods 20th Edition; Method No. 9222D

In addition to strict field and handling techniques, the use of trained professionals and volunteers, and the use of certified laboratories, Quality Assurance and Quality Control (QA/QC) procedures used in this study included submitting blank samples and duplicate samples to more than one lab. Additionally, there were occasions when two different samples were collected from the same site on the same date by two different agencies. These are considered duplicate samples (cross check of different labs for gross values) even though the timing of the collections were different.

3.2 DNA Fingerprinting Study

(Note: The DNA Fingerprinting Study was supported, in part, by funding from the Legislative Commission on Minnesota Resources through the Environment and Natural Resources Trust Fund and the MN Future Resource Fund, the Metropolitan Council Environmental Services, and The University of Minnesota Agricultural Experiment Station.)

Researchers at the University of Minnesota, Department of Soils, Water, and Climate, used samples collected from ten sites throughout the watershed (Figure 3.1) to help determine the source of the bacteria by matching *E. coli* DNA with bacteria from known human and animal sources. The rep-PCR DNA fingerprinting technique was modified to use florescent primers. This technique was used along with BioNumerics software to analyze 1,776 *E. coli* isolates obtained on 7/11/2001, 8/8/2001, 9/5/2002, 10/3/2002, 5/1/2002, 6/5/2002, and 7/2/2002. Approximately 25 *E. coli* isolates were obtained from each sampling site on each sampling date.

DNA fingerprints from these *E. coli* were compared with those in an existing DNA fingerprint library of known sources, consisting of the *E. coli* from 12 animals species and humans that was previously created. The library contains only “unique” DNA fingerprints (no duplicates), which were selected from the total library of all *E. coli* fingerprints using the rep-PCR technique. Unique DNA fingerprints were defined as DNA fingerprints from *E. coli* isolated from a single host animal whose cosine similarity coefficients were less than 90%. Statistical analyses used in the study included Jackknife analyses using Pearson’s product-moment curve-based correlation coefficient, and ID Bootstrap analysis.

At the end of the study, researchers determined that the study should be considered experimental in nature as the method has not been rigorously validated and the library of control clones is not large enough to capture all of the genetic diversity of *E. coli* present in the environment. When evaluating the methods, a Jackknife analysis, which measures group integrity, shows that when animals were analyzed separately the average value of group self-identity was only 57%. This makes it difficult to determine, with confidence, individual animal sources. This is especially true when trying to distinguish among cats, dogs, and humans because their DNA is commonly identified as one another in these analyses.

However, when *groupings* of animals within the control clones library were used such as cats and dogs in a “pets” group; ducks and geese in a “waterfowl” group; chicken, cow, goat, horse, pig, sheep, and turkey in a “domesticated” group; and deer and humans in their own “wildlife” and “human” groups, respectively, the reliability improves. Domesticated isolates grouped with themselves 82% of the time, while pets, human, waterfowl, and wildlife isolates grouped with themselves 58%, 56%, 71%, and 63% of the time, respectively.

When a human vs. non-human grouping was analyzed among the control clones in the library, non-human isolates were shown to reliably group with themselves 93% of the time, while human isolates grouped with themselves correctly only 55% of the time. There is a potential problem with this analysis due to the fact that the non-human group contains the vast majority of the individuals and hence the variation. This may explain the non-human group’s high integrity. (The Jackknife analyses described were performed with 1% optimization and maximum similarities using a curve-based Pearson correlation coefficient.)

3.3 Landcover Mapping

The Minnesota Land Cover Classification System (MLCCS) was used to describe such watershed characteristics as vegetation type and impervious surfaces. MLCCS was developed specifically for Minnesota, and classifies urban, suburban, agricultural, and vegetated areas. Different areas of the watershed were classified under various grants and programs (most not related to the Bacteria Study) between 1999 and 2002.

Large format maps were printed with current aerial photography as a background and rare community and wetland hydrology data in the foreground. Vegetation communities and cultural features were delineated in colored pencil on the map using aerial photo-interpretation techniques to identify dominant species within vegetation communities and levels of impervious surfaces within cultural features. MLCCS classification codes and modifiers are recorded within the outlined features and the delineated maps are taken out in the field to visually verify the accuracy of the interpretation and boundaries of the outlined communities and features. The maps are then converted into a digital format for use in a Geographic Information System (GIS). The final output of the mapping process is a digital Natural Resource Inventory (NRI) composed of polygons containing MLCCS classification information.

The MLCCS data was summarized into broad categories relating to the possible sources of bacteria. (See “Source Assessment” Section below.)

3.4 Source Load Allocation Calculations by Consulting Firm

The engineering firm of Montgomery Watson Harza (MWH) was hired to develop a hydrologic database for the Vermillion River watershed, review literature values of areal loading rates for fecal coliform bacteria, and calculate the Vermillion's source load allocations within the PCA's spreadsheet model for fecal coliform bacteria.

MWH divided the watershed into nine subwatersheds in order to better identify the pollution sources in each area. A hydrologic database for each subwatershed was constructed using data from six flow monitoring sites operated by the various watershed management authorities since 1998, and long-term monitoring sites operated by the USGS and the Metropolitan Council. Data gaps were filled using regression analysis and percent contributing area modeling.

The data used to determine the source loads in each subwatershed included: bacteria data collected at the mouth of each subwatershed (data collected upstream from subwatershed outlets were not taken into consideration), landuse data from the Minnesota Land Management Information Center (not detailed landcover mapping), feedlot locations and their proximity to streams, septic system locations and their proximity to streams, discharge and design flow information for the watershed's wastewater treatment plants, and information collected through the literature review.

3.5 Source Assessment by Stakeholder Group

The scope of the Vermillion River TMDL changed after the Regional TMDL Study for Fecal Coliform Bacteria in the Lower Mississippi River Basin in Minnesota was developed by the PCA and accepted by the EPA. Since the Vermillion River watershed is included in the Regional TMDL, the Vermillion River Study was changed from a formal TMDL to a technical supporting study for the Regional TMDL. Initial efforts to develop land-use bacteria loading coefficients based on sub-watershed analyses and monitoring proved to be problematic. In addition, initial efforts at numeric source load allocations demonstrated the inherent amount of uncertainty in the assessment process. Because these preliminary numeric allocations would likely provide a false-sense of accuracy, it was recommended by MPCA staff that relative load allocations would provide a better framework for understanding the importance of sources to the pollution problem under the various weather and flow regimes. The MPCA and SWCD staff agreed that all available data would be revisited by a larger group of stakeholders who would assign relative loadings among different sources in qualitative terms.

The panel of local stakeholders and technical advisors met in the fall of 2003 to review the bacteria, DNA fingerprinting, and landcover data for each Vermillion subwatershed and to assign relative loads from each source based on the data. The process used to assign relative loads to each subwatershed by a large stakeholder and technical panel was sound and justified. The panel spent several hours reviewing and discussing the data and usually agreed unanimously on the relative loads from sources in each subwatershed. The panel included technical experts, including those working specifically in Dakota County, local agricultural producers, city staff members, and township officials. Anecdotal evidence and a true knowledge of the watershed, its landscape, and particular landowners were very helpful in identifying possible sources.

There were some assumptions made for the process of assigning relative loads. These included:

1.) Sources were defined (and clarified by the group) to include:

<u>Source</u>	<u>Wet vs. Dry</u>	<u>Clarification/Definition</u>
Cattle in the Stream	Dry	Livestock in or near open water and wetlands
Feedlots	Wet	Includes unmanaged pastures near streams
ISTS	Dry	Not all ISTS are failing or non-compliant
Manure Application	Wet	Not all row crops and hayfields receive manure, much manure is incorporated into soil, other land spread substances such as sludge are also included here
WWTP	Dry	WWTP effluent
Pets/Urban	Wet	Renamed “urban” and includes pets and urban wildlife
Wildlife	Dry	Non-urban wildlife and rural pets

“Wet” sources are those that contribute bacterial pollution in runoff situations such as during storm events and snowmelt. “Dry” sources are those that contribute bacterial pollution during times of dry or wet weather. In other words, they are a more constant source of pollution.

2.) Significant seasonal variation in bacterial loadings were not detected by MWH. Therefore the data was not considered on a seasonal basis during this process.

3.) The numbers and locations of feedlots and the animal units in each subwatershed came from SWCD records of known and registered feedlots in 2001.

4.) The numbers and locations of individual sewage treatment systems (ISTS) came from Dakota County records and include the estimated location of all ISTS in the Dakota County portion of the watershed based on the locations of homesteads outside the Metropolitan Urban Services Area. Dakota County staff assume that systems installed before 1989 are failing or non-conforming, making up 75% of the total number of ISTS in the watershed.

5.) The landcover data was summarized into the following categories for each subwatershed:

- Golf Courses = all golf courses
- Residential = all rural, suburban and urban residential areas (does not include farmsteads)
- Total Urban/Pet = all parks, golf courses, and residential areas
- Parks = all city and county parks
- Pasture with Streams = all pastures (wooded, field, etc.) that intersect a watercourse
- Pasture = all pastures (wooded, field, etc.) that do not intersect a watercourse
- Row Crops and Hayfields = potential manure application areas (also includes sod farms)
- Open Water = all open water such as lakes, ponds, and open water wetlands
- Natural Areas = wetlands covered with emergent vegetation, woodlands, forests, prairies, grasslands

- Commercial, industrial, transportation, farmsteads, etc.

6.) Wastewater treatment plant discharge records were collected from all plants in the watershed and analyzed by MWH.

The local stakeholder and technical advisors panel included representatives from the following groups:

- Castle Rock Township
- City of Farmington
- City of Lakeville
- Dakota County Environmental Management
- Dakota County Office of Planning
- Dakota County Soil and Water Conservation District
- Local Agricultural Producers
- Minnesota Department of Agriculture
- Minnesota Department of Natural Resources
- Minnesota Pollution Control Agency
- Natural Resource Conservation Service
- Ravenna Township
- Scott County Soil and Water Conservation District
- University of Minnesota Extension
- Vermillion River Watershed Planning Commission
- Wenck Associates, Inc. (staff formerly with Montgomery Watson Harza)

3.6 Implementation Strategies

Due to the length of the first meeting with local stakeholders and technical advisors, a discussion on implementation strategies was deferred to another meeting. Approximately four weeks after the larger panel meeting, a smaller meeting was held among staff from the Dakota County SWCD, University of Minnesota Extension, Natural Resource Conservation Service, Dakota County Office of Planning, and Dakota County Environmental Management. In this meeting, attendees brainstormed and discussed possible implementation strategies to address the bacteria pollution from septic systems, land applied manure, feedlots, and livestock in waterways.

The strategies recommended through this meeting and some additional strategies aimed at addressing urban stormwater runoff were e-mailed to the larger panel for comments and additions. Comments and additions were received from Dakota County, MDNR, MPCA, City of Lakeville, and Wenck Associates, Inc.

3.7 Public and Stakeholder Outreach and Input

Throughout the Vermillion Bacteria Study, local residents, government officials, agency staff, and other stakeholders were kept informed about the study and its progress through a variety of formats. These included articles in newsletters such as the Dakota County SWCD News and Notes and the Dakota County Extension Line, and in local newspapers such as the Hastings Star Gazette, the Farmington Independent, This Week, and the South-west Review. A brief article also appeared in the national newsletter, Volunteer Monitor. Displays about the Vermillion River TMDL and Bacteria Study were also used to convey information at public venues such as the Dakota County Fair and local meetings focusing on the Vermillion.

Presentations about the bacteria problem in the river and the TMDL study were given at local and regional meetings including the 2001 River Summit, informational meetings on the feedlot rule changes, Vermillion River Watch Council meetings, the Vermillion River Stakeholder Meeting and Open House, Vermillion River Watershed Planning Commission meetings, the 2002 Lakes and Rivers Conference in St. Cloud, and the 2003 “Implementing TMDLs” conference in St. Paul. The Vermillion River Bacteria Study was also featured on a segment of the Environmental Journal, a cable television show.

Other, more non-traditional methods used to inform local stakeholders about the TMDL and/or the bacteria problem in the watershed were used as well. For instance, the PCA featured the Vermillion River TMDL Study on their “Indicators of the Month” web page in June 2001. Also in 2001 a map and poster of the Vermillion River Watershed was produced and distributed widely to landowners, local officials, and schools. Among other information, the map shows where the river has high bacteria levels. Fecal coliform levels were also reported in the 2000 Dakota County Indicators Report.

As described in the Section above, local stakeholders and technical advisors from state and local agencies met in the fall of 2003 to review the data, assign relative loads from each possible pollution source, and recommend implementation strategies for pollution abatement.

3.8 Coordination with VRWJPO Watershed Plan Development

The Vermillion River Watershed Planning Commission has been working hard on drafting a Watershed Management Plan over the past year. They have been provided with data on the bacteria pollution in the watershed, information on the Bacteria Study and its progress, and lists of possible implementation strategies to alleviate the pollution problem. The Commission is aware that the implementation strategies recommended in this document and in the regional TMDL implementation plan should be considered for inclusion in the watershed management plan. The Commission understands the importance of the Bacteria Study and the fact that most of the strategies would best be implemented at the watershed level. Correspondence from the SWCD to the Planning Commission regarding the Study’s progress has been regular and will continue as the watershed management plan is developed.

IV. Results

4.1 Quality Assurance/Quality Control

Analytical results from the field blank samples and duplicate samples indicate that quality control was maintained through the study. All of the 16 blank quality control samples submitted during the study were found to be below the laboratory detection limit of 10 bacteria / 100 ml (Appendix E). The majority of “duplicate sampling” (actual field duplicates and samples taken by different agencies on the same day at the same site) resulted in similar bacteria levels (Appendices B and E). Although there were some duplicates with higher differences, the results of all duplicates found bacteria levels in the same order of magnitude.

Duplicate and triplicate sampling was done on July 26 and September 21, 1999. The results are shown in Appendix E.

In addition, a quality assurance analysis was conducted after the first year’s citizens monitoring to assure that citizen data quality was compatible with other existing data. The summary in Appendix E explains the results of that analysis.

4.2 Data Analysis by Consulting Firm

The engineering consulting firm of Montgomery Watson Harza (MWH) was hired to calculate source load allocations for the PCA’s spreadsheet model for this study. The firm completed the task and included the data in a report entitled “Final Vermillion River Fecal Coliform TMDL Technical Memorandum, July 27, 2002.” The spreadsheet assessments for each subwatershed helped form the background for future evaluations. However, due to the changes in the scope of the Vermillion River Watershed TMDL Study since the completion of the Regional TMDL Study, numerical source load allocations were not carried forward into this final study report. As stated previously, it was decided among PCA and SWCD that all available data would be revisited and *relative* source loads would be decided upon by a large group of local stakeholders and technical advisors.

Other valuable data and ideas gathered by MWH were used in assigning the relative source loads including a computation of the point source allocations and an analysis of seasonal variation in the bacteria data.

Point Source Allocations

The only potential point sources of bacteria in the Vermillion River Watershed are four wastewater treatment plants (WWTPs) including the Empire WWTP operated by the Metropolitan Council, and the smaller plants of Elko-New Market, City of Vermillion, and City of Hampton. An analysis of the fecal coliform loadings from these plants on their respective subwatersheds was performed by Montgomery Watson Harza (MWH) and reported in their Technical Memorandum, July 2002. The data used by MWH in their analyses included available fecal coliform discharge data from the plants, permitted design flows for each plant, and the calculated bacterial load for each subwatershed. When all the available data was considered, it was determined that the percent

contributions for the affected subwatersheds ranged from a seasonal average of 0.4% in the Hastings Subwatershed, to 2.7% in the South Branch Subwatershed and 7.3% in the Eureka Subwatershed.

The local stakeholders and technical advisors panel considered this wastewater treatment plant data when assigning relative loads for each subwatershed.

Seasonal Variation

MWH found no significant differences in fecal coliform concentrations or average loads among spring, summer, and fall data. There is also the added complication that May was typically the only spring month sampled and September was typically the only fall month sampled. Although the data showed some differences among seasons, they were not statistically significant. Additionally, the weather and water conditions in May and September appeared to yield results more similar to summer. For these reasons, seasonality was not considered during the assignment of relative loads by the panel.

4.3 DNA Fingerprinting Study

Results from the DNA fingerprinting study performed by the University of Minnesota were mixed and use of the data is limited. Researchers determined that the study should be considered experimental in nature as the method has not been rigorously validated and the library of control clones is not large enough to capture all of the genetic diversity of *E. coli* present in the environment.

Although jackknife analyses using Pearson's curve-based correlation coefficient were performed on the Vermillion River data, the results offer only a cursory evaluation of the data and should not be used for source interpretation (Appendix D).

An ID Bootstrap analysis, done using BioNumerics software, was also used on the Vermillion data to reduce false-positives and give a higher confidence to the correctness of the groupings. This is a more stringent and refined analysis than correlation analysis and it commonly eliminates the vast majority of the isolates that do not meet strict cutoff standards. As such, only 10.4% of the Vermillion River isolates survived the cutoff and the data could only be reported as it applied to the watershed as a whole rather than to individual sampling sites. The Bootstrap data should only be considered suggestive in nature until a larger library of clones is built. Thus, although robust, the Bootstrap data only supplies a limited view of the environment tested. With that in mind, the results of the Bootstrap analysis indicate that of the 10.4% of the isolates left in the analysis, 45% are from pets, 23% from domesticated animals, 6% from humans, 7% from waterfowl, and 19% from wildlife. Thus, 94% of the bacteria can be traced back to non-human sources and 6% from human sources.

A general comparison of the DNA results to the relative load allocations, which were based on the more traditional correlations between in-stream bacterial concentrations and landuse, shows discrepancies in two areas. First, the DNA data suggests that the human component, in general, may be over-weighted and second, that the pet and wildlife contributions may be under-weighted.

Since there were only a limited number of animal comparisons, however, there are too many unknowns to currently accept the accuracy of the DNA results without further studies. For example, there may have been other animals in the watershed that influenced the results and there was a limited ability to correlate the DNA data to flow and stream conditions. Therefore, the data could be skewed by many unknown factors.

4.4 Subwatershed Results

Summarized Results

Average bacteria levels in specific subwatersheds (based on the geometric mean of all bacteria data in that subwatershed) ranged from 50 bacteria per 100 ml in the Lower Vermillion River (below 10th St. in Hastings) to 806 bacteria per 100 ml in the Middle Creek Subwatershed (Figures 4.1). The maximum bacteria levels measured in each subwatershed ranged from 900 bacteria per 100 ml in the Lower Vermillion River to 99,000 bacteria per 100 ml in the Goodwin Subwatershed (Figure 4.1).

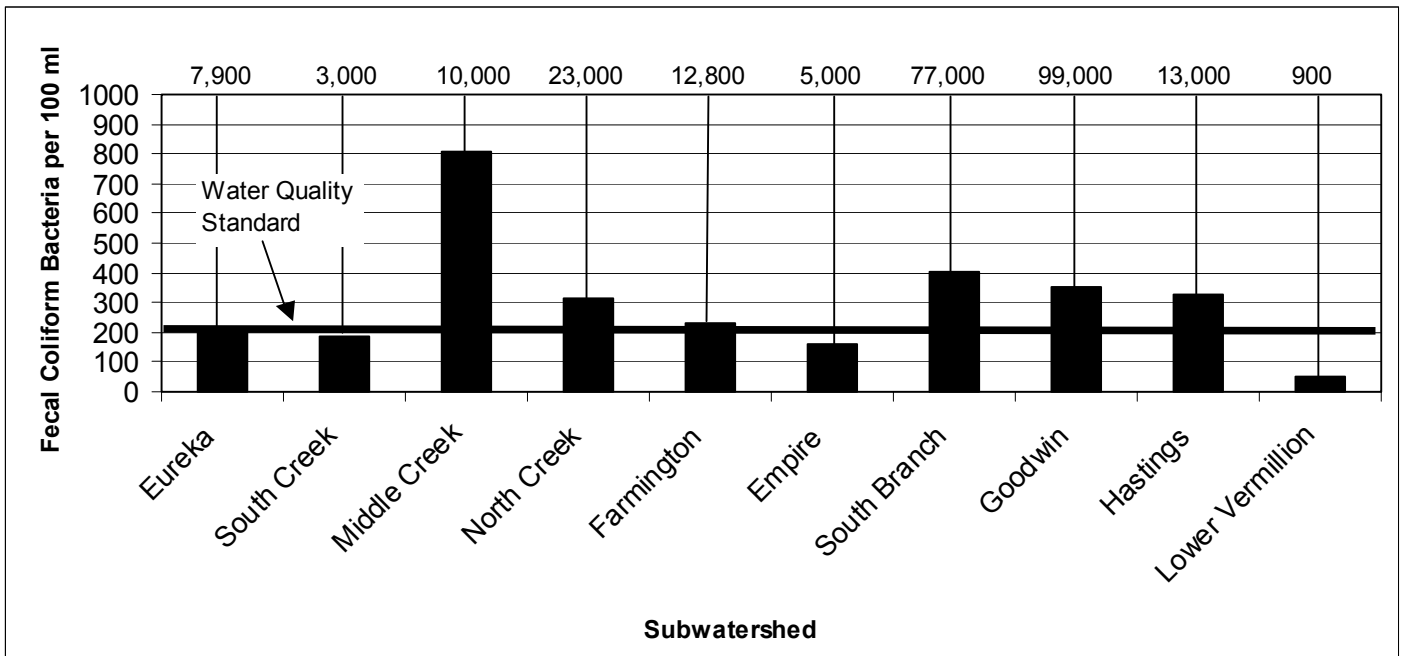


Figure 4.1 Geometric mean (shown with bars) and maximum (shown along top) bacteria levels for each subwatershed, all data combined.

The data show a large discrepancy between bacteria levels during runoff events versus levels measured during periods of base or low flow (Figure 4.2). Average event levels ranged from 247 bacteria per 100 ml in the Lower Vermillion River (below the falls in Hastings) to 3,349 bacteria per 100 ml in the Farmington Subwatershed. Average base flow levels ranged from 41 bacteria per 100 ml in the Lower Vermillion River to 420 bacteria per 100 ml in the Middle Creek Subwatershed (Figure 4.2).

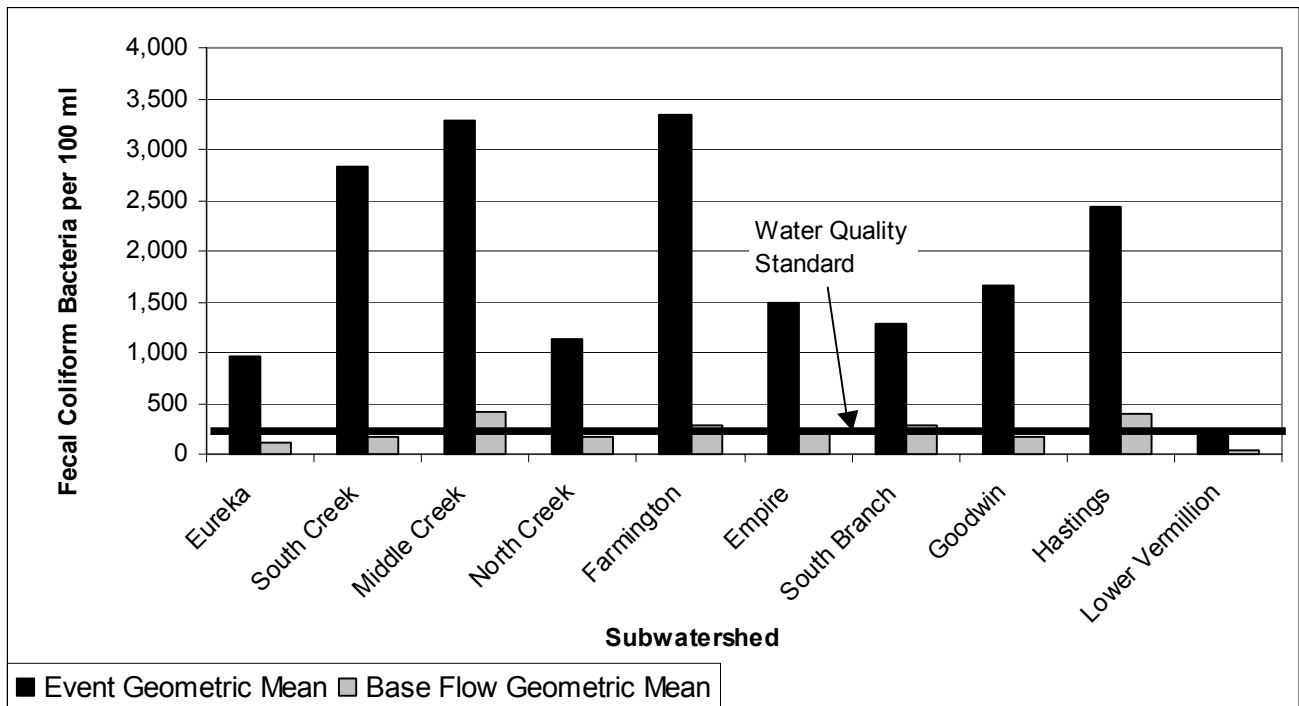


Figure 4.2 Geometric mean of bacteria levels during runoff events (snowmelt and rainfall) and periods of low flow for each subwatershed.

Figure 4.2 indicates that although bacteria levels rise significantly during runoff events, some subwatersheds experience bacteria levels above the standard even during periods of low flow. After careful consideration of all the available data, the local stakeholder and technical advisory panel found that, watershed-wide, individual sewage treatment systems (ISTS) were probably the leading cause of bacterial contamination in the watershed according to a summarization of relative load allocations (Table 4.1). Manure application to agricultural fields was found to be the second leading cause, followed by runoff from urban areas and feedlots (Table 4.1).

Table 4.1 Relative Load in Subwatersheds and Overall Ranking of Sources

Source	Eureka	Middle Creek	South Creek	North Creek	South Branch	Farmington	Empire	Goodwin	Hastings	Overall Ranking ¹
Livestock in water	Low	High	Low	NA	Mod.	Low	Low	Mod.	Low	1.3
Feedlots	Mod.	High	Low	NA	Mod.	NA	Low	Mod.	Mod.	1.4
ISTS	Mod.	Mod.	Low	Low	High	Mod.	High	Mod. - Hi	High	2.2
Manure Appl.	Mod.	High	Mod.	Low	Low	Mod.	Mod.	Mod.	Mod.	1.9
WWTP	Mod.	NA	NA	NA	Low	NA	Low	Lo - Mod	NA	0.6
Urban	Low	Mod.	Mod.	High	Low	Mod.	Low	Low	Low	1.5
Wildlife	Low	Low	Low	Low	Low	Low	Low	Low	Low	1.0

¹ Overall ranking was calculated by taking the average of the scores where NA (not applicable) = 0, low = 1 point, moderate = 2 points, and high = 3 points.

Note: Relative loads were not assigned in the Lower Vermillion River due to low bacteria levels there. See the “Lower Vermillion River” Section below.

The following sections report the results of the bacteria sampling and the landcover mapping on a sub-watershed basis and reports the results of the relative load assignments made by the local stakeholder and technical advisors panel upon review of this data.

The raw bacteria data for each subwatershed is found in Appendix B. Landuse/landcover maps and maps showing ISTS and feedlot locations for each subwatershed are found in Appendix C. Appendix D reports the results of the DNA Study.

Eureka Subwatershed

The Eureka subwatershed covers approximately 24,500 acres in the uppermost portions of the watershed (Figure 3.1) and comprises the rapidly developing headwaters of the Vermillion River mainstem in Scott County and much of Eureka Township in Dakota County. Approximately 40% of the subwatershed is covered by row crops and hayfields and another 30% is natural, consisting of wetlands, prairies, woodlands, and other open areas (Table 4.2 and Figure C-1). There is a low number of feedlots in this area, but a high number of individual sewage treatment systems (ISTS) (Table 4.2 and Figure C-2). The Elko – New Market wastewater treatment plant lies in this subwatershed in Scott County. It was noted by the panel that this plant is currently in the approval process for an upgrade from a design discharge of 95,000 gallons per day (gpd) to 859,000 gpd. Although the plant usually meets the fecal coliform discharge standard, the overall bacterial load from this plant will increase substantially if the upgrade is approved.

Table 4.2 Summarized Landcover Data for Eureka Subwatershed

Landcover (Total Area = 24,586 acres)	Acres or Number	Percent Area
Golf Courses	0	0
Residential (rural, suburban, urban residential areas)	2,351	9.6
Parks (city and county parks)	244	1.0
Total Urban/Pet	2,595	10.6
Number of ISTS	355	
Number of Feedlots	9	
Total Animal Units	559	
Animal Units/Area	0.0227	
Pastures with streams (pastures with watercourse)	164	0.7
Pastures (pastures w/out watercourse)	639	2.6
Row Crops and Hayfields (manure application)	9,664	39.3
Open Water (lakes, ponds, open water wetlands)	68	.3
Natural Areas (other wetlands, prairies, woodlands)	7,377	30.0
Commercial, Industrial, Transportation, Farmsteads	1,898	7.7
No Data	2,181	8.9

There were 6 fecal coliform sampling sites located in this subwatershed (Table 4.3 and Figures C-1 – C-2). The bacteria data collected indicate that there is an impairment only during and after storm events (Table 4.3). The mean discharge from this subwatershed is 22 cfs (May – October).

Table 4.3 Bacteria Data for Eureka Subwatershed

Sites/Measurement	Geometric Mean of Bacteria per 100 ml	No. of Observations
Total (all sites and data combined)	209	124
Events (all sites combined)	953	33
Base Flow (all sites combined)	121	91
804 (all data combined) *	222	28
804 Events *	382	16
804 Base Flows *	76	12
Veec235 (all data combined)	416	13
Veec235 Events	2,567	4
Veec235 Base Flows	186	9
Vwec23 (all data combined)	155	14
Vwec23 Events	1,306	4
Vwec23 Base Flows	66	10
Veureka (all data combined)	321	28
Veureka Events	3,846	3
Veureka Base Flows	238	25
V9head (all data combined)	127	27
V9head Events	1,897	2
V9head Base Flows	103	25
V23 (all data combined)	144	14
V23 Events	857	4
V23 Base Flows	71	10

* Denotes outlet of subwatershed

Although there are no sources considered to contribute highly to the relative load of bacteria, there are several sources considered a moderate contributor, indicating multiple problems (Table 4.4).

Table 4.4 Relative Load Allocations for the Eureka Subwatershed

Source	New Relative Load
Cattle in stream	Low
Feedlots	Moderate
ISTS	Moderate
Manure Application	Moderate
WWTP	Moderate
Pets/Urban	Low
Wildlife	Low

South Creek Subwatershed

The South Creek Subwatershed includes approximately 14,500 acres in the rapidly developing City of Lakeville and the southwest corner of the City of Farmington (Figure 3.1). Over 19% of this area includes suburban residential lands, golf courses, and parks, while 31% is in row crop agriculture or hayfields (Table 4.5 and Figures C-3). However, the suburban area continues to expand into the

agricultural land each year, changing these numbers significantly over time. Another 26% of the land is in wetlands, woodlands, and other natural areas. There are few feedlots and ISTS (Table 4.5 and Figure C-4) and no wastewater treatment plants in this subwatershed.

Table 4.5 Summarized Landcover Data for the South Creek Subwatershed

Landcover (Total Area = 14,537 acres)	Acres or Number	Percent Area
Golf Courses	21.5	0.15
Residential (rural, suburban, urban residential areas)	2,306	15.8
Parks (city and county parks)	449	3.1
Total Urban/Pet	2,776	19.1
Number of ISTS	55	
Number of Feedlots	4	
Total Animal Units	573	
Animal Units/Area	0.0394	
Pastures with streams (pastures with watercourse)	129	0.9
Pastures (pastures w/out watercourse)	232	1.6
Row Crops and Hayfields (manure application)	4,583	31.5
Open Water (lakes, ponds, open water wetlands)	471	3.2
Natural Areas (other wetlands, prairies, woodlands)	3,798	26.1
Commercial, Industrial, Transportation, Farmsteads	2,337	16.0
No Data	211	1.4

There were only two bacteria monitoring sites located in this subwatershed (Figures C-3 and C-4). Although the monitoring indicates no impairment when all the data is combined, there may be a problem during and after storm events, although only two events were caught during sampling (Table 4.6).

Table 4.6 Bacteria Data for South Creek Subwatershed

Sites/Measurement	Geometric Mean of Bacteria per 100 ml	No. of Observations
Total (all sites and data combined)	187	47
Events (all sites combined)	2,839	2
Base Flow (all sites combined)	166	45
VSCNB 1 (all data combined)	177	37
VSCNB 1 Events	2,839	2
VSCNB 1 Base Flows	151	35
VSCNB 2 (all data combined) *	233	10
VSCNB 2 Events *	na	na
VSCNB 2 Base Flows *	233	10

* Denotes outlet of subwatershed

There are no bacteria sources considered to be a high contributor in the South Creek Subwatershed. However, given the amount of land that could potentially receive manure application, and the high amount of urban/suburban areas, these are considered moderate sources (Table 4.7).

Table 4.7 Relative Load Allocations for the South Creek Subwatershed

Source	Relative Load
Cattle in stream	Low
Feedlots	Low
ISTS	Low
Manure Application	Moderate
WWTP	None
Pets/Urban	Moderate
Wildlife	Low

Middle Creek Subwatershed

The Middle Creek Subwatershed encompasses approximately 7,000 acres in the Cities of Lakeville and Farmington (Figure 3.1). Approximately 60% of the land is used for row crops and hayfields and approximately 14% is residential or parks (Table 4.8 and Figure C-5). There are very few feedlots and ISTS and no wastewater treatment plants in this subwatershed (Table 4.8 and Figure C-6).

Table 4.8 Summarized Landcover in the Middle Creek Subwatershed

Landcover (Total Area = 7,006 acres)	Acres or Number	Percent Area
Golf Courses	0	0
Residential (rural, suburban, urban residential areas)	760	10.8
Parks (city and county parks)	211	3.0
Total Urban/Pet	971	13.9
Number of ISTS	43	
Number of Feedlots	9	
Total Animal Units	1,692	
Animal Units/Area	0.2415	
Pastures with streams (pastures with watercourse)	124	1.8
Pastures (pastures w/out watercourse)	78	1.1
Row Crops and Hayfields (manure application)	4,227	61.0
Open Water (lakes, ponds, open water wetlands)	0	0
Natural Areas (other wetlands, prairies, woodlands)	1,026	14.6
Commercial, Industrial, Transportation, Farmsteads	540	7.7
No Data	0	0

Bacteria data in this subwatershed shows a definite impairment, even during periods of low flow (Table 4.9). Agency staff noted known instances of at least 100 head of cattle in a vegetated but unimproved pasture with a watercourse running through it. There are also at least two known feedlots that are probably impacting water quality, and agricultural fields with little or no buffers along the creek that may receive land applied manure. Additionally, stormwater runoff from residential areas ultimately reaches the creek. At its outlet Middle Creek has an average flow of 8 cfs May – October.

Table 4.9 Bacteria Data for Middle Creek Subwatershed

Sites/Measurement	Geometric Mean of Bacteria per 100 ml	No. of Observations
Total (all sites and data combined)	806	63
Events (all sites combined)	3,276	20
Base Flow (all sites combined)	420	43
VMC 190 (all data combined)	3,517	4
VMC 190 Events	3,517	4
VMC 190 Base Flows	na	0
VMC pk (all data combined)	999	15
VMC pk Events	4,669	5
VMC pk Base Flows	462	10
VMC (all data combined) *	735	25
VMC Events *	3,732	7
VMC Base Flows *	391	18
VMC west (all data combined)	555	8
VMC west Events	1,000	1
VMC west Base Flows	510	7
VMC east (all data combined)	419	8
VMC east Events	930	1
VMC east Base Flows	374	7

* Denotes Outlet of Subwatershed

Due to the landuse and known agricultural practices in this subwatershed, the panel assigned “high” relative load rankings to three of the source categories (Table 4.10).

Table 4.10 Relative Load Allocations for the Middle Creek Subwatershed

Source	Relative Load
Cattle in stream	High
Feedlots	High
ISTS	Moderate
Manure Application	High
WWTP	None
Pets/Urban	Moderate
Wildlife	Low

North Creek Subwatershed

The North Creek Subwatershed covers approximately 21,200 acres mostly in the Cities of Apple Valley and Lakeville and also includes portions of the City of Farmington and Empire Township. Over 42% of the land is residential, parks, and golf courses, while only 25% of the land is covered with row crops and hayfields. There are no feedlots or wastewater treatment plants, and few ISTS (Table 4.11 and Figures C-7 and C-8). Areas still used for agriculture are quickly giving way to development in this area. Actual landcover at the time of this writing would include more suburban areas and less agricultural land.

Table 4.11 Summarized Landcover Data for the North Creek Subwatershed

Landcover (Total Area = 21,236 acres)	Acres or Number	Percent Area
Golf Courses	209	1.0
Residential (rural, suburban, urban residential areas)	8,030	37.8
Parks (city and county parks)	764	3.6
Total Urban/Pet	9,003	42.4
Number of ISTS	71	
Number of Feedlots	0	
Total Animal Units	0	
Animal Units/Area	0	
Pastures with streams (pastures with watercourse)	62	0.3
Pastures (pastures w/out watercourse)	11	0.05
Row Crops and Hayfields (manure application)	5,321	25.0
Open Water (lakes, ponds, open water wetlands)	440	2.1
Natural Areas (other wetlands, prairies, woodlands)	2,347	11.0
Commercial, Industrial, Transportation, Farmsteads	4,051	19.1
No Data	0	0

Although there does not appear to be a bacteria problem during periods of low flow, bacteria levels increase significantly during and after runoff events (Table 4.12). At its outlet North Creek has an average flow of 26 cfs May – October.

Table 4.12 Bacteria Data for the North Creek Subwatershed

Sites/Measurement	Geometric Mean of Bacteria per 100 ml	No. of Observations
Total (all sites and data combined)	313	99
Events (all sites combined)	1,139	33
Base Flow (all sites combined)	164	66
VNC (all data combined) *	355	52
VNC Events *	952	22
VNC Base Flows *	156	30
VNC-170 (all data combined)	77	15
VNC-170 Events	590	4
VNC-170 Base Flows	37	11
VNC-175 (all data combined)	519	23
VNC-175 Events	3,006	6
VNC-175 Base Flows	279	17
VNC fs (all data combined)	606	9
VNC fs Events	2,400	1
VNC fs Base Flows	510	8

* Denotes outlet of subwatershed

Due to the lack of feedlots, agricultural land, and the low number of ISTS, urban sources are the only contributor considered to be “high” (Table 4.13). It was suggested by the panel that perhaps the high bacteria levels at VNC-175 are due to a leaking sewage conveyance pipe. (Although leaky sewer pipes often result in groundwater inflow to the pipe and not vice-versa.) It was also speculated that the low bacteria levels at VNC-170 may be the effect of bacteria dying due to sunlight exposure in a large pond immediately upstream from this site.

Table 4.13 Relative Load Allocations for the North Creek Subwatershed

Source	Relative Load
Cattle in stream	None
Feedlots	None
ISTS	Low
Manure Application	Low
WWTP	None
Pets/Urban	High
Wildlife	Low

Farmington Subwatershed

The Farmington Subwatershed is downstream from the four subwatersheds described above (Eureka, South Creek, Middle Creek, and North Creek) and covers approximately 2,600 acres in the City of Farmington and western Empire Township. Approximately 42% of the land is covered with parks, golf courses, and residential areas, while 40% is used for row crops and hayfields (Table 4.14

and Figure C-9). There are no feedlots in this area, but there are a moderate number of ISTS (Table 4.14 and Figure C-10).

Table 4.14 Summarized Landcover in the Farmington Subwatershed

Landcover (Total Area = 2,607 acres)	Acres or Number	Percent Area
Golf Courses	86	3.3
Residential (rural, suburban, urban residential areas)	918	35
Parks (city and county parks)	96	3.7
Total Urban/Pet	1,101	42
Number of ISTS	114	
Number of Feedlots	0	
Total Animal Units	0	
Animal Units/Area	0	
Pastures with streams (pastures with watercourse)	4	0.15
Pastures (pastures w/out watercourse)	6	.02
Row Crops and Hayfields (manure application)	1,053	40
Open Water (lakes, ponds, open water wetlands)	14	0.5
Natural Areas (other wetlands, prairies, woodlands)	18	0.7
Commercial, Industrial, Transportation, Farmsteads	412	16
No Data	0	0

The only bacteria monitoring in the Farmington Subwatershed was done at the outlet of the subwatershed on Biscayne Ave. Bacteria collected here includes the unknown dynamics of bacteria die-off from upstream sources, and bacteria growth within the stream. Data collected indicates a slight impairment during periods of low flow and very elevated bacteria levels during and after runoff events (Table 4.15). The Vermillion River has an average flow of 78 cfs in the Farmington Subwatershed May – October.

Table 4.15 Bacteria Data for the Farmington Subwatershed

Sites/Measurement	Geometric Mean of Bacteria per 100 ml	No. of Observations
Vbisc (all data combined)	228	121
V bisc Events (1999 and 2000 only)	3,349	11
V bisc Base Flow (1999 and 2000 only)	276	46

Although the sources of bacteria in this subwatershed include bacteria from upstream subwatersheds, the data for the Farmington Subwatershed were considered independently and upstream sources were not considered in assigning the relative loads. There are no sources considered to be a high contributor and, although there are no feedlots or animal units recorded for this subwatershed, some manure and sludge application is probably occurring on fields in the Farmington area (Table 4.16).

Table 4.16 Relative Load Allocations for the Farmington Subwatershed

Source	Relative Load
Cattle in stream	Low
Feedlots	None
ISTS	Moderate
Manure Application	Moderate
WWTP	None
Pets/Urban	Moderate
Wildlife	Low

Empire Subwatershed

The Empire Subwatershed is downstream from the five subwatersheds previously described (Eureka, South Creek, Middle Creek, North Creek, and Farmington) and covers approximately 9,500 acres almost entirely in Empire Township (Figure 3.1). The area is primarily agricultural with almost 64% of the land used for row crops and hayfields. Another 26% is in natural cover such as wetlands, woodlands, prairies and other open areas (Table 4.17 and Figure C-11). There are very few feedlots but a high number of ISTS (Table 4.17 and Figure C-12). Although the Empire wastewater treatment plant currently discharges into this subwatershed, the plant will begin discharging exclusively to the Mississippi River in 2005.

Table 4.17 Summarized Landcover in the Empire Subwatershed

Landcover (Total Area = 9,517 acres)	Acres or Number	Percent Area
Golf Courses	179	1.9
Residential (rural, suburban, urban residential areas)	127	1.3
Parks (city and county parks)	62	0.65
Total Urban/Pet	368	3.9
Number of ISTS	136	
Number of Feedlots	4	
Total Animal Units	565	
Animal Units/Area	0.059	
Pastures with streams (pastures with watercourse)	6.5	0.07
Pastures (pastures w/out watercourse)	110	1.15
Row Crops and Hayfields (manure application)	6,057	63.7
Open Water (lakes, ponds, open water wetlands)	22	0.23
Natural Areas (other wetlands, prairies, woodlands)	2,473	26
Commercial, Industrial, Transportation, Farmsteads	481	5
No Data	202	0.02

The only bacteria monitoring in the Empire Subwatershed was done at the outlet of the subwatershed on Blaine Ave. (Hwy. 79). Bacteria collected here includes the unknown dynamics of bacteria die-off from upstream sources, and bacteria growth within the stream. When all the

available data is averaged (using a geometric mean) the bacteria level is slightly below the standard. However, using data from 1999 and 2000 only (when periods of events vs. non-events were recorded) it is apparent that an impairment exists during and after runoff events (Table 4.18).

Table 4.18 Bacteria Data for the Empire Subwatershed

Sites/Measurement	Geometric Mean of Bacteria per 100 ml	No. of Observations
V79 (all data combined)	160	112
V79 Events (1999 and 2000 data only)	1,484	7
V79 Base Flows (1999 and 2000 data only)	245	41

Although the sources of bacteria in this subwatershed include bacteria from upstream subwatersheds, the data for the Empire Subwatershed were considered independently and upstream sources were not considered in assigning the relative loads. ISTS are considered the only high contributor in this subwatershed (Table 4.19). The panel received anecdotal evidence from Dakota County staff that most of the septic systems along Hwy. 66 and adjacent to the Vermillion River are older and some are known to be imminent public health threats. However, septic systems in the southern portion of this subwatershed are thought to be less than 20 years old. There are few feedlots in this subwatershed, however there is sludge application from the Empire WWTP, particularly to the north of the plant. Although the Empire WWTP will begin discharging exclusively to the Mississippi River in 2005, the plant was still considered a “low” source for purposes of this study (Table 4.19).

Table 4.19 Relative Load Allocations for the Empire Subwatershed

Source	Relative Load
Cattle in stream	Low
Feedlots	Low
ISTS	High
Manure Application	Moderate
WWTP	Low
Pets/Urban	Low
Wildlife	Low

South Branch Subwatershed

The South Branch Subwatershed covers approximately 21,000 acres in mostly in Castle Rock Township (Figure 3.1). Over 66% of the land is used for row crops and hayfields. (This number also includes sod farms.) Another 20% of the subwatershed is in a natural state with wetlands, woodlands, prairies, and other open areas (Table 4.20 and Figure C-13). The number of feedlots and animal units were moderate at the time of the feedlot registration in 2000, and there is a high number of ISTS (Table 4.20 and Figure C-14). The City of Hampton operates a wastewater treatment plant in this subwatershed.

Table 4.20 Summarized Landcover Data for the South Branch Subwatershed

Landcover (Total Area = 21,042 acres)	Acres or Number	Percent Area
Golf Courses	0	0
Residential (rural, suburban, urban residential areas)	346	1.7
Parks (city and county parks)	370	1.8
Total Urban/Pet	716	3.4
Number of ISTS	328	
Number of Feedlots	22	
Total Animal Units	2,995	
Animal Units/Area	0.1424	
Pastures with streams (pastures with watercourse)	100	0.5
Pastures (pastures w/out watercourse)	240	1.1
Row Crops and Hayfields (manure application)	13,893	66.1
Open Water (lakes, ponds, open water wetlands)	42	0.2
Natural Areas (other wetlands, prairies, woodlands)	4,150	19.8
Commercial, Industrial, Transportation, Farmsteads	1,590	7.6
No Data	311	1.5

Bacteria data for the South Branch Subwatershed indicates that there is a slight impairment even during periods of low flow. Additionally, bacteria levels increase substantially during and after runoff events (Table 4.21). At its outlet the South Branch has an average flow of 16 cfs May – October.

Table 4.21 Bacteria Data for the South Branch Subwatershed

Sites/Measurement	Geometric Mean of Bacteria per 100 ml	No. of Observations
Total (all sites and data combined)	405	128
Events (all sites combined)	1,280	33
Base Flow (all sites combined)	274	95
VSB (all data combined) *	394	63
VSB Events *	1,147	20
VSB Base Flows *	240	43
VSB trib (all data combined)	434	23
VSB trib Events	2,330	5
VSB trib Base Flows	272	18
VSB head (all data combined)	444	26
VSB head Events	5,396	2
VSB head Base Flows	361	24
VSB 3 (all data combined)	336	15
VSB 3 Events	593	5
VSB 3 Base Flows	253	10

* Denotes outlet of subwatershed

ISTS sources are considered a high contributor in this subwatershed due to the high number of systems and their proximity to streams (Table 4.22). Agricultural sources such as feedlots and livestock in the stream are considered moderate sources and field-applied manure is considered a

low source because there is evidence that many dairy operations and livestock operations have left this area in the past few years (since the feedlot and animal unit data was collected). In addition, the “row crop” landcover classification includes sod farms which do not apply manure. The Hampton WWTP was considered a low source because it only discharges twice a year and their effluent goes into a swale through a field rather than into an actual channel. Therefore, it may not reach a receiving water at all, especially during dry periods.

Table 4.22 Relative Load Allocations for South Branch Subwatershed

Source	Relative Load
Cattle in stream	Moderate
Feedlots	Moderate
ISTS	High
Manure Application	Low
WWTP	Low
Pets/Urban	Low
Wildlife	Low

Goodwin Subwatershed

The Goodwin Subwatershed covers approximately 21,000 acres in Vermillion Township and the City of Vermillion (Figure 3.1). This subwatershed is downstream from and includes inputs from the seven subwatersheds previously described (Empire, South Creek, Middle Creek, North Creek, Farmington, Empire, and South Branch). The area is predominantly agricultural with 76% of the land used for row crops and hayfields (and some sod farms) (Table 4.23 and Figure C-15). There is a high number of ISTS and a moderate number of feedlots in this subwatershed (Table 4.23 and Figure C-16). Additionally, the City of Vermillion operates a small continuous-discharge wastewater treatment plant on the Vermillion River.

Table 4.23 Summarized Landcover for the Goodwin Subwatershed

Landcover (Total Area = 20,978 acres)	Acres or Number	Percent Area
Golf Courses	0	0
Residential (rural, suburban, urban residential areas)	319	1.5
Parks (city and county parks)	152	0.74
Total Urban/Pet	471	2.2
Number of ISTS	322	
Number of Feedlots	27	
Total Animal Units	4,102	
Animal Units/Area	0.196	
Pastures with streams (pastures with watercourse)	121	0.56
Pastures (pastures w/out watercourse)	308	1.46
Row Crops and Hayfields (manure application)	16,014	76.3
Open Water (lakes, ponds, open water wetlands)	51	0.24
Natural Areas (other wetlands, prairies, woodlands)	2,451	11.7
Commercial, Industrial, Transportation, Farmsteads	1,360	6.4
No Data	0	0

The only bacteria monitoring in the Goodwin Subwatershed was done at the outlet of the subwatershed on Goodwin Ave. (Hwy. 85). Bacteria collected here includes the unknown dynamics of bacteria die-off from upstream sources, and bacteria growth within the stream. Although bacteria levels are below the standard during periods of low flow, levels increase substantially during and after runoff events (Table 4.24).

Table 4.24 Bacteria Data for the Goodwin Subwatershed

Sites/Measurement	Geometric Mean of Bacteria per 100 ml	No. of Observations
Vverm (all data combined)	350	61
Vverm Events	1,658	19
Vverm Base Flows	174	42

Although the sources of bacteria in this subwatershed include bacteria from upstream subwatersheds, the data for the Goodwin Subwatershed were considered independently and upstream sources were not considered in assigning the relative loads. Although there is a high amount of agriculture and ISTS in this subwatershed, many sources are considered only moderate contributors due to the very sandy, porous soils in the area and few actual channels tributary to the River (Table 4.25). The City of Vermillion's WWTP has an unknown impact on the River with regards to bacteria contamination.

Table 4.25 Relative Load Allocations for the Goodwin Subwatershed

Source	Relative Load
Cattle in stream	Moderate
Feedlots	Moderate
ISTS	Moderate – High
Manure Application	Moderate
WWTP	Low – Moderate
Pets/Urban	Low
Wildlife	Low

Hastings Subwatershed

The Hastings Subwatershed covers approximately 46,500 acres in Nininger and Marshan Townships and the Cities of Hastings and Inver Grove Heights (Figure 3.1). This subwatershed is downstream from and includes inputs from the eight subwatersheds previously described (Empire, South Creek, Middle Creek, North Creek, Farmington, Empire, South Branch, and Goodwin). The area is primarily agricultural with 58% of the land used for row crops and hayfields (Table 4.26 and Figure C-17). Another 18% of the land is covered by wetlands, woodlands, prairies, and other natural features. There is a very high number of ISTS and feedlots in this area and some suburban land in the northern part of the subwatershed (Table 4.26 and Figure C-18).

Table 4.26 Summarized Landcover for the Hastings Subwatershed

Landcover (Total Area = 46,544 acres)	Acres or Number	Percent Area
Golf Courses	315	0.67
Residential (rural, suburban, urban residential areas)	4,273	9.2
Parks (city and county parks)	516	1.1
Total Urban/Pet	5,103	11
Number of ISTS	1323	
Number of Feedlots	45	
Total Animal Units	5,992	
Animal Units/Area	0.129	
Pastures with streams (pastures with watercourse)	314	0.66
Pastures (pastures w/out watercourse)	341	0.73
Row Crops and Hayfields (manure application)	26,880	57.8
Open Water (lakes, ponds, open water wetlands)	36	0.08
Natural Areas (other wetlands, prairies, woodlands)	8,443	18
Commercial, Industrial, Transportation, Farmsteads	5,427	11.6
No Data	0	0

The only bacteria monitoring site in the Hastings Subwatershed was done near the outlet of the subwatershed on Hwy. 47. Bacteria collected here includes the unknown dynamics of bacteria die-off from upstream sources, and bacteria growth within the stream. The data indicates an

impairment of twice the standard even during periods of low flow and bacteria levels 12 times the standard during and after runoff events (Table 4.27). The Vermillion River has an average flow of 129 cfs May – October above the falls in Hastings.

Table 4.27 Bacteria Data for the Hastings Subwatershed

Sites/Measurement	Geometric Mean of Bacteria per 100 ml	No. of Observations
V47 (all sites and data combined)	324	149
V47 Events (not all data included due to unknown flow)	2,433	16
V47 Base Flow (not all data included due to unknown flow)	403	72

Although the sources of bacteria in this subwatershed include bacteria from upstream subwatersheds, the data for the Hastings Subwatershed were considered independently and upstream sources were not considered in assigning the relative loads. Like the Goodwin Subwatershed, this area has sandy soils and high infiltration with few channels tributary to the River. ISTS sources are considered a high contributor of bacteria because anecdotal evidence suggests a high number of older homes and probably older septic systems very near the river (Table 4.28). Feedlots are considered a moderate source because although most feedlots are not along the River or tributaries, there is evidence that some of those along the River are known to be a problem. Livestock in the stream is considered a low source because many pastures have been recently fenced, excluding livestock access to the River.

Table 4.28 Relative Load Allocations for the Hastings Subwatershed

Source	Relative Load
Cattle in stream	Low
Feedlots	Moderate
ISTS	High
Manure Application	Moderate
WWTP	None
Pets/Urban	Low
Wildlife	Low

Lower Vermillion River

While historically anything below the falls is considered the "Lower Vermillion", based on the water sampling done for this study, the Lower Vermillion River is effectively considered as that area below the 10th St. Bridge (Hwy. 54) in Hastings. Samples for the Lower Vermillion were taken near the mouth of the river at Hwy. 18 (near the Treasure Island Casino). Bacteria levels here were low, 50 organisms per 100 ml on average; therefore the River is not considered to be impaired here (Table 4.29).

Table 4.29 Bacteria Data for the Lower Vermillion River

Sites/Measurement	Geometric Mean of Bacteria per 100 ml	No. of Observations
Vmouth (all data combined)	50	29
Vmouth Events	247	3
Vmouth Base Flows	41	26

Five samples were also taken at the 10th St. Bridge in Hastings. Average bacteria levels here were high (610 organisms per 100 ml) and more consistent with bacteria levels upstream. Although it is unclear why bacteria levels drop significantly between 10th St. and the mouth of the Vermillion River; it may be due to the inflow of water from the Mississippi River allowing for the bacteria to be diluted or dilution is coupled with some mechanisms of predation and/or die-off. High bacteria levels at 10th St. are considered to be a reflection of the bacteria levels upstream of the falls. There are no known sources of bacteria (besides wildlife) between the falls and Hwy. 54. (It should be noted that kayakers who frequently recreate in the turbid waters below the falls often complain of gastrointestinal illness directly following contact with the River.)

Because the Lower Vermillion River is not considered to be impaired, relative loads were not assigned to this subwatershed. Efforts made upstream to alleviate bacteria pollution will undoubtedly serve to improve the Lower Vermillion as well.

V. Implementation Strategies

Strategies for alleviating bacterial contamination throughout the watershed were developed and proposed by a group of technical advisors (including the Natural Resource Conservation Service, the University of Minnesota Extension, Dakota County SWCD, Dakota County Office of Planning, and Dakota County Environmental Management) and sent to the larger local stakeholder and technical advisors panel for comments and recommendations. The following implementation strategies were developed.

Most of these strategies would best be implemented (administered and/or funded) at the watershed scale, and thus, by the watershed management authority, the Vermillion River Watershed Joint Powers Organization (JPO). Currently, these strategies are being considered by the Vermillion River Watershed Planning Commission for inclusion in the watershed management plan.

Those strategies that are not adopted by JPO for implementation may be implemented at a more local level by cities and townships.

5.1 Septic Systems

Septic system compliance identification and upgrade program.

Human sewage presents the highest risk for human pathogen exposure and has been ranked as some of the highest relative loads in some subwatersheds. Addressing this risk is clearly a priority to ensuring swimming and recreational contact opportunities.

- Program phased in, starting in shoreland areas in the South Branch, Empire, and Hastings subwatersheds where failing and non-compliant ISTS are thought to be a high source of bacteria contamination. “Shoreland area” could be defined as the within the County’s shoreland jurisdiction, or even further up smaller tributaries and could be specifically mapped.
- Program would include contracting with a specific pool of independent third party inspectors. Homeowners not able to supply the inspector with recent as-built specifications would have to get their system inspected for compliance with State and County rules. If the system is deemed non-compliant and/or failing, the homeowner would have 12 months to upgrade the system (at the expense of the homeowner). The program would have an appeal mechanism built into it.

Low or no-interest loan program for septic system upgrade

- Priority could be given to systems within shoreland and/or those found non-compliant by the above program.

Septic system education.

- Work with the Counties, local units of government, and other organizations to print and distribute educational literature regarding septic system rules, standards, etc.

5.2 Land Applied Manure

In addition to reducing bacteria loading to the river system, eliminating manure runoff also reduces the potential for livestock disease transmission, and decreases BOD, ammonia, and nutrient loadings to the river.

Riparian filter strip and buffer program

A technical advisory group consisting of agency and community staff and/or elected officials would lay out appropriate details and buffer widths for this program.

Identify, map, and prioritize waterways in need of buffers. This will include all DNR-protected waters and "waters of special interest" including perennial streams and ditches tributary to DNR-protected waters. Appropriate buffer widths will be determined according to priorities within each subwatershed, type of stream, and landuse. Buffers may range from 50-ft to 300-ft +.

- The first five years of the program would be voluntary with hefty incentives for buffer establishment. No easements or land acquisition is being considered through this program. Buffers would be vegetated and would exclude cropland, structures including stormwater ponds, and livestock (except for appropriate rotational grazing plans). Implementation could occur on a subwatershed basis with a focus on certain subwatersheds each year. A strong educational and advertising campaign would accompany the program.
- After 5-years the voluntary buffer program would be evaluated for effectiveness in each subwatershed and the implementing agency should then consider moving to a mandatory buffer program. The mandatory program could include different buffer requirements according to stream type (as previously mapped), subwatershed, zoning, landuse, etc. A mandatory program should include an inspection and compliance program.
- Buffers would be required, through local ordinances, for all new development where more permanent land altering activities occur and a permit is required from the LGU. Buffer requirements (width, etc.) would depend upon stream type (as previously mapped), subwatershed, zoning, landuse, etc.

Riparian filter strip and buffer educational campaign

- Program would include informational meetings, literature, and door-to-door contact. Should be phased in with priority given to subwatersheds where land applied manure and/or livestock in waterways is considered a high source of bacteria pollution.

5.3 Urban Runoff

Urban stormwater runoff can contain high concentrations of fecal matter from pets, wildlife, rodents, and birds, etc. and exposure to these bacteria and protozoa can be harmful. Comprehensive management and treatment of stormwater is crucial to protecting the chemical, biological and physical integrity of the river system.

Reducing stormwater runoff volumes

Bacteria pollution from urban sources can be alleviated indirectly through the management of stormwater runoff. The following strategies address runoff volumes and quality and hence, bacteria loadings.

- Incentive program that charges new developments and redevelopments on a per acre basis of impervious surface if ½ inch of stormwater is retained. However, the fee is waived entirely if 1.5” or more stormwater is retained (based on findings of hydrologic study completed for Watershed which supports the need for 1.5 inch of infiltration/filtration). The rate per acre is prorated for infiltration between 0.5” and 1.5”. Areas of graded and compacted soils, such as lawns in new developments, will be considered impervious unless the soil structure is restored. (See Dane County, Wisconsin ordinance.)
- Review of preliminary plats for each development in the watershed and with analysis of the development at the beginning of the planning process such that water quality, wetland and natural area protection, erosion control, and stormwater practices can be addressed and discussed before plans are fully developed. The implementing agency could charge the developer for plan reviews. (Model after Scott County’s DIRT team protocols.)
- Requirement for new developments to incorporate at least two elements of alternative site design practices or low impact development options into overall grading plans. Examples include but are not limited to cluster developments, porous pavement, drainage swales, infiltration basins, infiltration trenches, rainwater gardens, sand filters, organic filters, bioretention areas, enhanced swales, dry storage ponds with underdrain discharge, off-line retention areas and natural depressions.

Pet Waste Abatement

- Pet waste education and control by providing waste receptacles and “baggies” in high density residences, parks, and trails.

5.4 Feedlots

Feedlot inventory

- Conduct a Level 3 inventory of all feedlots through a personal, on-the-farm interview by a trained technician.
- Information gathered would include animal units, proximity to water, manure management techniques, etc.
- This program would update the current list of registered feedlots from 2001 and would help prioritize and assess needs. It could also identify and assess the growing number of hobby farms.

Promote and cost share best management practices for use on all feedlots

- Work with all feedlot operations (regardless of size) to improve feedlots and manure handling by implementing standard set of best management practices including water diversions and filters on all feedlots.
- Develop a program to help augment the 50% cost share currently offered by the Federal EQIP. (Feedlot operators with less than 300 animal units are not required make improvements if they total over \$3,000 and there is not 75% cost sharing available. This program could add 25% cost share to the 50% offered by EQIP.)

5.5 Livestock in Water

Livestock exclusion from riparian areas

- This program would be incorporated into the buffer strategy described above and would include an incentive program, education, and technical assistance for fencing, remote watering systems, and rotational grazing plans.

5.6 Wastewater Treatment Plants

WWTPs are required to monitor their effluent to ensure that concentrations of bacteria stay below the discharge limit of 200 organisms/100 ml. The PCA regularly reviews the Discharge Monitoring Reports from WWTPs to determine whether violations have occurred.

WWTPs in the Vermillion River Watershed rarely exceed the discharge limit. The Elko/New Market WWTP upgraded its facility in 2000 by installing an UV disinfection system. Additionally, the Empire WWTP discharge will be moved to the Mississippi River in 2005.

Monitor WWTP performance

- The VRWJPO, in addition to the PCA, should review Discharge Monitoring Reports from the watershed's WWTPs to monitor their performance and advocate for upgrades or changes if necessary in the future.
- WWTPs in the watershed should be required to report any by-passes or overflows which occur during plant operation to the VRWJPO.

VI. Future Monitoring

Water quality monitoring, including testing for fecal coliform bacteria (or *E. coli*) will continue into the foreseeable future through a variety of programs. The Vermillion River Watershed Joint Powers Organization is committed to its monitoring network for water quality and quantity. Currently, grab samples are collected once a month during periods of low flow and 6 – 10 times a season during periods of snowmelt or stormwater runoff. There are six such monitoring sites currently, with two more being proposed in the Scott County portion of the watershed.

Additionally, the Metropolitan Council monitors the Vermillion River at four different locations throughout the watershed.

These programs and the data they produce will help determine the success or failure of the strategies as they are implemented.