Wisconsin's Long Term Trend Water Quality Monitoring Program for Rivers

July 2001 - June 2005

Prepared by the
WDNR Bureau of Watershed Management
River Long Term Trends Work Group
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Cover Photo: Willow River at former site of Burkhart Dam in Willow River State Park (Ken Schreiber).

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Contributors: Dale Robertson (USGS), and contributions from many of our Water Program colleagues. We are grateful for their reviews and insightful comments.

Figures: John Sullivan and Jim Ruppel.

Introduction

Wisconsin has had a variety of water quality monitoring networks over the past 30 years. In 1979, the network consisted of 29 National Ambient Stations (EPA) and 18 other stations for a total of 47 sites. In 2000, the state water quality monitoring network consisted of 24 stations operated by the Wisconsin Department of Natural Resources (WDNR) and 16 stations operated by United States Geological Survey (USGS) and other agencies. As many as 70 stations previously monitored by WDNR have substantial periods of record (Wis. Water Resources Center, 1998). The primary criteria for site selection typically included: broad spatial coverage, representation of a range of land coverage and ecotypes, historic long-term trend sampling locations, and availability of continuous flow data (preferably from a nearby USGS station).

The current Long-term Trend (LTT) water quality-monitoring network, initiated in 2001, consists of 42 sites, with a minimum of one site per major river basin, generally located near the mouth of each river (Figure 1 and Table 1). Most of these sites are part of an earlier trend monitoring effort.

Selection of the 42 trend monitoring sites considered different land coverage in the state varying from urban areas in the southeast, heavy agricultural use in central and southwest and forest cover dominating in the north (Figure 2). Water chemistry is greatly influenced by land cover/ use conditions. Table 2 shows the percentages of various land cover types in drainage areas associated with the LTT monitoring sites. In instances where the drainage areas cross state boundaries, land cover percentages reflect only the portion of the drainage area within the state.

The purpose of this report is to summarize monitoring data that has been conducted since the LTT network was revised in 2001. The report presents site information, water chemistry data summaries and some interpretation of the findings to date. This report does not include trend analysis or constituent loading information. A concurrent report being completed by the USGS will provide loading and trend analysis on a limited number of parameters based on LTT monitoring network data (Robertson et al. 2006). The WDNR Water Quality Sub-team will provide additional trend analysis updates and reports in the future.

Benefits and Goals of the Long-term River Monitoring Network

The long-term, statewide river water quality monitoring network provides the following benefits:

- Basic information to DNR staff to help assess general water quality conditions/trends in basins of interest. Each major river basin has at least one site that serves as a focal point for assessing existing conditions and long-term water quality changes;

- Historical and current water quality data on rivers allowing for statewide assessment of water quality conditions and trends. This information is used in preparing 305(b) reports, 303(d) listings (or de-listings), and other water quality reports and documents;

- Data to help develop water quality-based effluent limits, water quality standards and biocriteria. This monitoring may also identify new water quality problems or issues and evaluate responses to point and nonpoint source pollution abatement activities;

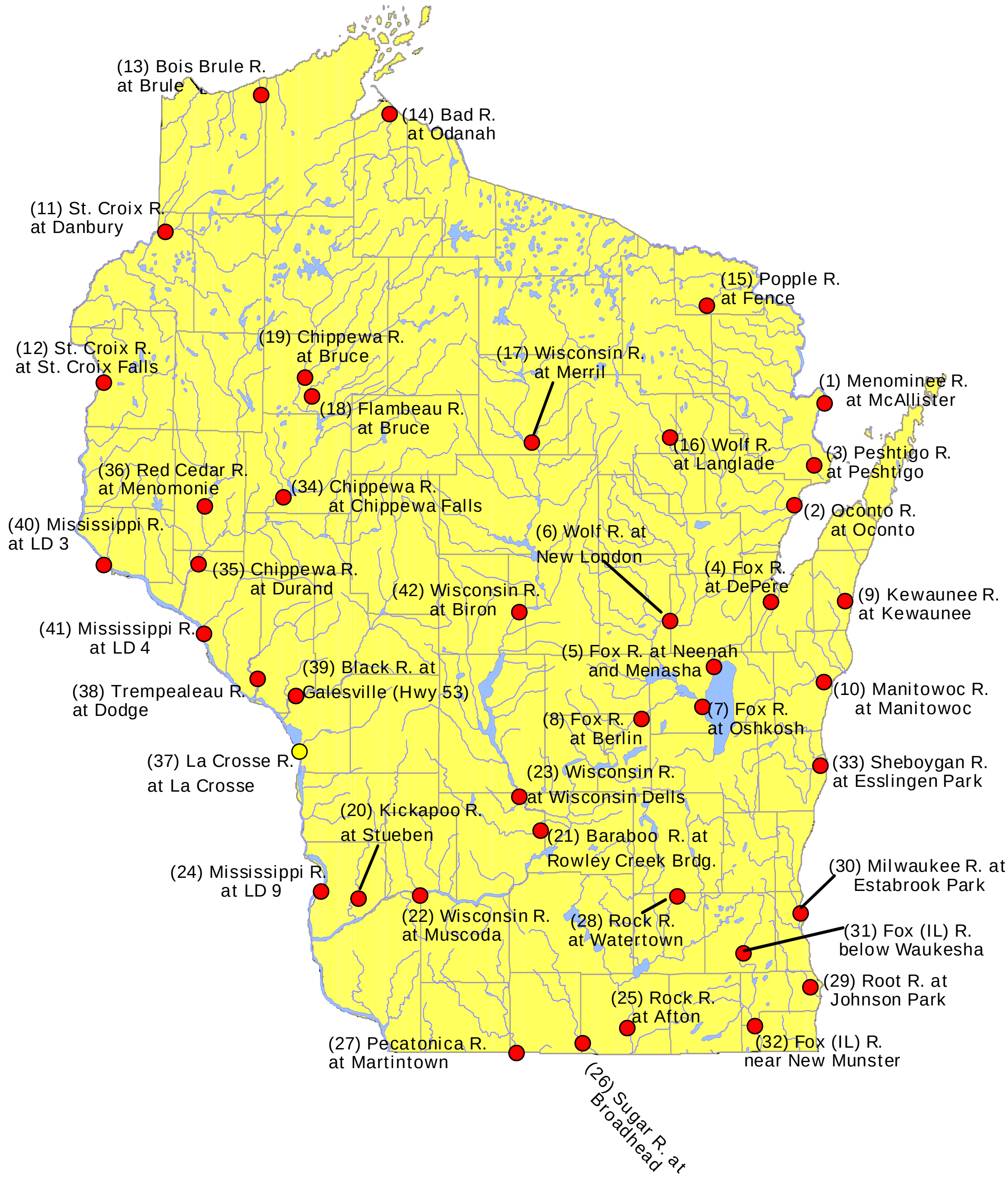


Figure 1. Wisconsin's long term trend river monitoring network (Site numbers shown in parentheses, LD = Lock & Dam).

Table 1. Wisconsin's long term trend river monitoring network**.**

LTT Site Number	Storet Number	Site Description	Region	Nearest USGS Gauging Site
1	383088	MENOMINEE R. AT MCALLISTER	NE	04067500 MENOMINEE RIVER NEAR MC ALLISTER, WI
2	433002	OCONTO R. AT OCONTO	NE	04071765 OCONTO RIVER NEAR OCONTO, WI
3	383001	PESHTIGO R. AT PESHTIGO	NE	04069500 PESHTIGO RIVER AT PESHTIGO, WI
4	053210	FOX R. AT DEPERE	NE	040851385 FOX RIVER AT OIL TANK DEPOT AT GREEN BAY, WI
5	713002	FOX R. AT NEENAH AND MENASHA	NE	04084445 FOX RIVER AT APPLETON, WI
6	693035	WOLF R. AT NEW LONDON	NE	04079000 WOLF RIVER AT NEW LONDON, WI
7	713056	FOX R. AT OSHKOSH	NE	04082400 FOX RIVER AT OSHKOSH, WI
8	243020	FOX R. AT BERLIN	NE	04073500 FOX RIVER AT BERLIN, WI
9	313038	KEWAUNEE R. AT KEWAUNEE	NE	04085200 KEWAUNEE RIVER NEAR KEWAUNEE, WI
10	363069	MANITOWOC R. AT MANITOWOC	NE	04085427 MANITOWOC RIVER AT MANITOWOC, WI
11	073132	ST. CROIX R. AT DANBURY	NO	05333500 ST. CROIX RIVER NEAR DANBURY, WI
12	493210	ST. CROIX R. AT ST. CROIX FALLS	NO	05340500 ST. CROIX RIVER AT ST. CROIX FALLS, WI
13	163002	BOIS BRULE R. AT BRULE	NO	04025500 BOIS BRULE RIVER AT BRULE, WI
14	023001	BAD R. AT ODANAH	NO	04027000 BAD RIVER NEAR ODANAH, WI
15	193003	POPPLE R. AT FENCE	NO	04063700 POPPLE RIVER NEAR FENCE, WI
16	343033	WOLF R. AT LANGLADE	NO	04074950 WOLF RIVER AT LANGLADE, WI
17	353068	WISCONSIN R. AT MERRIL	NO	05395000 WISCONSIN RIVER AT MERRILL, WI
18	553149	FLAMBEAU R. AT BRUCE	NO	05360500 FLAMBEAU RIVER NEAR BRUCE, WI
19	553003	CHIPPEWA R. AT BRUCE	NO	05356500 CHIPPEWA RIVER NEAR BRUCE, WI
20	123017	KICKAPOO R. AT STUEBEN	WC	05410490 KICKAPOO RIVER AT STEUBEN, WI
21	573051	BARABOO R. AT ROWLEY CREEK BRDG.	SC	05405000 BARABOO RIVER NEAR BARABOO, WI
22	223282	WISCONSIN R. AT MUSCODA	SC	05407000 WISCONSIN RIVER AT MUSCODA, WI
23	573052	WISCONSIN R. AT WISCONSIN DELLS	SC	05404000 WISCONSIN RIVER NEAR WISCONSIN DELLS, WI
24	123016	MISSISSIPPI R. AT LD 9	WC	05389500 Mississippi River at McGregor, IA
25	543001	ROCK R. AT AFTON	SC	05430500 ROCK RIVER AT AFTON, WI
26	233001	SUGAR R. AT BROADHEAD	SC	05436500 SUGAR RIVER NEAR BRODHEAD, WI
27	233002	PECATONICA R. AT MARTINTOWN	SC	05434500 PECATONICA RIVER AT MARTINTOWN, WI
28	285004	ROCK R. AT WATERTOWN	SC	05425500 ROCK RIVER AT WATERTOWN, WI
29	523061	ROOT R. AT JOHNSON PARK	SE	04087240 ROOT RIVER AT RACINE, WI
30	413640	MILWAUKEE R. AT ESTABROOK PARK	SE	04087000 MILWAUKEE RIVER AT MILWAUKEE, WI
31	683096	FOX (IL) R. BELOW WAUKESHA	SE	05543830 FOX RIVER AT WAUKESHA, WI
32	303066	FOX (IL) R. NEAR NEW MUNSTER	SE	05545750 FOX RIVER NEAR NEW MUNSTER, WI
33	603095	SHEBOYGAN R. AT ESSLINGEN PARK	SE	04086000 SHEBOYGAN RIVER AT SHEBOYGAN, WI
34	093001	CHIPPEWA R. AT CHIPPEWA FALLS	WC	05365500 CHIPPEWA RIVER AT CHIPPEWA FALLS, WI
35	473008	CHIPPEWA R. AT DURAND	WC	05369500 CHIPPEWA RIVER AT DURAND, WI
36	173208	RED CEDAR R. AT MENOMONIE	WC	05369000 RED CEDAR RIVER AT MENOMONIE, WI
37	323017	LA CROSSE R. NEAR MOUTH	WC	05383075 LA CROSSE RIVER NEAR LA CROSSE, WI
38	623039	TREMPEALEAU R. AT DODGE	WC	05379500 TREMPEALEAU RIVER AT DODGE, WI
39	623001	BLACK R. AT GALESVILLE (HWY 53)	WC	05382000 BLACK RIVER NEAR GALESVILLE, WI
40	483027	MISSISSIPPI R. AT ABOVE LD 3	WC	05344500 MISSISSIPPI RIVER AT PRESCOTT, WI
41	063029	MISSISSIPPI R. AT ABOVE LD 4	WC	05378500 MISSISSIPPI RIVER AT WINONA, MN
42	723002	WISCONSIN R. AT BIRON	WC	05400760 WISCONSIN RIVER AT WISCONSIN RAPIDS, WI

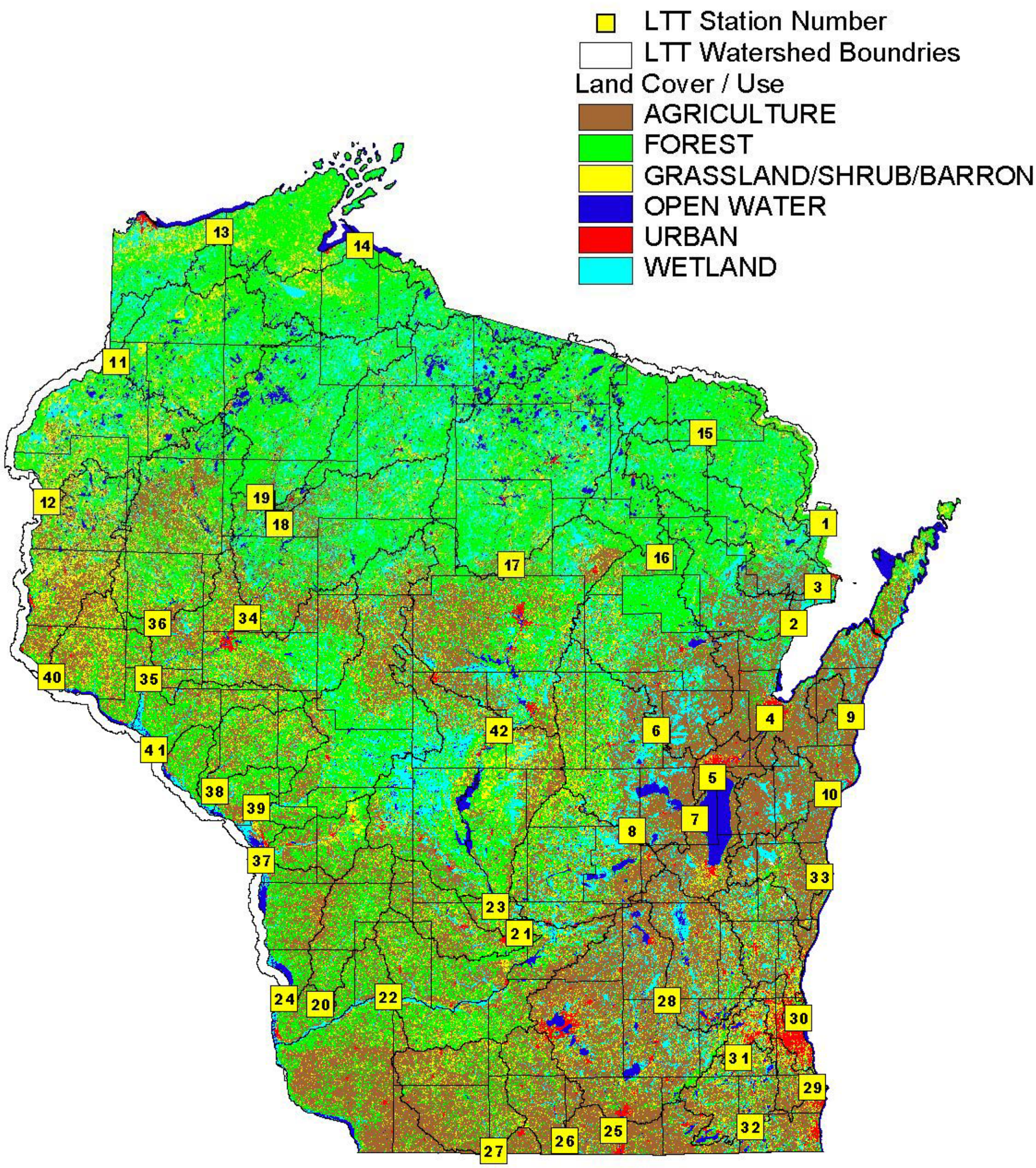


Figure 2. Land Cover in Wisconsin (Source: WISCLAND**)**

Table 2. Summary of land cover in the long term trend watersheds.

LTT Site Number [2]	Site Description	Urban	Forested	Agriculture	Wetlands	Barron, Shrub or Grasslands	Open Water
1	MENOMINEE R. AT MCALLISTER [1]	0.1%	71.4%	2.1%	16.8%	7.0%	2.6%
2	OCONTO R. AT OCONTO	0.2%	46.6%	26.5%	20.3%	4.5%	1.8%
3	PESHTIGO R. AT PESHTIGO	0.2%	53.5%	14.7%	22.1%	7.4%	2.2%
4	FOX R. AT DEPERE	1.7%	27.4%	36.2%	17.0%	11.5%	6.2%
5	FOX R. AT NEENAH AND MENASHA	1.1%	28.3%	35.0%	17.6%	11.7%	6.3%
6	WOLF R. AT NEW LONDON	0.5%	42.0%	28.2%	19.7%	7.3%	2.2%
7	FOX R. AT OSHKOSH	0.8%	31.0%	34.1%	18.9%	12.0%	3.2%
8	FOX R. AT BERLIN	0.9%	24.1%	35.2%	18.5%	17.7%	3.6%
9	KEWAUNEE R. AT KEWAUNEE	0.5%	6.2%	81.6%	7.7%	4.1%	0.0%
10	MANITOWOC R. AT MANITOWOC	0.8%	4.5%	73.9%	17.1%	3.5%	0.1%
11	ST. CROIX R. AT DANBURY	0.1%	65.9%	0.9%	16.1%	12.2%	4.8%
12	ST. CROIX R. AT ST. CROIX FALLS	0.2%	57.7%	3.4%	16.8%	17.2%	4.7%
13	BOIS BRULE R. AT BRULE	0.0%	76.8%	0.1%	12.5%	8.8%	1.8%
14	BAD R. AT ODANAH	0.0%	71.5%	0.8%	16.0%	9.6%	2.1%
15	POPPLE R. AT FENCE	0.0%	67.4%	0.9%	28.9%	1.9%	0.7%
16	WOLF R. AT LANGLADE	0.2%	67.9%	2.7%	18.3%	6.0%	4.9%
17	WISCONSIN R. AT MERRIL[1]	0.5%	57.0%	2.3%	24.4%	9.0%	6.9%
18	FLAMBEAU R. AT BRUCE	0.3%	55.3%	2.6%	28.0%	6.2%	7.6%
19	CHIPPEWA R. AT BRUCE	0.0%	61.7%	4.1%	22.8%	5.7%	5.6%
20	KICKAPOO R. AT STUEBEN	0.2%	41.6%	43.1%	1.8%	13.2%	0.1%
21	BARABOO R. AT ROWLEY CREEK BRDG.	1.3%	31.1%	47.8%	4.2%	15.1%	0.4%
22	WISCONSIN R. AT MUSCODA	1.1%	40.9%	24.7%	16.4%	13.4%	3.7%
23	WISCONSIN R. AT WISCONSIN DELLS	1.1%	42.5%	19.9%	19.4%	12.8%	4.3%
25	ROCK R. AT AFTON	3.6%	7.3%	60.1%	12.5%	12.9%	3.6%
26	SUGAR R. AT BROADHEAD	1.6%	16.1%	65.3%	4.1%	12.6%	0.4%
27	PECATONICA R. AT MARTINTOWN	0.5%	19.7%	64.7%	1.1%	13.7%	0.2%
28	ROCK R. AT WATERTOWN	2.1%	5.9%	58.4%	16.8%	13.6%	3.1%
29	ROOT R. AT JOHNSON PARK	11.5%	10.5%	51.7%	4.9%	20.6%	0.7%
30	MILWAUKEE R. AT ESTABROOK PARK	7.3%	11.7%	45.8%	14.7%	18.3%	1.6%
31	FOX (IL) R. BELOW WAUKESHA	17.2%	10.3%	22.5%	12.8%	34.4%	2.9%
32	FOX (IL) R. NEAR NEW MUNSTER	6.4%	13.4%	41.0%	11.6%	23.1%	4.5%
33	SHEBOYGAN R. AT ESSLINGEN PARK	1.5%	9.5%	61.4%	14.5%	11.7%	0.9%
34	CHIPPEWA R. AT CHIPPEWA FALLS	0.2%	54.2%	9.1%	24.0%	7.2%	5.3%
35	CHIPPEWA R. AT DURAND	0.5%	48.0%	18.5%	18.0%	10.8%	4.1%
36	RED CEDAR R. AT MENOMONIE	0.5%	41.4%	31.2%	7.3%	16.3%	3.3%
37	LA CROSSE R. AT LA CROSSE	2.5%	44.4%	33.0%	4.5%	15.2%	0.4%
38	TREMPEALEAU R. AT DODGE	0.3%	43.9%	31.9%	5.3%	18.4%	0.2%
39	BLACK R. AT GALESVILLE (HWY 53)	0.3%	44.7%	24.9%	15.7%	13.2%	1.2%
42	WISCONSIN R. AT BIRON[1]	1.2%	46.3%	17.6%	19.4%	11.1%	4.5%

1- For instances where the drainage area associated with a monitoring station crosses state boundaries the percentages of land use shown reflect only the portion of the drainage area with the State of Wisconsin.
2- Mississippi River Sites are not shown.

- Information to compare water quality between basins reflecting land cover, hydrology and other anthropogenic impacts/changes. Long-term sites also provide an important reference for assessing other water quality data collected within a basin during more abbreviated monitoring periods. These data may also be used to supplement baseline monitoring activities;

- The network allows statewide evaluation of “contaminants of concern" (e.g. pesticides, heavy metals, etc.) and testing of new water quality evaluation techniques. These data can also be used to assess regional and/or national issues such as nitrogen loading and Gulf of Mexico hypoxia.

Methods

The trend monitoring network currently consists of 42 sites distributed across the state (Figures 1 and Table 1). Just over half the sites (24) are sampled monthly and the other sites are sampled quarterly. Monthly sites are generally located near the mouth of major rivers, whereas, quarterly sites are often located at additional sites on major rivers some distance above the mouth. Sampling at a lower frequency reduces the ability for assessing temporal changes and decreases the power to detect long term trends (Galarneau 1996 and Lubinski et al. 2001). However, a lack of available funding prevented the establishment of a monthly monitoring network across the state. The number of water quality measurements for some sites on the Mississippi River (Lock and Dams (LD) 3 and 4) were reduced due to the availability of monitoring data from other agencies.

Monthly samples are collected approximately every 30 days and are scheduled at least one week in advance to avoid bias from weather conditions. Quarterly sampling is conducted during the following time periods:

Winter – December/January
Spring – March/April
Summer – July/August
Autumn – October/November

The goal of the sampling protocol is to collect water samples in an unbiased fashion with respect to flow, weather and other factors. Samples are collected in free flowing, well-mixed areas of rivers generally between the hours of 8 a.m. and 2 p.m.

Field water quality measurements generally include dissolved oxygen, temperature and pH following field procedure established by the Department (http://intranet.dnr.state.wi.us/int/es/science/ls/fpm/table.htm). Water quality samples are sent overnight on ice to the Wisconsin State Laboratory of Hygiene in Madison, Wisconsin, where they are analyzed for nutrients, solids, specific conductance, pH, hardness, alkalinity, bacteria chlorophyll, and triazine herbicides following approved U.S. EPA methods. Low level metal sampling using "clean hands" and laboratory procedures is conducted quarterly at a subset of the monthly monitoring sites and biannual sampling of triazine is done during winter vs. summer periods. A complete listing of the monitoring design, sampling frequency and analyses are presented in Tables 1 and 3. The data used in this report was extracted from the WI DNR Lab Data System maintained by the WDNR Technical Services Section. The data was screened to remove duplicate entries and records where the result was marked as "Not Verified" by the laboratory. When the sample concentration was below the laboratory limit of detection the detection limit was substituted for the result. Both inorganic and biological lab slips allow field staff to record field observations to be entered into the data bank by laboratory staff. For this report only field information from the inorganic lab slips is included in the data set for data analysis purposes.

GIS land cover information was obtained from the Wisconsin Initiative for Statewide Cooperation on Landscape Analysis and Data (WISCLAND). Metadata information is available online at: (http://www.dnr.state.wi.us/maps/gis/datalandcover.html#metadata).
WISCLAND data is a raster representation of vegetation and land use for the state of Wisconsin. The source of the data were acquired from the nationwide Multi-Resolution Land Characteristics Consortium acquisition of dual-date Landsat Thematic Mapper ™ data primarily from 1992 (http://edc.usgs.gov/products/landcover/nlcd.html). This information was

Table 3 . Sampling frequency and parameters of the long term trend monitoring network.

LTT Site Number	Site Description	Field - pH, DO, Cond	Lab - pH, Alk, & Cond	Turb	TKN	NOx	NH4	TP	DisP	TSS	All Pig. Chla	Fecal	E-coli	Cl	Ca Mg Hard	Low Level Metals	Triazine	Diss Silica
1	MENOMINEE R. AT MCALLISTER	4	4	4	4	4	4	4	4	4	4	4	4	4	0	0	2	0
2	OCONTO R. AT OCONTO	4	4	4	4	4	4	4	4	4	4	4	4	4	0	0	2	0
3	PESHTIGO R. AT PESHTIGO	4	4	4	4	4	4	4	4	4	4	4	4	4	0	0	2	0
4	FOX R. AT DEPERE	12	12	12	12	12	12	12	12	12	12	12	12	12	4	4	2	12
5	FOX R. AT NEENAH AND MENASHA	12	12	12	12	12	12	12	12	12	12	12	12	12	0	0	2	12
6	WOLF R. AT NEW LONDON	12	12	12	12	12	12	12	12	12	12	12	12	12	4	4	2	12
7	FOX R. AT OSHKOSH	12	12	12	12	12	12	12	12	12	12	12	12	12	0	0	2	12
8	FOX R. AT BERLIN	4	4	4	4	4	4	4	4	4	4	4	4	4	0	0	2	0
9	KEWAUNEE R. AT KEWAUNEE	4	4	4	4	4	4	4	4	4	4	4	4	4	0	0	2	0
10	MANITOWOC R. AT MANITOWOC	4	4	4	4	4	4	4	4	4	4	4	4	4	0	0	2	0
11	ST. CROIX R. AT DANBURY	4	4	4	4	4	4	4	4	4	4	4	4	4	0	0	2	0
12	ST. CROIX R. AT ST. CROIX FALLS	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	2	0
13	BOIS BRULE R. AT BRULE	4	4	4	4	4	4	4	4	4	4	4	4	4	0	0	2	0
14	BAD R. AT ODANAH	4	4	4	4	4	4	4	4	4	4	4	4	4	0	0	2	0
15	POPPLE R. AT FENCE	12	12	12	12	12	12	12	12	12	12	12	12	12	4	4	2	12
16	WOLF R. AT LANGLADE	12	12	12	12	12	12	12	12	12	12	12	12	12	0	0	2	12
17	WISCONSIN R. AT MERRIL	12	12	12	12	12	12	12	12	12	12	12	12	12	0	0	2	12
18	FLAMBEAU R. AT BRUCE	4	4	4	4	4	4	4	4	4	4	4	4	4	0	0	2	0
19	CHIPPEWA R. AT BRUCE	4	4	4	4	4	4	4	4	4	4	4	4	4	0	0	2	0
20	KICKAPOO R. AT STUEBEN	12	12	12	12	12	12	12	12	12	12	12	12	12	0	0	2	0
21	BARABOO R. AT ROWLEY CREEK BRDG.	12	12	12	12	12	12	12	12	12	12	12	12	12	0	0	2	0
22	WISCONSIN R. AT MUSCODA	12	12	12	12	12	12	12	12	12	12	12	12	12	0	0	2	0
23	WISCONSIN R. AT WISCONSIN DELLS	12	12	12	12	12	12	12	12	12	12	12	12	12	4	4	2	0
24	MISSISSIPPI R. AT LD 9	12	12	12	12	12	12	12	12	12	12	12	12	12	0	0	0	0
25	ROCK R. AT AFTON	12	12	12	12	12	12	12	12	12	12	12	12	12	4	4	2	0
26	SUGAR R. AT BROADHEAD	12	12	12	12	12	12	12	12	12	12	12	12	12	0	0	2	0
27	PECATONICA R. AT MARTINTOWN	12	12	12	12	12	12	12	12	12	12	12	12	12	0	0	2	0
28	ROCK R. AT WATERTOWN	12	12	12	12	12	12	12	12	12	12	12	12	12	0	0	2	0
29	ROOT R. AT JOHNSON PARK	12	12	12	12	12	12	12	12	12	12	12	12	12	4	4	2	12
30	MILWAUKEE R. AT ESTABROOK PARK	4	4	4	4	4	4	4	4	4	4	4	4	4	0	0	2	4
31	FOX (IL) R. BELOW WAUKESHA	4	4	4	4	4	4	4	4	4	4	4	4	4	0	0	2	0
32	FOX (IL) R. NEAR NEW MUNSTER	4	4	4	4	4	4	4	4	4	4	4	4	4	0	0	2	0
33	SHEBOYGAN R. AT ESSLINGEN PARK	12	12	12	12	12	12	12	12	12	12	12	12	12	4	4	2	12
34	CHIPPEWA R. AT CHIPPEWA FALLS	4	4	4	4	4	4	4	4	4	4	4	4	4	0	0	2	0
35	CHIPPEWA R. AT DURAND	12	12	12	12	12	12	12	12	12	12	12	12	12	4	4	2	12
36	RED CEDAR R. AT MENOMONIE	12	12	12	12	12	12	12	12	12	12	12	12	12	0	0	2	12
37	LA CROSSE R. AT LA CROSSE	12	12	12	12	12	12	12	12	12	12	12	12	12	0	0	2	0
38	TREMPEALEAU R. AT DODGE	12	12	12	12	12	12	12	12	12	12	12	12	12	0	0	2	12
39	BLACK R. AT GALESVILLE (HWY 53)	12	12	12	12	12	12	12	12	12	12	12	12	12	4	4	2	12
40	MISSISSIPPI R. AT LD 3	4	4	0	0	0	0	0	0	0	0	0	0	0	4	4	2	0
41	MISSISSIPPI R. AT LD 4	4	4	0	0	0	0	0	0	0	0	0	0	0	4	4	2	0
42	WISCONSIN R. AT BIRON	12	12	12	12	12	12	12	12	12	12	12	12	12	0	0	2	0

used to evaluate general relationships between a basin's land cover and its associated stream's water quality condition.

Statistix™ 8 (Analytical Software, 2003) was use to conduct basic statistical analyses and prepare graphics. Excel™ 2003 (Microsoft Corp.) spreadsheet software was utilized to store raw data and was also used to prepare graphs relating land cover and water quality. State maps of land cover, site locations were prepared using Arcview ™ 3.3 (Environmental Systems Research Institute, Inc.).

Results and Discussion

Water quality data from 2001 through 2005 were collected from 42 monitoring stations throughout Wisconsin on either a quarterly or monthly basis. All stations are associated with a USGS flow station (Table 1). A brief description of the water quality measurement is provided, followed by a general discussion of the results from a statewide perspective. Monitoring data for each constituent is represented in box plots (Figure 3) that are grouped by WDNR Administrative Regions as a means of illustrating general differences between major geographic areas of the state. It should be noted that box plots were prepared on the entire data set and seasonal differences in water quality were not evaluated. Seasonal water quality changes can be significant and will be considered in future water quality assessments.

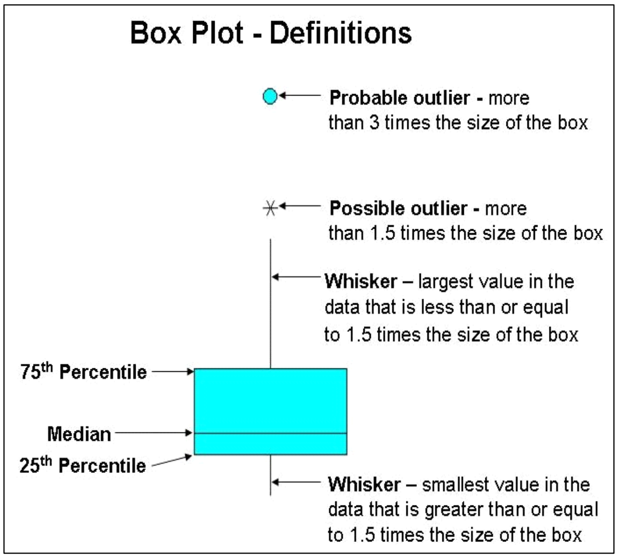


Figure 3. Description of box plot diagrams

Water Temperature

Water temperature is an important physical property that influences the growth and distribution of aquatic organisms and is important factor regulating chemical and biochemical reactions. Surface water temperature is strongly influenced by solar radiation, local climate and groundwater inflows. Differential heating of water induces thermal stratification, which may affect mixing and other water quality conditions. Wisconsin uses water temperature as an important variable in the designation of fish and aquatic life uses.

Long term water temperature data are useful for interpreting temporal variations. Seasonal adjusted data can be particularly useful in interpreting other water quality data and are used for effluent limits calculations.

Water temperature measurements show substantial seasonal changes due to Wisconsin's temperate climate. Monitoring frequency was inconsistent due to the nature of the monitoring design (monthly versus quarterly sampling). A detailed discussion of the temperature data is not warranted due to the variability in frequency and range of temperature measurements reported.

Dissolved Oxygen

Dissolved oxygen (DO) is a gas found in water that is critical for sustaining aquatic life. Dissolved oxygen enters water through mixing with air or through photosynthetic processes by aquatic macrophytes and algae. Decomposition of organic materials from point or nonpoint source inputs, plant respiration and benthic oxygen demand are important factors contributing to DO losses in the aquatic environment. Large fluctuations in diurnal DO levels generally indicate increased photosynthesis and respiration due to elevated levels of macrophyte and/or algal growth. Wisconsin has a minimum criterion of 5 mg/L to protect fish and aquatic life use.

Sites in Northeast Region were the only locations where minimum dissolved oxygen (DO) concentrations fell below the 5 mg/L criterion (Figure 4). The Fox River at Neenah-Menasha (Site 5) showed the greatest range in DO concentrations ranging from just below 5 mg/L to highs in the teens. The Kickapoo River (Site 20) in West Central Region approached 5 mg/L DO, while the Mississippi River sites (24, 41 & 42) showed the greatest range of DO values. The La Crosse River (Site 37) had the highest median value in the State at 12.8 mg/L dissolved oxygen.

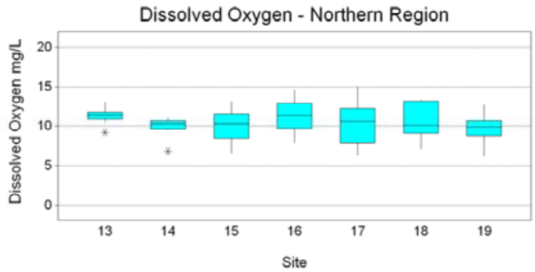
In South Central Region the Rock River approached a low of 5 mg/L instantaneous DO but also had some of the highest values reported with concentrations in the upper teens. The highest median DO value (11.9 mg/L) and greatest range in Southeast Region was in the Root River. The Root River and Fox (IL) River near New Munster had low values near 5 mg/L. Highest DO values were typically associated with high chlorophyll *a* concentrations suggesting increased photosynthetic activity by algae (see chlorophyll discussion below).

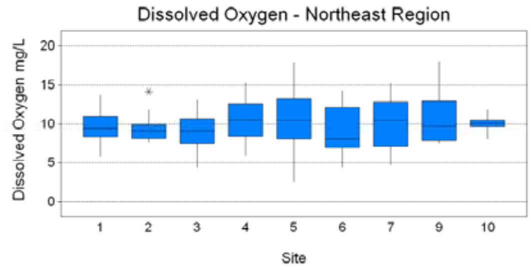
pH

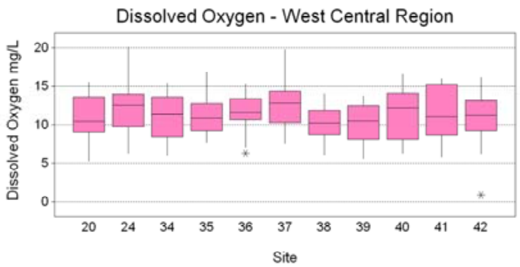
pH is a measure of the hydrogen-ion activity of water and is expressed as a logarithmic unit that ranges from 1 to 14 Standard Units (su). Waters with high hydrogen-ion activity have low pH and are considered acidic. Dissolved carbon dioxide, carbonic acid, bicarbonate ions and carbonate ions form complex acid-base equilibrium reactions that strongly influence the pH of freshwater systems (Hem 1970). pH may exhibit strong diurnal fluctuations associated with carbon dioxide utilization (photosynthesis) or release (respiration) by aquatic plants and algae in poorly buffered (low alkalinity) waters. Dissolved metal ions typically exhibit increasing concentrations with increased acidity and as a result, pH is an important factor influencing toxicity of metals. pH also affects the concentration of un-ionized ammonia N, a form of reduced N that is extremely toxic to aquatic life (see nitrogen below). Wisconsin's has adopted a pH standard that incorporates a range from 6 to 9 units to protect and support aquatic life use.

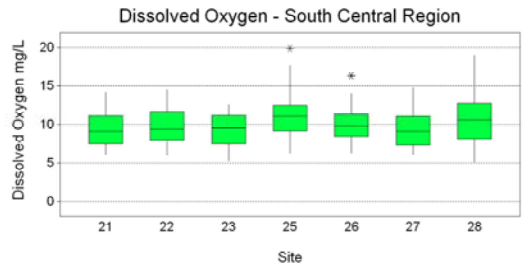
Both field and laboratory pH measurements were recorded in the monitoring program. Only laboratory measurements are discussed to ensure statewide consistency and potential problems encountered with meter variation and field calibration. Laboratory pH measurements indicated generally higher values in the southern parts of the State (Figure 5). This likely reflects the higher alkalinity and hardness that characterize these waters. pH measurements in Northern Region sites ranged from near 7.0 to 8.4 with the greatest range observed in the Popple River (Site 15). The highest median pH values in Northeast Region were observed in the Manitowoc River (Site 10) and the three Fox River sites.

The Fox River at De Pere (Site 4) and at Neenah and Menasha (Site 5) had values greater than 9.0 and were likely influenced by algal photosynthetic activity. The Red Cedar River (Site 36) showed the greatest range of pH in West Central Region from 7.5 to 9.4, due to photosynthetic activity from algal cells washed out of Lake Menomin.

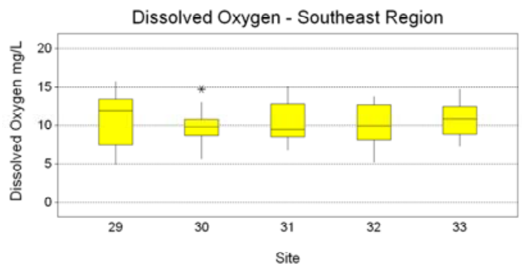








Site No.	Site Description	Region	Sample Freq.	N	Median mg/L
1	Menominee R. at McAllister	NE	Qtr.	14	9.5
2	Oconto R. at Oconto	NE	Qtr.	14	9.2
3	Peshtigo R. at Peshtigo	NE	Qtr.	15	9.2
4	Fox R. at DePere	NE	Mon.	40	10.6
5	Fox R. at Neenah and Menasha	NE	Mon.	41	10.5
6	Wolf R. at New London	NE	Mon.	35	8.1
7	Fox R. at Oshkosh	NE	Mon.	41	10.5
8	Fox R. at Berlin	NE	Qtr.	0	
9	Kewaunee R. at Kewaunee	NE	Qtr.	6	9.8
10	Manitowoc R. at Manitowoc	NE	Qtr.	5	10.1
11	St. Croix R. at Danbury	NO	Qtr.	1	
12	St. Croix R. at St. Croix Falls	NO	Qtr.	0	
13	Bois Brule R. at Brule	NO	Qtr.	7	11.4
14	Bad R. at Odanah	NO	Qtr.	6	10.3
15	Popple R. at Fence	NO	Mon.	42	10.3
16	Wolf R. at Langlade	NO	Mon.	43	11.3
17	Wisconsin R. at Merril	NO	Mon.	44	10.6
18	Flambeau R. at Bruce	NO	Qtr.	6	10.1
19	Chippewa R. at Bruce	NO	Qtr.	6	9.9
20	Kickapoo R. at Stueben	WC	Mon.	44	10.5
21	Baraboo R. at Rowley Creek Br.	SC	Mon.	33	9.1
22	Wisconsin R. at Muscoda	SC	Mon.	37	9.4
23	Wisconsin R. at Wisconsin Dells	SC	Mon.	36	9.6
24	Mississippi R. at LD 9	WC	Mon.	29	12.5
25	Rock R. at Afton	SC	Mon.	39	11.1
26	Sugar R. at Broadhead	SC	Mon.	37	9.8
27	Pecatonica R. at Martintown	SC	Mon.	36	9.1
28	Rock R. at Watertown	SC	Mon.	39	10.6
29	Root R. at Johnson Park	SE	Mon.	33	11.9
30	Milwaukee R. at Estabrook Park	SE	Qtr.	13	9.8
31	Fox (IL) R. below Waukesha	SE	Qtr.	9	9.5
32	Fox (IL) R. near New Munster	SE	Qtr.	9	10.0
33	Sheboygan R. at Esslingen Park	SE	Mon.	44	10.8
34	Chippewa R. at Chippewa Falls	WC	Qtr.	13	11.4
35	Chippewa R. at Durand	WC	Mon.	41	10.9
36	Red Cedar R. at Menomonie	WC	Mon.	42	11.6
37	La Crosse R. near Mouth	WC	Mon.	41	12.8
38	Trempealeau R. at Dodge	WC	Mon.	43	10.2
39	Black R. at Galesville (Hwy 53)	WC	Mon.	42	10.5
40	Mississippi R. at LD 3	WC	Qtr.	14	12.2
41	Mississippi R. at LD 4	WC	Qtr.	12	11.1
42	Wisconsin R. at Biron	WC	Mon.	44	11.2



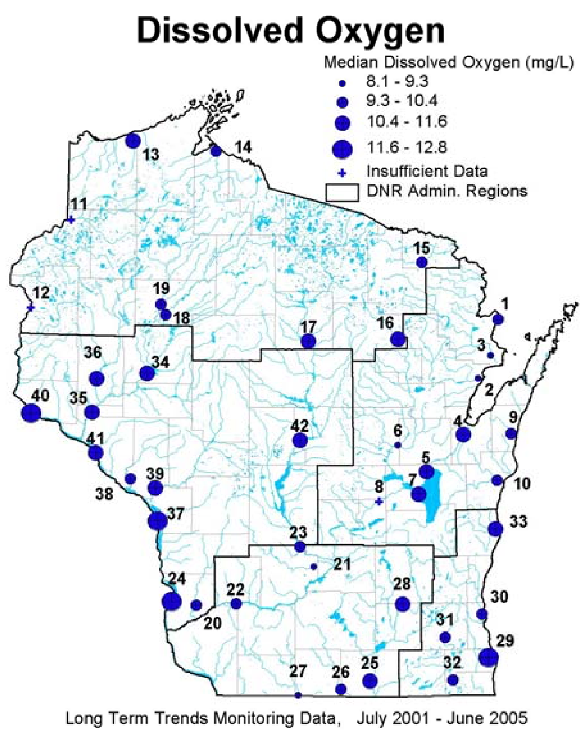
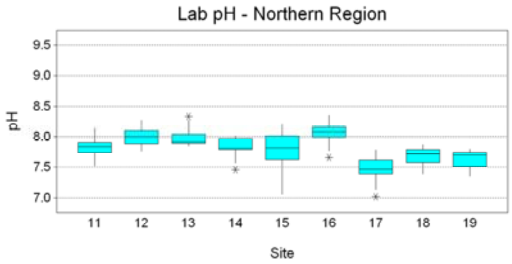
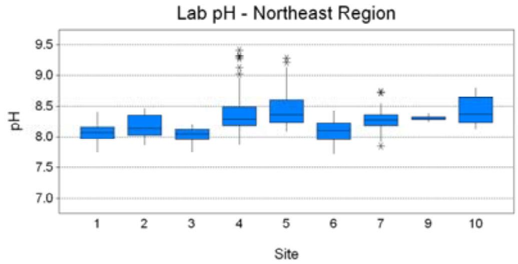
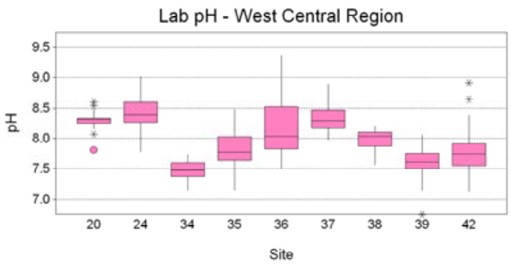
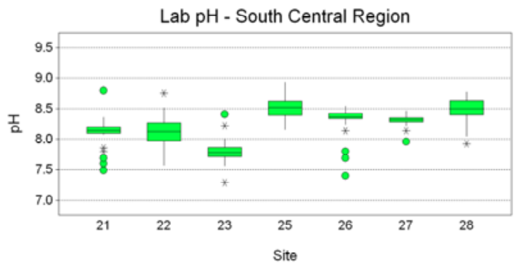


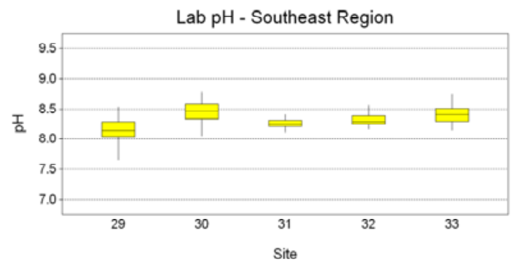
Figure 4. Dissolved oxygen concentrations at Wisconsin's long term trends sites.











Site No.	Site Description	Region	Sample Freq.	N	Median mg/L
1	Menominee R. at McAllister	NE	Qtr.	15	8.1
2	Oconto R. at Oconto	NE	Qtr.	14	8.1
3	Peshtigo R. at Peshtigo	NE	Qtr.	15	8.1
4	Fox R. at DePere	NE	Mon.	40	8.3
5	Fox R. at Neenah and Menasha	NE	Mon.	40	8.4
6	Wolf R. at New London	NE	Mon.	36	8.1
7	Fox R. at Oshkosh	NE	Mon.	40	8.3
8	Fox R. at Berlin	NE	Qtr.	2	
9	Kewaunee R. at Kewaunee	NE	Qtr.	7	8.3
10	Manitowoc R. at Manitowoc	NE	Qtr.	8	8.4
11	St. Croix R. at Danbury	NO	Qtr.	7	7.8
12	St. Croix R. at St. Croix Falls	NO	Qtr.	7	8.0
13	Bois Brule R. at Brule	NO	Qtr.	11	7.9
14	Bad R. at Odanah	NO	Qtr.	9	7.8
15	Popple R. at Fence	NO	Mon.	36	7.8
16	Wolf R. at Langlade	NO	Mon.	40	8.1
17	Wisconsin R. at Merril	NO	Mon.	40	7.5
18	Flambeau R. at Bruce	NO	Qtr.	6	7.7
19	Chippewa R. at Bruce	NO	Qtr.	6	7.7
20	Kickapoo R. at Stueben	WC	Mon.	41	8.3
21	Baraboo R. at Rowley Creek Br.	SC	Mon.	33	8.2
22	Wisconsin R. at Muscoda	SC	Mon.	36	8.1
23	Wisconsin R. at Wisconsin Dells	SC	Mon.	36	7.8
24	Mississippi R. at LD 9	WC	Mon.	26	8.4
25	Rock R. at Afton	SC	Mon.	40	8.5
26	Sugar R. at Broadhead	SC	Mon.	40	8.4
27	Pecatonica R. at Martintown	SC	Mon.	36	8.3
28	Rock R. at Watertown	SC	Mon.	40	8.5
29	Root R. at Johnson Park	SE	Mon.	32	8.1
30	Milwaukee R. at Estabrook Park	SE	Qtr.	12	8.5
31	Fox (IL) R. below Waukesha	SE	Qtr.	7	8.2
32	Fox (IL) R. near New Munster	SE	Qtr.	8	8.3
33	Sheboygan R. at Esslingen Park	SE	Mon.	43	8.4
34	Chippewa R. at Chippewa Falls	WC	Qtr.	15	7.5
35	Chippewa R. at Durand	WC	Mon.	42	7.8
36	Red Cedar R. at Menomonie	WC	Mon.	43	8.0
37	La Crosse R. near Mouth	WC	Mon.	23	8.3
38	Trempealeau R. at Dodge	WC	Mon.	41	8.0
39	Black R. at Galesville (Hwy 53)	WC	Mon.	43	7.6
40	Mississippi R. at LD 3	WC	Qtr.	0	
41	Mississippi R. at LD 4	WC	Qtr.	0	
42	Wisconsin R. at Biron	WC	Mon.	45	7.7

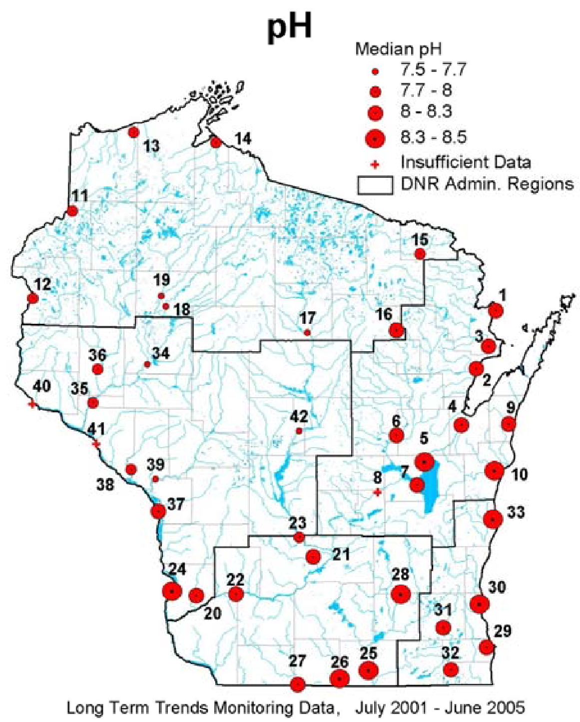


Figure 5. Lab pH values at Wisconsin's long term trends sites.

Median pH values near 7.5 were observed in the Chippewa River (Sites 19, 34 & 35) and Black River (Site 39) in WCR, which have relatively low alkalinity. In South Central Region the highest pH values were observed at the two Rock River sites (25 & 28).

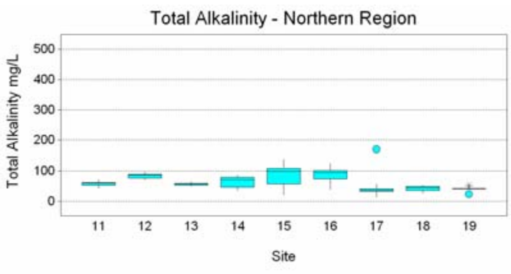
The lowest median value was observed at the Wisconsin River at Wisconsin Dells (Site 23) at 7.8, but a number of outliers ranged from around 7.3 to near 8.5. In Southeast Region all of the median pH values were between 8.1 and 8.5.

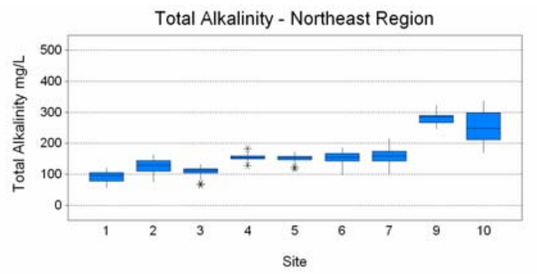
Total Alkalinity

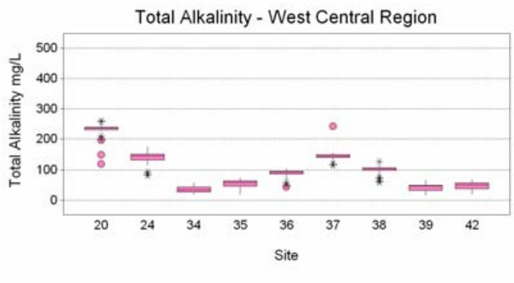
Total alkalinity is a measure of the buffering capacity of water contributed by bases in solution. Waters that are well buffered resist abrupt changes or fluctuations in pH that may arise from snowmelt runoff and rainfall, which typically have low pH, or by caustic or acidic wastewater inflows. Bicarbonates and carbonates are typically the dominant bases found in surface waters though other anions (hydroxides, borates, silicates, and phosphates) can add additional alkalinity (Hem 1970). Total alkalinity is expressed in units of milligrams per liter calcium carbonate though the actual bases contributing to alkalinity is not defined. Waters draining regions of limestone and other sedimentary rocks contain carbonate minerals that contribute to high alkalinity. In contrast, igneous rocks are carbonate-poor and yield low alkalinity values. Low alkaline waters favor methylation of mercury, influence the bioavailability of other metals and may promote greater pH fluctuations due to photosynthetic activity by aquatic macrophytes and algae.

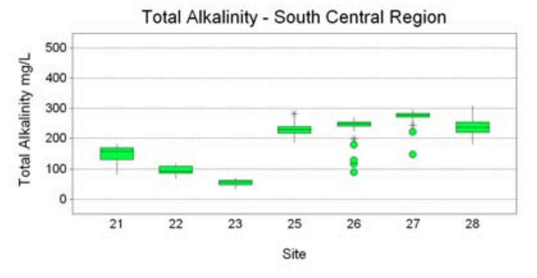
Sites in Northern Region consistently have the lowest buffering capacity in the state with all of the median values of total alkalinity less than or equal to 100 mg/L (Figure 6). A large portion of Northern Region contains igneous bedrock which yields groundwater and surface runoff low in carbonate minerals. The Chippewa River (Sites 19, 34 & 35), Black River (Site 39) and Wisconsin River at Biron (Site 42) in West Central Region also had median total alkalinity values less than 100 mg/L. The Kickapoo River had the highest median value in West Central Region at 237 mg/l. The Rock, Sugar, and Pecatonica rivers in South Central Region all had median total alkalinity values over 200 mg/L likely influenced by soils formed over sedimentary rock containing carbonate minerals. The two Wisconsin River sites in the South Central Region (Sites 22 & 23) had median values less than 100 mg/L, consistent with upstream measurements at Merrill & Biron. All of the sites in Southeast Region had similar median concentrations ranging from 232 to 256 mg/L total alkalinity, a region also influenced by carbonate-rich bedrock.

Alkalinity measurements exhibited a positive non-linear correlation to laboratory pH measurements (Figure 7). High levels of algae, as measured by chlorophyll *a* analysis, contributed to pH standard exceedances (> 9.0) in waters with alkalinity less than 150 mg/L. The median chlorophyll concentration associated with these high pH values was 76 ug/L. These relationships may be an important consideration when developing nutrient criteria for rivers and streams in Wisconsin.

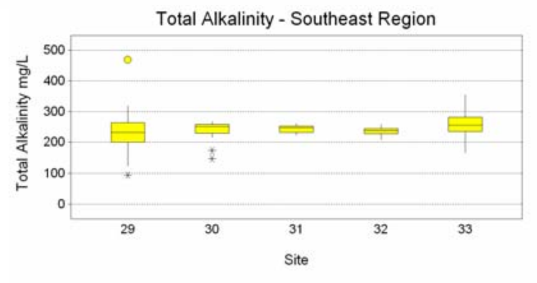








Site No.	Site Description	Region	Sample Freq.	N	Median mg/L
1	Menominee R. at McAllister	NE	Qtr.	15	96
2	Oconto R. at Oconto	NE	Qtr.	14	129
3	Peshtigo R. at Peshtigo	NE	Qtr.	15	112
4	Fox R. at DePere	NE	Mon.	40	154
5	Fox R. at Neenah and Menasha	NE	Mon.	40	154
6	Wolf R. at New London	NE	Mon.	36	156
7	Fox R. at Oshkosh	NE	Mon.	40	160
8	Fox R. at Berlin	NE	Qtr.	1	
9	Kewaunee R. at Kewaunee	NE	Qtr.	7	286
10	Manitowoc R. at Manitowoc	NE	Qtr.	8	249
11	St. Croix R. at Danbury	NO	Qtr.	7	60
12	St. Croix R. at St. Croix Falls	NO	Qtr.	7	87
13	Bois Brule R. at Brule	NO	Qtr.	11	58
14	Bad R. at Odanah	NO	Qtr.	9	72
15	Popple R. at Fence	NO	Mon.	36	100
16	Wolf R. at Langlade	NO	Mon.	40	95
17	Wisconsin R. at Merril	NO	Mon.	40	38
18	Flambeau R. at Bruce	NO	Qtr.	6	45
19	Chippewa R. at Bruce	NO	Qtr.	6	41
20	Kickapoo R. at Stueben	WC	Mon.	41	237
21	Baraboo R. at Rowley Creek Br.	SC	Mon.	33	159
22	Wisconsin R. at Muscoda	SC	Mon.	36	94
23	Wisconsin R. at Wisconsin Dells	SC	Mon.	36	58
24	Mississippi R. at LD 9	WC	Mon.	25	147
25	Rock R. at Afton	SC	Mon.	37	229
26	Sugar R. at Broadhead	SC	Mon.	39	249
27	Pecatonica R. at Martintown	SC	Mon.	35	277
28	Rock R. at Watertown	SC	Mon.	39	236
29	Root R. at Johnson Park	SE	Mon.	31	232
30	Milwaukee R. at Estabrook Park	SE	Qtr.	12	252
31	Fox (IL) R. below Waukesha	SE	Qtr.	7	247
32	Fox (IL) R. near New Munster	SE	Qtr.	8	237
33	Sheboygan R. at Esslingen Park	SE	Mon.	43	256
34	Chippewa R. at Chippewa Falls	WC	Qtr.	15	35
35	Chippewa R. at Durand	WC	Mon.	42	59
36	Red Cedar R. at Menomonie	WC	Mon.	43	93
37	La Crosse R. near Mouth	WC	Mon.	23	146
38	Trempealeau R. at Dodge	WC	Mon.	41	104
39	Black R. at Galesville (Hwy 53)	WC	Mon.	43	48
40	Mississippi R. at LD 3	WC	Qtr.	0	
41	Mississippi R. at LD 4	WC	Qtr.	0	
42	Wisconsin R. at Biron	WC	Mon.	45	51



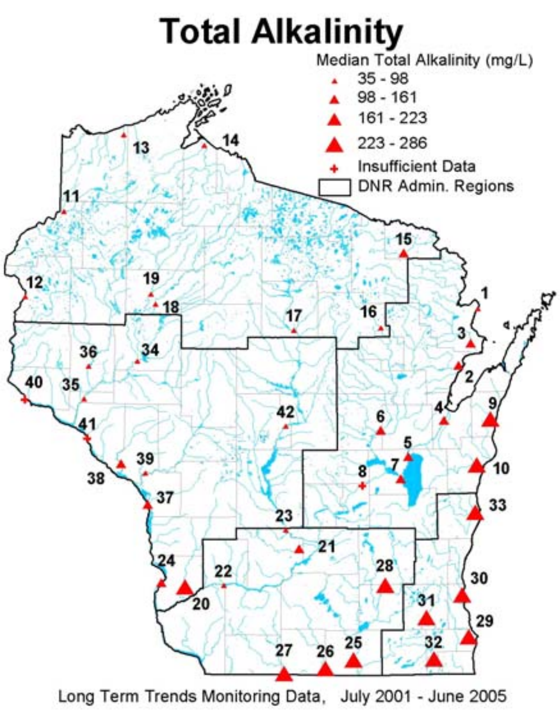


Figure 6. Total alkalinity concentrations at Wisconsin's long term trends sites.

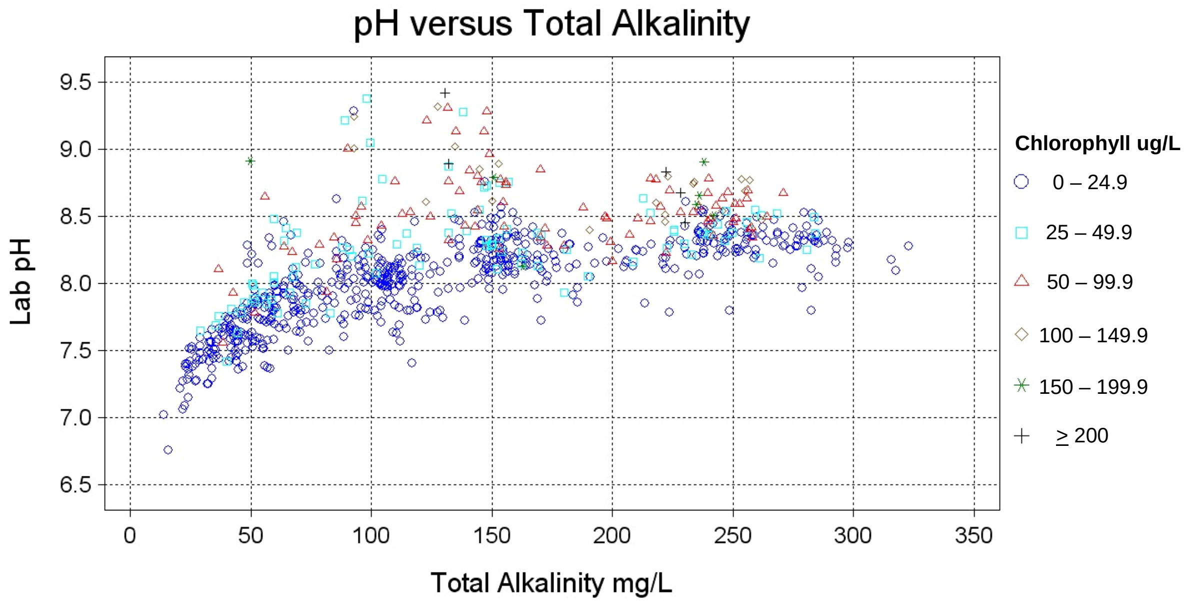
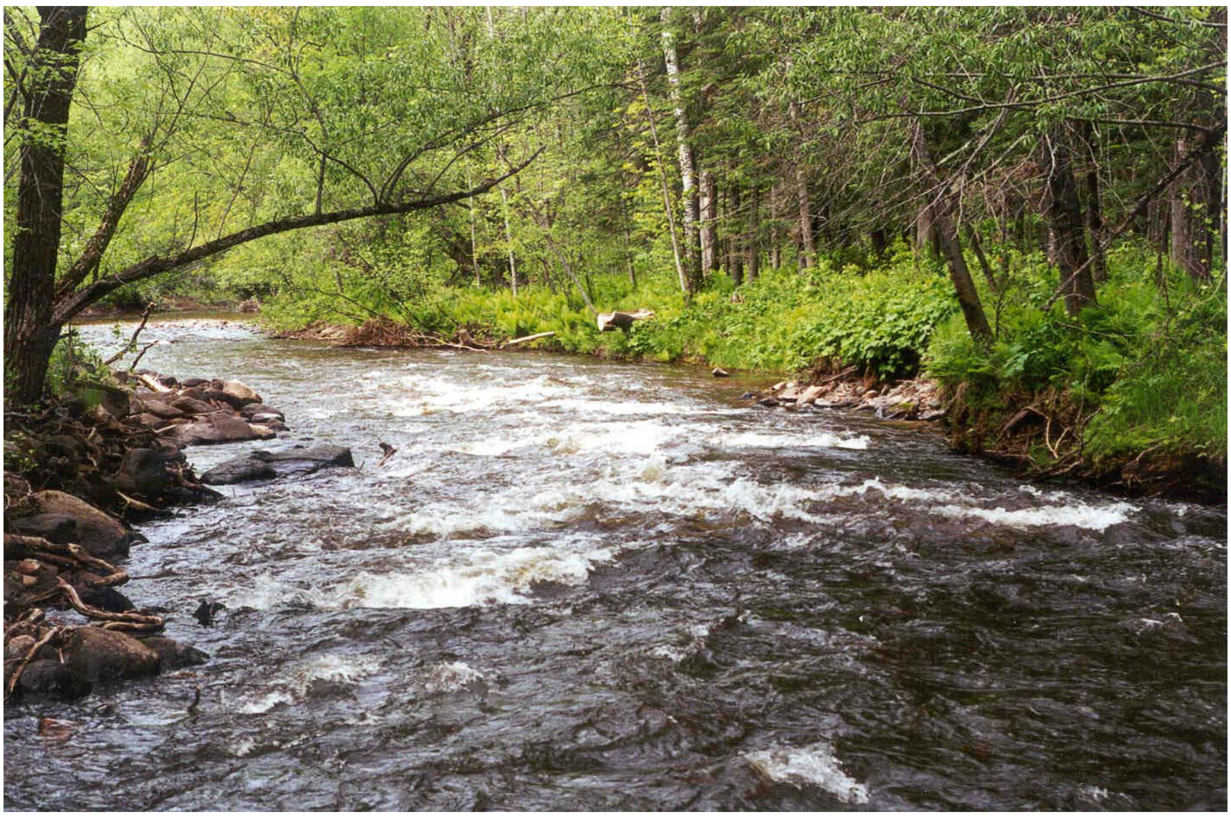


Figure 7. Relationship between laboratory pH, total alkalinity and chlorophyll at Wisconsin's long term sites. Long term trend monitoring data, July 2001-June2005



Bois Brule River below Highway FF Douglas County (John Sullivan).

Conductivity

Conductivity is a measure of water's capacity to conduct an electrical current and varies directly with the dissolved solids content of water. Conductivity increases with increasing temperature, therefore, specific conductivity measurements are temperature-adjusted to 25^{o} C to discount the influence of water temperature. Municipal and industrial wastewater or groundwater inflows containing dissolution products of rocks and minerals may contribute to high conductivity values in surface waters. Rainwater or snowmelt runoff contains little dissolved solids and as result usually have low conductance.

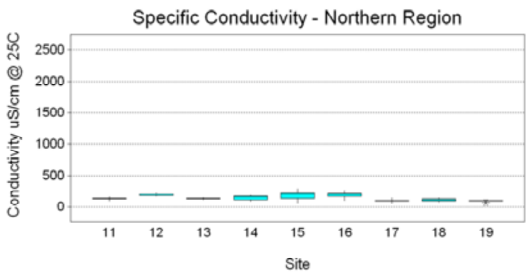
The median specific conductivity in Northern Region was relatively low ranging from around 100 to 200 uS/cm and reflects groundwater and surface runoff with low mineral content (Figure 8). The Menominee (Site 1), Oconto (Site 2) and Peshtigo rivers (Site 3) had the lowest conductivity in Northeast Region with medians ranging from 246 to 291 uS/cm. The highest median conductivity was reported for Kewaunee River (Site 9) and Manitowoc River (Site 10) at greater than 650 uS/cm, which were notably higher than other sites in the Region. These two sites also had the highest median chloride concentrations in the Region. The Sheboygan River (Site 33) is geographically close to these rivers and has a similar median conductivity value (683 uS/cm). The Wolf River at New London (Site 6) had a median specific conductivity of 363 uS/cm but had an event value greater than 1,000 uS/cm in February 2003 which may have been influenced by road salt runoff since chloride levels in this sample exceeded 200 mg/L.

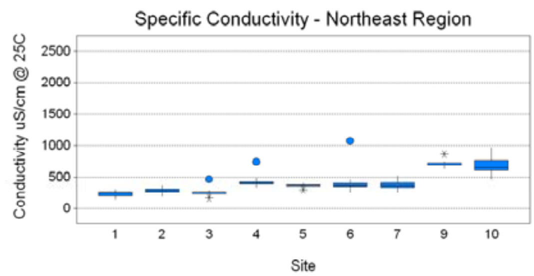
The Chippewa, Black and Wisconsin rivers sites in West Central Region all had median conductivity values less than 200 uS/cm. The highest median value in West Central Region was in the Kickapoo River (Site 20). The lowest median conductivity values in South Central Region were for the Wisconsin River at the Dells (Site 23) and Muscoda (Site 22). Median conductivity values greater than 600 uS/cm were observed at the Rock, Sugar, and Pecatonica rivers in South Central Region. The highest median and highest reported value of specific conductivity were reported in Southeast Region. Median values ranged from 683 uS/cm in the Sheboygan River (Site 33) to 1,290 uS/cm in the Fox River below Waukesha (Site 31), a site influenced by a municipal wastewater treatment plant. The Root River (Site 29) had a median value of 1,010 uS/cm and reported event values over 2,000 uS/cm. Most of these high values occurred during January or February when chloride values exceeded 200 mg/L suggesting an influence by road salt runoff.

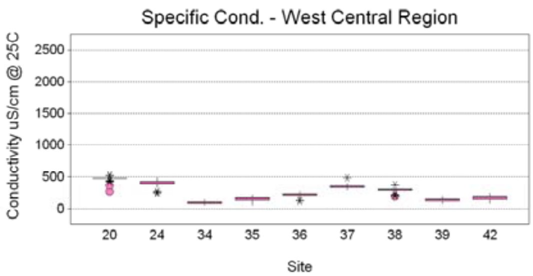
Chloride

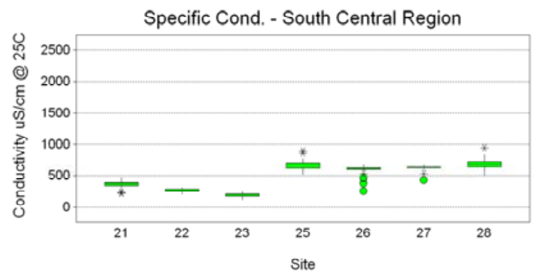
Chloride is a stable anion of the element chlorine, which is commonly found in surface waters. Natural sources of chloride include sedimentary rocks with formations closely tied to seawater or in enclosed drainage basins (Hem 1970). Important anthropogenic inputs to surface waters include road salt runoff and wastewater treatment plant discharges, especially those that are affected by water softening treatments. Wisconsin has established acute and chronic chloride criteria of 757 and 395 mg/L, respectively, to protect fish and aquatic life.

In general, chloride concentrations follow a pattern very close to that previously described for specific conductance. Chloride concentrations were low at all of the sites in Northern Region with median values ranging from 2.3 to 5.4 mg/L and likely reflect the absence of sedimentary bedrock with minor point or nonpoint source inputs (Figure 9). Some rivers in Northeast Region had low median chloride concentrations including the Menominee (Site 1), Oconto (Site 2) and Peshtigo rivers (Site 3).

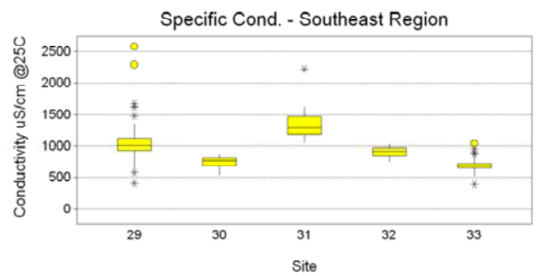








Site No.	Site Description	Region	Sample Freq.	N	Median uS
1	Menominee R. at McAllister	NE	Qtr.	15	246
2	Oconto R. at Oconto	NE	Qtr.	14	291
3	Peshtigo R. at Peshtigo	NE	Qtr.	15	252
4	Fox R. at DePere	NE	Mon.	39	406
5	Fox R. at Neenah and Menasha	NE	Mon.	39	369
6	Wolf R. at New London	NE	Mon.	36	363
7	Fox R. at Oshkosh	NE	Mon.	39	362
8	Fox R. at Berlin	NE	Qtr.	2	
9	Kewaunee R. at Kewaunee	NE	Qtr.	7	695
10	Manitowoc R. at Manitowoc	NE	Qtr.	8	654
11	St. Croix R. at Danbury	NO	Qtr.	7	139
12	St. Croix R. at St. Croix Falls	NO	Qtr.	7	206
13	Bois Brule R. at Brule	NO	Qtr.	11	140
14	Bad R. at Odanah	NO	Qtr.	9	166
15	Popple R. at Fence	NO	Mon.	35	216
16	Wolf R. at Langlade	NO	Mon.	39	212
17	Wisconsin R. at Merril	NO	Mon.	39	100
18	Flambeau R. at Bruce	NO	Qtr.	6	119
19	Chippewa R. at Bruce	NO	Qtr.	6	99
20	Kickapoo R. at Stueben	WC	Mon.	41	484
21	Baraboo R. at Rowley Creek Br.	SC	Mon.	33	380
22	Wisconsin R. at Muscoda	SC	Mon.	35	269
23	Wisconsin R. at Wisconsin Dells	SC	Mon.	36	197
24	Mississippi R. at LD 9	WC	Mon.	26	409
25	Rock R. at Afton	SC	Mon.	40	673
26	Sugar R. at Broadhead	SC	Mon.	40	613
27	Pecatonica R. at Martintown	SC	Mon.	36	636
28	Rock R. at Watertown	SC	Mon.	40	680
29	Root R. at Johnson Park	SE	Mon.	32	1010
30	Milwaukee R. at Estabrook Park	SE	Qtr.	12	769
31	Fox (IL) R. below Waukesha	SE	Qtr.	7	1290
32	Fox (IL) R. near New Munster	SE	Qtr.	8	920
33	Sheboygan R. at Esslingen Park	SE	Mon.	43	683
34	Chippewa R. at Chippewa Falls	WC	Qtr.	15	95
35	Chippewa R. at Durand	WC	Mon.	41	164
36	Red Cedar R. at Menomonie	WC	Mon.	42	229
37	La Crosse R. near Mouth	WC	Mon.	23	354
38	Trempealeau R. at Dodge	WC	Mon.	41	300
39	Black R. at Galesville (Hwy 53)	WC	Mon.	43	150
40	Mississippi R. at LD 3	WC	Qtr.	0	
41	Mississippi R. at LD 4	WC	Qtr.	0	
42	Wisconsin R. at Biron	WC	Mon.	44	178



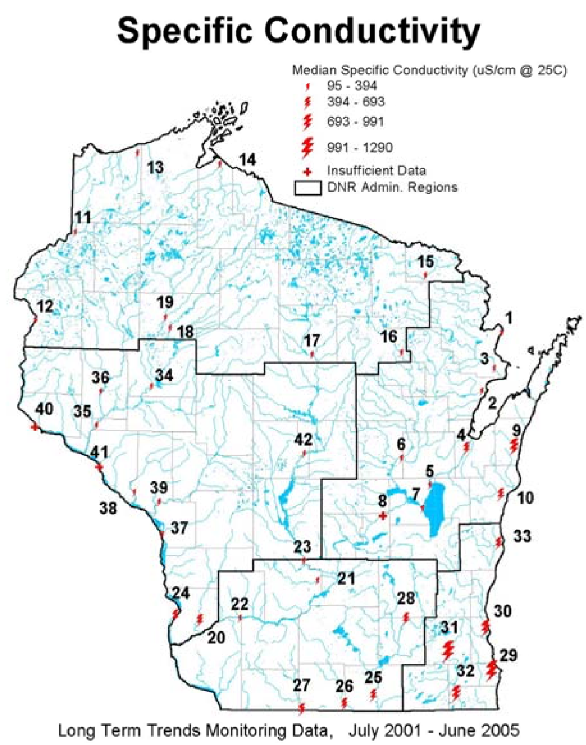
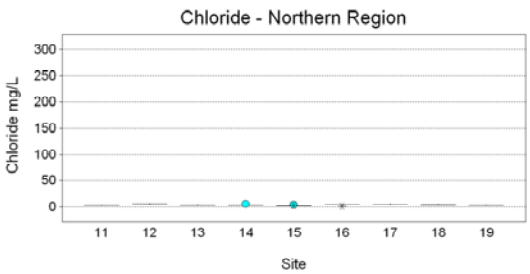
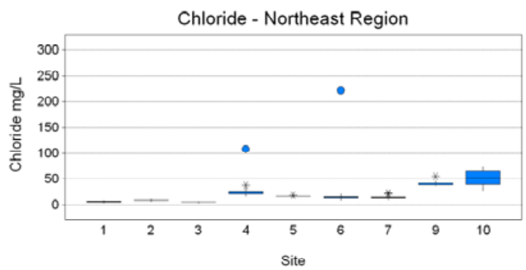
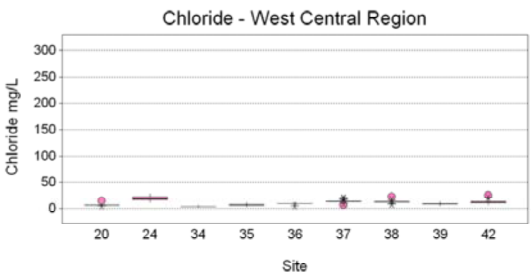
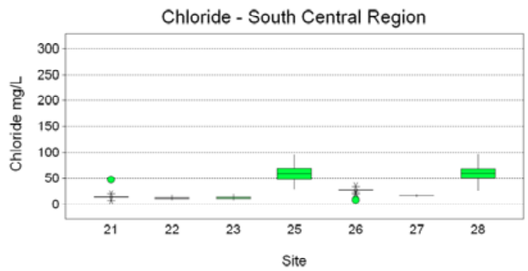


Figure 8. Specific Conductivity (lab) values at Wisconsin's long term trends sites.

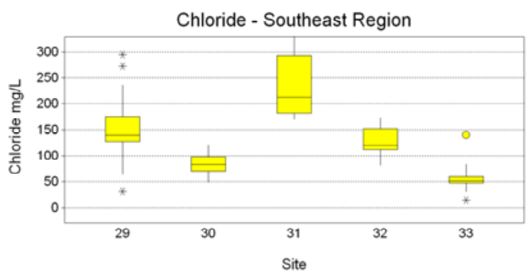


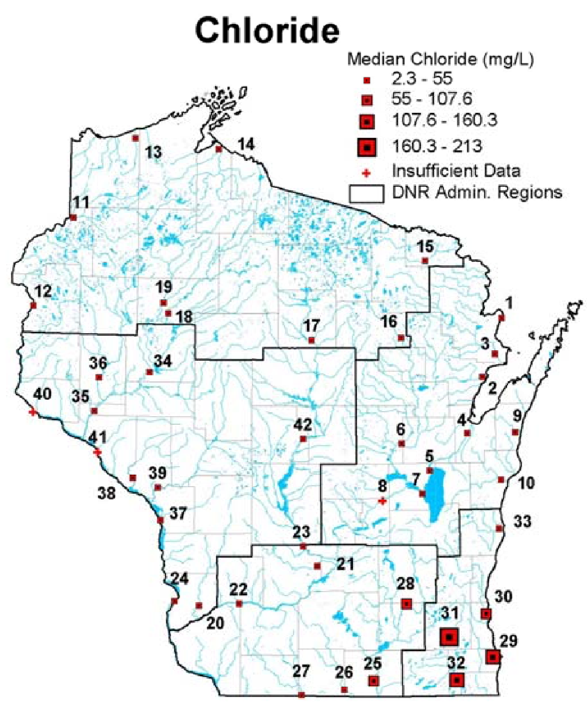






Site No.	Site Description	Region	Sample Freq.	N	Median mg/L
1	Menominee R. at McAllister	NE	Qtr.	15	7.1
2	Oconto R. at Oconto	NE	Qtr.	14	8.7
3	Peshtigo R. at Peshtigo	NE	Qtr.	15	5.7
4	Fox R. at DePere	NE	Mon.	35	23.6
5	Fox R. at Neenah and Menasha	NE	Mon.	35	16.3
6	Wolf R. at New London	NE	Mon.	32	14.6
7	Fox R. at Oshkosh	NE	Mon.	35	13.6
8	Fox R. at Berlin	NE	Qtr.	2	
9	Kewaunee R. at Kewaunee	NE	Qtr.	7	38.5
10	Manitowoc R. at Manitowoc	NE	Qtr.	8	52.0
11	St. Croix R. at Danbury	NO	Qtr.	8	3.0
12	St. Croix R. at St. Croix Falls	NO	Qtr.	8	5.4
13	Bois Brule R. at Brule	NO	Qtr.	11	3.1
14	Bad R. at Odanah	NO	Qtr.	9	3.2
15	Popple R. at Fence	NO	Mon.	37	2.3
16	Wolf R. at Langlade	NO	Mon.	43	4.1
17	Wisconsin R. at Merril	NO	Mon.	43	4.5
18	Flambeau R. at Bruce	NO	Qtr.	6	3.7
19	Chippewa R. at Bruce	NO	Qtr.	6	3.2
20	Kickapoo R. at Stueben	WC	Mon.	44	7.0
21	Baraboo R. at Rowley Creek Br.	SC	Mon.	35	14.1
22	Wisconsin R. at Muscoda	SC	Mon.	38	12.9
23	Wisconsin R. at Wisconsin Dells	SC	Mon.	38	12.7
24	Mississippi R. at LD 9	WC	Mon.	29	19.3
25	Rock R. at Afton	SC	Mon.	40	59.9
26	Sugar R. at Broadhead	SC	Mon.	40	28.1
27	Pecatonica R. at Martintown	SC	Mon.	36	17.4
28	Rock R. at Watertown	SC	Mon.	40	61.3
29	Root R. at Johnson Park	SE	Mon.	33	140.0
30	Milwaukee R. at Estabrook Park	SE	Qtr.	13	83.6
31	Fox (IL) R. below Waukesha	SE	Qtr.	8	213.0
32	Fox (IL) R. near New Munster	SE	Qtr.	9	120.0
33	Sheboygan R. at Esslingen Park	SE	Mon.	45	51.8
34	Chippewa R. at Chippewa Falls	WC	Qtr.	15	3.8
35	Chippewa R. at Durand	WC	Mon.	43	7.4
36	Red Cedar R. at Menomonie	WC	Mon.	44	9.3
37	La Crosse R. near Mouth	WC	Mon.	24	13.6
38	Trempealeau R. at Dodge	WC	Mon.	43	12.5
39	Black R. at Galesville (Hwy 53)	WC	Mon.	42	8.5
40	Mississippi R. at LD 3	WC	Qtr.	0	
41	Mississippi R. at LD 4	WC	Qtr.	0	
42	Wisconsin R. at Biron	WC	Mon.	46	12.7





Long Term Trends Monitoring Data, July 2001 - June 2005

Figure 9. Chloride concentrations at Wisconsin's long term trends sites.

The highest median chloride values in Northeast Region were observed in the Kewaunee River (Site 9) and Manitowoc River (Site 10). Relatively high event-related chloride concentrations were observed at the Fox River at DePere (Site 4) and Wolf River at New London (Site 6). These correspond with high event-related conductivity values that occurred in February 2003 and suggest inputs of road salt runoff as discussed above. Chloride concentrations in West Central Region were all relatively low with median values ranging from 3.8 mg/L in the Chippewa River at Chippewa Falls (Site 34) to 19.3 mg/L in the Mississippi River at Lock and Dam # 9 (Site 24). In South Central Region median chloride concentrations were less than 30 mg/L at all sites except the Rock River sites (25 & 28) which had median values near 60 mg/L.

The highest instantaneous and median chloride concentrations were observed in Southeast Region, reflecting point and nonpoint source inputs. The Fox (IL) River below Waukesha (Site 31), which is within 5 miles of the Waukesha WWTP, had the highest median value of chlorides in the State at 213 mg/L. The Root River (Site 29) had the greatest variability, with values ranging from less than 50 mg/L to near 700 mg/L with a median value of 140 mg/L. The highest chloride values were reported during December to February, periods when road salt runoff would be expected. Overall, chloride concentrations tend to be highest in urban areas, as in southern Wisconsin (Figure 10). All instantaneous chloride concentration values were below the acute chloride criteria of 757 mg/L, and all median values were below the chronic criteria of 395 mg/L.

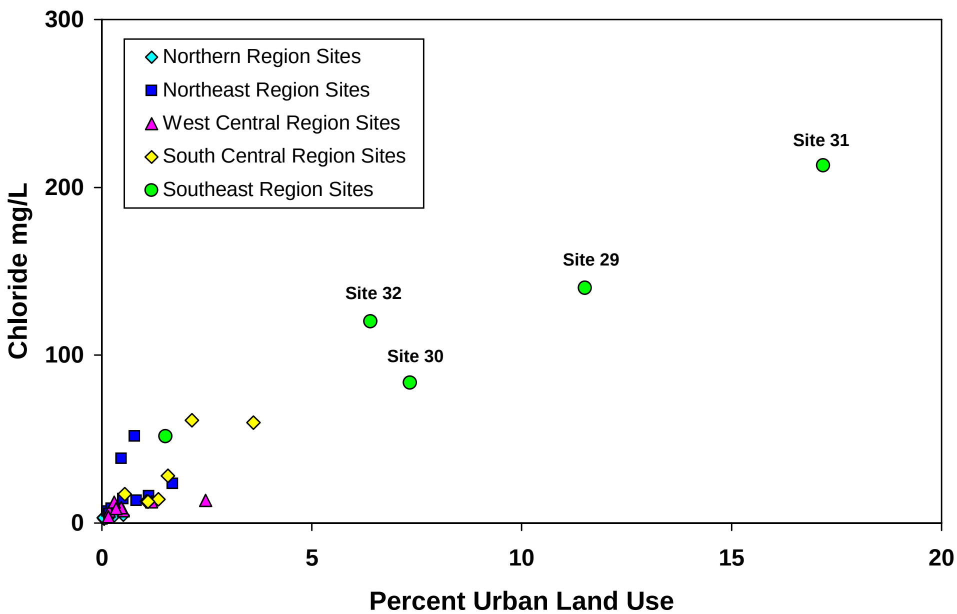


Figure 10. Relationship between chloride concentrations and percent urban land use at Wisconsin's long term trend sites.

Turbidity

Turbidity is a measure of water "cloudiness" caused primarily by the presence of suspended particulate matter in solution. It is basically an optical measurement of the amount of light scattering or adsorption caused by fine organic or inorganic particles and to a lesser extent some dissolved substances. In general, turbidity correlates directly with total suspended solids or transparency and can offer a surrogate measurement to these water quality variables. Measurement of turbidity is relatively easy to perform in the field or lab, though comparability problems can arise due to differing instrumentation, sample dilution procedures and varying turbidity standards. These problems were avoided in this work since the analysis was performed using consistent methods by one laboratory. Sources and impacts of high turbidity are basically similar to those described for total suspended solids (see below).

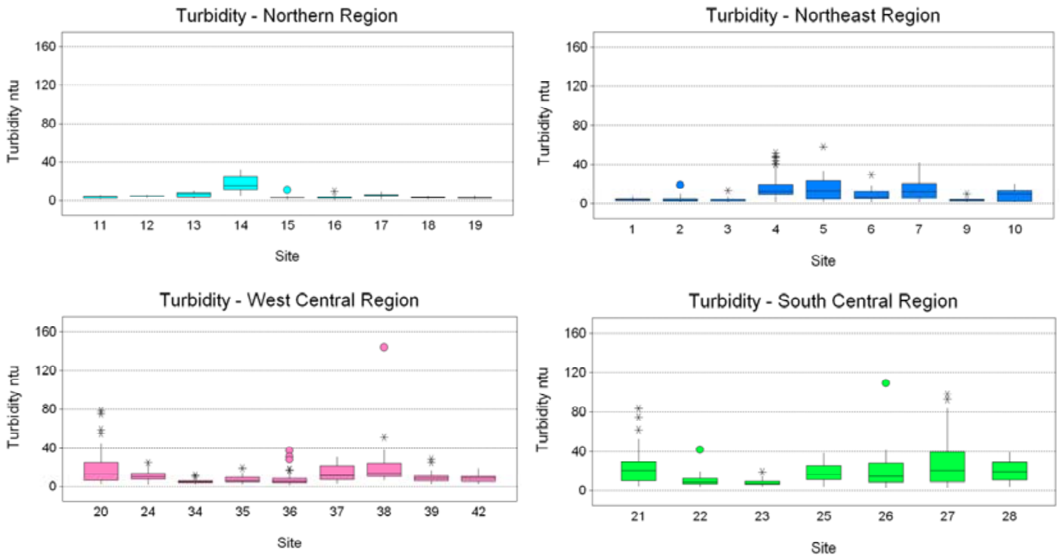
Turbidity in Northern Region was lowest in the State with the greatest median value of 15.2 NTU reported for the Bad River (Site 14) (Figure 11). Northeast Region also had relatively low median turbidity with the Menominee (Site 1), Oconto (Site 2), Peshtigo (Site 3) and Kewaunee (Site 9) rivers, ranging from 3.2 to 4.5 NTU. The Fox River sites (4, 5 & 7) and Manitowoc River (Site 10) showed more variable turbidity with median values around 12 NTU. The Mississippi (Site 24), Wisconsin (Site 42), Chippewa (Sites 34 & 35) and Black Rivers (Site 39) in West Central Region had relatively low median turbidity values.

The greatest range of values occurred in the Trempealeau River at Dodge (Site 38). The Kickapoo River (Site 20) and Trempealeau River (Site 38) had maximum values of approximately 80 and 150 NTU, respectively. The Wisconsin River sites in South Central Region were similar to West Central Region with relatively low median turbidity values and minimal variability. The Baraboo (Site 21), Rock (Sites 25 & 28), Sugar (Site 26), and Pecatonica (Site 27) rivers were turbid streams with the latter having the greatest variability and highest median value at 21.0 NTU. The Root (Site 29), Milwaukee (Site 30) and Sheboygan (Site 33) rivers had slightly higher median turbidity values than the Fox (IL) River sites (31 & 32) and reflect greater turbidity during periods of higher flows.

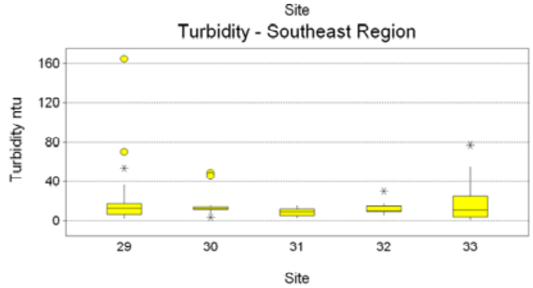
Total Suspended Solids

Total suspended solids (TSS) represent the weight of filtered particulate material in water. Sources of this solid matter may include both inorganic and organic material from soil or stream bank erosion, decaying plant matter, algae, and wastewater discharges. In general, the concentration of TSS increases with increasing river flow due to erosional processes and bed sediment resuspension. Particulate material in water strongly limits light penetration, which may have a negative impact on aquatic primary production. Excessive TSS levels may also impair aquatic organism by blocking gas exchange in membranes used for respiration, interfering with filter feeding mussels or by restricting predation by sight-feeding fish. In general, TSS concentrations in Wisconsin's streams increase as the percentage of agricultural land use increases (Figure 12).

Total suspended solids (TSS) were lowest in the Northern Region with median concentrations ranging from 2.0 to 4.5 mg/L. Northeast Region also had some stations reporting very low TSS including the Menominee (Site 1), Oconto (Site 2), Peshtigo (Site 3), Wolf (Site 6) and Kewaunee (Site 9) rivers with median values ranging from 3.0 to 6.0 mg/L (Figure 13). In general, lowest TSS concentrations were typically found at Northern and Northeast Region sites where land cover is dominated by forested cover (Figure 2). The Northeast Region Fox River sites all demonstrated a greater range of TSS values and consequently higher median values. The Manitowoc River (Site 10) drains an area dominated by agricultural land use in the upper reaches and urban land use at the mouth where the sample station is located. This station had the highest median value with a TSS concentration of 17.0 mg/L. The Kewaunee River (Site 9) watershed is dominated by agricultural land use but does not have the urban component and the median TSS level was 4.0 mg/l.



Site No.	Site Description	Region	Sample Freq.	N	Median ntu
1	Menominee R. at McAllister	NE	Qtr.	15	4.2
2	Oconto R. at Oconto	NE	Qtr.	14	3.4
3	Peshtigo R. at Peshtigo	NE	Qtr.	15	3.2
4	Fox R. at DePere	NE	Mon.	39	12.1
5	Fox R. at Neenah and Menasha	NE	Mon.	39	12.6
6	Wolf R. at New London	NE	Mon.	35	6.5
7	Fox R. at Oshkosh	NE	Mon.	39	11.9
8	Fox R. at Berlin	NE	Qtr.	1	
9	Kewaunee R. at Kewaunee	NE	Qtr.	7	4.5
10	Manitowoc R. at Manitowoc	NE	Qtr.	7	9.5
11	St. Croix R. at Danbury	NO	Qtr.	7	3.9
12	St. Croix R. at St. Croix Falls	NO	Qtr.	7	4.7
13	Bois Brule R. at Brule	NO	Qtr.	10	7.2
14	Bad R. at Odanah	NO	Qtr.	9	15.2
15	Popple R. at Fence	NO	Mon.	34	3.0
16	Wolf R. at Langlade	NO	Mon.	39	3.3
17	Wisconsin R. at Merril	NO	Mon.	39	5.2
18	Flambeau R. at Bruce	NO	Qtr.	6	3.2
19	Chippewa R. at Bruce	NO	Qtr.	6	2.9
20	Kickapoo R. at Stueben	WC	Mon.	38	12.6
21	Baraboo R. at Rowley Creek Br.	SC	Mon.	33	21.2
22	Wisconsin R. at Muscoda	SC	Mon.	37	9.0
23	Wisconsin R. at Wisconsin Dells	SC	Mon.	36	7.4
24	Mississippi R. at LD 9	WC	Mon.	24	10.4
25	Rock R. at Afton	SC	Mon.	38	16.4
26	Sugar R. at Broadhead	SC	Mon.	38	15.1
27	Pecatonica R. at Martintown	SC	Mon.	34	21.0
28	Rock R. at Watertown	SC	Mon.	38	19.9
29	Root R. at Johnson Park	SE	Mon.	31	12.8
30	Milwaukee R. at Estabrook Park	SE	Qtr.	11	12.3
31	Fox (IL) R. below Waukesha	SE	Qtr.	7	9.1
32	Fox (IL) R. near New Munster	SE	Qtr.	7	10.2
33	Sheboygan R. at Esslingen Park	SE	Mon.	42	10.9
34	Chippewa R. at Chippewa Falls	WC	Qtr.	15	5.3
35	Chippewa R. at Durand	WC	Mon.	42	6.0
36	Red Cedar R. at Menomonie	WC	Mon.	43	5.6
37	La Crosse R. near Mouth	WC	Mon.	19	11.9
38	Trempealeau R. at Dodge	WC	Mon.	40	13.9
39	Black R. at Galesville (Hwy 53)	WC	Mon.	38	9.0
40	Mississippi R. at LD 3	WC	Qtr.	0	
41	Mississippi R. at LD 4	WC	Qtr.	0	
42	Wisconsin R. at Biron	WC	Mon.	43	9.1



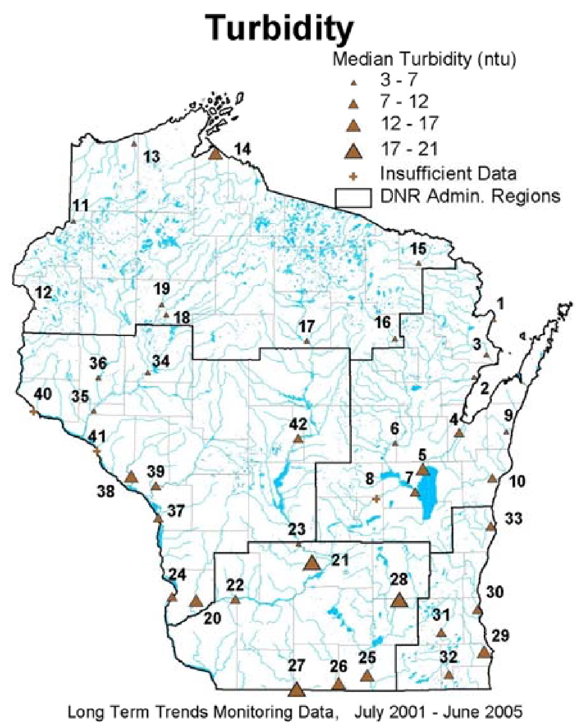


Figure 11. Turbidity values at Wisconsin's long term trends sites.

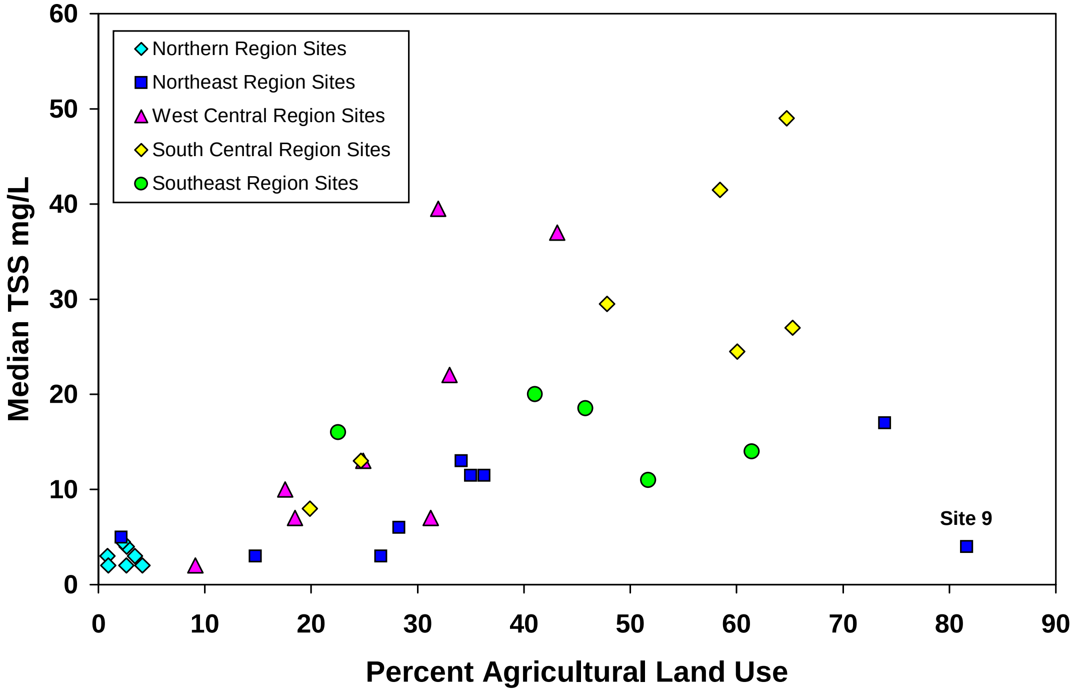
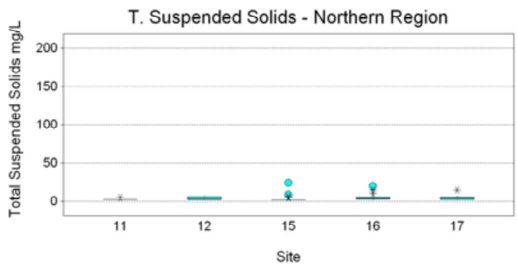
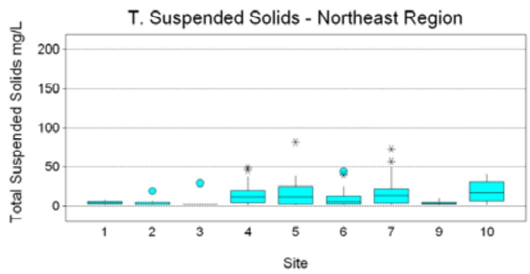
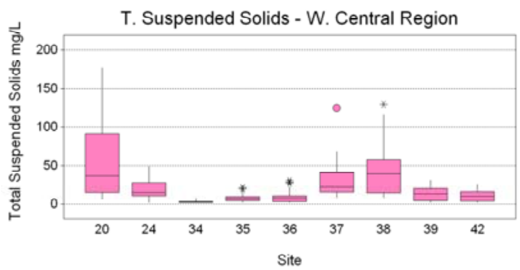


Figure 12. Relationship between median TSS concentrations and percent agricultural land cover at Wisconsin's long term trend sites. July 2001 – June 2005

Popple River below Forest Road 2159 (John Sullivan).







Site No.	Site Description	Region	Sample Freq.	N	Median mg/L
1	Menominee R. at McAllister	NE	Qtr.	14	5.0
2	Oconto R. at Oconto	NE	Qtr.	13	3.0
3	Peshtigo R. at Peshtigo	NE	Qtr.	13	3.0
4	Fox R. at DePere	NE	Mon.	36	11.5
5	Fox R. at Neenah and Menasha	NE	Mon.	38	11.5
6	Wolf R. at New London	NE	Mon.	33	6.0
7	Fox R. at Oshkosh	NE	Mon.	37	13.0
8	Fox R. at Berlin	NE	Qtr.	1	
9	Kewaunee R. at Kewaunee	NE	Qtr.	7	4.0
10	Manitowoc R. at Manitowoc	NE	Qtr.	8	17.0
11	St. Croix R. at Danbury	NO	Qtr.	7	3.0
12	St. Croix R. at St. Croix Falls	NO	Qtr.	7	3.0
13	Bois Brule R. at Brule	NO	Qtr.	1	
14	Bad R. at Odanah	NO	Qtr.	0	
15	Popple R. at Fence	NO	Mon.	37	2.0
16	Wolf R. at Langlade	NO	Mon.	40	4.0
17	Wisconsin R. at Merril	NO	Mon.	40	4.5
18	Flambeau R. at Bruce	NO	Qtr.	3	2.0
19	Chippewa R. at Bruce	NO	Qtr.	3	2.0
20	Kickapoo R. at Stueben	WC	Mon.	40	37.0
21	Baraboo R. at Rowley Creek Br.	SC	Mon.	34	29.5
22	Wisconsin R. at Muscoda	SC	Mon.	36	13.0
23	Wisconsin R. at Wisconsin Dells	SC	Mon.	36	8.0
24	Mississippi R. at LD 9	WC	Mon.	25	15.0
25	Rock R. at Afton	SC	Mon.	38	24.5
26	Sugar R. at Broadhead	SC	Mon.	38	27.0
27	Pecatonica R. at Martintown	SC	Mon.	34	49.0
28	Rock R. at Watertown	SC	Mon.	38	41.5
29	Root R. at Johnson Park	SE	Mon.	33	11.0
30	Milwaukee R. at Estabrook Park	SE	Qtr.	12	18.5
31	Fox (IL) R. below Waukesha	SE	Qtr.	7	16.0
32	Fox (IL) R. near New Munster	SE	Qtr.	7	20.0
33	Sheboygan R. at Esslingen Park	SE	Mon.	43	14.0
34	Chippewa R. at Chippewa Falls	WC	Qtr.	12	2.0
35	Chippewa R. at Durand	WC	Mon.	41	7.0
36	Red Cedar R. at Menomonie	WC	Mon.	41	7.0
37	La Crosse R. near Mouth	WC	Mon.	23	22.0
38	Trempealeau R. at Dodge	WC	Mon.	38	39.5
39	Black R. at Galesville (Hwy 53)	WC	Mon.	38	13.0
40	Mississippi R. at LD 3	WC	Qtr.	0	
41	Mississippi R. at LD 4	WC	Qtr.	0	
42	Wisconsin R. at Biron	WC	Mon.	44	10.0

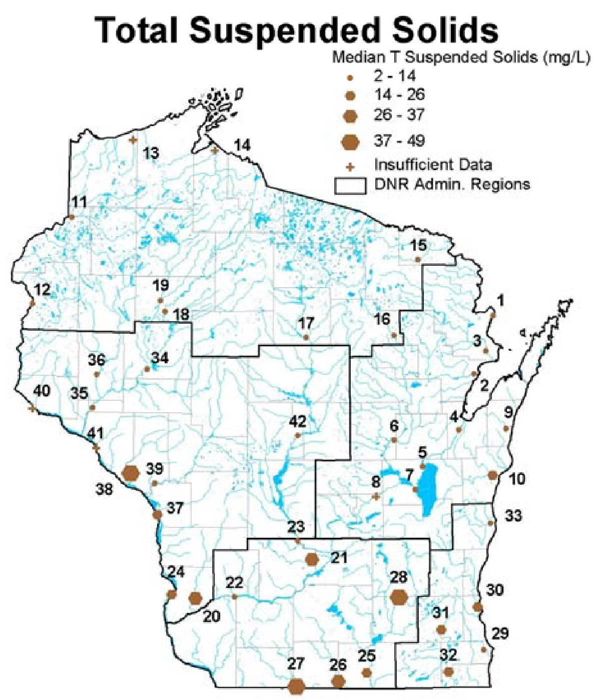


Figure 13. Total suspended solids concentrations at Wisconsin's long term trends sites.

West Central Region has two streams with high median values of TSS, the Kickapoo (Site 20) and Trempealeau (Site 38) rivers, likely due to steep topography and agricultural land use in the watersheds. Conversely, the Chippewa River sites (34 & 35) and the Red River (Site 36) had fairly low median concentrations of TSS ranging from 2.0 to 7.0 mg/L. The Pecatonica River (Site 27) had the highest median value of TSS in the state at 49.0 mg/L. The two Rock River sites (25 & 28) and the Sugar River (Site 26) also had relatively high TSS median concentrations likely due to agricultural land use. The Rock River sites also exhibited high chlorophyll concentrations, suggesting sestonic algae contributes to high TSS values observed at these sites. The Wisconsin River (Sites 22 & 23) had the lowest median TSS reflecting lower levels of agricultural land use and sediment trapping by large upstream impoundments. Southeast Region sites did not have any high or very low median total suspended solids levels.

Sites with elevated total suspended solids also generally had elevated total phosphorus and nitrogen concentrations indicative of nonpoint source runoff, including the Manitowoc, Kickapoo, LaCrosse, Trempealeau, Baraboo, Rock, Sugar, Pecatonica, Root and Sheboygan rivers.

Nitrogen

Nitrogen in surface water may be present in various organic and inorganic forms and has a complex cycle. Ammonia nitrogen is a reduced form of inorganic N and is usually associated with the decay of organic matter, animal waste runoff or municipal wastewater discharges that lack the nitrification process (conversion of ammonia to nitrate N). Ammonia nitrogen occurs in water as ammonium and un-ionized ammonia N with both forms represented as total ammonia N. Un-ionized ammonia N is toxic to aquatic life and its proportion of total ammonia increases at higher pH and temperature.

Nitrite and nitrate (NOx-N) are oxidized forms of inorganic N that are present in surface runoff or groundwater discharges from areas dominated with agricultural lands and from municipal wastewater inputs that receive advanced treatment (nitrification). Surface waters generally have little nitrite nitrogen.

Organic N includes those forms of nitrogen that are “combined” into various organic molecules such as proteins, amino acids and other cellular materials. Organic N in surface waters may be present as suspended particulate matter or as dissolved organic molecules. In sediments, bacteria may convert organic and inorganic nitrogen to molecular N though a process of ammonification and denitrification.

Nitrogen is an important plant nutrient and has been used in agricultural fertilizers to stimulate the production of agricultural crops. In oxygenated surface waters, the dominant form of nitrogen is normally nitrate nitrogen. As a result, total nitrogen concentrations closely follow the patterns and trends exhibited by nitrate nitrogen. Excessive nitrogen inputs from the Mississippi River basin to the Gulf of Mexico have been implicated in nutrient enrichment and hypoxic problems in the Gulf (CENR, 2000).

Wisconsin has adopted acute and chronic criteria for total ammonia N in Chapter NR 105 (Wis. Adm. Code) that varies as a function of pH, water temperature and aquatic life use. For surfaces waters serving as a source-water for drinking water, the maximum nitrate-N criterion is 10 mg/L. The discussion of nitrogen will focus primarily on NOx-N since this was the dominant form of nitrogen found and it can be linked to agricultural land use and wastewater inputs.

Median NOx-N concentrations at all sites ranged from 0.02 to 5.08 mg/L (Figure 14). The highest observed value in the Northern Region was just under 2 mg/L NOx-N, a single outlier found in the Popple River (Site 15). Most sites in the Northeast Region had maximum values less than 2 mg/L NOx-N except for the Kewaunee (Site 9) and Manitowoc rivers (Site 10) which had maximum values of 7 and 4 mg/L NOx-N, respectively. The Kewaunee River site had a median value of 4.28 mg/L NOx-N. The highest median values of NOx-N in West Central Region were at the Mississippi River at Lock and Dam 9 (Site 24), Red Cedar (Site 36), La Crosse (Site 37) and Trempealeau rivers (Site 38).

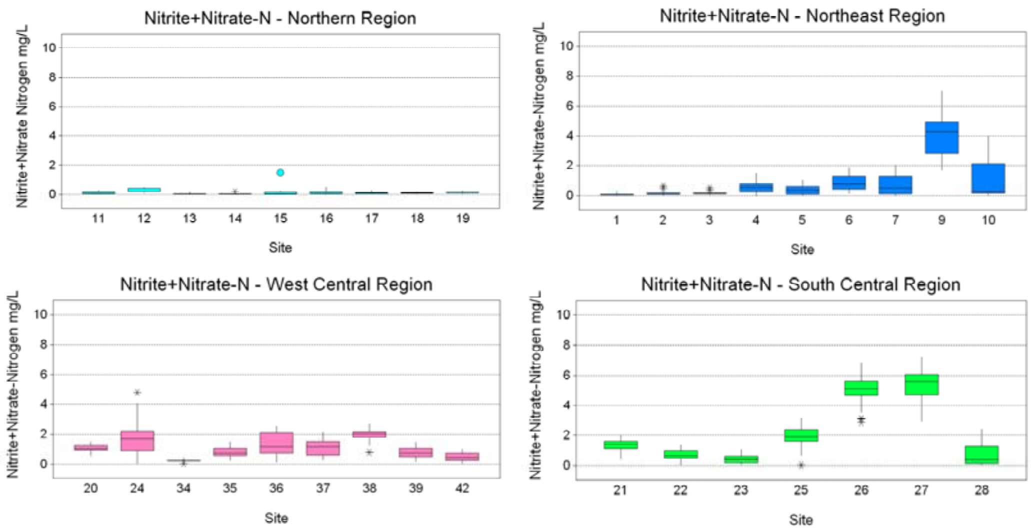
The highest overall nitrogen concentrations were observed in South Central Region in watersheds where agricultural land use is high and forest cover is low. In general, highest NOx concentrations increase as the percentage of agricultural land increases (Figure 15). The Baraboo (Site 21) and Rock rivers (Sites 25 & 28) had maximum NOx-N values near 2 mg/L. The highest nitrogen values in the State were observed in the Sugar (Site 26) and Pecatonica rivers (Site 27) with median NOx-N concentrations of 5.14 and 5.58 mg/L, respectively. The Sugar River site is downstream of a WWTP and likely influenced by the treatment system, whereas the Pecatonica River is predominately influenced by agricultural runoff and is often turbid during late spring, summer and early autumn (Jim Amrhein, WDNR, Pers. Comn.). In Southeast Region, the highest NOx-N concentrations (near 8 mg/L) were observed for the Root River (Site 29) and Fox (IL) River below Waukesha (Site 31). Site 31 is likely influenced by the Waukesha municipal wastewater treatment plant outfall located 5 miles upstream.

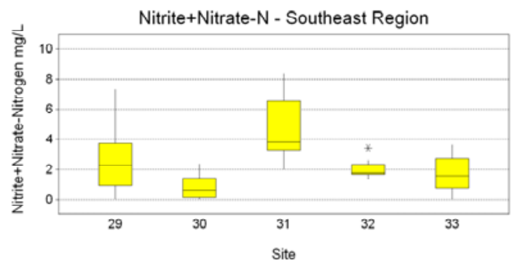
Median total ammonia nitrogen (NHx-N) concentrations were relatively low with the highest concentration (0.131 mg/L) found at the Fox River at Depere (Site 4) in Northeast Region (Figure 16). Moderately elevated NHx-N levels exceeding 0.5 mg/L occurred at two sites in West Central Region, Red Cedar (Site 36) and Black rivers (Site 39) and four sites in South Central Region, Baraboo (Site 21), Rock (Sites 25 and 28), Sugar (Site 26) and Pecatonica (Site 27) rivers. A majority of these higher NHx-N values occurred during January or February, a period when the in stream nitrification is low.

Phosphorus

Like nitrogen, phosphorus is an essential plant nutrient and is normally the major element affecting eutrophication in freshwater systems. Phosphorus can be measured in several forms, but total P and dissolved inorganic P (reactive or ortho-P) are the forms most commonly measured in water quality monitoring programs. Although dissolved inorganic P, is more directly available for plant uptake, this form of phosphorus may cycle quickly in aquatic systems and may often be assimilated by plants in excess of nutritional needs (luxury consumption). Phosphorus sources are similar to those reported for nitrogen. However, phosphorus tends to bind or adsorb to particulate material and is normally not found in high concentrations in groundwater.

The U.S. EPA has previously suggested a total phosphate phosphorus concentration of 0.1 mg/L P as a general goal for protection of flowing waters from “plant nuisances” (Mackenthun, 1973). National and state efforts are currently underway to develop more formal nutrient criteria for lakes and streams (USEPA, 1998).





Site No.	Site Description	Region	Sample Freq.	N	Median mg/L
1	Menominee R. at McAllister	NE	Qtr.	14	0.06
2	Oconto R. at Oconto	NE	Qtr.	14	0.14
3	Peshtigo R. at Peshtigo	NE	Qtr.	15	0.16
4	Fox R. at DePere	NE	Mon.	40	0.54
5	Fox R. at Neenah and Menasha	NE	Mon.	40	0.36
6	Wolf R. at New London	NE	Mon.	36	0.77
7	Fox R. at Oshkosh	NE	Mon.	40	0.49
8	Fox R. at Berlin	NE	Qtr.	1	
9	Kewaunee R. at Kewaunee	NE	Qtr.	7	4.28
10	Manitowoc R. at Manitowoc	NE	Qtr.	7	0.25
11	St. Croix R. at Danbury	NO	Qtr.	7	0.08
12	St. Croix R. at St. Croix Falls	NO	Qtr.	7	0.20
13	Bois Brule R. at Brule	NO	Qtr.	10	0.02
14	Bad R. at Odanah	NO	Qtr.	9	0.03
15	Popple R. at Fence	NO	Mon.	39	0.04
16	Wolf R. at Langlade	NO	Mon.	39	0.09
17	Wisconsin R. at Merril	NO	Mon.	40	0.10
18	Flambeau R. at Bruce	NO	Qtr.	4	0.12
19	Chippewa R. at Bruce	NO	Qtr.	4	0.16
20	Kickapoo R. at Stueben	WC	Mon.	44	1.05
21	Baraboo R. at Rowley Creek Br.	SC	Mon.	31	1.40
22	Wisconsin R. at Muscoda	SC	Mon.	35	0.66
23	Wisconsin R. at Wisconsin Dells	SC	Mon.	34	0.41
24	Mississippi R. at LD 9	WC	Mon.	26	1.71
25	Rock R. at Afton	SC	Mon.	37	1.90
26	Sugar R. at Broadhead	SC	Mon.	37	5.14
27	Pecatonica R. at Martintown	SC	Mon.	33	5.58
28	Rock R. at Watertown	SC	Mon.	37	0.38
29	Root R. at Johnson Park	SE	Mon.	31	2.29
30	Milwaukee R. at Estabrook Park	SE	Qtr.	12	0.65
31	Fox (IL) R. below Waukesha	SE	Qtr.	8	3.83
32	Fox (IL) R. near New Munster	SE	Qtr.	8	1.78
33	Sheboygan R. at Esslingen Park	SE	Mon.	43	1.60
34	Chippewa R. at Chippewa Falls	WC	Qtr.	15	0.27
35	Chippewa R. at Durand	WC	Mon.	42	0.73
36	Red Cedar R. at Menomonie	WC	Mon.	43	1.19
37	La Crosse R. near Mouth	WC	Mon.	22	1.19
38	Trempealeau R. at Dodge	WC	Mon.	42	2.03
39	Black R. at Galesville (Hwy 53)	WC	Mon.	40	0.74
40	Mississippi R. at LD 3	WC	Qtr.	0	
41	Mississippi R. at LD 4	WC	Qtr.	0	
42	Wisconsin R. at Biron	WC	Mon.	44	0.44

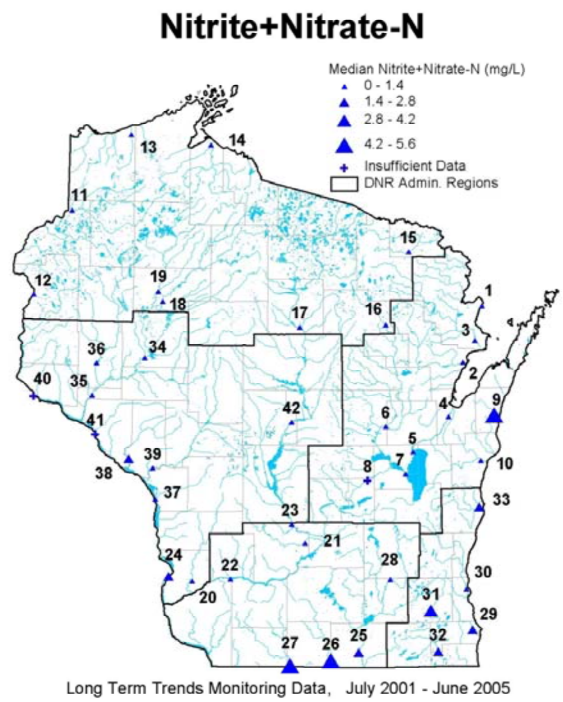


Figure 14. Nitrite+nitrate nitrogen concentrations at Wisconsin's long term trends sites.

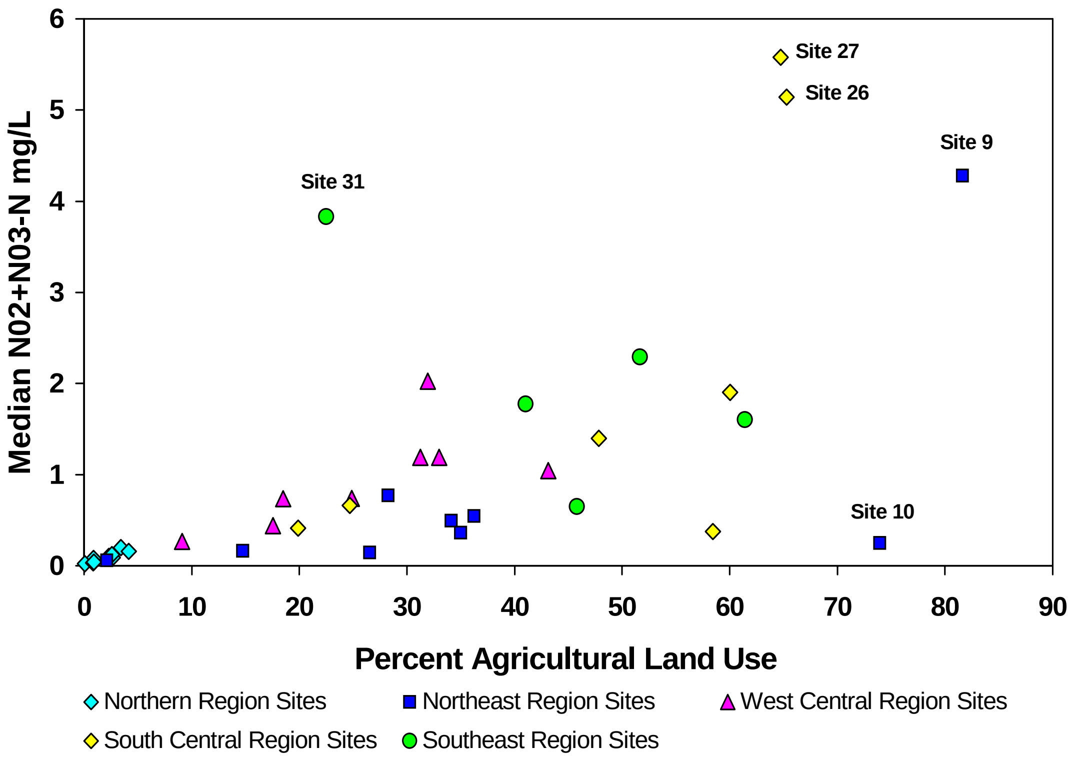
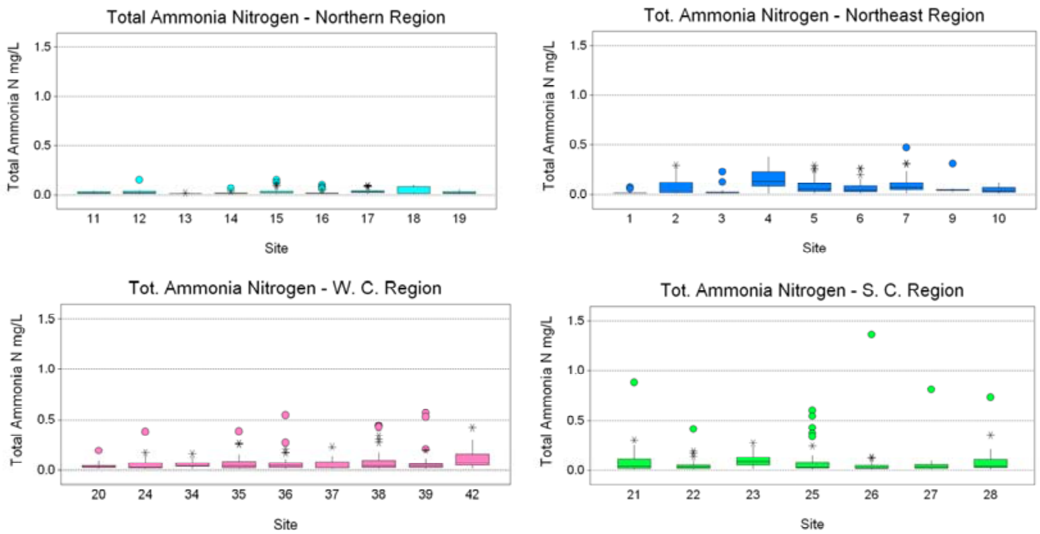
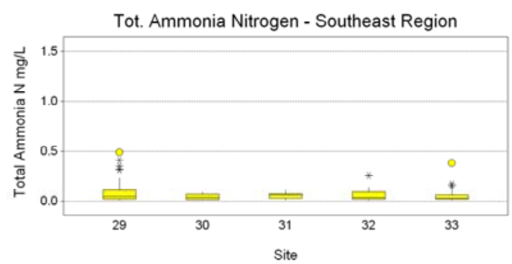


Figure 15. Relationship between median NOx concentrations and percent agricultural land cover at Wisconsin's long term trend sites.

Winter sampling - Sheboygan River at Esslingen Park, (John Masterson).



Site No.	Site Description	Region	Sample Freq.	N	Median mg/L
1	Menominee R. at McAllister	NE	Qtr.	15	0.015
2	Oconto R. at Oconto	NE	Qtr.	14	0.022
3	Peshtigo R. at Peshtigo	NE	Qtr.	15	0.018
4	Fox R. at DePere	NE	Mon.	39	0.131
5	Fox R. at Neenah and Menasha	NE	Mon.	39	0.052
6	Wolf R. at New London	NE	Mon.	35	0.043
7	Fox R. at Oshkosh	NE	Mon.	39	0.070
8	Fox R. at Berlin	NE	Qtr.	1	
9	Kewaunee R. at Kewaunee	NE	Qtr.	7	0.048
10	Manitowoc R. at Manitowoc	NE	Qtr.	7	0.029
11	St. Croix R. at Danbury	NO	Qtr.	7	0.017
12	St. Croix R. at St. Croix Falls	NO	Qtr.	7	0.018
13	Bois Brule R. at Brule	NO	Qtr.	11	0.015
14	Bad R. at Odanah	NO	Qtr.	9	0.015
15	Popple R. at Fence	NO	Mon.	41	0.019
16	Wolf R. at Langlade	NO	Mon.	40	0.017
17	Wisconsin R. at Merril	NO	Mon.	41	0.031
18	Flambeau R. at Bruce	NO	Qtr.	6	0.015
19	Chippewa R. at Bruce	NO	Qtr.	6	0.016
20	Kickapoo R. at Stueben	WC	Mon.	42	0.032
21	Baraboo R. at Rowley Creek Br.	SC	Mon.	33	0.041
22	Wisconsin R. at Muscoda	SC	Mon.	37	0.032
23	Wisconsin R. at Wisconsin Dells	SC	Mon.	37	0.088
24	Mississippi R. at LD 9	WC	Mon.	25	0.025
25	Rock R. at Afton	SC	Mon.	37	0.030
26	Sugar R. at Broadhead	SC	Mon.	37	0.026
27	Pecatonica R. at Martintown	SC	Mon.	33	0.034
28	Rock R. at Watertown	SC	Mon.	38	0.041
29	Root R. at Johnson Park	SE	Mon.	32	0.044
30	Milwaukee R. at Estabrook Park	SE	Qtr.	12	0.039
31	Fox (IL) R. below Waukesha	SE	Qtr.	8	0.062
32	Fox (IL) R. near New Munster	SE	Qtr.	8	0.037
33	Sheboygan R. at Esslingen Park	SE	Mon.	41	0.029
34	Chippewa R. at Chippewa Falls	WC	Qtr.	15	0.042
35	Chippewa R. at Durand	WC	Mon.	42	0.042
36	Red Cedar R. at Menomonie	WC	Mon.	42	0.044
37	La Crosse R. near Mouth	WC	Mon.	22	0.022
38	Trempealeau R. at Dodge	WC	Mon.	40	0.043
39	Black R. at Galesville (Hwy 53)	WC	Mon.	40	0.043
40	Mississippi R. at LD 3	WC	Qtr.	0	
41	Mississippi R. at LD 4	WC	Qtr.	0	
42	Wisconsin R. at Biron	WC	Mon.	43	0.068



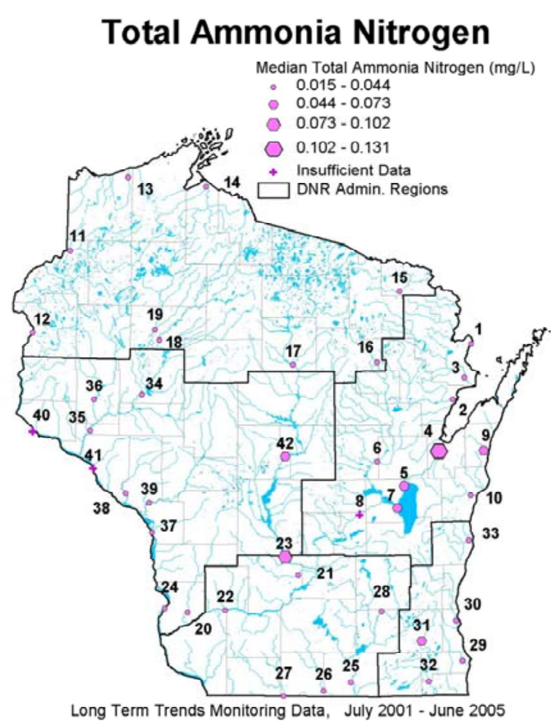


Figure 16. Total ammonia nitrogen concentrations at Wisconsin's long term trends sites.

Median total phosphorus (TP) concentrations in Northern Region were at or below 0.05 mg/L at all sites (Figure 17) and reflect watersheds with low agricultural land use and high forested cover (Table land cover). The Menominee (Site 1), Oconto (Site 2) and Peshtigo (Site 3) rivers in Northeast Region also had relatively low median TP concentrations. The Manitowoc River (Site 10) had the highest median TP concentration in Northeast Region at 0.127 mg/L.

The Chippewa (Sites 34 & 35), Red Cedar (Site 36) and Wisconsin (Site 42) rivers in West Central Region had median total phosphorus concentrations less than 0.1 mg/L. The Kickapoo (Site 20), Mississippi (Site 24), La Crosse (37) and Black (Site 39) rivers all exceeded a median TP concentration of 0.1 mg/L and reflect point and nonpoint source inputs of phosphorus. The Trempealeau River (Site 38) had the highest median TP concentration of the LTT monitoring sites in the State (0.369 mg/L). This site also had the highest median fecal coliform levels (see Fecal Coliform Bacteria below) and high total suspended solid concentrations (Figure 13). Collectively, these data suggest water quality problems associated with agricultural land use.

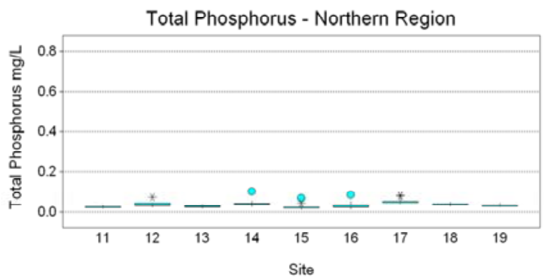
The Wisconsin River sites (22 & 23) in South Central Region were below 0.1 mg/L median TP. All other South Central Region sites exceeded that value with the Rock River sites (25 & 28) indicating median TP values of approximately 0.2 mg/L, reflecting a watershed dominated by agricultural land use. All of the sites in Southeast Region had median total phosphorus concentrations near or above 0.1 mg/L. Median phosphorus concentrations are generally greater in watersheds where agricultural land use is high (Figure 18).

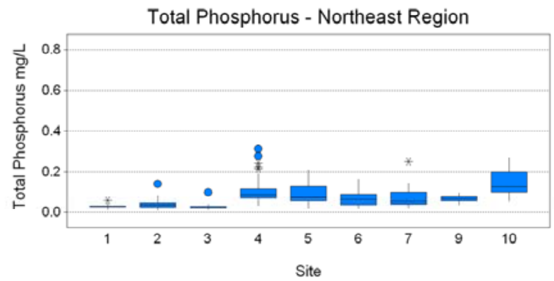
Dissolved reactive phosphorus (DRP) concentrations (Figure 19) at the monitoring sites reflected a similar pattern to that described for total phosphorus. DRP concentrations in Northern Region were low for all sites with medians ranging from 0.004 to 0.012 mg/L. Greater DRP concentrations were observed in other regions, especially in watersheds dominated by agricultural land use. Maximum DRP concentrations exceeded 0.05 mg/L in the Baraboo (Site 21), Pecatonica (Site 27), Trempealeau (Site 38) and Black (Site 39) rivers.

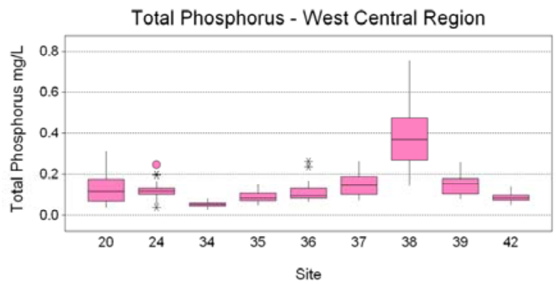
Dissolved Silica

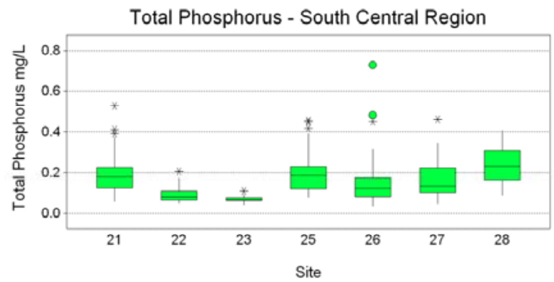
Silica is an important plant nutrient to a large group of unicellular and colonial algae called diatoms which use silica to form their cell walls. Diatoms represent an important group of algae in rivers and streams. Silica is derived from compounds containing silicon (Si), one of the most abundant elements on earth (Hem 1970). Silica can be present in both dissolved and particulate forms but it is the dissolved form that is necessary to sustain diatom growth. High diatom concentrations have a great potential to assimilate a large quantities of dissolved silica during periods of peak growth during spring and fall periods. Silica may limit diatom growth especially in those waters enriched with N and P.

Monitoring dissolved silica provides an indirect index to diatom activity and a useful supplement to chlorophyll *a* analysis. Median dissolved silica concentrations were greatest at sites in the Northern and West Central Regions with values near or exceeding 10 mg/L (Figure 20). Lowest median silica levels were found at the lower Fox River (Sites 4 & 5) in the Northeast Region and the Rock River (Site 28) in the South Central Region. An evaluation of monthly data for all sites indicate silica levels were lowest during April and May and likely associated with silica utilization during spring diatom growth.

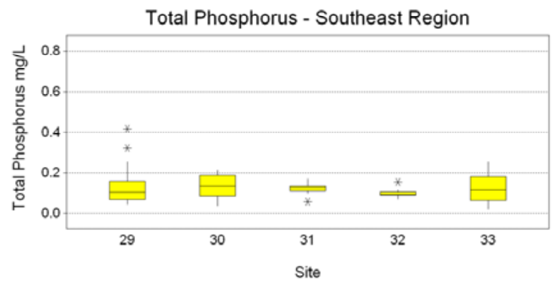








Site No.	Site Description	Region	Sample Freq.	N	Median mg/L
1	Menominee R. at McAllister	NE	Qtr.	14	0.030
2	Oconto R. at Oconto	NE	Qtr.	13	0.035
3	Peshtigo R. at Peshtigo	NE	Qtr.	14	0.029
4	Fox R. at DePere	NE	Mon.	39	0.088
5	Fox R. at Neenah and Menasha	NE	Mon.	39	0.077
6	Wolf R. at New London	NE	Mon.	35	0.065
7	Fox R. at Oshkosh	NE	Mon.	39	0.056
8	Fox R. at Berlin	NE	Qtr.	1	
9	Kewaunee R. at Kewaunee	NE	Qtr.	8	0.069
10	Manitowoc R. at Manitowoc	NE	Qtr.	8	0.127
11	St. Croix R. at Danbury	NO	Qtr.	7	0.021
12	St. Croix R. at St. Croix Falls	NO	Qtr.	7	0.037
13	Bois Brule R. at Brule	NO	Qtr.	11	0.027
14	Bad R. at Odanah	NO	Qtr.	9	0.040
15	Popple R. at Fence	NO	Mon.	42	0.021
16	Wolf R. at Langlade	NO	Mon.	41	0.027
17	Wisconsin R. at Merril	NO	Mon.	42	0.052
18	Flambeau R. at Bruce	NO	Qtr.	5	0.036
19	Chippewa R. at Bruce	NO	Qtr.	5	0.032
20	Kickapoo R. at Stueben	WC	Mon.	43	0.116
21	Baraboo R. at Rowley Creek Br.	SC	Mon.	35	0.180
22	Wisconsin R. at Muscoda	SC	Mon.	38	0.081
23	Wisconsin R. at Wisconsin Dells	SC	Mon.	38	0.067
24	Mississippi R. at LD 9	WC	Mon.	26	0.118
25	Rock R. at Afton	SC	Mon.	38	0.187
26	Sugar R. at Broadhead	SC	Mon.	38	0.124
27	Pecatonica R. at Martintown	SC	Mon.	34	0.134
28	Rock R. at Watertown	SC	Mon.	38	0.232
29	Root R. at Johnson Park	SE	Mon.	31	0.104
30	Milwaukee R. at Estabrook Park	SE	Qtr.	12	0.134
31	Fox (IL) R. below Waukesha	SE	Qtr.	7	0.127
32	Fox (IL) R. near New Munster	SE	Qtr.	7	0.093
33	Sheboygan R. at Esslingen Park	SE	Mon.	43	0.114
34	Chippewa R. at Chippewa Falls	WC	Qtr.	15	0.053
35	Chippewa R. at Durand	WC	Mon.	42	0.083
36	Red Cedar R. at Menomonie	WC	Mon.	42	0.097
37	La Crosse R. near Mouth	WC	Mon.	21	0.148
38	Trempealeau R. at Dodge	WC	Mon.	41	0.369
39	Black R. at Galesville (Hwy 53)	WC	Mon.	40	0.152
40	Mississippi R. at LD 3	WC	Qtr.	0	
41	Mississippi R. at LD 4	WC	Qtr.	0	
42	Wisconsin R. at Biron	WC	Mon.	46	0.083



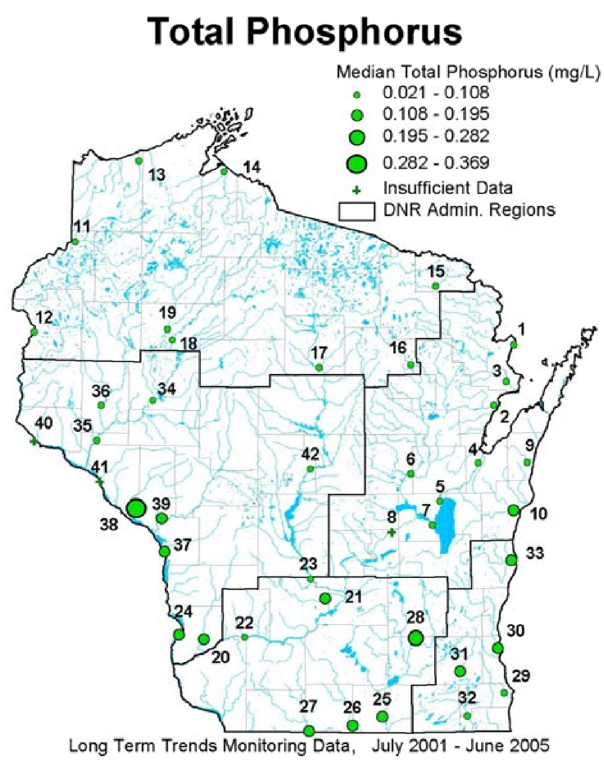


Figure 17. Total phosphorus concentrations at Wisconsin's long term trends sites.

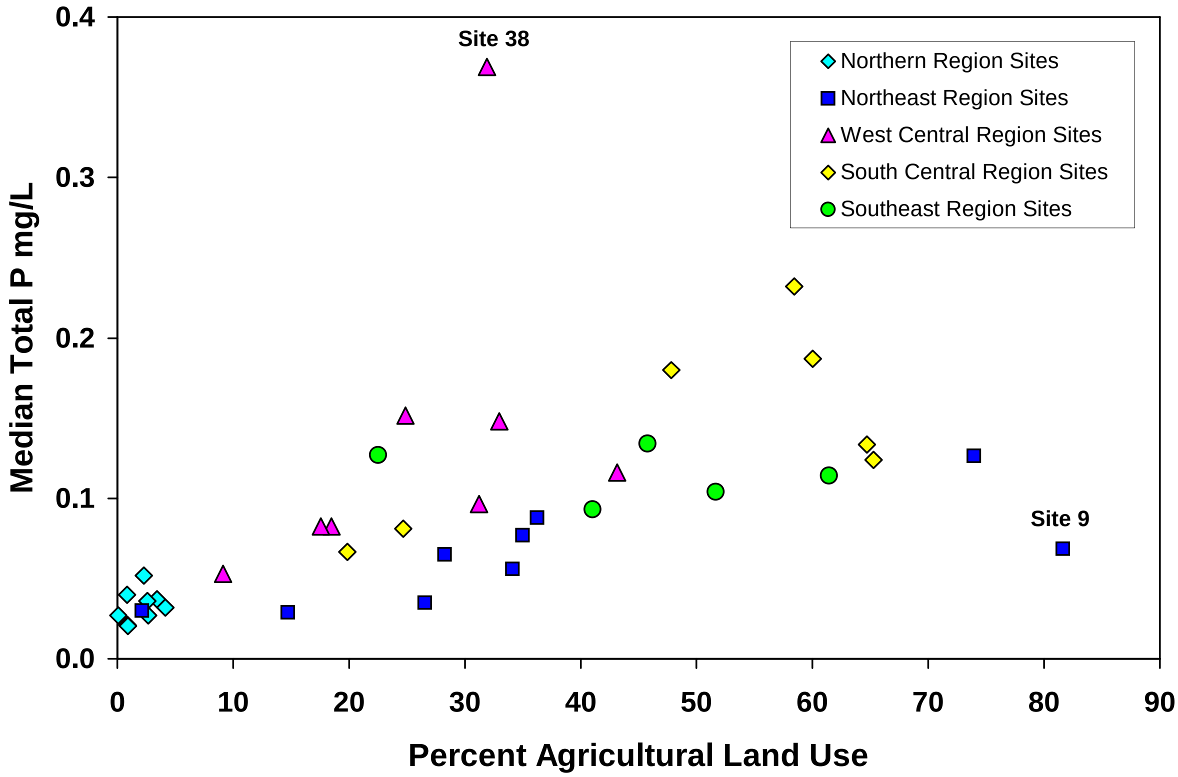
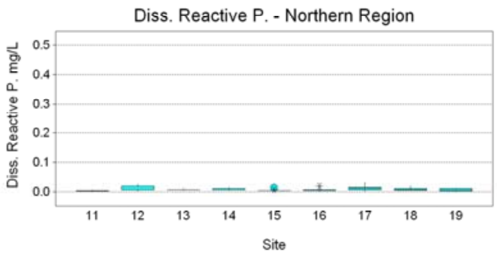
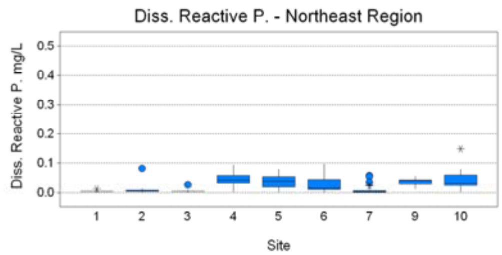
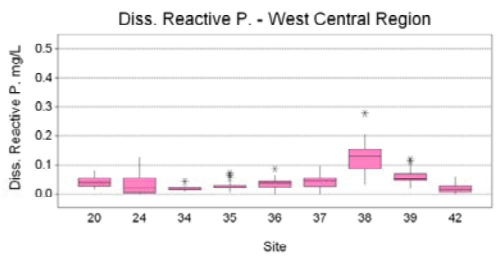


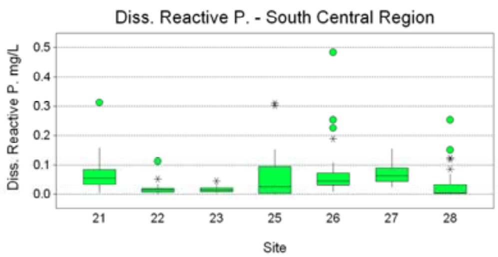
Figure18. Relationship between median total phosphorus and percent agricultural land cover at Wisconsin's long term trend sites.

St. Croix River above St. Croix Falls, Wisconsin. Islands mark the site of the old Nevers Dam, (John Sullivan).

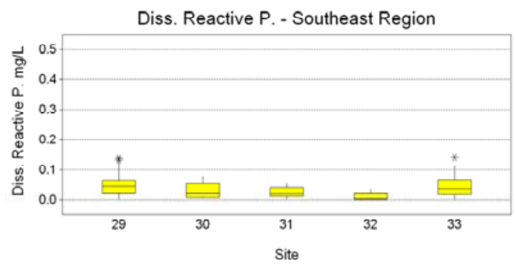








Site No.	Site Description	Region	Sample Freq.	N	Median mg/L
1	Menominee R. at McAllister	NE	Qtr.	14	0.004
2	Oconto R. at Oconto	NE	Qtr.	14	0.008
3	Peshtigo R. at Peshtigo	NE	Qtr.	14	0.004
4	Fox R. at DePere	NE	Mon.	36	0.043
5	Fox R. at Neenah and Menasha	NE	Mon.	35	0.039
6	Wolf R. at New London	NE	Mon.	33	0.015
7	Fox R. at Oshkosh	NE	Mon.	36	0.002
8	Fox R. at Berlin	NE	Qtr.	1	
9	Kewaunee R. at Kewaunee	NE	Qtr.	7	0.041
10	Manitowoc R. at Manitowoc	NE	Qtr.	7	0.032
11	St. Croix R. at Danbury	NO	Qtr.	6	0.004
12	St. Croix R. at St. Croix Falls	NO	Qtr.	6	0.007
13	Bois Brule R. at Brule	NO	Qtr.	10	0.007
14	Bad R. at Odanah	NO	Qtr.	9	0.007
15	Popple R. at Fence	NO	Mon.	43	0.004
16	Wolf R. at Langlade	NO	Mon.	43	0.004
17	Wisconsin R. at Merril	NO	Mon.	43	0.012
18	Flambeau R. at Bruce	NO	Qtr.	6	0.006
19	Chippewa R. at Bruce	NO	Qtr.	6	0.007
20	Kickapoo R. at Stueben	WC	Mon.	43	0.040
21	Baraboo R. at Rowley Creek Br.	SC	Mon.	32	0.056
22	Wisconsin R. at Muscoda	SC	Mon.	34	0.016
23	Wisconsin R. at Wisconsin Dells	SC	Mon.	35	0.014
24	Mississippi R. at LD 9	WC	Mon.	22	0.021
25	Rock R. at Afton	SC	Mon.	39	0.025
26	Sugar R. at Broadhead	SC	Mon.	39	0.046
27	Pecatonica R. at Martintown	SC	Mon.	35	0.063
28	Rock R. at Watertown	SC	Mon.	39	0.004
29	Root R. at Johnson Park	SE	Mon.	31	0.045
30	Milwaukee R. at Estabrook Park	SE	Qtr.	10	0.020
31	Fox (IL) R. below Waukesha	SE	Qtr.	7	0.019
32	Fox (IL) R. near New Munster	SE	Qtr.	7	0.002
33	Sheboygan R. at Esslingen Park	SE	Mon.	40	0.037
34	Chippewa R. at Chippewa Falls	WC	Qtr.	15	0.016
35	Chippewa R. at Durand	WC	Mon.	41	0.024
36	Red Cedar R. at Menomonie	WC	Mon.	42	0.038
37	La Crosse R. near Mouth	WC	Mon.	19	0.045
38	Trempealeau R. at Dodge	WC	Mon.	39	0.131
39	Black R. at Galesville (Hwy 53)	WC	Mon.	39	0.052
40	Mississippi R. at LD 3	WC	Qtr.	0	
41	Mississippi R. at LD 4	WC	Qtr.	0	
42	Wisconsin R. at Biron	WC	Mon.	44	0.015



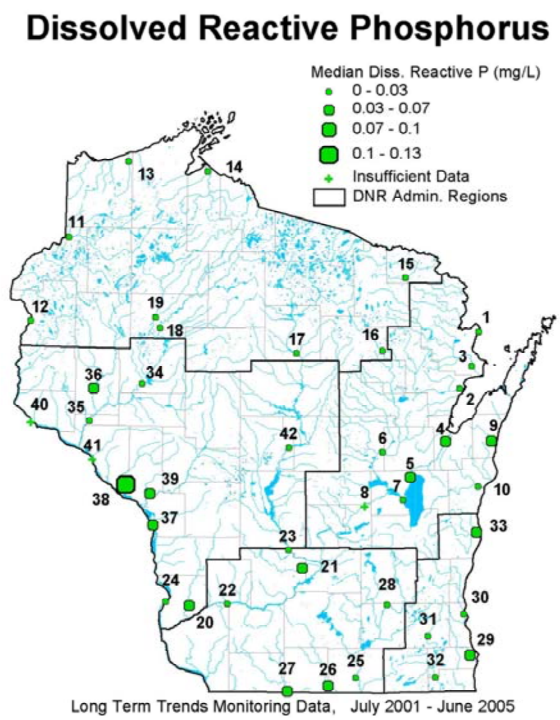
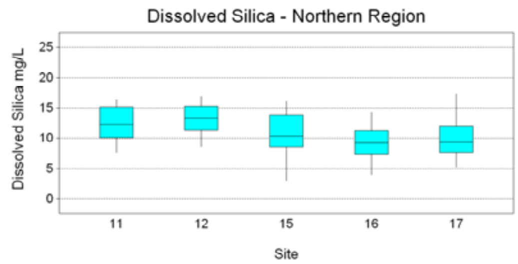
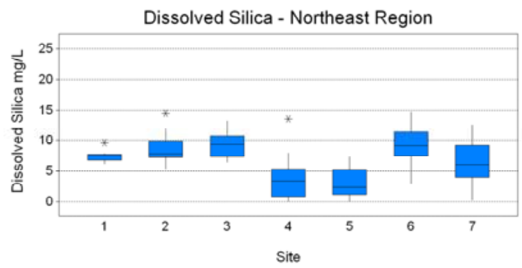
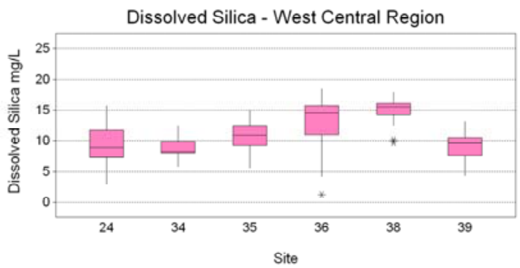
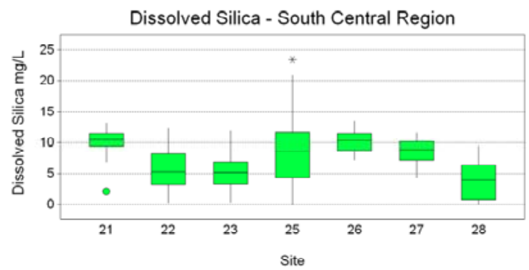


Figure 19. Dissolved reactive phosphorus concentrations at Wisconsin's long term trends sites.

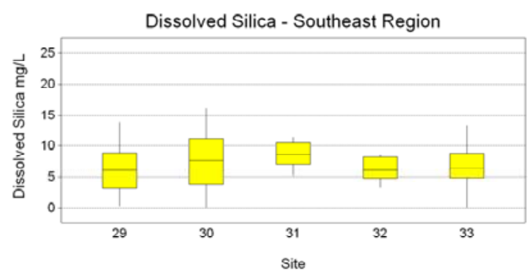








Site No.	Site Description	Region	Sample Freq.	N	Median mg/L
1	Menominee R. at McAllister	NE	Qtr.	8	7.5
2	Oconto R. at Oconto	NE	Qtr.	12	7.8
3	Peshtigo R. at Peshtigo	NE	Qtr.	7	9.4
4	Fox R. at DePere	NE	Mon.	39	3.4
5	Fox R. at Neenah and Menasha	NE	Mon.	39	2.4
6	Wolf R. at New London	NE	Mon.	35	9.2
7	Fox R. at Oshkosh	NE	Mon.	39	6.0
8	Fox R. at Berlin	NE	Qtr.	0	
9	Kewaunee R. at Kewaunee	NE	Qtr.	0	
10	Manitowoc R. at Manitowoc	NE	Qtr.	0	
11	St. Croix R. at Danbury	NO	Qtr.	7	12.3
12	St. Croix R. at St. Croix Falls	NO	Qtr.	7	13.3
13	Bois Brule R. at Brule	NO	Qtr.	0	
14	Bad R. at Odanah	NO	Qtr.	0	
15	Popple R. at Fence	NO	Mon.	42	10.4
16	Wolf R. at Langlade	NO	Mon.	42	9.3
17	Wisconsin R. at Merril	NO	Mon.	42	9.4
18	Flambeau R. at Bruce	NO	Qtr.	0	
19	Chippewa R. at Bruce	NO	Qtr.	0	
20	Kickapoo R. at Stueben	WC	Mon.	0	
21	Baraboo R. at Rowley Creek Br.	SC	Mon.	33	10.5
22	Wisconsin R. at Muscoda	SC	Mon.	34	5.3
23	Wisconsin R. at Wisconsin Dells	SC	Mon.	37	5.2
24	Mississippi R. at LD 9	WC	Mon.	26	8.9
25	Rock R. at Afton	SC	Mon.	36	8.5
26	Sugar R. at Broadhead	SC	Mon.	24	10.4
27	Pecatonica R. at Martintown	SC	Mon.	32	8.8
28	Rock R. at Watertown	SC	Mon.	36	3.9
29	Root R. at Johnson Park	SE	Mon.	33	6.1
30	Milwaukee R. at Estabrook Park	SE	Qtr.	12	7.6
31	Fox (IL) R. below Waukesha	SE	Qtr.	8	8.6
32	Fox (IL) R. near New Munster	SE	Qtr.	8	6.1
33	Sheboygan R. at Esslingen Park	SE	Mon.	44	6.3
34	Chippewa R. at Chippewa Falls	WC	Qtr.	8	8.2
35	Chippewa R. at Durand	WC	Mon.	41	10.9
36	Red Cedar R. at Menomonie	WC	Mon.	42	14.6
37	La Crosse R. near Mouth	WC	Mon.	0	
38	Trempealeau R. at Dodge	WC	Mon.	20	15.5
39	Black R. at Galesville (Hwy 53)	WC	Mon.	20	9.7
40	Mississippi R. at LD 3	WC	Qtr.	0	
41	Mississippi R. at LD 4	WC	Qtr.	0	
42	Wisconsin R. at Biron	WC	Mon.	0	



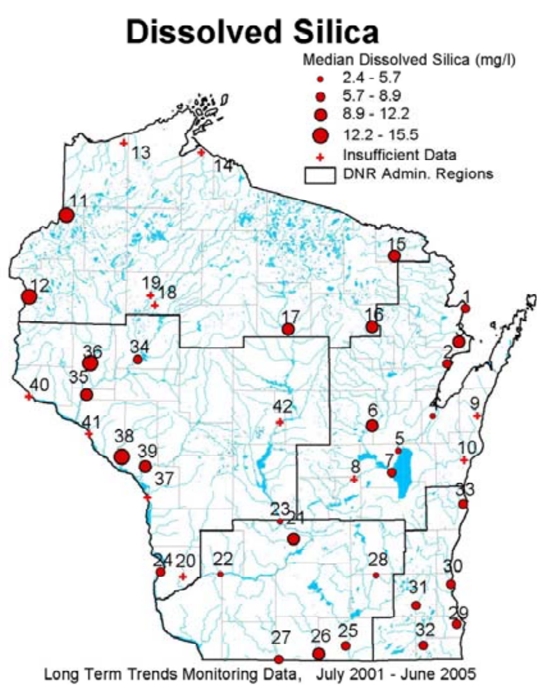


Figure 20. Dissolved silica concentrations at at Wisconsin's long term trends sites.

For example, the Rock River at Watertown had several values less than 1 mg/L during April-May and those were associated with chlorophyll concentrations exceeding 100 ug/L. Other sites with occasional low spring silica concentrations included the Wisconsin River (Sites 22 & 23), Fox River at Oshkosh (Site 7), Rock River at Afton (Site 25) and the Sheboygan River (Sites 33). Low silica concentrations during July and August were also present below the outlet of Lake Winnebago (Neenah & Menasha - Site 5) and the Rock River at Watertown (Site 28) suggesting these sites were also influenced by an active summer diatom flora during this period.

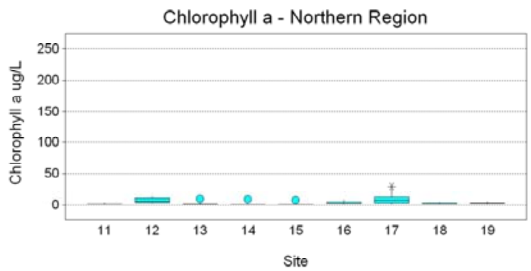
Chlorophyll *a*

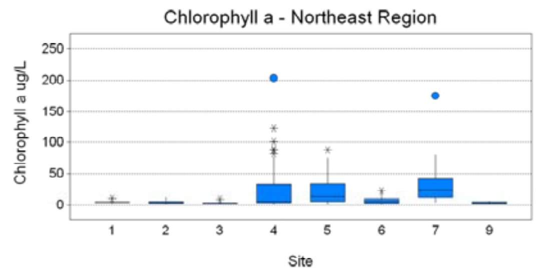
Chlorophyll *a* is a major plant pigment and provides an indication of the biomass of algae that is present in water. Excessive algae growth may develop in lakes, impoundments, and slow moving rivers that are enriched with N and P. Chlorophyll analysis provides a way to quantify eutrophication impacts. Chlorophyll pigments are extracted from water samples that may contain a diverse phytoplankton community including diatoms and other chrysophytes, green algae, and cyanobacteria (blue-green "algae"). However, most serious nuisance algae problems are generally attributed to several members of the blue-green algae family that may form surface blooms during the warm summer months in eutrophic waters.

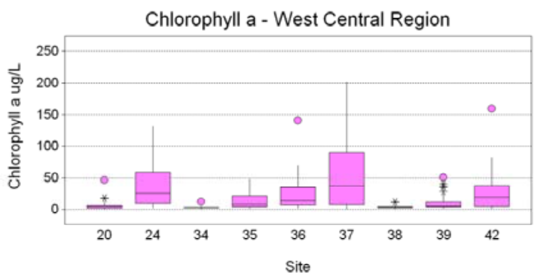
Chlorophyll concentrations at Northern Region sites were very low with median values less than 6 ug/L (Figure 21). Similarly, several sites in the Northeast Region (Sites 1-3) also exhibited low median levels and reflect low nutrient concentrations, especially total phosphorus (Figure 17). It is also suspected that the velocity and mixing processes in these streams may be less conducive for sestonic algae production due to short retention times (high flushing) and lack of upstream impoundments or lakes containing high phytoplankton concentrations. Chlorophyll concentrations exceeding 50 ug/L were present at all Fox River sites (4, 5, & 7) and are likely influenced by large upstream lakes and greater nutrient availability. The highest median chlorophyll concentration in the West Central Region was found at the La Crosse River (Site 37) which is downstream of Lake Neshonoc. Periods of high chlorophyll exceeding 50 ug/L were also common in the Mississippi (Site 24), Red Cedar (Site 36) and Wisconsin (Site 42) rivers and are also influenced by large upstream impoundments. Relatively low chlorophyll concentrations were found in the Kickapoo (Site 20) and Trempealeau (Site 38) rivers and are likely light-limited due to high total suspended solids (Figure 13).

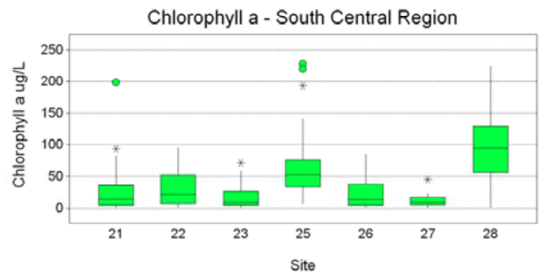
The Chippewa River at Chippewa Falls (Site 34) had low chlorophyll and nutrient levels similar to sites in the Northern Region. The Rock River at Afton (Site 25) and Watertown (Site 28) had the highest chlorophyll concentrations in the State with medians exceeding 50 ug/L and maximums greater than 200 ug/L. The Rock River is an impounded system with slow moving, nutrient enriched waters favorable for algae growth. Other sites in the South Central Region also indicated moderate chlorophyll levels with maximums exceeding 50 ug/L. The exception was the Pecatonica River (Site 27) which had relatively low chlorophyll and was likely light-limited due to high TSS. The Root River (Site 29) in Southeast Region had the lowest median chlorophyll concentration in the region with 6.2 ug/L, but also reported concentrations greater than 50 ug/L. The Milwaukee River (Site 30), Fox (IL) River near New Munster (Site 32), and the Sheboygan River (Site 33) are all fairly high in nutrients and had periods of high chlorophyll concentrations exceeding 50 ug/L. The Fox (IL) River below Waukesha (Site 31) is downstream of the Waukesha wastewater treatment plant and was the only site in Southeast Region that was always below 50 ug/L.

Chlorophyll levels in Wisconsin's streams during May through September were found to be significantly correlated to total phosphorus concentrations (Figure 22). Interestingly the log-

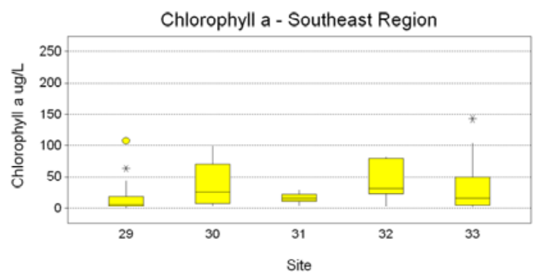


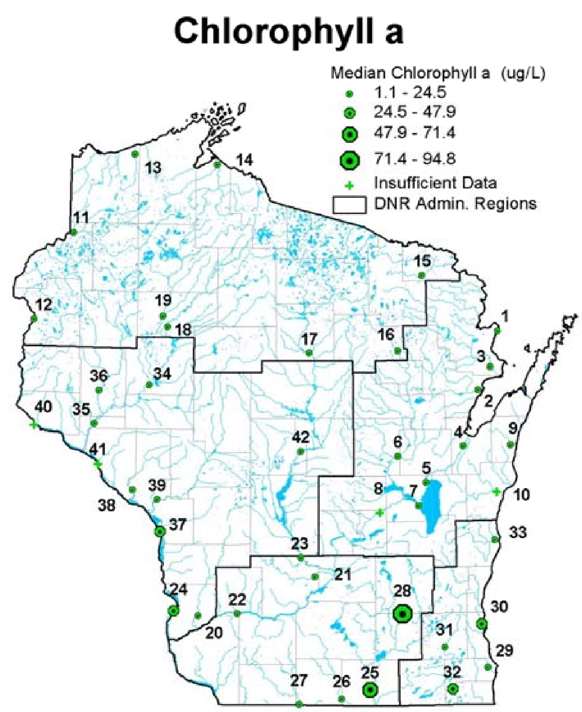






Site No.	Site Description	Region	Sample Freq.	N	Median ug/L
1	Menominee R. at McAllister	NE	Qtr.	11	4.2
2	Oconto R. at Oconto	NE	Qtr.	9	3.7
3	Peshtigo R. at Peshtigo	NE	Qtr.	11	1.8
4	Fox R. at DePere	NE	Mon.	31	5.7
5	Fox R. at Neenah and Menasha	NE	Mon.	31	13.0
6	Wolf R. at New London	NE	Mon.	27	4.9
7	Fox R. at Oshkosh	NE	Mon.	31	24.2
8	Fox R. at Berlin	NE	Qtr.	1	
9	Kewaunee R. at Kewaunee	NE	Qtr.	8	4.3
10	Manitowoc R. at Manitowoc	NE	Qtr.	1	
11	St. Croix R. at Danbury	NO	Qtr.	6	2.2
12	St. Croix R. at St. Croix Falls	NO	Qtr.	6	5.7
13	Bois Brule R. at Brule	NO	Qtr.	11	1.6
14	Bad R. at Odanah	NO	Qtr.	8	1.1
15	Popple R. at Fence	NO	Mon.	34	1.1
16	Wolf R. at Langlade	NO	Mon.	33	2.6
17	Wisconsin R. at Merril	NO	Mon.	33	7.3
18	Flambeau R. at Bruce	NO	Qtr.	4	2.1
19	Chippewa R. at Bruce	NO	Qtr.	4	2.8
20	Kickapoo R. at Stueben	WC	Mon.	30	4.5
21	Baraboo R. at Rowley Creek Br.	SC	Mon.	24	14.2
22	Wisconsin R. at Muscoda	SC	Mon.	28	21.7
23	Wisconsin R. at Wisconsin Dells	SC	Mon.	27	8.9
24	Mississippi R. at LD 9	WC	Mon.	25	26.3
25	Rock R. at Afton	SC	Mon.	28	52.8
26	Sugar R. at Broadhead	SC	Mon.	28	13.7
27	Pecatonica R. at Martintown	SC	Mon.	25	9.0
28	Rock R. at Watertown	SC	Mon.	28	94.8
29	Root R. at Johnson Park	SE	Mon.	32	6.2
30	Milwaukee R. at Estabrook Park	SE	Qtr.	8	26.2
31	Fox (IL) R. below Waukesha	SE	Qtr.	8	15.9
32	Fox (IL) R. near New Munster	SE	Qtr.	6	32.3
33	Sheboygan R. at Esslingen Park	SE	Mon.	32	15.8
34	Chippewa R. at Chippewa Falls	WC	Qtr.	12	2.7
35	Chippewa R. at Durand	WC	Mon.	32	8.2
36	Red Cedar R. at Menomonie	WC	Mon.	33	14.4
37	La Crosse R. near Mouth	WC	Mon.	28	36.9
38	Trempealeau R. at Dodge	WC	Mon.	28	3.4
39	Black R. at Galesville (Hwy 53)	WC	Mon.	30	5.7
40	Mississippi R. at LD 3	WC	Qtr.	0	
41	Mississippi R. at LD 4	WC	Qtr.	0	
42	Wisconsin R. at Biron	WC	Mon.	33	20.0





Long Term Trends Monitoring Data, July 2001 - June 2005

Figure 21. Chlorophyll *a* concentrations at Wisconsin's long term trends sites.

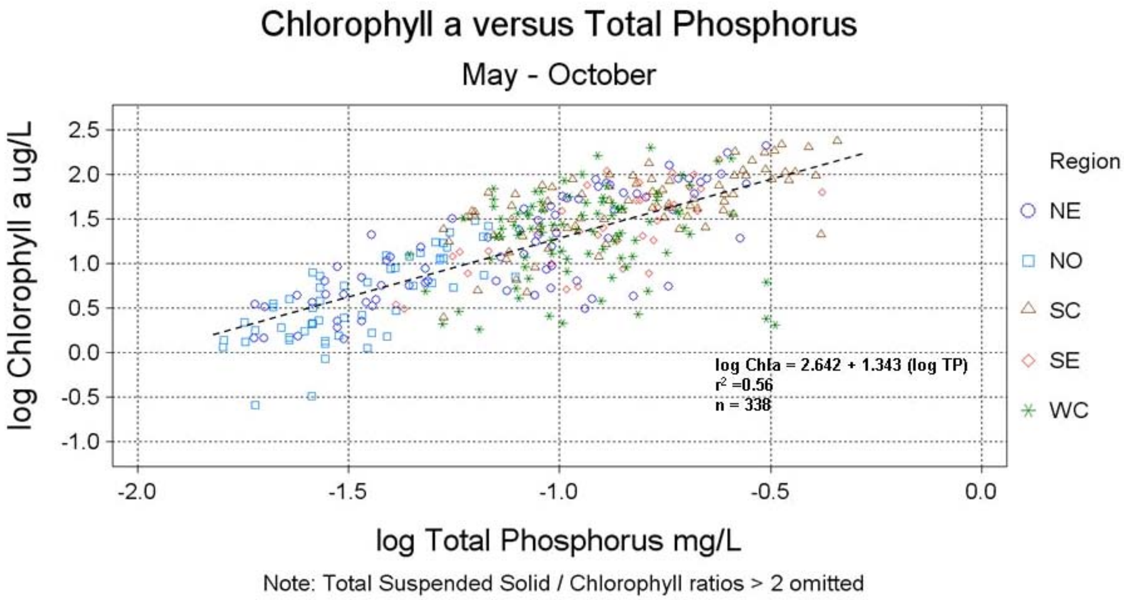


Figure 22. Relationship between total phosphorus and chlorophyll a at Wisconsin's long term trend sites.

Lower Dells on the Wisconsin River (John Sullivan).

log relationship described here closely matched similar data derived from information provided on Minnesota Rivers (Steve Heiskary, Minnesota Pollution Control Agency, Pers. Comm.).

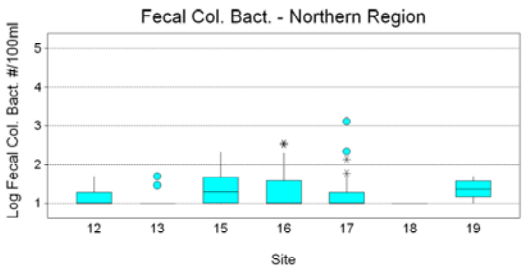
Fecal Coliform Bacteria

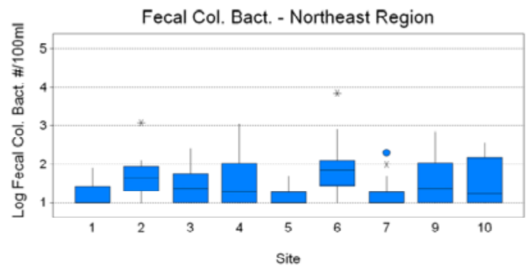
Fecal coliform bacteria provide a general index to fecal contamination in surface water. This group includes a specific bacterium, *Escherhia coli* (E-coli), which are thought to be a more specific indicator of fecal contamination. These bacteria live in the intestinal tracks of animals and birds and because they are eliminated with feces, their presence may indicate the presence of other pathogenic organisms. Important cultural sources of fecal contamination include animal waste runoff, human sewage and untreated domestic wastewater. Wisconsin has established fecal coliform standards to protect recreational use and is evaluating similar standards for E-coli bacteria. Wisconsin has been monitoring both fecal coliform and E-coli bacteria as a means to compare both results in the advent that the Department switches to new standards for E-coli. The current fecal coliform criterion specifies these bacteria are not to exceed 200 colony forming units (#) per 100 ml (200 #/100 ml) applied as a geometric mean based on a minimum of 5 samples per month, nor exceed 400 #/100 ml in more than 10% of the samples during any month. Bacteria samples are not collected for evaluation against the current codified standards which require a minimum of five samples per month. Consequently, for overall water quality evaluation it was determined to use the median rather than the geometric mean.

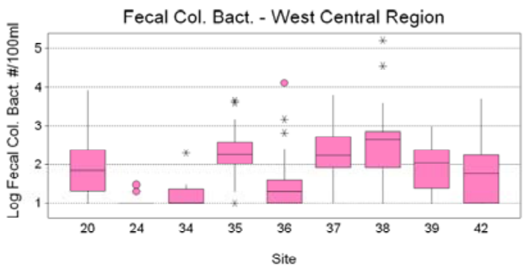
The median concentration of fecal coliform bacteria levels in northern Wisconsin was between 10 and 70 #/100 mL (Figure 23). The highest median concentration (70 #/100 ml) was at the Wolf River (Site 6) in Northeast Region. One sample at the Wolf River exceeded 7,000 #/ 100 ml. The Mississippi River at LD 9 (Site 24) and Chippewa River at Chippewa Falls (Site 34) in West Central Region had low median concentrations. Further downstream on the Chippewa River Site 35 at Durand had a substantially higher median concentration. The Black and LaCrosse rivers (Sites 39 & 37) had median concentrations of 110 and 170 #/100 ml, respectively. The highest median concentration of fecal coliform bacteria in the State was 440 #/100 ml in the Trempealeau River at Dodge. The Baraboo (Site 21) and Pecatonica (Site 27) rivers in South Central Region had median values of 335 and 300 #/100 mL. In Southeast Region the highest median concentrations were at the Fox (IL) River below Waukesha (Site 31) at 225 #/100 mL and Milwaukee River (Site 30) with 160 #/100 mL. Fecal coliform levels in state rivers were normally greater in watersheds with greater agricultural land use (Figure 24).

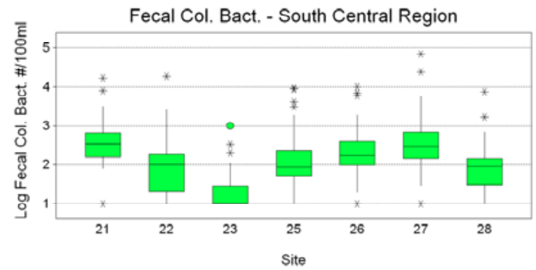
Triazine Herbicides

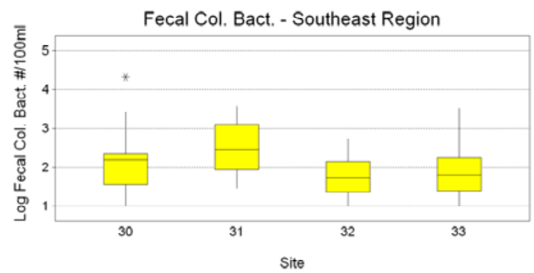
The triazine herbicides include a large group of pre- and post-emergent chemicals that are used to control undesirable weeds in the production of cultivated crops, especially corn. Common examples of these herbicides include atrazine, cyanazine and simazine. Historically atrazine has been the most commonly used herbicide in Wisconsin. The analytical method used to detect triazines is an immunoassay technique and is not specific to any one herbicide, though the analysis is especially sensitive to atrazine and closely related triazine compounds. Therefore the triazine results provided here should be considered a screening test for these herbicides. The triazine immunoassay offers the advantage of very low detection limits and lower cost than other analytical methods.











Site No.	Site Description	Region	Sample Freq.	N	Median #/100ml
1	Menominee R. at McAllister	NE	Qtr.	15	10
2	Oconto R. at Oconto	NE	Qtr.	14	45
3	Peshtigo R. at Peshtigo	NE	Qtr.	14	25
4	Fox R. at DePere	NE	Mon.	32	20
5	Fox R. at Neenah and Menasha	NE	Mon.	32	10
6	Wolf R. at New London	NE	Mon.	32	70
7	Fox R. at Oshkosh	NE	Mon.	33	10
8	Fox R. at Berlin	NE	Qtr.	1	
9	Kewaunee R. at Kewaunee	NE	Qtr.	8	25
10	Manitowoc R. at Manitowoc	NE	Qtr.	8	20
11	St. Croix R. at Danbury	NO	Qtr.	3	10
12	St. Croix R. at St. Croix Falls	NO	Qtr.	7	10
13	Bois Brule R. at Brule	NO	Qtr.	11	10
14	Bad R. at Odanah	NO	Qtr.	0	
15	Popple R. at Fence	NO	Mon.	40	20
16	Wolf R. at Langlade	NO	Mon.	39	10
17	Wisconsin R. at Merril	NO	Mon.	40	10
18	Flambeau R. at Bruce	NO	Qtr.	4	10
19	Chippewa R. at Bruce	NO	Qtr.	4	25
20	Kickapoo R. at Stueben	WC	Mon.	43	70
21	Baraboo R. at Rowley Creek Br.	SC	Mon.	28	335
22	Wisconsin R. at Muscoda	SC	Mon.	35	100
23	Wisconsin R. at Wisconsin Dells	SC	Mon.	33	10
24	Mississippi R. at LD 9	WC	Mon.	23	10
25	Rock R. at Afton	SC	Mon.	38	85
26	Sugar R. at Broadhead	SC	Mon.	39	170
27	Pecatonica R. at Martintown	SC	Mon.	35	300
28	Rock R. at Watertown	SC	Mon.	40	90
29	Root R. at Johnson Park	SE	Mon.	0	
30	Milwaukee R. at Estabrook Park	SE	Qtr.	11	160
31	Fox (IL) R. below Waukesha	SE	Qtr.	8	225
32	Fox (IL) R. near New Munster	SE	Qtr.	8	55
33	Sheboygan R. at Esslingen Park	SE	Mon.	44	65
34	Chippewa R. at Chippewa Falls	WC	Qtr.	15	10
35	Chippewa R. at Durand	WC	Mon.	41	180
36	Red Cedar R. at Menomonie	WC	Mon.	43	20
37	La Crosse R. near Mouth	WC	Mon.	41	170
38	Trempealeau R. at Dodge	WC	Mon.	45	440
39	Black R. at Galesville (Hwy 53)	WC	Mon.	43	110
40	Mississippi R. at LD 3	WC	Qtr.	0	
41	Mississippi R. at LD 4	WC	Qtr.	0	
42	Wisconsin R. at Biron	WC	Mon.	41	60

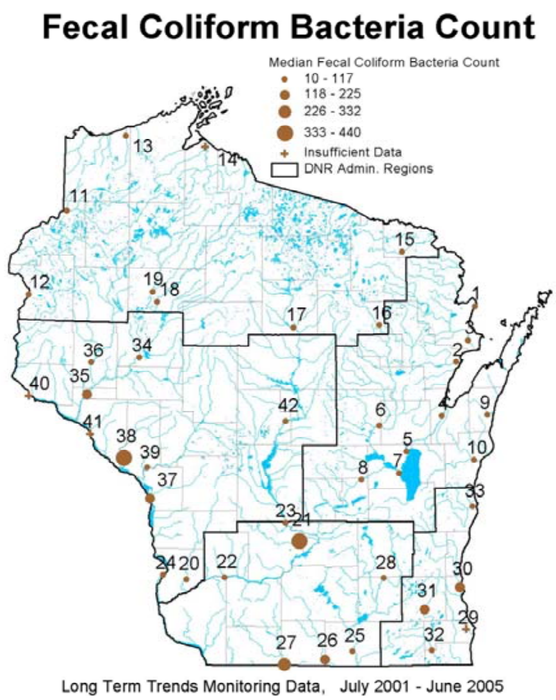


Figure 23. Fecal coliform bacteria concentrations at Wisconsin's long term trends sites.

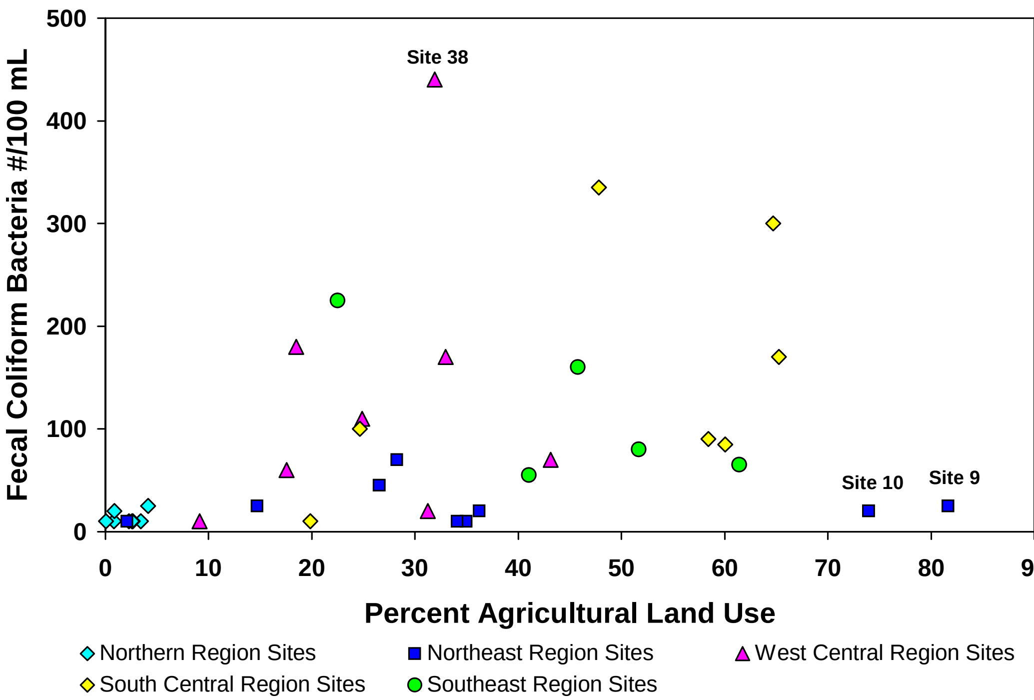


Figure 24. Relationship between median fecal coliform concentrations and percent agricultural land cover at Wisconsin's long term trend sites.

Triazine samples were collected twice a year at selected stations. Herbicide screening samples were collected in winter and mid summer for a gross evaluation of differences between the growing season, when herbicides may be used, and winter when none would be used. A conservative evaluation of the triazine data from the river samples can be done by comparing the results to the atrazine maximum contaminant level (MCL) for drinking water (NR 809.20). The drinking water MCL for atrazine is 3.0 ug/L. Ninety-two triazine samples were collected from 34 rivers throughout the state. All samples were less than the MCL and the maximum value of 1.0 ug/L was observed at the Wolf River at New London (Site 6).

Total Hardness

A high level of hardness in water can interfere with the cleaning effectiveness of detergents and can result in precipitates (hard water stains) when the water is heated (Hem 1970). Hardness is an important property of water that influences the toxicity of some metals. Waters with low hardness increase the bioavailability of metals and as a result, water quality criterion concentrations for many metals are lower as compared to waters with high hardness. Receiving water hardness information is necessary for the calculation of water quality based effluent limits for wastewaters containing regulated metals. Calcium and magnesium are the primary ions contributing to hardness and their combined concentrations are used to derive a value for total hardness. As with alkalinity, hardness is expressed as equivalent concentrations of calcium carbonate.

All of Northern Region, Northeast Region and all sites except for the Kickapoo River in West Central Region have median total hardness concentrations less than 200 mg/L likely reflecting groundwater inputs from areas with soils and bedrock that are low in calcium-containing materials (Figure 25). The Kickapoo River had a median value of 266 mg/L and all of the sites in South Central Region and Southeast Region had median total hardness values greater than 300 mg/L. The Root River in Southeast Region had the greatest variability with two values in excess of 500 mg/L. In general, sites with high hardness were found in the Southern and Southeast Regions where limestone bedrock contributes to elevated calcium and magnesium concentrations in groundwater and surface waters.

Metals

Metals in the aquatic environment are an important factor in determining the ability of surface waters to support aquatic communities. Metals occur naturally in our waters and vary in concentration based on the soil types and bedrock geology. When combined with anthropogenic sources some locations may approach or exceed concentrations that are considered harmful to human heath and aquatic life. The data collected as part of the LTT network provide necessary background data for water quality assessments and effluent limit calculations. Urban areas generally contribute higher concentrations of metals than rural areas. However, mercury concentrations in fish tissue have resulted in fish consumption advisories for many of our lakes and streams primarily from atmospheric deposition.

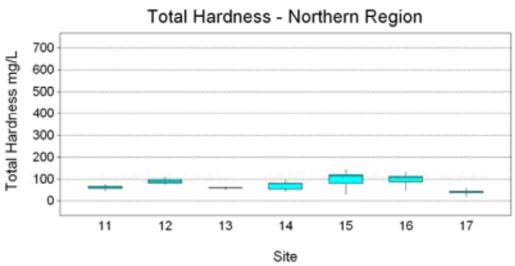
Quarterly low-level total recoverable metals sampling is conducted at just over a third of the network sites (Table 3) Analysis included aluminum, cadmium, chromium, copper, lead, zinc, and mercury. Total recoverable aluminum, cadmium, lead and zinc were all well below the water quality criteria in Ch. NR 105 (Wis. Adm. Code); consequently, specific narratives for these metals are not included in this report.

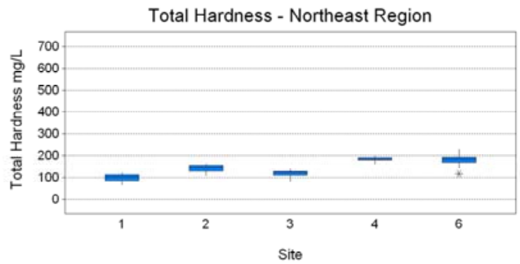
Mercury

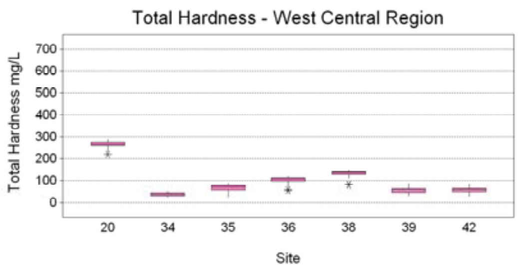
The wildlife criterion for Mercury from NR 105 is 1.3 ng/L. All sample sites that were tested for total mercury had some exceedances of the wildlife criteria and only the Wolf and Root rivers (Sites 6 & 29) had median values below the criterion. The highest median concentrations were observed at the Fox River at DePere (Site 4) and Mississippi River at LD 3 (Site 40) (Figure 26) both below large urban areas. Over 80% of the samples tested for those sites exceeded the wildlife criterion. When all sites were considered, more than 70% of the samples exceeded the wildlife criterion. The lowest frequency of criterion exceedances (43%) was at the Root River (Site 29). The Wolf River (Site 6) and Mississippi River at LD 4 (Site 41) had median values of 1.38 and 1.50 ng/L. Median mercury levels dropped substantially between Mississippi River Sites 40 and 41 as a result of solids settling in Lake Pepin.

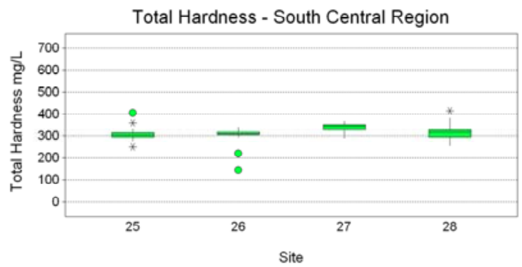
Cadmium

Nine sites were sampled for total recoverable cadmium using the low-level metals method (Figure 27). The highest median concentration was 0.036 ug/L at the Mississippi River LD # 3 (Site 40) and the highest single concentration was at the Wisconsin River, Site 23, at 0.08 ug/L. All concentrations were well below the chronic toxicity criteria of 1,430 ug/L using a very conservative hardness value of 50 mg/L (Ch. NR 105.06, Wis. Adm. Code). EPA is currently examining revising the cadmium criteria to a more stringent value (James Schmidt, WDNR, Pers. Comm.).

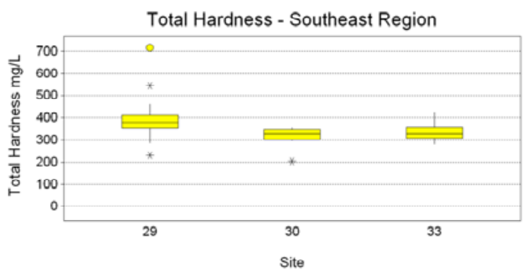








Site No.	Site Description	Region	Sample Freq.	N	Median mg/L
1	Menominee R. at McAllister	NE	Qtr.	8	102
2	Oconto R. at Oconto	NE	Qtr.	8	147
3	Peshtigo R. at Peshtigo	NE	Qtr.	8	125
4	Fox R. at DePere	NE	Mon.	11	183
5	Fox R. at Neenah and Menasha	NE	Mon.	0	M
6	Wolf R. at New London	NE	Mon.	11	184
7	Fox R. at Oshkosh	NE	Mon.	0	
8	Fox R. at Berlin	NE	Qtr.	0	
9	Kewaunee R. at Kewaunee	NE	Qtr.	0	
10	Manitowoc R. at Manitowoc	NE	Qtr.	0	
11	St. Croix R. at Danbury	NO	Qtr.	8	63
12	St. Croix R. at St. Croix Falls	NO	Qtr.	8	89
13	Bois Brule R. at Brule	NO	Qtr.	11	62
14	Bad R. at Odanah	NO	Qtr.	9	79
15	Popple R. at Fence	NO	Mon.	44	115
16	Wolf R. at Langlade	NO	Mon.	44	109
17	Wisconsin R. at Merril	NO	Mon.	43	42
18	Flambeau R. at Bruce	NO	Qtr.	2	
19	Chippewa R. at Bruce	NO	Qtr.	2	
20	Kickapoo R. at Stueben	WC	Mon.	21	266
21	Baraboo R. at Rowley Creek Br.	SC	Mon.	0	
22	Wisconsin R. at Muscoda	SC	Mon.	0	
23	Wisconsin R. at Wisconsin Dells	SC	Mon.	0	
24	Mississippi R. at LD 9	WC	Mon.	0	
25	Rock R. at Afton	SC	Mon.	23	304
26	Sugar R. at Broadhead	SC	Mon.	22	309
27	Pecatonica R. at Martintown	SC	Mon.	20	345
28	Rock R. at Watertown	SC	Mon.	22	318
29	Root R. at Johnson Park	SE	Mon.	20	378
30	Milwaukee R. at Estabrook Park	SE	Qtr.	10	328
31	Fox (IL) R. below Waukesha	SE	Qtr.	1	
32	Fox (IL) R. near New Munster	SE	Qtr.	1	
33	Sheboygan R. at Esslingen Park	SE	Mon.	23	326
34	Chippewa R. at Chippewa Falls	WC	Qtr.	7	38
35	Chippewa R. at Durand	WC	Mon.	27	70
36	Red Cedar R. at Menomonie	WC	Mon.	21	107
37	La Crosse R. near Mouth	WC	Mon.	1	
38	Trempealeau R. at Dodge	WC	Mon.	20	136
39	Black R. at Galesville (Hwy 53)	WC	Mon.	26	61
40	Mississippi R. at LD 3	WC	Qtr.	1	
41	Mississippi R. at LD 4	WC	Qtr.	1	
42	Wisconsin R. at Biron	WC	Mon.	19	61



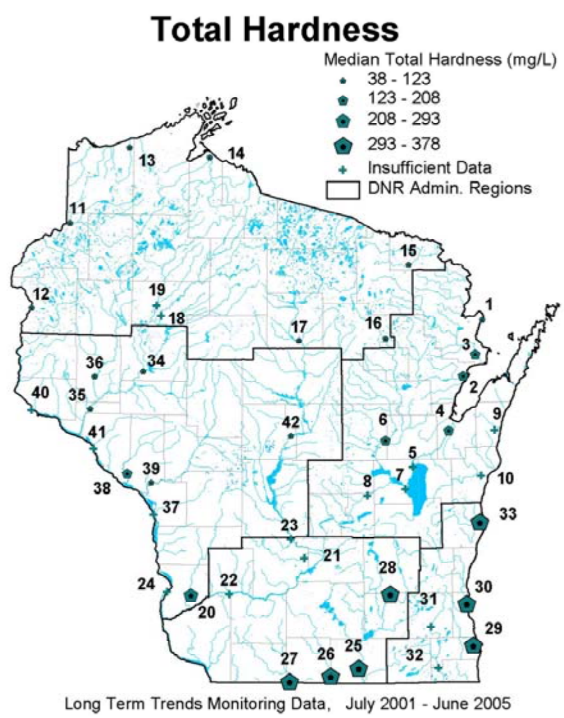
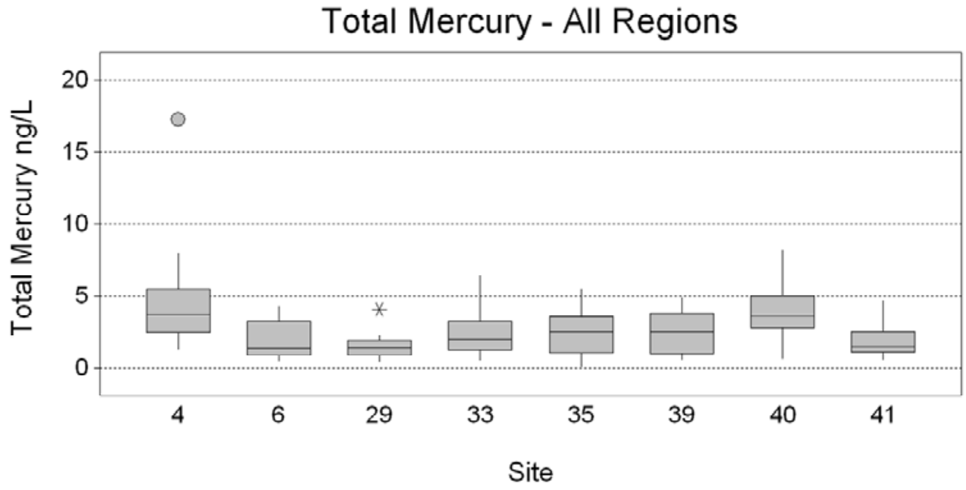


Figure 25. Total hardness concentrations at Wisconsin's long term trends sites.



Site No.	Site Description	Region	Sample Freq.	N	Median ng/L
1	Menominee R. at McAllister	NE	Qtr.	0	
2	Oconto R. at Oconto	NE	Qtr.	0	
3	Peshtigo R. at Peshtigo	NE	Qtr.	0	
4	Fox R. at DePere	NE	Mon.	12	3.68
5	Fox R. at Neenah and Menasha	NE	Mon.	0	
6	Wolf R. at New London	NE	Mon.	11	1.38
7	Fox R. at Oshkosh	NE	Mon.	0	
8	Fox R. at Berlin	NE	Qtr.	0	
9	Kewaunee R. at Kewaunee	NE	Qtr.	0	
10	Manitowoc R. at Manitowoc	NE	Qtr.	0	
11	St. Croix R. at Danbury	NO	Qtr.	1	
12	St. Croix R. at St. Croix Falls	NO	Qtr.	1	
13	Bois Brule R. at Brule	NO	Qtr.	0	
14	Bad R. at Odanah	NO	Qtr.	0	
15	Popple R. at Fence	NO	Mon.	2	
16	Wolf R. at Langlade	NO	Mon.	1	
17	Wisconsin R. at Merril	NO	Mon.	0	
18	Flambeau R. at Bruce	NO	Qtr.	0	
19	Chippewa R. at Bruce	NO	Qtr.	0	
20	Kickapoo R. at Stueben	WC	Mon.	0	
21	Baraboo R. at Rowley Creek Br.	SC	Mon.	0	
22	Wisconsin R. at Muscoda	SC	Mon.	0	
23	Wisconsin R. at Wisconsin Dells	SC	Mon.	0	
24	Mississippi R. at LD 9	WC	Mon.	0	
25	Rock R. at Afton	SC	Mon.	1	
26	Sugar R. at Broadhead	SC	Mon.	0	
27	Pecatonica R. at Martintown	SC	Mon.	0	
28	Rock R. at Watertown	SC	Mon.	0	
29	Root R. at Johnson Park	SE	Mon.	11	1.44
30	Milwaukee R. at Estabrook Park	SE	Qtr.	0	
31	Fox (IL) R. below Waukesha	SE	Qtr.	0	
32	Fox (IL) R. near New Munster	SE	Qtr.	0	
33	Sheboygan R. at Esslingen Park	SE	Mon.	14	1.98
34	Chippewa R. at Chippewa Falls	WC	Qtr.	0	
35	Chippewa R. at Durand	WC	Mon.	11	2.50
36	Red Cedar R. at Menomonie	WC	Mon.	0	
37	La Crosse R. near Mouth	WC	Mon.	0	
38	Trempealeau R. at Dodge	WC	Mon.	0	
39	Black R. at Galesville (Hwy 53)	WC	Mon.	14	2.52
40	Mississippi R. at LD 3	WC	Qtr.	16	3.61
41	Mississippi R. at LD 4	WC	Qtr.	15	1.50
42	Wisconsin R. at Biron	WC	Mon.	0	

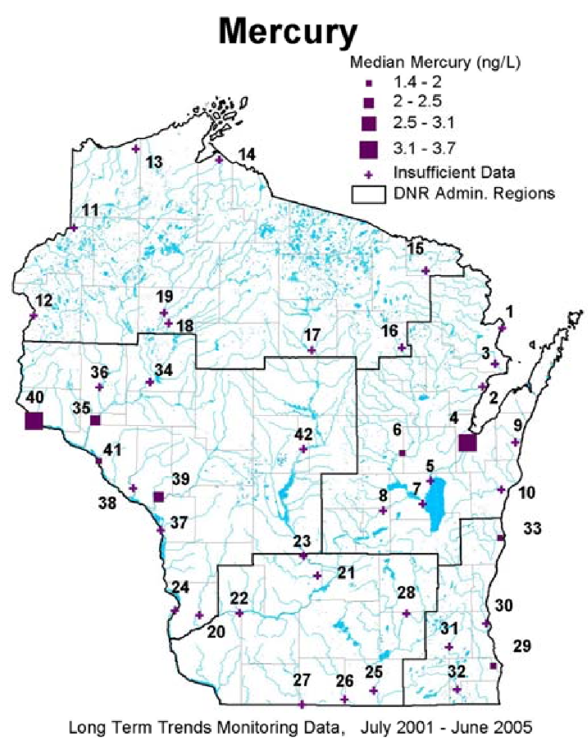
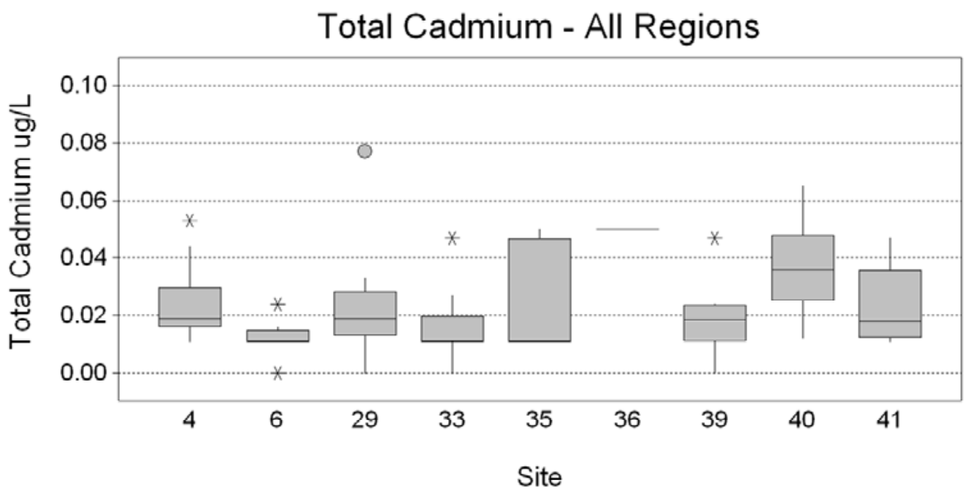


Figure 26. Total mercury concentrations at Wisconsin's long term trends sites.



Site No.	Site Description	Region	Sample Freq.	N	Median ug/L
1	Menominee R. at McAllister	NE	Qtr.	0	
2	Oconto R. at Oconto	NE	Qtr.	0	
3	Peshtigo R. at Peshtigo	NE	Qtr.	0	
4	Fox R. at DePere	NE	Mon.	13	0.019
5	Fox R. at Neenah and Menasha	NE	Mon.	0	
6	Wolf R. at New London	NE	Mon.	13	0.011
7	Fox R. at Oshkosh	NE	Mon.	0	
8	Fox R. at Berlin	NE	Qtr.	0	
9	Kewaunee R. at Kewaunee	NE	Qtr.	0	
10	Manitowoc R. at Manitowoc	NE	Qtr.	0	
11	St. Croix R. at Danbury	NO	Qtr.	1	
12	St. Croix R. at St. Croix Falls	NO	Qtr.	1	
13	Bois Brule R. at Brule	NO	Qtr.	0	
14	Bad R. at Odanah	NO	Qtr.	0	
15	Popple R. at Fence	NO	Mon.	3	0.006
16	Wolf R. at Langlade	NO	Mon.	1	
17	Wisconsin R. at Merril	NO	Mon.	2	
18	Flambeau R. at Bruce	NO	Qtr.	0	
19	Chippewa R. at Bruce	NO	Qtr.	0	
20	Kickapoo R. at Stueben	WC	Mon.	0	
21	Baraboo R. at Rowley Creek Br.	SC	Mon.	0	
22	Wisconsin R. at Muscoda	SC	Mon.	0	
23	Wisconsin R. at Wisconsin Dells	SC	Mon.	2	
24	Mississippi R. at LD 9	WC	Mon.	0	
25	Rock R. at Afton	SC	Mon.	2	
26	Sugar R. at Broadhead	SC	Mon.	0	
27	Pecatonica R. at Martintown	SC	Mon.	0	
28	Rock R. at Watertown	SC	Mon.	0	
29	Root R. at Johnson Park	SE	Mon.	12	0.019
30	Milwaukee R. at Estabrook Park	SE	Qtr.	0	
31	Fox (IL) R. below Waukesha	SE	Qtr.	0	
32	Fox (IL) R. near New Munster	SE	Qtr.	0	
33	Sheboygan R. at Esslingen Park	SE	Mon.	16	0.011
34	Chippewa R. at Chippewa Falls	WC	Qtr.	1	
35	Chippewa R. at Durand	WC	Mon.	14	0.011
36	Red Cedar R. at Menomonie	WC	Mon.	4	0.050
37	La Crosse R. near Mouth	WC	Mon.	0	
38	Trempealeau R. at Dodge	WC	Mon.	0	
39	Black R. at Galesville (Hwy 53)	WC	Mon.	14	0.019
40	Mississippi R. at LD 3	WC	Qtr.	17	0.036
41	Mississippi R. at LD 4	WC	Qtr.	16	0.018
42	Wisconsin R. at Biron	WC	Mon.	0	

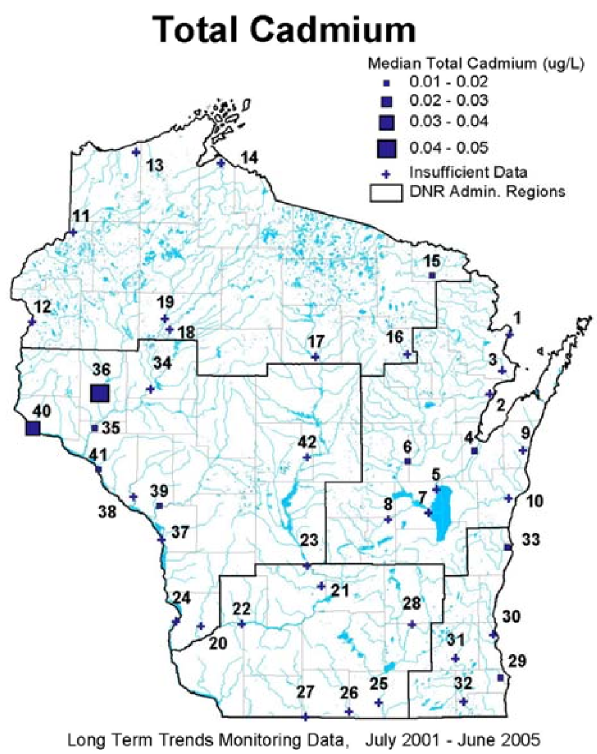
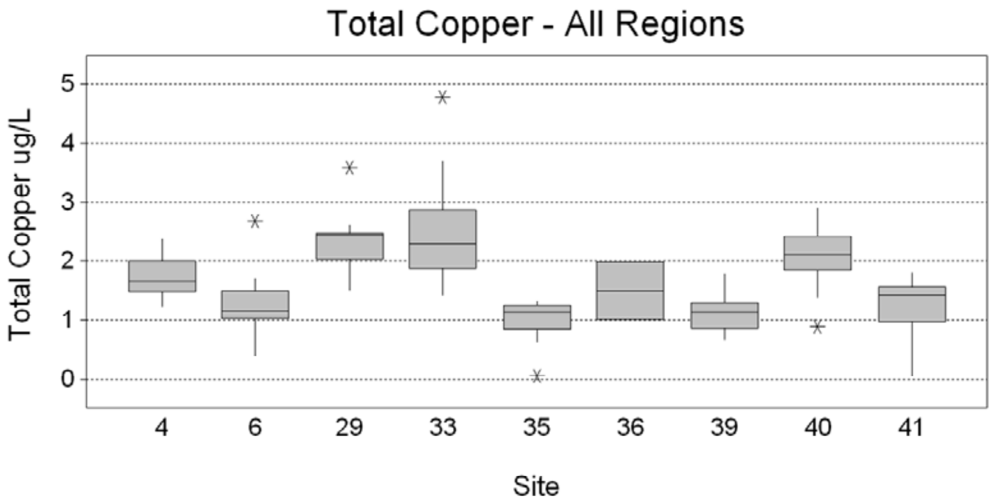


Figure 27. Total cadmium concentrations at Wisconsin's long term trends sites.

Copper

Total recoverable copper was sampled multiple times at nine stations. The highest median concentrations were observed in the Root River (Site 29) and the Sheboygan River (Site 33) (Figure 28). All values were well below the chronic toxicity criteria for total recoverable copper of 6,580 ug/L using the conservative hardness value of 50 mg/L (ch. NR 105.06, Wis. Adm. Code). Copper is the metal most often requiring water quality based effluent limits in wastewater permits (James Schmidt, WDNR, Pers. Comm.).

Chippewa River near Jim Falls, Wisconsin (Ken Schreiber)



Site No.	Site Description	Region	Sample Freq.	N	Median ug/L
1	Menominee R. at McAllister	NE	Qtr.	0	
2	Oconto R. at Oconto	NE	Qtr.	0	
3	Peshtigo R. at Peshtigo	NE	Qtr.	0	
4	Fox R. at DePere	NE	Mon.	8	1.67
5	Fox R. at Neenah and Menasha	NE	Mon.	0	M
6	Wolf R. at New London	NE	Mon.	8	1.15
7	Fox R. at Oshkosh	NE	Mon.	0	
8	Fox R. at Berlin	NE	Qtr.	0	
9	Kewaunee R. at Kewaunee	NE	Qtr.	0	
10	Manitowoc R. at Manitowoc	NE	Qtr.	0	
11	St. Croix R. at Danbury	NO	Qtr.	1	
12	St. Croix R. at St. Croix Falls	NO	Qtr.	1	
13	Bois Brule R. at Brule	NO	Qtr.	0	
14	Bad R. at Odanah	NO	Qtr.	0	
15	Popple R. at Fence	NO	Mon.	2	
16	Wolf R. at Langlade	NO	Mon.	1	
17	Wisconsin R. at Merril	NO	Mon.	1	
18	Flambeau R. at Bruce	NO	Qtr.	0	
19	Chippewa R. at Bruce	NO	Qtr.	0	
20	Kickapoo R. at Stueben	WC	Mon.	0	
21	Baraboo R. at Rowley Creek Br.	SC	Mon.	0	
22	Wisconsin R. at Muscoda	SC	Mon.	0	
23	Wisconsin R. at Wisconsin Dells	SC	Mon.	2	
24	Mississippi R. at LD 9	WC	Mon.	0	
25	Rock R. at Afton	SC	Mon.	1	
26	Sugar R. at Broadhead	SC	Mon.	0	
27	Pecatonica R. at Martintown	SC	Mon.	0	
28	Rock R. at Watertown	SC	Mon.	0	
29	Root R. at Johnson Park	SE	Mon.	10	2.45
30	Milwaukee R. at Estabrook Park	SE	Qtr.	0	
31	Fox (IL) R. below Waukesha	SE	Qtr.	0	
32	Fox (IL) R. near New Munster	SE	Qtr.	0	
33	Sheboygan R. at Esslingen Park	SE	Mon.	12	2.30
34	Chippewa R. at Chippewa Falls	WC	Qtr.	1	
35	Chippewa R. at Durand	WC	Mon.	12	1.15
36	Red Cedar R. at Menomonie	WC	Mon.	4	1.50
37	La Crosse R. near Mouth	WC	Mon.	0	
38	Trempealeau R. at Dodge	WC	Mon.	0	
39	Black R. at Galesville (Hwy 53)	WC	Mon.	11	1.14
40	Mississippi R. at LD 3	WC	Qtr.	13	2.12
41	Mississippi R. at LD 4	WC	Qtr.	13	1.43
42	Wisconsin R. at Biron	WC	Mon.	0	

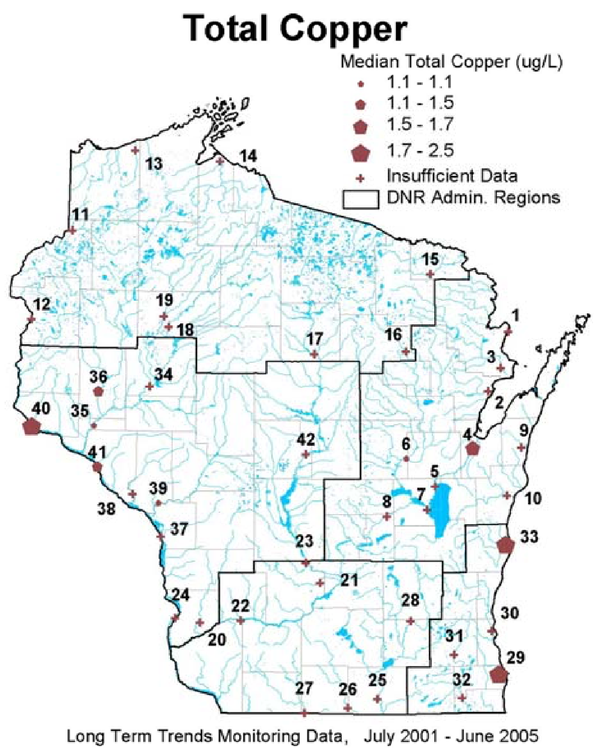


Figure 28. Total copper concentrations at Wisconsin's long term trends sites.

Summary and Conclusions

Wisconsin DNR has been monitoring water quality in rivers and streams throughout the State for more than 30 years. Site locations, sampling frequency and water quality measurements have changed over time due to funding constraints, program priorities and changing staff work assignments. The primary criterion for selecting monitoring sites was to provide broad statewide coverage to characterize the varied hydrology, geology and land use/cover of Wisconsin's river basins. The purpose of this monitoring effort is to provide information for assessing water quality conditions, changes with time (trends), point and non point source pollution impact evaluations, water quality-based permits and other water resource management needs.

In 2001, the Long Term Trends Water Quality Monitoring program for rivers was revised and efforts were implemented to re-establish a network of stations throughout the state. This report describes changes to the monitoring program, results of recent monitoring efforts, program evaluation and recommendations to improve the monitoring program. This monitoring program evaluation covers the four year period from July 2001 to June 2005.

A network of 42 monitoring sites was established on rivers throughout the state with roughly half sampled monthly and the rest quarterly during winter, spring, summer and autumn seasons. Field measurements typically included dissolved oxygen, temperature and pH. Water samples were sent to the Wisconsin State Laboratory of Hygiene in Madison, Wisconsin for chemical analysis including nutrients, solids, heavy metals, bacteria, chlorophyll, triazine herbicides and other water quality measurements. This monitoring effort resulted in the collection of approximately 1000 samples during the four year assessment period. In order to simplify the assessment, water quality data for each site were considered in aggregate and not evaluated on a seasonal basis. Monitoring data were grouped by WDNR administrative regions to facilitate a broad comparison between different geographic areas of the State.

Water quality in Wisconsin's rivers differed noticeably between DNR Administrative Regions and sometimes within these geographic areas. These differences in quality were related to major changes in land use/cover, bedrock geology, topography and major point source inputs (urban areas) and other factors. In particular, the percentage of land cover in agriculture land was a dominant factor affecting stream water quality. In general, total suspended solids, phosphorus, nitrogen and bacteria levels increased as the percentage of agricultural land cover increased. In contrast, rivers draining the heavily forested watersheds in Northern and Northeast Wisconsin usually exhibited very good water quality with low concentrations of these pollutants. Monitoring sites below the large urban areas in the Southeast generally had elevated concentrations of chloride, heavy metals, nitrite+nitrate nitrogen and were attributed to increased point source pollutant contributions and nonpoint source urban runoff.

We found few exceedances of Wisconsin's water quality standards. The only exception was mercury, which exceeded the wildlife criterion of 1.3 ng/L in about 70% of the samples collected, though sampling for this metal was limited to about a dozen sites. Median fecal coliform concentrations in some rivers were high (> 300 counts/100 ml) in the Baraboo, Sugar and Trempealeau Rivers in South Central and West Central Wisconsin. However, bacteria sampling could not be directly tied to standards for recreational use because this monitoring program had insufficient sampling frequency for evaluating standards. The high fecal coliform levels found in these streams suggest that site specific evaluations may be warranted to assess compliance with the recreational use standards.

High levels of nutrients in slow moving impounded river systems with low total suspended solid concentrations revealed high concentrations of algae (chlorophyll a) which contributed to elevated pH, especially in soft waters with low alkalinity. Chlorophyll a levels were significantly correlated to total phosphorus and followed a similar relationship found in Minnesota's rivers.

Wisconsin River at Mosinee Flowage. (John Sullivan).

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