Prepared in cooperation with the Milwaukee Metropolitan Sewerage District

Use of Real-Time Monitoring to Predict Concentrations of Select Constituents in the Menomonee River Drainage Basin, Southeast Wisconsin, 2008–9

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U.S. Department of the Interior
U.S. Geological Survey

Cover. Water-quality sonde deployment at Underwood Creek at Wauwatosa, Wisconsin, October 27, 2009. (Photograph by Austin K. Baldwin, U.S. Geological Survey.)

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Conversion Factors and Abbreviations

Inch/Pound to SI

Multiply	By	To obtain
	Length	
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
	Area	
square mile (mi^2)	2.590	square kilometer (km^2)
	Flow rate	
cubic foot per second (ft^3/s)	0.02832	cubic meter per second (m^3/s)

Temperature in degrees Celsius (°C) may be converted to degrees Fahrenheit (°F) as follows:
°F=(1.8×°C)+32

Horizontal coordinate information is referenced to the Wisconsin Transverse Mercator (WTM) Projection and the North American Datum of 1983 (NAD 83), with 1991 adjustment.

Concentrations of chemical constituents in water are given in milligrams per liter (mg/L), micrograms per liter (µg/L), most probable number per 100 milliliters (MPN/100 mL), or colony forming units per 100 milliliters (CFU/100 mL).

Abbreviations used in this report

ADCP	acoustic Doppler current profiler
EPA	U.S. Environmental Protection Agency
EWI	equal-width increment
MLR	multiple linear regression
MMSD	Milwaukee Metropolitan Sewerage District
MSPE	model standard percent error
NTU	nephelometric turbidity units
NWIS	National Water Information System
PRESS	prediction error sum of squares
PVC	polyvinyl chloride
QA/QC	quality assurance/quality control
RMSE	root-mean-squared error
RPD	relative percent difference
SLR	simple linear regression
SSE	sum of squared error
USGS	U.S. Geological Survey

Use of Real-Time Monitoring to Predict Concentrations of Select Constituents in the Menomonee River Drainage Basin, Southeast Wisconsin, 2008–9

By Austin K. Baldwin,[1] David J. Graczyk,[1] Dale M. Robertson,[1] David A. Saad,[1] and Christopher Magruder[2]

Abstract

The Menomonee River drainage basin in southeast Wisconsin is undergoing changes that may affect water quality. Several rehabilitation and flood-management projects are underway, including removal of concrete channels and the construction of floodwater retention basins. The city of Waukesha may begin discharging treated wastewater into Underwood Creek, thus approximately doubling the current base-flow discharge. In addition, the headwater basins, historically dominated by agriculture and natural areas, are becoming increasingly urbanized.

In an effort to monitor these and future changes to the basin, the U.S. Geological Survey and the Milwaukee Metropolitan Sewerage District initiated a study in 2008 to develop regression models to estimate real-time concentrations and loads of selected water-quality constituents. Water-quality sensors and automated samplers were installed at five sites in the Menomonee River drainage basin. The sensors continuously measured four explanatory variables: water temperature, specific conductance, dissolved oxygen, and turbidity. Discrete water-quality samples were collected and analyzed for five response variables: chloride, total suspended solids, total phosphorus, *Escherichia coli* bacteria, and fecal coliform bacteria. Regression models were developed to continuously estimate the response variables on the basis of the explanatory variables.

The models to estimate chloride concentrations all used specific conductance as the explanatory variable, except for the model for the Little Menomonee River near Freistadt, which used both specific conductance and turbidity as explanatory variables. Adjusted R^2 values for the chloride models ranged from 0.74 to 0.97. Models to estimate total suspended solids and total phosphorus used turbidity as the only explanatory variable. Adjusted R^2 values ranged from 0.77 to 0.94 for the total suspended solids models and from 0.55 to 0.75 for the total phosphorus models. Models to estimate indicator bacteria used water temperature and turbidity as the explanatory variables, with adjusted R^2 values from 0.54 to 0.69 for *Escherichia coli* bacteria models and from 0.54 to 0.74 for fecal coliform bacteria models. Dissolved oxygen was not used in any of the final models. These models may help managers measure the effects of land-use changes and improvement projects, establish total maximum daily loads, estimate important water-quality indicators such as bacteria concentrations, and enable informed decision making in the future.

Introduction

Increasingly, real-time water-quality monitors are being used to estimate continuous concentrations of water-quality constituents. Certain water-quality constituents, such as bacteria concentrations, cannot easily be measured in real-time because of limitations in cost and sensor technology. However, studies have demonstrated that water-quality constituents can be estimated based on more easily measured surrogates, such as water temperature and turbidity (Christensen and others, 2000; Rasmussen and others, 2005). Using surrogates allows for continuous concentration estimates of the constituent(s) of interest and, when combined with discharges, constituent loads.

There are several advantages of load estimation with continuous concentration over traditional constituent load estimation methods. Traditional studies rely heavily on discrete sampling, which provides only snapshots of water-quality concentrations; therefore, the vast majority of the water-quality record is entirely unknown and must be estimated. Traditional estimation methods, such as the Graphical Constituent Loading Analysis System (Koltun and others, 2006), can be subjective, and results can vary from one estimate to the next. Daily, monthly, and annual fluctuations in concentrations, as well as concentration changes during a storm event, may not be accurately described. By providing a continuous record (for example, measurements every 5 minutes) of surrogates, real-time monitoring captures the variability in water-quality concentrations and reduces estimation errors associated with methods that do not use real-time data.

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In November 2008, the U.S. Geological Survey (USGS) and the Milwaukee Metropolitan Sewerage District (MMSD) began a cooperative study to develop regression models to estimate continuous real-time concentrations of selected water-quality constituents. Continuous real-time sensors and water-quality samplers were installed at five sites in the Menomonee River drainage basin. The real-time sensors measured four explanatory variables as surrogates: water temperature, turbidity, dissolved oxygen, and specific conductance. Discrete water-quality samples were collected for a range of streamflows and seasons and were analyzed for five response variables: chloride, total suspended solids, total phosphorus, *Escherichia coli* (*E. coli*) bacteria, and fecal coliform bacteria. A set of concurrently measured explanatory variables was used to develop regression equations for each of the response variables. These regressions between explanatory and response variables were then used to calculate continuous estimates of each of the water-quality constituents of interest.

Real-time water-quality information can be beneficial in public and ecosystem health management and facilitate water-resource management. For example, managers can use real-time estimates of chloride to determine if elevated levels are toxic to aquatic organisms (Corsi and others, 2010). Real-time estimates can be used for public health notices, such as whether fecal coliform concentrations may be above water-quality standards that may present public health risks (Francy and Darner, 2007). Real-time concentration estimates in conjunction with stream discharge data can be used to calculate loads of water-quality constituents of interest. Load estimates can then be used in the development of total maximum daily loads (TMDLs). Long-term continuous monitoring of surrogate explanatory variables and estimation of water-quality constituents may be used to evaluate the effects of land-use changes, improvement projects, and implementation of best-management practices.

Purpose and Scope

The purpose of this report is to describe the process used to create regression models to estimate real-time concentrations and loads of selected water-quality constituents based on data from real-time water-quality monitors. The regression models presented in this report may help provide MMSD with a means to document improvements in water quality related to capital projects, assist with basin planning efforts, and provide water-quality information to communities served by MMSD and the general public.

Description of the Study Area

The Menomonee River Basin drains 146 square miles (mi^2) in southeast Wisconsin (fig. 1). The basin is within the MMSD planning and service area and includes parts of Milwaukee, Waukesha, Ozaukee, and Washington Counties. The largest tributaries within the basin include Underwood Creek, Honey Creek, and the Little Menomonee River. The Menomonee River joins the Milwaukee and Kinnickinnic Rivers to form the Milwaukee estuary in Lake Michigan near downtown Milwaukee.

The Menomonee River drainage basin is currently (2007) 64 percent urban, an increase from 51 percent urban in 1970 (Southeastern Wisconsin Regional Planning Commission, 2007). Although the northern third of the basin is dominated by agriculture (fig. 1*B*), the area has experienced recent urban growth. Between 1990 and 2000, the population in the basin remained nearly stable at 322,000, although the number of households rose by 3.5 percent (Southeastern Wisconsin Regional Planning Commission, 2007).

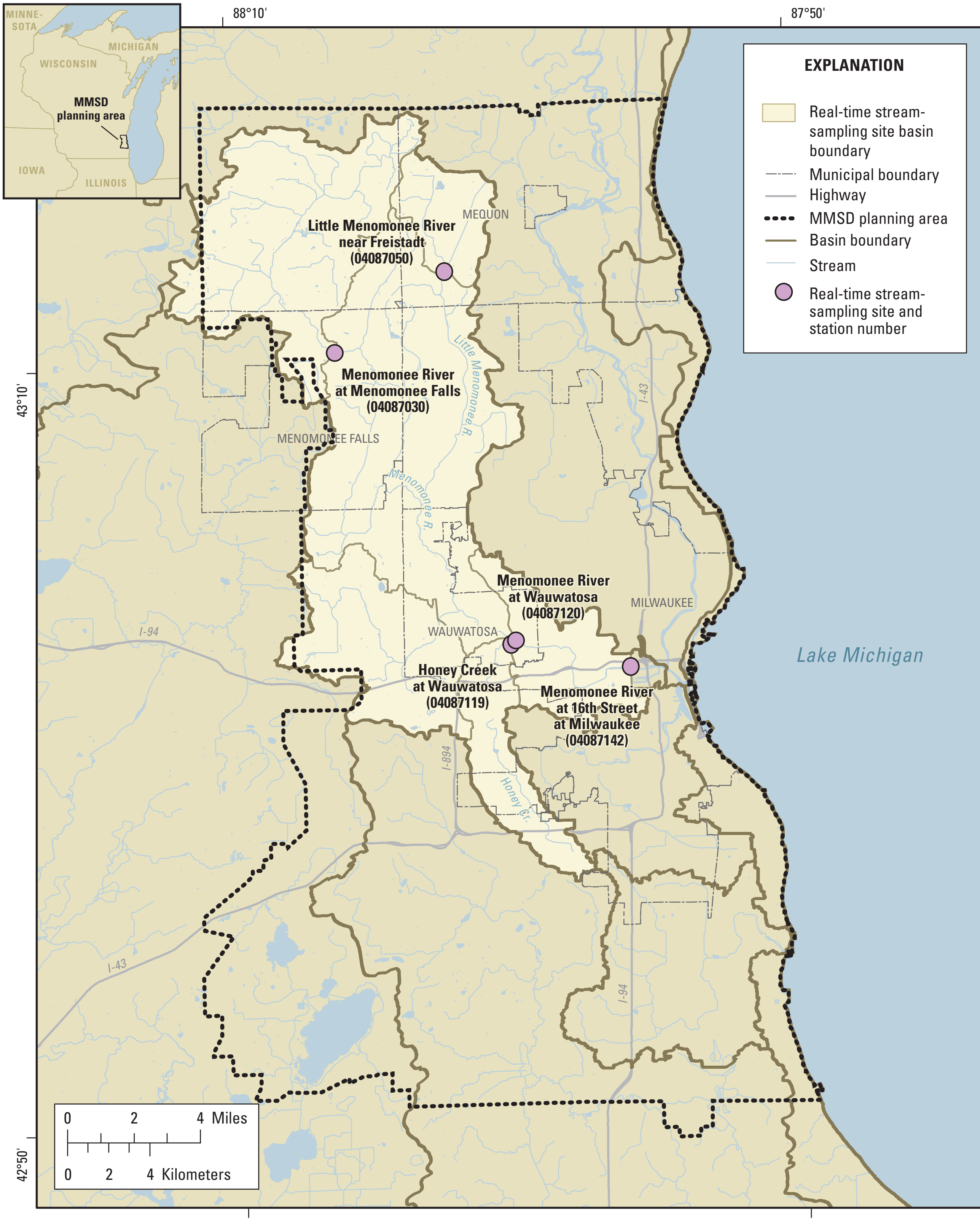
Five sites within the basin were monitored and sampled as part of this study: the Little Menomonee River near Freistadt, the Menomonee River at Menomonee Falls, Honey Creek at Wauwatosa, the Menomonee River at Wauwatosa, and the Menomonee River at Milwaukee (fig. 1). General basin characteristics upstream of these sites, including land use, are listed in table 1. The basin with the smallest urban area is the Little Menomonee River (20 percent); the basin with the largest urban area is Honey Creek (96 percent).

Data Collection

Data for the regression model development were collected from November 2008 to September 2009. Types of data collected included continuous real-time data and discrete water-quality samples. Quality assurance/quality control (QA/QC) samples were collected, as well.

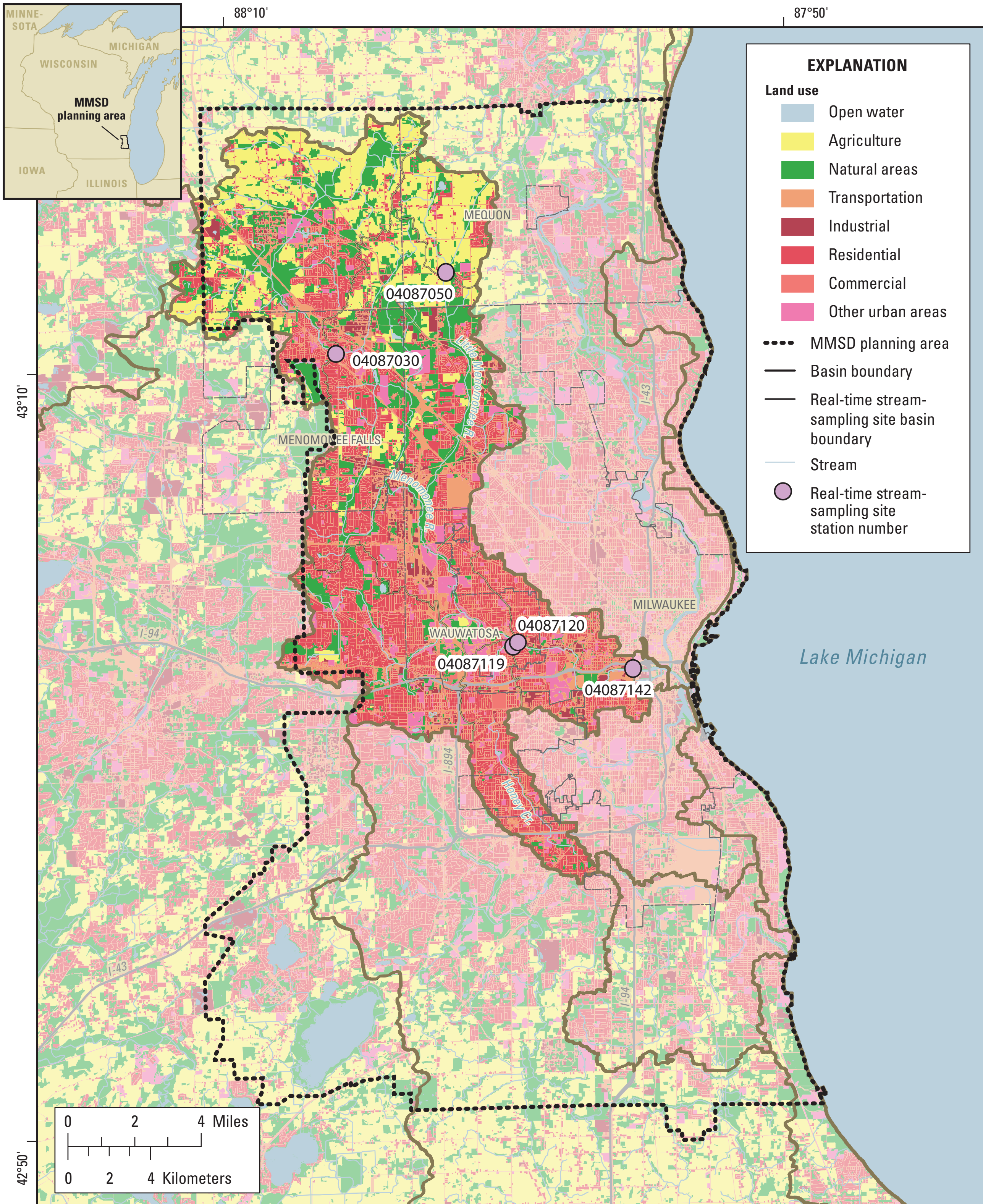
Continuous Real-Time Data

At four of the five sites, stream stage was measured every 5 minutes and was used to calculate stream discharge (Rantz and others, 1982). These four sites are the Menomonee River at Menomonee Falls, Little Menomonee River, Honey Creek, and Menomonee River at Wauwatosa. Stream stages were measured by a gas-purge-pressure system and recorded on a datalogger. Discharge measurements at these sites were made according to standard USGS methods (Turnipseed and Sauer, 2010) every 4 to 6 weeks and more frequently during high flows to define the stage-discharge relation for each site. At the fifth site, the Menomonee River at Milwaukee (16^{th} Street), an acoustic Doppler current profiler (ADCP) was installed to measure water velocities because this site is affected by backwater and seiche effects from Lake Michigan. Water velocities and the cross-sectional area were used to determine the discharge at this site (Laenen, 1985; Oberg and others, 2005; Ruhl and Simpson, 2005).



Base composited from Southeastern Wisconsin Regional Planning Commission regional base map, 1:2,000, 1995; U.S. Geological Survey digital line graph hydrography, 1:100,000, 1989; Wisconsin Department of Natural Resources minor civil divisions, 1:100,000, 1998; Wisconsin Department of Natural Resources state trunk highways, 1:100,000, 1998; Wisconsin Department of Natural Resources version 2 hydrography, 1:24,000, 2002. Wisconsin Transverse Mercator Projection, referenced to North American Datum of 1983, 1991 adjustment.

Figure 1*A*. Location of real-time water-quality monitoring sites and drainage basins in the Menomonee River Basin. Dotted line demarcates the Milwaukee Metropolitan Sewerage District (MMSD) planning area.



Base composited from Southeastern Wisconsin Regional Planning Commission digital land use inventory, 1:4,800, 2000; Southeastern Wisconsin Regional Planning Commission regional base map, 1:2,000, 1995; U.S. Geological Survey digital line graph hydrography, 1:100,000, 1989; Wisconsin Department of Natural Resources version 2 hydrography, 1:24,000, 2002. Wisconsin Transverse Mercator Projection, referenced to North American Datum of 1983, 1991 adjustment.

Figure 1*B*. Location of real-time water-quality monitoring sites and land use in the Menomonee River Basin. Dotted line demarcates the Milwaukee Metropolitan Sewerage District (MMSD) planning area.

Table 1. Basin characteristics of monitoring sites, Menomonee River Basin, Southeast Wisconsin.

[Periods of record for annual mean discharge range from 4 years at Menomonee River at 16th Street (2008 to present) to 51 years at Menomonee River at Wauwatosa (1961 to present). Land use percentages are from 2007 (Southeastern Wisconsin Regional Planning Commission); USGS, U.S. Geological Survey; mi^2, square mile; ft^3/s, cubic foot per second]

Monitoring site	USGS station number	Drainage area (mi^2)	Annual mean discharge (ft^3/s)	Percent urban	Percent agriculture	Percent natural areas
Menomonee River at Menomonee Falls	04087030	34.7	31.5	35	38	27
Little Menomonee River near Freistadt	04087050	8.0	7.3	20	63	16
Honey Creek at Wauwatosa	04087119	10.3	11.4	96	0	4
Menomonee River at Wauwatosa	04087120	123.0	106.0	60	19	20
Menomonee River at 16th Street at Milwaukee	04087142	146.0	184.5	64	17	19

A multiparameter water-quality sonde was installed at each site in November 2008. Each sonde was equipped with an optical dissolved-oxygen sensor, an optical turbidity sensor, and a specific conductivity and temperature sensor. The sonde was installed in a polyvinyl chloride (PVC) tube in a fixed position in the stream, and water-quality measurements were made every 5 minutes. Sonde maintenance, data correction, and reporting procedures followed standard USGS protocol (Wagner and others, 2006). Sites were visited approximately every 2 weeks during the open-water period (March through November) and monthly in the winter when the streams were usually ice covered. Extensive fouling at some sites during the summer necessitated weekly visits.

Continuous monitoring data for use in the regression models was downloaded from the USGS National Water Information System database on January 25, 2010. For most sites and water-quality measurements, the continuous monitoring record was at least 95 percent complete (table 2). Reasons for missing records include equipment malfunctions, flood damage to equipment, and excessive fouling. The quality of the continuous monitoring data was rated according to criteria outlined in Wagner and others (2006). This rating scheme is based on the combined fouling and calibration drift corrections applied to the data. For example, specific conductance data are considered excellent if the combined fouling and drift corrections are less than or equal to +/– 3 percent of the specific conductance value. The quality of the continuous monitoring data was mostly considered good to excellent, but varied substantially by site and water-quality measurements. The water temperature record was considered excellent at all five sites. The percentage of the specific conductance record rated as either good or excellent ranged from 77 percent at Honey Creek to 96 percent at the Little Menomonee River and the Menomonee River at Wauwatosa. The percentage of the dissolved oxygen record rated as either good or excellent ranged from 67 percent at the Menomonee River at Menomonee Falls to 95 percent at Honey Creek. The percentage of the turbidity record rated as either good or excellent ranged from 48 percent at Honey Creek to 82 percent at the Little Menomonee River. For dissolved oxygen, turbidity, specific conductivity, and temperature, the measured values were within the ranges of sensor operation.

Table 2. Water-quality sonde ratings (as percentages of the record) at the continuous water-quality monitoring sites in the Menomonee River drainage basin, Southeast Wisconsin.

[Ratings based on criteria outlined in Wagner and others, 2006, table 18]

	Excellent	Good	Fair	Poor or missing
Menomonee River at Menomonee Falls, WI 04087030				
Water temperature	99	0	0	1
Specific conductance	50	45	5	1
Dissolved oxygen	43	24	10	24
Turbidity	73	5	0	23
Little Menomonee River near Freistadt, WI 04087050				
Water temperature	99	0	0	1
Specific conductance	64	32	0	5
Dissolved oxygen	48	24	19	9
Turbidity	68	14	0	18
Honey Creek at Wauwatosa, WI 04087119				
Water temperature	95	0	0	5
Specific conductance	68	9	3	20
Dissolved oxygen	85	10	1	4
Turbidity	35	13	14	39
Menomonee River at Wauwatosa, WI 04087120				
Water temperature	95	0	0	5
Specific conductance	82	14	2	2
Dissolved oxygen	75	10	8	7
Turbidity	32	21	13	34
Menomonee River at 16th Street at Milwaukee, WI 04087142				
Water temperature	99	0	0	1
Specific conductance	78	11	5	6
Dissolved oxygen	71	15	8	6
Turbidity	57	12	8	23

Continuous in-stream water-quality monitor data were compared to cross-sectional data at the monitor location to determine if the continuous data were representative of the water-quality conditions across the stream. Four to five cross-sectional surveys were conducted at each site during both base-flow and stormflow conditions. The cross-sectional surveys show that the streams at all sites are generally well mixed, with no consistent differences from one side of the channel to the other. No corrections were made to the continuous water-quality monitor record. Continuous streamflow and water-quality data are available at the USGS Web site at *http://waterdata.usgs.gov/wi/nwis* (accessed February 2012).

Discrete Water-Quality Samples

Each site was equipped with a stage-activated, refrigerated automated sampler for the collection of water samples over a full range of hydrologic conditions. These samplers were controlled using dataloggers that were programmed to collect a sample with each 0.5 foot (ft) increase in stage once the stage reached an initial sampling threshold. The initial sampling threshold varied at each site and changed seasonally. After the stage peaked, samples were collected with each 1.0 ft decrease in stage. This sampling strategy was designed to maximize the number of samples collected during each event and to collect more samples on the rising limb of the hydrograph when water-quality constituents typically change the most. At the Menomonee River at 16th Street, the sampler was activated by turbidity rather than stage because of backwater and reverse flows from the seiche effects of Lake Michigan. Once the turbidity reached a predefined threshold, sampling would begin, and samples would be collected at set time intervals until the turbidity dropped below the threshold. The turbidity threshold was changed as needed depending on current turbidity and season.

For most sites and constituents (chloride, total suspended solids, total phosphorus, *E. coli* bacteria, and fecal coliform bacteria), between 50 and 100 samples were collected and analyzed. At some of the sites between one and four samples were not used in the final regression models because of fouling on the water-quality meter. Fewer samples were collected at the Little Menomonee River: 39 samples for chloride, total suspended solids, and total phosphorus; 37 samples for *E. coli* bacteria; and 32 samples for fecal coliform bacteria. The Little Menomonee River site is the most rural of the sampling sites and high-flow events were less frequent. Christensen and others (2000) found that 35 to 55 samples, collected throughout 90 to 95 percent of the stream's flow duration, were sufficient to define relations between constituents and surrogates for two Kansas streams.

The distribution of samples over the range of observed hydrologic conditions is at least as important in creating a regression model as is the total number of samples (Rasmussen and others, 2009). To evaluate whether the collected samples adequately represent the range of observed hydrologic conditions, the samples were plotted on duration curves of associated time-series data for each site and constituent. The turbidity duration curve in figure 2 was developed from 5-minute data from the Menomonee River at Menomonee Falls for the period from November 2008 to September 2010. The samples plotting on top of the curve are associated total suspended solids samples. The plot shows very good sample coverage for the observed turbidity values between 10 and 220 nephelometric turbidity units (NTU) and good coverage for turbidity values between 2 and 10 NTU. Duration curves showing sample coverage for all sites and constituents are provided in the appendixes.

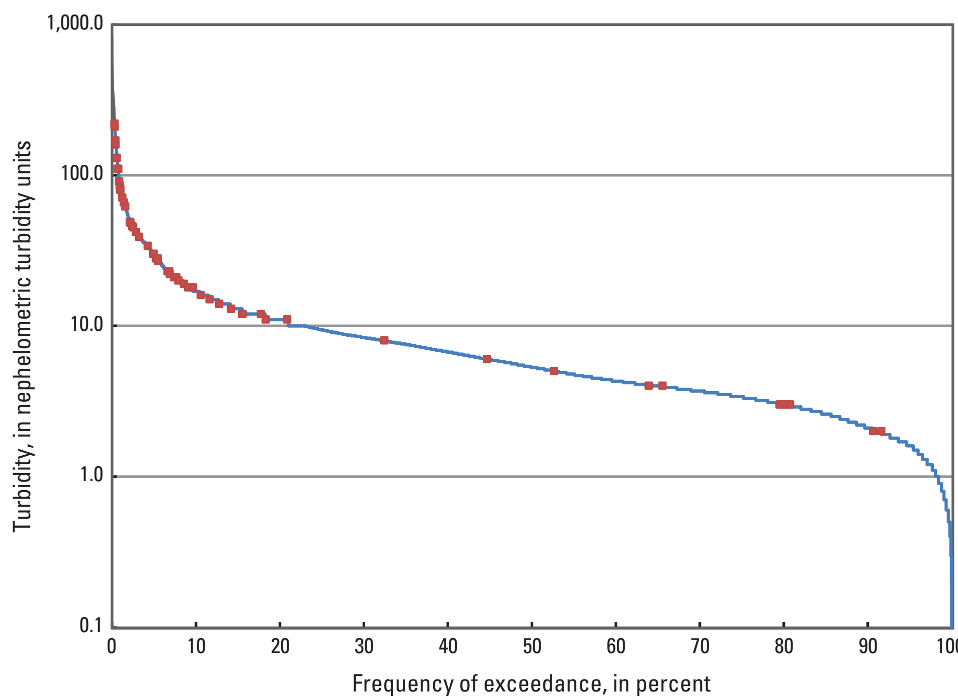


Figure 2. Turbidity duration curve developed from 5-minute data from November 2008 to September 2010, with associated samples used in the total suspended solids regression model, Menomonee River at Menomonee Falls, Wisconsin.

Quality Assurance/Quality Control

Quality-assurance and quality-control (QA/QC) samples collected during this study accounted for about 6 percent of the water-quality samples. Sampler blanks were collected at each site to check for sampler contamination by pumping Milli-Q® water through the entire sample line and into a sample bottle. The sample was split into bottles and analyzed at the MMSD laboratory. None of the constituents had concentrations above the detection limit except for one total suspended solids sample that had a concentration of 2.8 milligrams per liter (mg/L). Splitter blanks were also collected to check for contamination from the sample processing equipment. The splitter blanks were collected by running Milli-Q water through a decaport sample splitter, then collecting and analyzing that water. All of the constituents analyzed for the splitter blanks were below the detection limit.

Multiple pairs of concurrent automated sampler and equal-width-increment (EWI) samples were collected at each site to evaluate whether the automated sampler samples were chemically and physically representative of the stream cross section. The EWI sampling method is designed to accurately represent the discharge-weighted concentrations of the stream (Edwards and Glysson, 1999). Relative percent differences (RPDs) were calculated between the EWI and automated sampler sample concentrations. Median RDPs for chloride, total suspended solids, and total phosphorus were all less than 10 percent. Median RDPs for fecal coliform bacteria and *E. coli* bacteria were 36 and 18 percent, respectively. The higher variability in the bacteria samples may be the result of rapidly changing flows in these urban basins and the inherent variability of bacteria concentrations in the stream. No corrections were applied on the basis of the EWI results.

Preparation and analysis of the water samples were performed by the MMSD laboratory. The preparatory steps included dividing samples into representative subsamples using a splitting device developed for aqueous matrices and preserving the subsamples according to U.S. Environmental Protection Agency (EPA) protocols. The subsamples were analyzed for chloride, total suspended solids, total phosphorus, and *E. coli* and fecal coliform bacteria. The analytical methods used by MMSD are based on procedures described by the U.S. Environmental Protection Agency (1993) or by Clesceri and others (1998). Specific procedure references are listed in appendix 1. The MMSD follows extensive QA/QC guidelines set forth in the 2003 National Environmental Laboratory Accreditation Conference NELAC Standard (National Environmental Laboratory Accreditation Conference, 2003).

Regression Model Development

Simple and multiple linear regression (SLR and MLR) models were developed to estimate chloride, total suspended solids, total phosphorus, *E. coli* bacteria, and fecal coliform bacteria by using continuous in-stream temperature, specific conductance, dissolved oxygen, and turbidity sensor measurements. These models were used to calculate continuous (5-minute) estimates of chloride, total suspended solids, total phosphorus, *E. coli bacteria*, and fecal coliform bacteria suitable for evaluating exceedance criteria in the sampled streams. A detailed description of the process used to develop the regression models using continuously measured sensor data can be found in Rasmussen and others (2009). A brief description of the methods used for this study follows.

Regression models were developed using a two-step approach: (1) initial model development and (2) final model selection. Initial regression models were developed for each of the response variables by using stepwise regression with all of the continuous in-stream sensor measurements as explanatory variables. Initial models were developed with $\log_{10}$-transformed response variables. Untransformed and $\log_{10}$-transformed explanatory variables, as well as seasonal variables (sine Julian day and cosine Julian day), were considered during model development by using the SAS software PROC REG command (SAS Institute Inc., 2004). An alpha value of 0.05 was used for the stepwise selection (for both entry into and removal from the model). Final models were selected manually and typically included a subset of the explanatory variables chosen during initial model development. Considerations for selecting the final models included (1) simplicity of the model (preference for fewer variables), (2) consistency between models (preference for a consistent set of variables), and (3) similar fit and explanatory power as the initial model while including considerations (1) and (2). For example, in the initial models for total suspended solids, one of the five models found sine Julian day to be a significant variable, and another model found water temperature to be significant. Because each of these variables was found to be significant in only one of the five models and because they lacked explanatory power, both of these variables were omitted from the final regression models.

Initial models used between one and six explanatory variables. All final models used one or two variables. Final models for chloride included specific conductance as the only explanatory variable, except for the Little Menomonee River model, which used both specific conductance and turbidity as explanatory variables. Final models for both total suspended solids and total phosphorus included turbidity as the only explanatory variable. Final models for *E. coli* and fecal coliform bacteria included both water temperature and turbidity as explanatory variables. Dissolved oxygen was not used in any of the final models. Although dissolved oxygen was significant in some of the initial models, it was not included in the final models to maintain simplicity and consistency between models, and because it lacked explanatory power.

Similar fit and explanatory power between the initial and final models were compared primarily using plots of observed versus computed values and the adjusted coefficient of determination (adj R^2). Plots of observed versus computed values appeared to have similar fit. Adj R^2 values of the final models were typically within 5 to 15 percent of the initial models. The adj R^2 and additional regression model statistics considered in model development are described in more detail below. Statistics and graphs describing the final models are included in the appendixes.

Regression models were evaluated for fit and explanatory power by using graphs and several measures of variance between computed and observed values. Plots of observed versus computed values were evaluated for fit relative to a 1:1 line and distribution across the range of observed values. Plots of residuals versus computed values, date, and a normal quantile distribution were evaluated for bias and normality. Measures of variance between computed and observed values used include the sum of squared errors (SSE), root-mean-squared error (RMSE), adjusted coefficient of determination (adj R^2), and prediction error sum of squares (PRESS). The SSE represents the total model error, and the RMSE is a measure of the average error between computed and observed values. The SSE and RMSE have the same units as the response variable. Smaller values of SSE and RMSE indicate better fit for a particular model. The model standard percent error (MSPE) is the RMSE expressed as a percentage and allows regression model comparison. The adj R^2 is adjusted for the number of explanatory variables in the model and represents the fraction of variability in the response variable that is explained by the model. Adj R^2 ranges from 0 to 1, where 1 represents 100 percent of variability explained. PRESS is a validation-type estimator of error based on regression with one observation left out of the regression and repeated for each observation.

All models developed in this study were based on $\log_{10}$-transformed response variables. Retransforming the computed values back into the original units introduces a bias because regression estimates are the mean of y given x in logarithmic units, and retransformation of these estimates is not equal to the mean of y given x in linear space. Therefore, the retransformation bias of these models was corrected by applying a bias correction factor (Duan, 1983). Bias correction factors for each model are included in the appendixes. Also provided in the appendixes are 90-percent prediction, or confidence, intervals. These confidence intervals can be used for evaluating uncertainty of the computed values. Smaller prediction intervals indicate less uncertainty associated with the computed value.

Regression Model Results

Chloride

Chloride occurs naturally in streams, but at high concentrations chloride poses a significant threat to aquatic ecosystems. According to the EPA, chronic chloride concentrations above 230 mg/L, and acute chloride concentrations above 860 mg/L, pose a potential threat to aquatic life (U.S. Environmental Protection Agency, 1988). Road-salt runoff, caused by melting snow and ice that contains road salt, is a common source of elevated chloride concentrations in urban areas. Samples collected from 7 of 13 streams in the Milwaukee area during road-salt runoff periods exhibited toxicity in bioassays (Corsi and others, 2010). Chloride increases the conductivity of water and is, therefore, directly related to specific conductivity (Christensen and others, 2000). The relation between chloride concentrations and specific conductivity should make specific conductivity an effective surrogate for estimating chloride concentrations in streams.

Chloride regression models for four of the five sites use specific conductance as the only explanatory variable, with adjusted R^2 values between 0.81 and 0.97 and RMSE values between 0.07 and 0.23 (table 3). The model for the fifth site, the Little Menomonee River, uses both specific conductance and turbidity as explanatory variables, with an R^2 of 0.74 and an RMSE of 0.1. Figure 3 is an example from the Honey Creek at Wauwatosa monitoring site, showing predicted chloride values with 90-percent confidence intervals as well as the measured chloride values used in the regression model. The model-calibration dataset, model summary, summary statistics, plots of the explanatory and response variables, and residual plots are provided in appendix 2.

Table 3. Regression models and summary statistics for estimating chloride concentrations in water at five water-quality monitoring sites in the Menomonee River Basin, Southeast Wisconsin, November 2008–September 2009.

[R^2, coefficient of determination; RMSE, root mean square error; PRESS, prediction error sum of squares; n, number of discrete samples; mg/L, milligrams per liter; SC, specific conductance, in microsiemens per centimeter at 25 degrees Celsius; CL, chloride, dissolved, in mg/L; Turb, turbidity, in nephelometric turbidity units]

Monitoring site	Regression model	Model diagnostics				Model inputs			
		Adjusted R^2	RMSE	PRESS	n	Range of values in variable measurements	Mean	Median	Standard deviation
Menomonee River at Menomonee Falls, Wis. 04087030	$Log_{10}CL = -1.63 + 1.28log_{10}(SC)$	0.94	0.07	0.32	59	CL 24–960 SC 252–3,700	171 960	120 784	167 643
Little Menomonee River near Freistadt, Wis. 04087050	$Log_{10}CL = -4.16 + 1.99log_{10}(SC) + 0.1511log_{10}(Turb)$	.74	.10	.38	39	CL 23–130 SC 384–1,123 Turb 0.7–290	54 698 72	50 676 46	26 192 78
Honey Creek at Wauwatosa, Wis. 04087119	$Log_{10}CL = -0.984 + 1.12log_{10}(SC)$	.81	.23	3.88	70	CL 11–1,700 SC 124–5,930	297 1,150	235 629	321 1,186
Menomonee River at Wauwatosa, Wis. 04087120	$Log_{10}CL = -1.41 + 1.23log_{10}(SC)$	.92	.12	1.35	101	CL 29–2,300 SC 235–6,890	334 1,429	190 970	418 1,295
Menomonee River at Milwaukee, Wis. 04087142	$Log_{10}CL = -1.50 + 1.26log_{10}(SC)$	.97	.07	.44	79	CL 18–1,400 SC 174–4,763	249 1,180	160 938	254 910

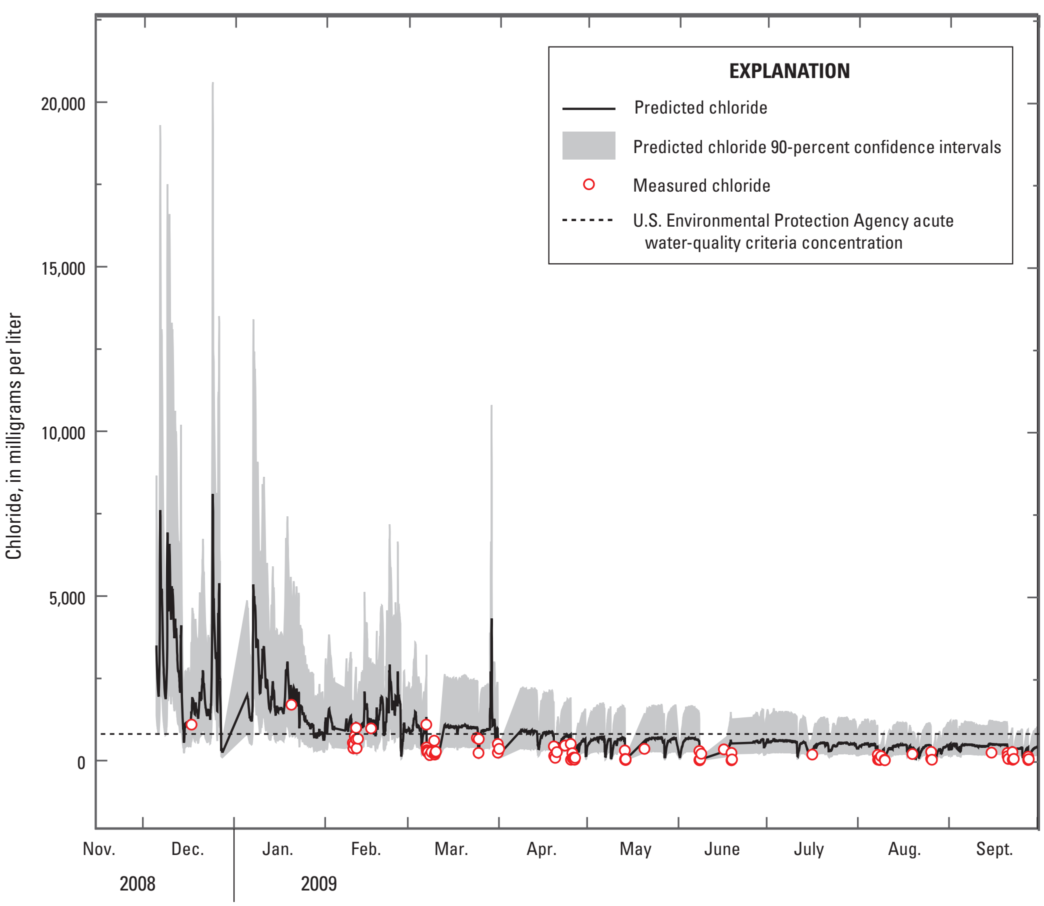


Figure 3. Predicted and measured chloride concentrations at the U.S. Geological Survey streamgage on Honey Creek at Wauwatosa, Wisconsin, December 2008–September 2009.

Total Suspended Solids

Total suspended solids are a combination of suspended sediment and organic matter. Because total suspended solids have numerous adverse effects on stream ecosystems, it is often considered a major pollutant (Ritchie, 1972). Total suspended solids may be detrimental to stream communities by reducing light penetration and oxygen levels, smothering, scouring, reducing habitat through deposition, and introduction of absorbed pollutants (Lenat and others, 1981; Alabaster and Lloyd, 1982). Effects on fish include mechanical abrasion, gill damage, fin rot, reduced survival of eggs, and death by clogging gills (Ritchie, 1972). Turbidity, caused by dissolved and suspended material such as clay, silt, fine organic material, microscopic organisms, organic acids, and dyes (ASTM International, 2003), is often used as a surrogate for total suspended solids.

The regression models for total suspended solids at all five sites use turbidity as the explanatory variable (table 4). The adjusted R^2 ranged from 0.77 at the Menomonee River at Wauwatosa to 0.94 at the Little Menomonee River. The RMSE ranged from 0.16 at the Menomonee River at Menomonee Falls to 0.25 at Honey Creek (table 4). Figure 4 is an example from Honey Creek at Wauwatosa, showing predicted total suspended solids values with 90-percent confidence intervals as well as the measured total suspended solids values used in the regression model. The model-calibration dataset, model summary, summary statistics, plots of the explanatory and response variables, and residual plots are provided in appendix 3.

Table 4. Regression models and summary statistics for estimating total suspended solids concentrations in water at five water-quality monitoring sites in the Menomonee River Basin, Southeast Wisconsin, November 2008–September 2009.

[R^2, coefficient of determination; RMSE, root mean square error; PRESS, prediction error sum of squares; n, number of discrete samples; mg/L, milligrams per liter; SS, suspended solids; Turb, turbidity, in nephelometric turbidity units]

Monitoring site	Regression model	Model diagnostics				Model inputs			
		Adjusted R^2	RMSE	PRESS	n	Range of values in variable measurements	Mean	Median	Standard deviation
Menomonee River at Menomonee Falls, Wis. 04087030	$Log_{10}SS = 0.256 + 0.953log_{10}(Turb)$	0.92	0.16	1.54	59	SS 4−500 Turb 2.3–220	81 47	46 25	95 52
Little Menomonee River near Freistadt, Wis. 04087050	$Log_{10}SS = 0.334 + 0.910log_{10}(Turb)$	.94	.17	1.25	39	SS 1.6−410 Turb 0.7–290	108 72	71 46	121 78
Honey Creek at Wauwatosa, Wis. 04087119	$Log_{10}SS = 0.160 + 0.967log_{10}(Turb)$	.86	.25	4.25	66	SS 1–530 Turb 1.3–390	136 95	73 57	147 91
Menomonee River at Wauwatosa, Wis. 04087120	$Log_{10}SS = 0.567 + 0.779log_{10}(Turb)$	.77	.22	4.92	95	SS 5.2–390 Turb 1.1–210	105 66	76 53	93 52
Menomonee River at Milwaukee, Wis. 04087142	$Log_{10}SS = 0.108 + 0.974log_{10}(Turb)$	.85	.21	3.61	79	SS 5−1,800 Turb 2.9−530	105 64	35 35	249 88

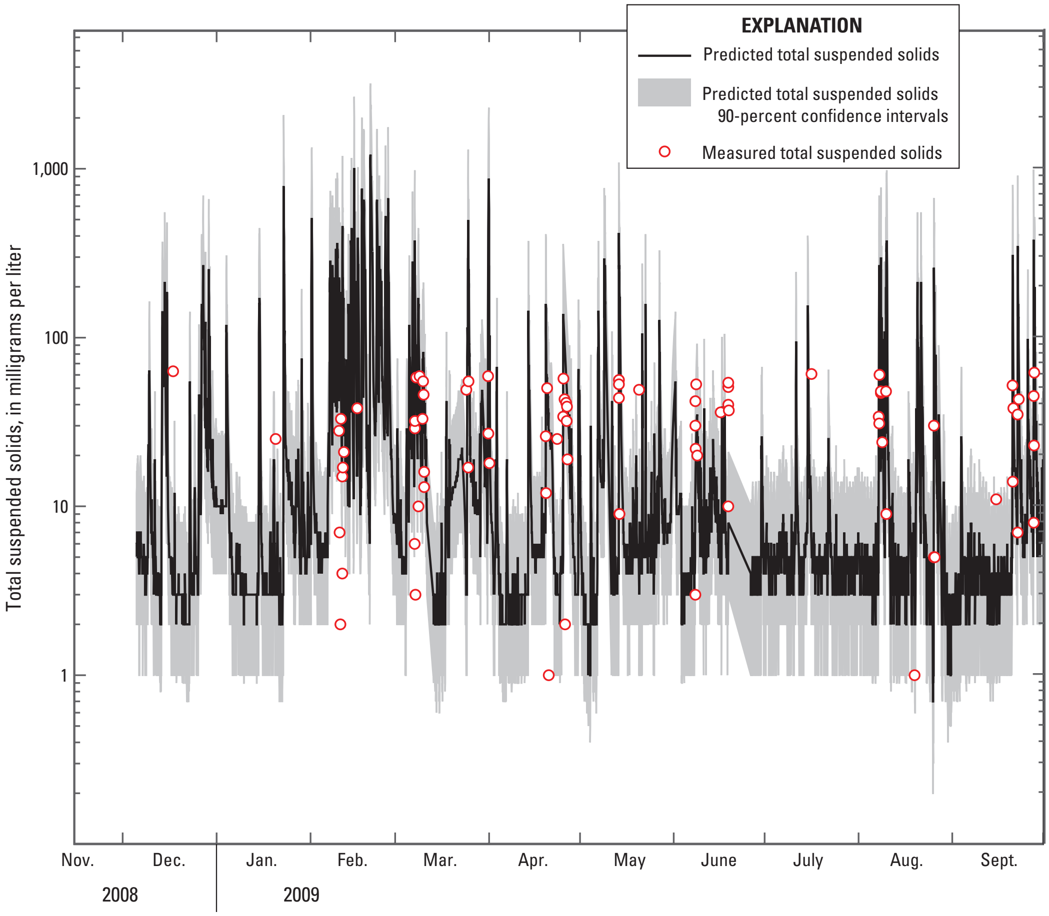


Figure 4. Predicted and measured total suspended solids concentrations at the U.S. Geological Survey streamgage on Honey Creek at Wauwatosa, Wisconsin, December 2008–September 2009.

Total Phosphorus

Elevated concentrations of nutrients, especially phosphorus, are some of the most common stressors affecting rivers and streams throughout the United States (Robertson and others, 2006). High nutrient concentrations may cause excessive aquatic plant growth, which may result in low dissolved-oxygen concentrations from respiration and decomposing plants. Excessive nutrients may also cause nuisance algal blooms in receiving waters. Because phosphorus is likely to adsorb to suspended sediment, turbidity is often used as a surrogate for the estimation of total phosphorus.

The regression models for total phosphorus at each site all used turbidity as the explanatory variable (table 5). The adjusted R^2 ranged from 0.55 at the Menomonee River at Wauwatosa to 0.75 at the Little Menomonee River. The RMSE ranged from 0.19 at the Little Menomonee River to 0.22 at Honey Creek at Wauwatosa. Figure 5 is an example from Honey Creek at Wauwatosa, showing predicted total phosphorus values with 90-percent confidence intervals as well as the measured total phosphorus values used in the regression model. The model-calibration dataset, model summary, summary statistics, plots of the explanatory and response variables, and residual plots are provided in appendix 4.

Indicator Bacteria

Wastewater may enter surface waters through leaking sewage lines or septic tanks, wastewater-treatment plants, or runoff from agricultural sources. *E. coli* and fecal coliform are common types of bacteria used as wastewater indicators. The presence of these bacteria suggests the presence of fecal wastes from either humans or other warm-blooded animals (Dufour, 1977). Pathogens that may be present in waters contaminated by fecal waste include *Cryptosporidium* spp., *Giardia* spp., Hepatitis A, enteric adenovirus, Norwalk-like viruses, and rotavirus (Craun and Calderon, 1999). Exposure to these and other pathogens is a serious human health risk. Because suspended material is a medium for bacterial accumulation and transport, turbidity is often used as a surrogate for bacteria. In addition to turbidity, water temperature was determined to be a significant variable in the indicator bacteria regression models, likely because *E. coli* and fecal coliform bacteria grow better in warmer temperatures than in cold (Madigan and others, 1997).

Table 5. Regression models and summary statistics for estimating total phosphorus concentrations in water at five water-quality monitoring sites in the Menomonee River Basin, Southeast Wisconsin, November 2008–September 2009.

[R^2, coefficient of determination; RMSE, root mean square error; PRESS, prediction error sum of squares; n, number of discrete samples; mg/L, milligrams per liter; TP, total phosphorus, in mg/L; Turb, turbidity, in nephelometric turbidity units]

Monitoring site	Regression model	Model diagnostics				Model inputs			
		Adjusted R^2	RMSE	PRESS	n	Range of values in variable measurements	Mean	Median	Standard deviation
Menomonee River at Menomonee Falls, Wis. 04087030	$Log_{10}TP = -1.55 + 0.492log_{10}(Turb)$	0.62	0.21	2.67	59	TP 0.034–0.78 Turb 2.3–220	0.19 47	0.17 25	0.15 52
Little Menomonee River near Freistadt, Wis. 04087050	$Log_{10}TP = -1.37 + 0.486log_{10}(Turb)$	.75	.19	1.75	39	TP 0.038–0.83 Turb 0.7–290	.30 72	.26 46	.21 78
Honey Creek at Wauwatosa, Wis. 04087119	$Log_{10}TP = -1.45 + 0.451log_{10}(Turb)$	.64	.22	3.35	66	TP 0.03–0.88 Turb 1.3–390	.28 95	.24 57	.21 91
Menomonee River at Wauwatosa, Wis. 04087120	$Log_{10}TP = -1.42 + 0.431log_{10}(Turb)$	.55	.20	3.96	91	TP 0.035–0.66 Turb 1.1–210	.66 65	.23 52	.20 51
Menomonee River at Milwaukee, Wis. 04087142	$Log_{10}TP = -1.51 + 0.462log_{10}(Turb)$	.61	.19	2.97	77	TP 0.039–1.8 Turb 2.9–530	.21 64	.14 35	.26 88

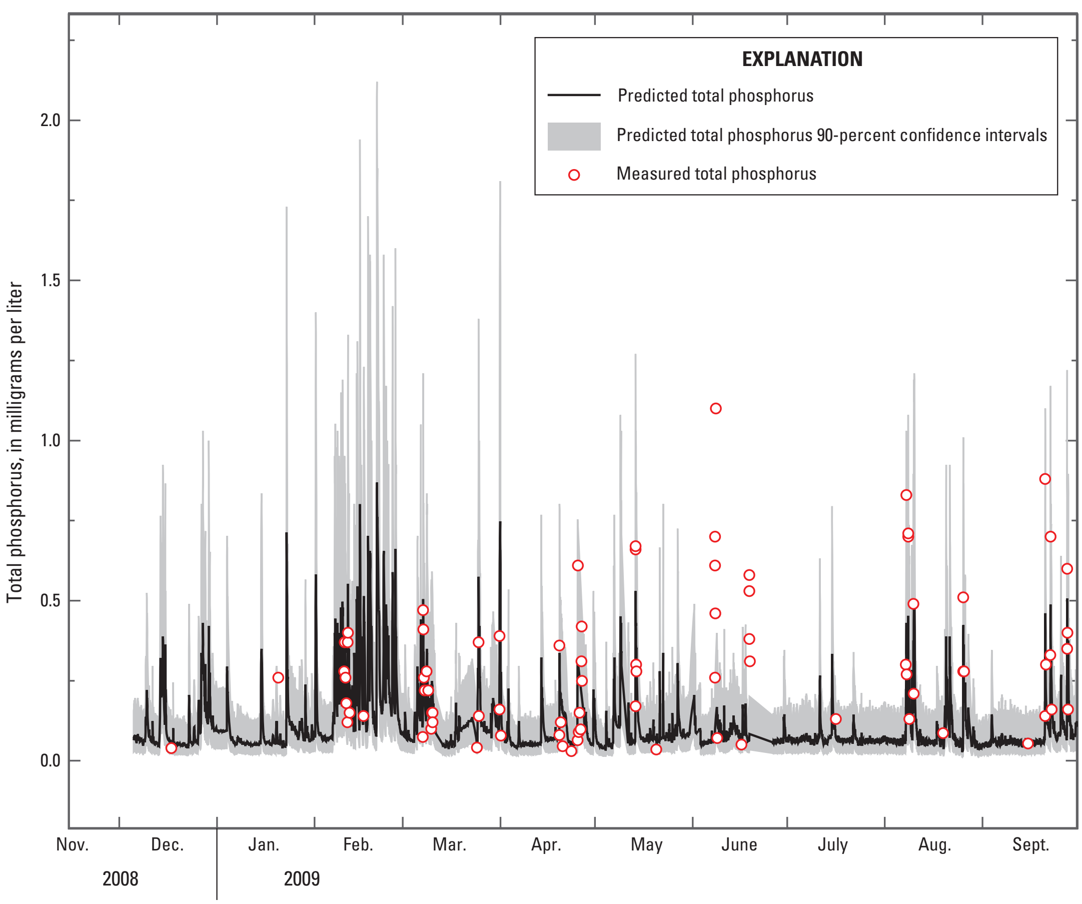


Figure 5. Predicted and measured total phosphorus concentrations at the U.S. Geological Survey streamgage on Honey Creek at Wauwatosa, Wisconsin, December 2008–September 2009.

Escherichia coli

The regression model for *E. coli* bacteria for each site used water temperature and turbidity as explanatory variables (table 6). The adjusted R^2 ranged from 0.54 at the Menomonee River at Milwaukee to 0.69 at Honey Creek. The RMSE ranged from 0.45 at the Little Menomonee to 0.56 at the Menomonee River at Menomonee Falls. Figure 6 is an example from Honey Creek at Wauwatosa, showing predicted *E. coli* values with 90-percent confidence intervals as well as the measured *E. coli* values used in the regression model. The model-calibration dataset, model summary, summary statistics, plots of the explanatory and response variables, and residual plots are provided in appendix 5.

Fecal Coliform

The regression model for fecal coliform bacteria at each site used water temperature and turbidity as the explanatory variables (table 7). The adjusted R^2 ranged from 0.54 at the Menomonee River at Milwaukee to 0.74 at Honey Creek and Menomonee River at Wauwatosa. The RMSE ranged from 0.49 at the Menomonee River at Wauwatosa to 0.65 at Menomonee River at Milwaukee. Figure 7 is an example from Honey Creek at Wauwatosa, showing predicted fecal coliform values with 90-percent confidence intervals as well as the measured fecal coliform values used in the regression model. The model-calibration dataset, model summary, summary statistics, plots of the explanatory and response variables, and residual plots are provided in appendix 6.

Model Predictability

The fit of the regression models, on the basis of the adjusted R^2, RMSE, and PRESS statistics, varies by constituent. This variability in fit is demonstrated by the varied width of the confidence limits in each of the time series plots (figs. 3–7). The models for chloride, total suspended solids, and total phosphorus have better fits (higher adj. R^2 values and lower RMSE and PRESS values) than those for the indicator bacteria (fig. 8). In general, the fits for each of these constituents are comparable to those found in similar regression studies (Christensen and others, 2001; Rasmussen and others, 2009). There is no apparent relation between model fit and percentage of urban area in the respective basins, nor between model fit and number of samples collected at each site. The site with the fewest number of samples, the Little Menomonee River, had some of the better fitting models.

Turbidity was the most frequently used explanatory variable of the continuous variables examined and was used in 21 of the 25 developed models. This frequency is likely because turbidity is a measure of particulates, and indicator bacteria and total phosphorus attach to particulates. All chloride models used specific conductance as the only explanatory variable, except for the Little Menomonee River model, which also included turbidity. This may be related to the fact that the Little Menomonee River is the most rural site and, therefore, the least affected by road-salt runoff. None of the models found season to be a significant factor, but water temperature was significant in all of the indicator bacteria models.

Table 6. Regression models and summary statistics for estimating *Escherichia coli* (*E. coli*) bacteria concentrations in water at five water-quality monitoring sites in the Menomonee River Basin, Southeast Wisconsin, November 2008–September 2009.

[R^2, coefficient of determination; RMSE, root mean square error; PRESS, prediction error sum of squares; n, number of discrete samples; mg/L, milligrams per liter; EC, *E. coli*, in colonies per 100 milliliters; WT, water temperature in degrees Celsius (°C); Turb, turbidity, in nephelometric turbidity units]

Monitoring site	Regression model	Model diagnostics				Model inputs			
		Adjusted R^2	RMSE	PRESS	n	Range of values in variable measurements	Mean	Median	Standard deviation
Menomonee River at Menomonee Falls, Wis. 04087030	$Log_{10}EC = 1.30 + 0.057(WT) + 0.674log_{10}(Turb)$	0.60	0.56	17.84	55	EC 10–52,000 WT 0–23.1 Turb 2.3–220	4,778 11 47	520 13 25	9,252 8 52
Little Menomonee River near Freistadt, Wis. 04087050	$Log_{10}EC = 1.81 + 0.025(WT) + 0.693log_{10}(Turb)$	.58	.45	8.17	37	EC 10–25,000 WT 0–18.8 Turb 0.70–290	2,840 6 72	1,100 2 46	4,870 7 78
Honey Creek at Wauwatosa, Wis. 04087119	$Log_{10}EC = 1.68 + 0.071(WT) + 0.626log_{10}(Turb)$	.69	.48	16.22	66	EC 200–200,000 WT 0–21.9 Turb 1.3–390	19,239 11 95	1,850 9 57	41,203 8 91
Menomonee River at Wauwatosa, Wis. 04087120	$Log_{10}EC = 1.28 + 0.063(WT) + 0.884log_{10}(Turb)$	.66	.53	23.37	81	EC 60–200,000 WT 0–22.4 Turb 1.1–190	16,476 10 64	1,700 10 52	40,762 8 50
Menomonee River at Milwaukee, Wis. 04087142	$Log_{10}EC = 1.29 + 0.059(WT) + 0.886log_{10}(Turb)$	.54	.54	24.05	76	EC 41–140,000 WT 0–26.0 Turb 2.9–530	7,936 10 64	1,550 10 35	19,897 8 88

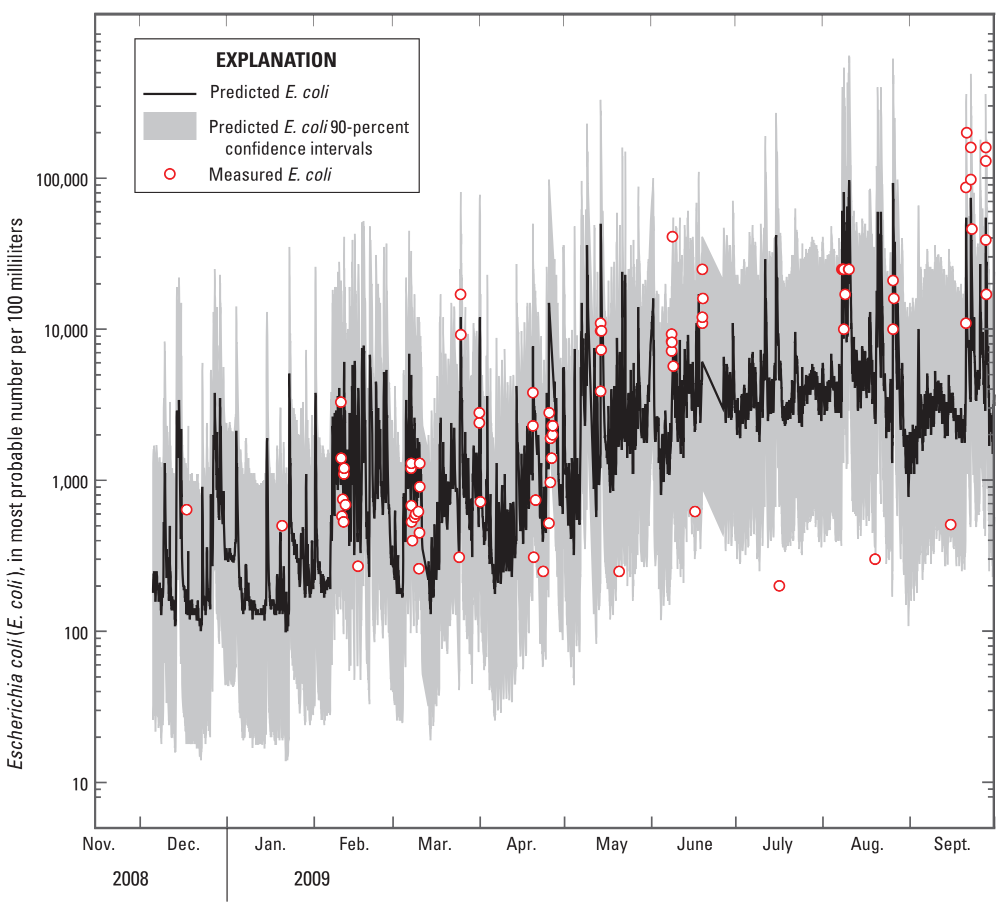


Figure 6. Predicted and measured *Escherichia coli* (*E. coli*) bacteria concentrations at the U.S. Geological Survey streamgage on Honey Creek at Wauwatosa, Wisconsin, December 2008–September 2009.

Table 7. Regression models and summary statistics for estimating fecal coliform bacteria concentrations in water at five water-quality monitoring sites in the Menomonee River Basin, Southeast Wisconsin, November 2008–September 2009.

[R^2, coefficient of determination; RMSE, root mean square error; PRESS, prediction error sum of squares; n, number of discrete samples; mg/L, milligrams per liter; FC, fecal coliform, in colonies per 100 milliliters; WT, water temperature in degrees Celsius (°C); Turb, turbidity, in nephelometric turbidity units]

Monitoring site	Regression model	Model diagnostics: Adjusted R^2	RMSE	PRESS	n	Model inputs: Range of values in variable measurements	Mean	Median	Standard deviation
Menomonee River at Menomonee Falls, Wis. 04087030	$Log_{10}FC = 1.07 + 0.063(WT) + 0.834log_{10}(Turb)$	0.68	0.54	14.99	49	FC 10−46,000	6,975	570	11,911
						WT 0−23.1	13	15	8
						Turb 2.2–220	47	23	52
Little Menomonee River near Freistadt, Wis. 04087050	$Log_{10}FC = 1.49 + 0.035(WT) + 0.777log_{10}(Turb)$	.58	.51	8.97	32	FC 10−30,000	2,912	740	5,533
						WT 0−18.8	7	7	7
						Turb 0.70−290	77	52	80
Honey Creek at Wauwatosa, Wis. 04087119	$Log_{10}FC = 1.46 + 0.089(WT) + 0.648log_{10}(Turb)$	.74	.50	17.81	65	FC 95−17,000	25,116	1,600	44,560
						WT 0−21.9	11	10	7
						Turb 1.3–390	95	57	91
Menomonee River at Wauwatosa, Wis. 04087120	$Log_{10}FC = 1.38 + 0.078(WT) + 0.79log_{10}(Turb)$	.74	.49	17.10	68	FC 48−180,000	22,956	3,300	36,566
						WT 0−22.4	12	15	8
						Turb 1.1–210	70	62	52
Menomonee River at Milwaukee, Wis. 04087142	$Log_{10}FC = 1.07 + 0.062(WT) + 1.001log_{10}(Turb)$	.54	.65	25.56	56	FC 24−110,000	12,128	2,150	23,421
						WT 0−26.0	10	10	8
						Turb 2.9–530	64	35	88

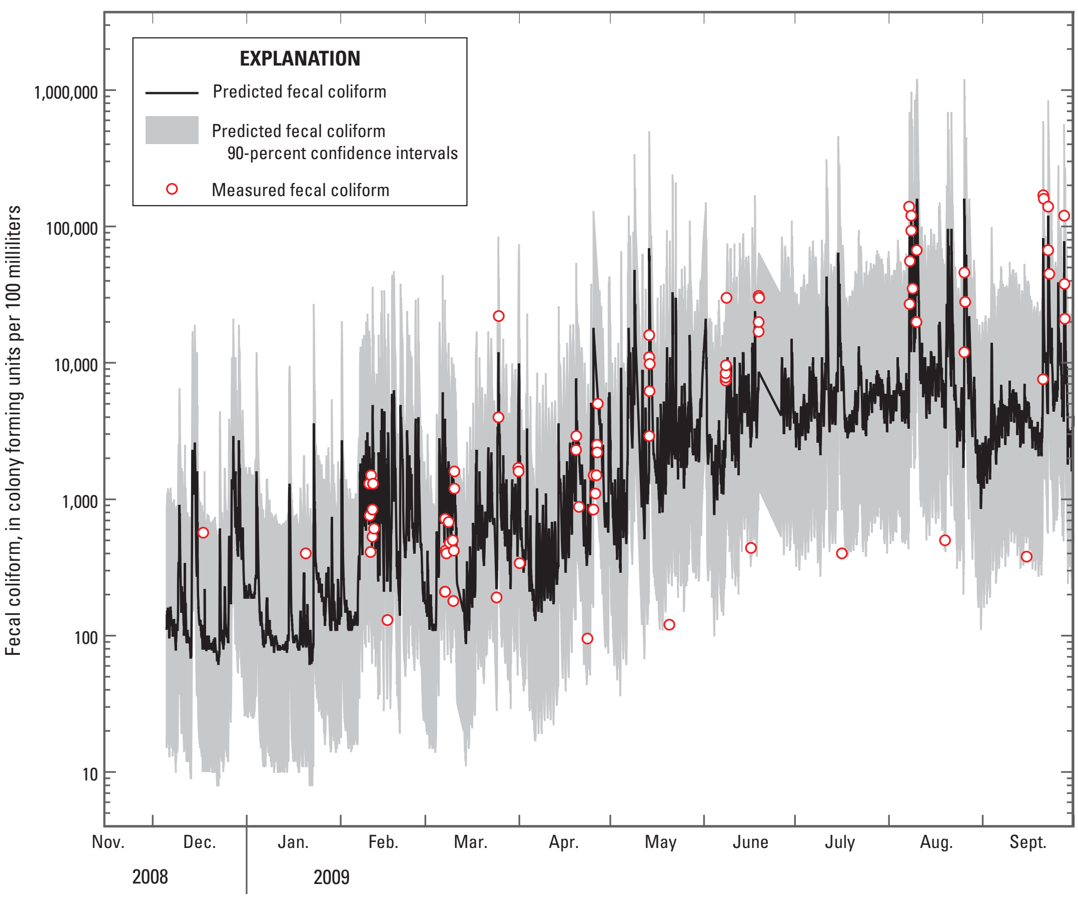


Figure 7. Predicted and measured fecal coliform bacteria concentrations at the U.S. Geological Survey streamgage on Honey Creek at Wauwatosa, Wisconsin, December 2008–September 2009.

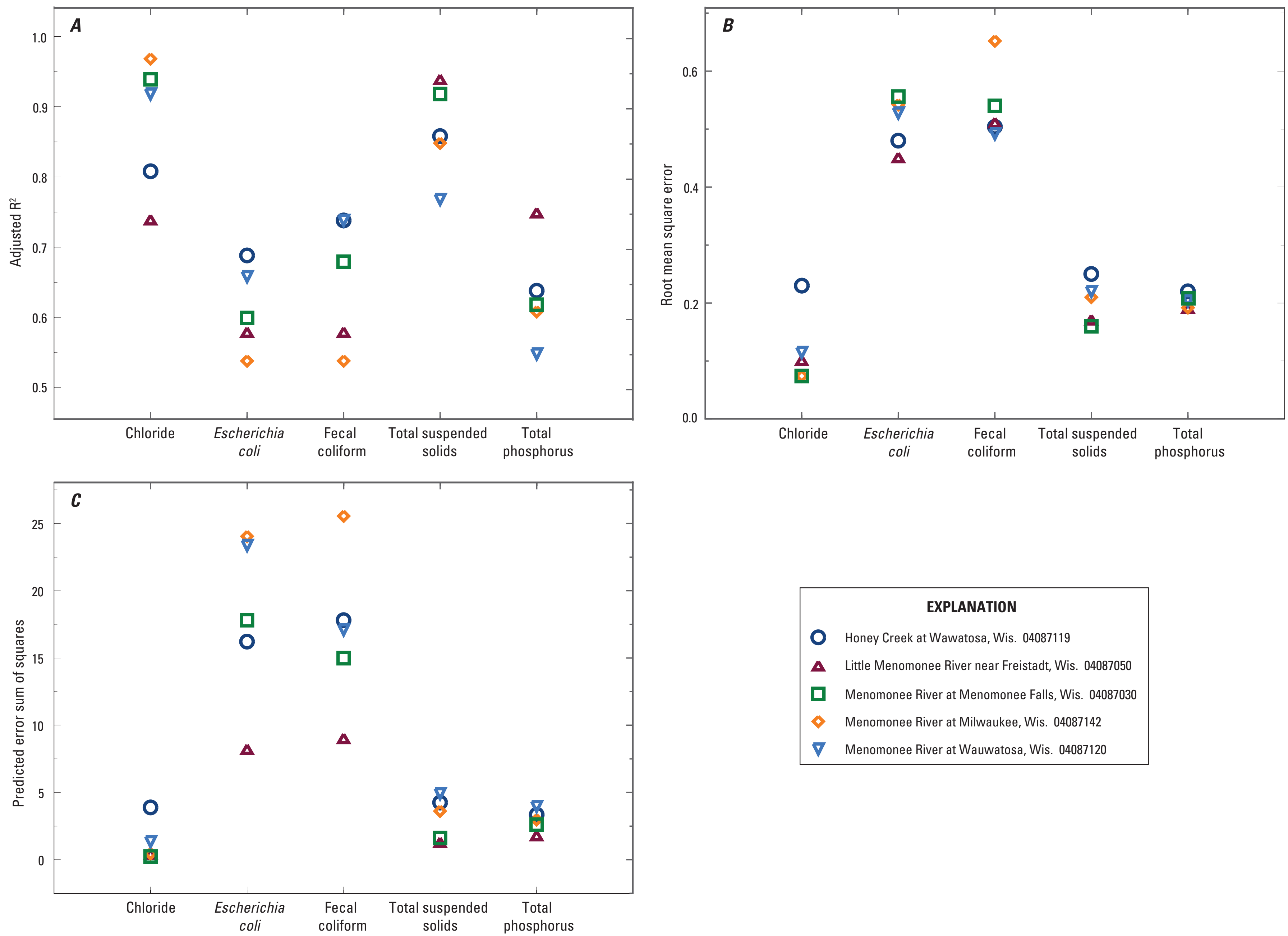


Figure 8. Statistics by constituent and monitoring site in the Menomonee River Basin, Wisconsin. *A*, Adjusted R^2. *B*, root mean square error (RMSE). *C*, prediction error sum of squares (PRESS).

Summary and Conclusions

With increasing headwater urbanization, channel restorations, and implementation of best management practices, the Menomonee River drainage basin in southeast Wisconsin faces changes which may affect water quality in the coming years. In an effort to monitor these and future changes to the basin, the U.S. Geological Survey and the Milwaukee Metropolitan Sewerage District (MMSD) initiated a study in 2008 to develop regression models to estimate real-time concentrations and loads of selected water-quality constituents. Water-quality sensors and automated samplers were installed at five sites in the Menomonee River drainage basin. The sensors continuously measured four explanatory variables: water temperature, specific conductance, dissolved oxygen, and turbidity. Discrete water-quality samples were collected and analyzed for five response variables: chloride, total suspended solids, total phosphorus, *Escherichia coli* (*E. coli*) bacteria, and fecal coliform bacteria.

Regression models were developed to estimate the response variables on the basis of the explanatory variables. The models to estimate chloride concentrations all used specific conductance as the explanatory variable, except for the model for the Little Menomonee River near Freistadt, which used both specific conductance and turbidity. Adj. R^2 values for the chloride models ranged from 0.74 to 0.97. Models to estimate total suspended solids and total phosphorus used turbidity as the only explanatory variable. Adj. R^2 values ranged from 0.77 to 0.94 for the total suspended solids models and from 0.55 to 0.75 for the total phosphorus models. Models to estimate indicator bacteria used water temperature and turbidity as the explanatory variables, with adj. R^2 ranges from 0.54 to 0.69 for *E. coli* bacteria models and 0.54 to 0.74 for fecal coliform bacteria models. Dissolved oxygen was not used in any of the final models. Although there was a significant correlation between dissolved oxygen and the modeled constituent in a few of the bacteria models, dissolved oxygen was not used because it lacked explanatory power and because we wanted consistency among the sites.

The regression models can be used to continuously estimate concentrations of chloride, total suspended solids, total phosphorus, *E. coli* bacteria, and fecal coliform bacteria. Managers can use the resulting data to estimate important water-quality indicators such as bacteria concentrations, understand variability in constituent concentrations, develop total maximum daily loads, assess the effects of improvement projects and land-use changes, provide water-quality information to communities served by MMSD and the general public, and focus where future improvement projects could be implemented to maximize benefits.

Continued periodic sampling will be important to test the validity of the models in the future. Annual and longer-term climate variability, changes in land use, and improvements to infrastructure may necessitate making future model adjustments.

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Appendix 1. Analytical procedures used for water-quality samples

Variable	Method reference
Chloride	SM(20)4500-Cl E, Clesceri and others (1998)
Total suspended solids	SM(20)2540D, Clesceri and others (1998)
Total phosphorus	EPA 365.1, U.S. Environmental Protection Agency (1993)
Escherichia coli bacteria	SM(20)9223B, Clesceri and others (1998)
Fecal coliform bacteria	SM(20)9222D, Clesceri and others (1998)

Appendix 2. Regression analysis results for estimating chloride concentration

All data were collected using U.S. Geological Survey (USGS) protocols and are stored in the USGS National Water Information System (NWIS) database (*http://waterdata.usgs.gov/nwis*). The regression models are based on measurements of specific conductance and turbidity and concurrent chloride samples collected from November 2008 to September 2009. Continuous water-quality data were collected at 5-minute intervals using a YSI model 6920 V2 multiparameter water-quality monitor with a 6560 specific conductance and water temperature sensor, and a 6136 optical turbidity sensor. Specific conductance and turbidity values are instantaneous unit values temporally corresponding to the collection of the chloride samples. Samples were collected throughout the range of continuously observed hydrologic conditions. Summary statistics and the complete model-calibration dataset are provided. A comparison of cross-section mean and corresponding time-series monitor readings is archived at the Wisconsin Water Science Center and is available by request to Austin Baldwin (akbaldwi@usgs.gov).

Chloride at Little Menomonee River near Freistadt, WI (04087050)

Sample data on 2/16/2009 were not used in the regression development because there was a program change and the sonde data were lost.
MODEL SUMMARY—Summary of final regression results for estimating chloride concentrations at Little Menomonee River near Freistadt, WI.

$\log_{10}$ (Chloride) = -4.16 +1.99 $\log_{10}$ (SC) + 0.1511 $\log_{10}$ (Turb),
Where:

Chloride = chloride concentration in mg/L
SC = Specific Conductance in µS/cm at 25° C; and
Turb = Turbidity (YSI 6136) in NTU

Model Information (in log units unless otherwise specified):
Number of measurements = 39,
Root-mean-squared error (RMSE) = 0.10
Model standard percentage error (MPSE) = +25 and -20 percent
90-percent prediction intervals (based on units in mg/L) = +/- 39 percent
Adjusted coefficient of determination (Adj R^2) = 0.74
Sum of squared error = 0.34
PRESS = 0.38

Coefficients:

	Coefficient	Standard error	t statistic	p-value
Intercept	**-4.16**	**0.662**	**-6.28**	**<0.0001**
$\log_{10}$ (SC)	**1.99**	**0.218**	**9.11**	**<0.0001**
$\log_{10}$ (Turb)	**0.151**	**0.037**	**4.04**	**0.0003**

Correlation matrix of coefficients:

	Intercept	$\log_{10}$ (SC)	$\log_{10}$ (Turb)
Intercept	**1**	**-0.998**	**-0.831**
$\log_{10}$ (SC)	**-0.998**	**1**	**0.802**
$\log_{10}$ (Turb)	**-0.831**	**0.802**	**1**

Duan’s bias correction factor **= 1.02**

Table 2-1. Model-calibration dataset for Little Menomonee River near Freistadt, Wisconsin.

[mg/L, milligrams per liter; NTU, Nephelometric turbidity units; µS/cm, microsiemens per centimeter; °C, degrees Celsius]

Date	Time	Chloride (mg/L)	Turbidity (NTU)	Specific conductance (µS/cm at 25 °C)
11/20/2008	9:45	44	1.2	877
12/17/2008	11:30	85	2.1	1,060
12/27/2008	13:05	130	11.2	1,123
12/28/2008	1:05	120	52.3	838
12/28/2008	7:15	110	45.0	749
1/20/2009	10:55	57	0.7	963
2/7/2009	18:50	80	19.7	822
2/9/2009	22:40	85	11.3	937
2/10/2009	10:45	69	38.0	697
2/10/2009	14:40	50	113.3	556
2/10/2009	20:40	42	46.0	520
2/11/2009	2:40	49	21.3	599
3/2/2009	7:10	62	4.2	935
3/7/2009	12:55	77	130.0	762
3/7/2009	18:05	52	220.0	538
3/8/2009	7:05	51	62.0	613
3/8/2009	19:00	26	210.0	384
3/9/2009	0:30	33	140.0	455
3/10/2009	3:20	43	68.0	570
3/10/209	8:15	34	94.0	454
3/10/2009	20:15	32	51.0	485
3/24/2009	10:40	57	2.8	844
4/23/2009	9:45	63	2.1	875
4/25/2009	15:10	53	100.0	676
4/26/2009	5:30	35	180.0	517
4/26/2009	19:30	23	200.0	413
4/27/2009	1:30	24	80.0	447
5/9/2009	7:25	41	81.0	638
5/9/2009	13:30	30	54.0	573
5/9/2009	19:30	33	15.0	636
5/14/2009	2:30	24	270.0	485
5/20/2009	9:00	48	4.5	787
6/8/2009	5:20	35	120.0	569
6/16/2009	8:45	50	12.0	805
6/19/2009	2:50	28	290.0	510
6/19/2009	8:50	34	89.0	605
7/16/2009	10:05	51	19.0	786
8/19/2009	10:00	46	8.8	786
9/15/2009	9:30	44	10.0	799
MINIMUM		**23**	**0.7**	**384**
MAXIMUM		**130**	**290.0**	**1,123**
MEAN		**53**	**73.8**	**684**
MEDIAN		**48**	**51.0**	**638**
STANDARD DEVIATION		**26**	**79.0**	**188**

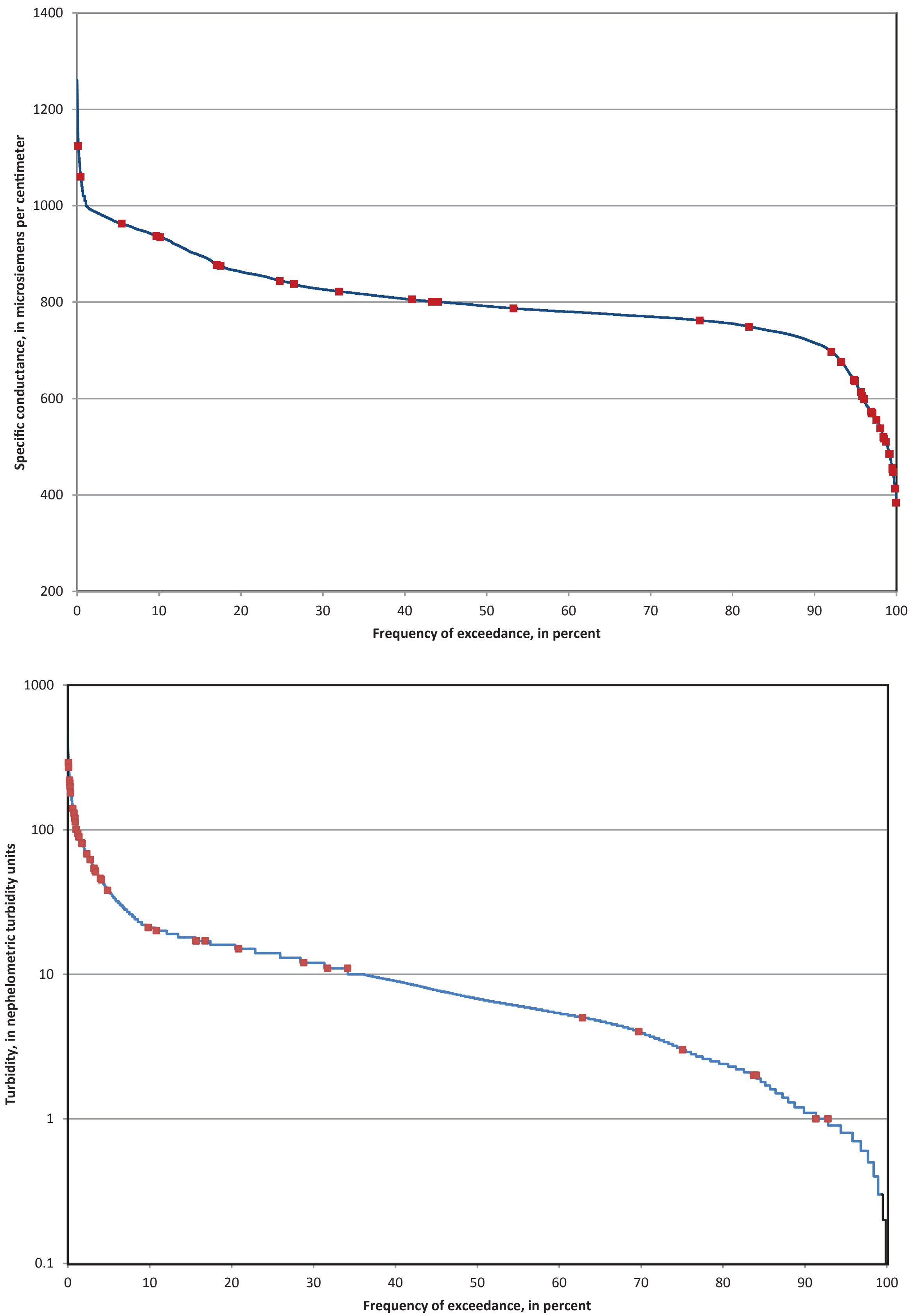
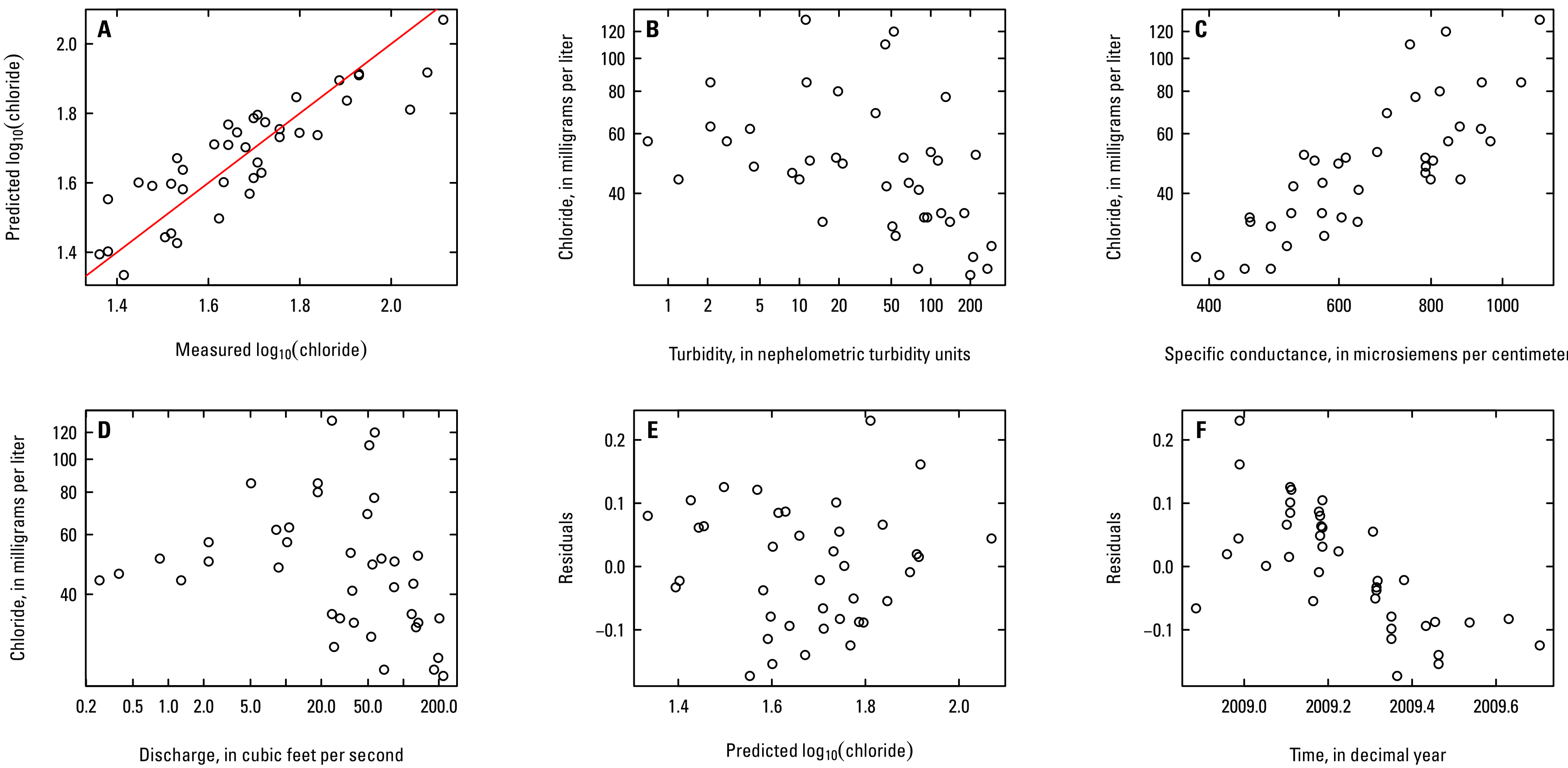


Figure 2-1. Duration curves for specific conductivity and turbidity (November 2008–September 2010) and corresponding values associated with chloride concentration samples collected November 2008 to September 2009 at U.S.Geological Survey streamgage on Little Menomonee River near Freistadt, Wisconsin.

Chloride at Little Menomonee River near Freistadt, Wisconsin, November 2008–September 2009



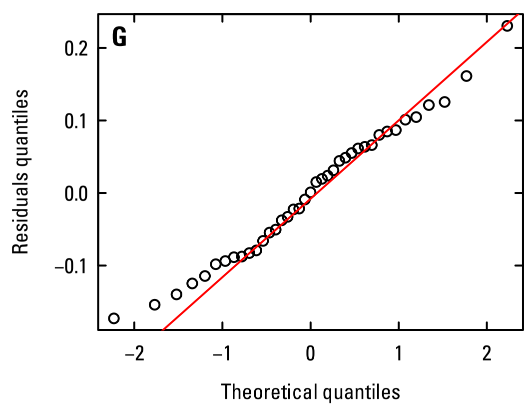


Figure 2-2. U.S. Geological Survey streamgage on Little Menomonee River near Freistadt, Wisconsin, November 2008 to September 2009. *A*, Relation between measured and predicted $\log_{10}$ (chloride concentration). *B*, Relation between turbidity and chloride concentration in log10 space. *C*, Relation between specific conductance and chloride concentration in $\log_{10}$ space. *D*, Relation between discharge and chloride concentration in $\log_{10}$ space. *E*, Relation between predicted $\log_{10}$ (chloride concentration) and regression residuals. *F*, Relation between time and chloride regression residuals. *G*, Probability plot of chloride regression residuals.

Chloride at Menomonee River at Menomonee Falls, WI (04087030)

Summary of final regression results for estimating chloride concentrations at Menomonee River at Menomonee Falls, WI.

Log_{10} (Chloride) = -1.63 +1.28 log_{10} (SC),
Where:

Chloride = chloride concentration in mg/L
SC = Specific Conductance in µS/cm at 25^{o} C

Model Information (in log units unless otherwise specified):
Number of measurements = 59,
Root-mean-squared error (RMSE) = 0.073
Model standard percentage error (MPSE) = +18 and -15 percent
90-percent prediction intervals (based on units in mg/L) = +/- 29 percent
Adjusted coefficient of determination (Adj R^2) = 0.94
Sum of squared error = 0.30
PRESS = 0.32

Coefficients:

	Coefficient	Standard error	t statistic	p-value
Intercept	**-1.63**	**0.120**	**-13.56**	**<0.0001**
Log $_{10}$ (SC)	**1.29**	**0.041**	**31.20**	**<0.0001**

Correlation matrix of coefficients:

	Intercept	log_{10} (SC)
Intercept	**1**	**-0.997**
Log_{10} (SC)	**-0.997**	**1**

Duan’s bias correction factor **= 1.01**

Table 2-2. Model-calibration dataset for Little Menomonee River at Menomonee Falls, Wisconsin.

[mg/L, milligrams per liter; µS/cm, microsiemens per centimeter; °C, degrees Celsius]

Date	Time	Chloride (mg/L)	Specific conductance (µS/cm at 25 °C)
11/20/2008	9:15	130	1,130
12/17/2008	12:00	250	1,450
12/27/2008	0:35	840	3,487
12/27/2008	6:15	960	3,700
12/27/2008	14:20	560	2,347
12/27/2008	20:20	400	1,873
12/28/2008	8:20	300	1,320
1/20/2009	9:55	190	1,270
2/16/2009	11:00	160	1,110
2/26/2009	15:05	370	1,860
2/26/2009	18:15	280	1,370
2/27/2009	0:15	250	1,180
3/2/2009	7:15	190	1,170
3/7/2009	9:30	180	976
3/7/2009	15:30	190	969
3/8/2009	10:30	150	848
3/8/2009	14:00	140	745
3/9/2009	2:00	120	708
3/24/2009	10:00	160	1,010
3/25/2009	5:25	210	1,070
4/19/2009	23:00	150	866
4/20/2009	11:15	210	1,090
4/20/2009	23:15	200	1,120
4/23/2009	9:15	150	1,050
4/25/2009	10:50	110	756
4/25/2009	11:00	80	642
4/26/2009	5:00	120	749
4/26/2009	16:00	96	671
4/27/2009	4:00	90	657
5/9/2009	1:05	94	744
5/9/2009	1:15	72	654
5/9/2009	10:25	110	749
5/9/2009	22:25	120	839
5/10/2009	10:25	110	810
5/13/2009	23:00	60	703
5/20/209	9:30	110	901
6/8/2009	3:15	71	547
6/8/2009	3:25	41	354
6/8/2009	9:35	110	670
6/16/2009	10:15	140	990
6/19/2009	0:10	72	529
6/19/2009	0:50	24	252
6/19/2009	2:00	42	361
6/20/2009	2:00	110	758
7/16/2009	9:30	180	984
8/7/2009	19:35	83	573
8/8/2009	9:05	46	327
8/19/2009	9:00	190	1,090
8/25/2009	18:20	120	600
8/25/2009	18:45	46	314
8/26/2009	1:30	88	523
8/26/2009	1:55	53	340
9/15/2009	9:30	190	1,120
9/22/2009	13:15	110	685
9/22/2009	14:05	33	308
9/22/2009	15:20	120	733
9/27/2009	19:25	120	658
9/27/2008	21:30	95	583
9/28/2009	5:55	100	592
MINIMUM		**24**	**252**
MAXIMUM		**960**	**3,700**
MEAN		**171**	**957**
MEDIAN		**120**	**758**
STANDARD DEVIATION		**167**	**636**

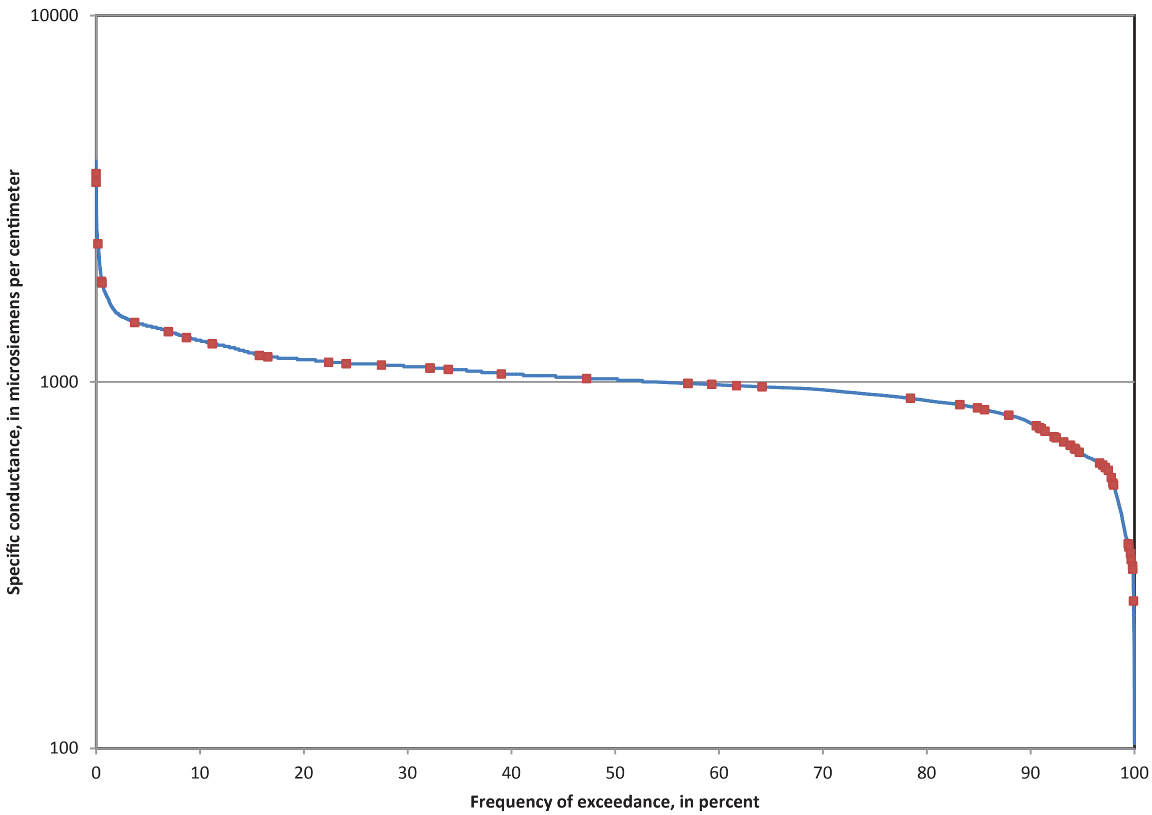


Figure 2-3. Duration curve for specific conductivity (November 2008–September 2010) and corresponding values associated with chloride concentration samples collected November 2008 to September 2009 at U.S.Geological Survey streamgage on Menomonee River at Menomonee Falls, Wisconsin.

Chloride at Menomonee River at Menomonee Falls, Wisconsin, November 2008–September 2009

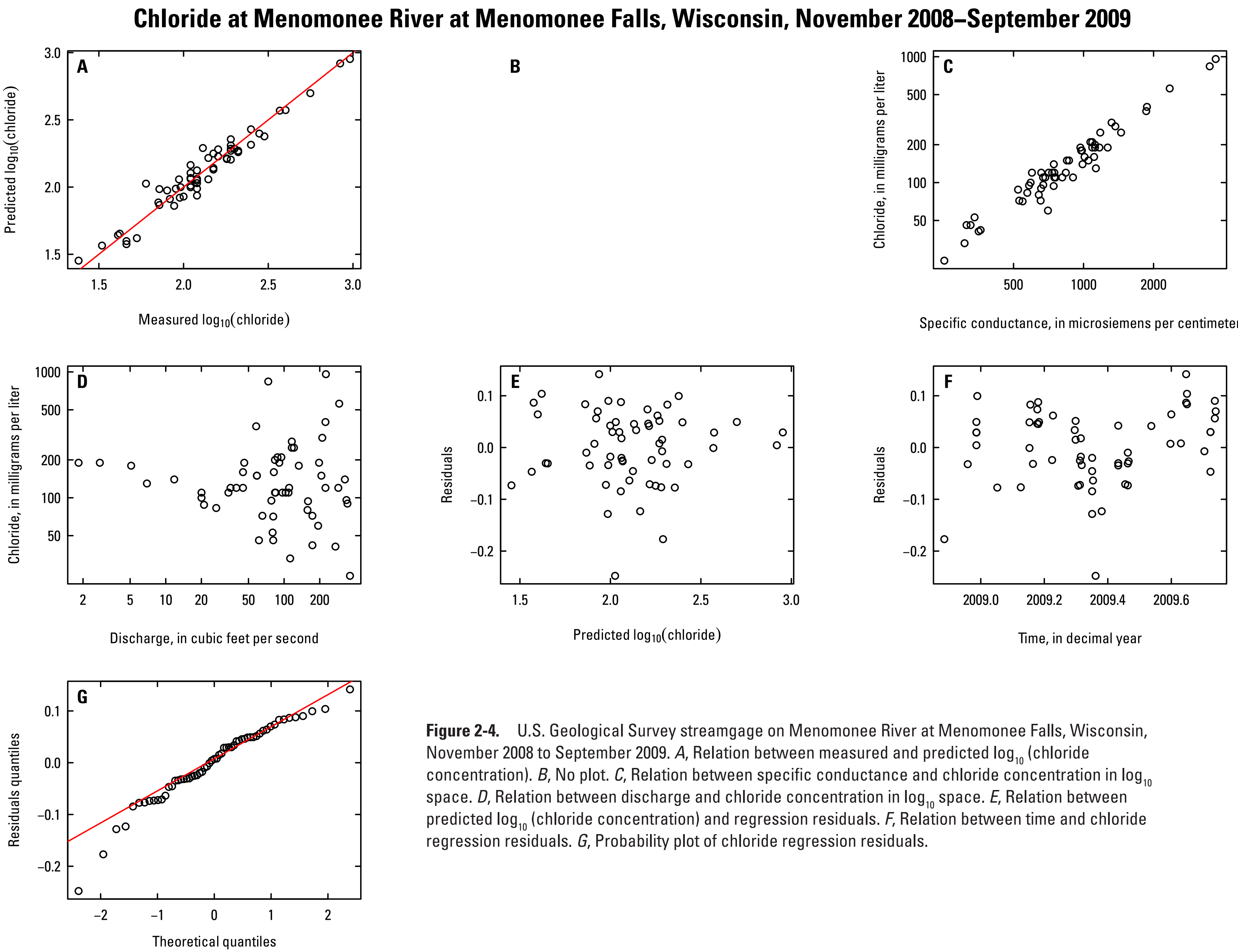


Figure 2-4. U.S. Geological Survey streamgage on Menomonee River at Menomonee Falls, Wisconsin, November 2008 to September 2009. *A*, Relation between measured and predicted $\log_{10}$ (chloride concentration). *B*, No plot. *C*, Relation between specific conductance and chloride concentration in $\log_{10}$ space. *D*, Relation between discharge and chloride concentration in $\log_{10}$ space. *E*, Relation between predicted $\log_{10}$ (chloride concentration) and regression residuals. *F*, Relation between time and chloride regression residuals. *G*, Probability plot of chloride regression residuals.

Chloride at Honey Creek at Wauwatosa, WI (04087119)

Sample data from 5/20/2009 through 6/19/2009 were not used in the regression development because of excessive fouling of the YSI data sonde, followed by damage to the sonde and sampler line during an extreme flood event.

MODEL SUMMARY—Summary of final regression results for estimating chloride concentrations at Honey Creek at Wauwatosa, WI.

Log_{10} (Chloride) = -0.984 +1.12 log_{10} (SC),

Where:

Chloride = chloride concentration in mg/L

SC = Specific Conductance in µS/cm at 25^{o} C

***Model Information (in log units unless otherwise specified)*:**

Number of measurements = 70,

Root-mean-squared error (RMSE) = 0.23

Model standard percentage error (MPSE) = +71 and -42 percent

90-percent prediction intervals (based on units in mg/L) = +/- 121 percent

Adjusted coefficient of determination (Adj R^2) = 0.81

Sum of squared error = 3.70

PRESS = 3.88

***Coefficients*:**

	Coefficient	**Standard error**	**t statistic**	**p-value**
Intercept	**-.984**	**0.186**	**-5.29**	**<0.0001**
Log_{10} (SC)	**1.99**	**0.218**	**9.11**	**<0.0001**

Correlation matrix of coefficients:

	Intercept	**log_{10} (SC)**
Intercept	**1**	**-0.989**
Log_{10} (SC)	**-0.989**	**1**

Duan's bias correction factor **= 1.19**

Table 2-3. Model-calibration dataset for Honey Creek at Wauwatosa, Wisconsin.

[mg/L, milligrams per liter; µS/cm, microsiemens per centimeter; °C, degrees Celsius]

Date	Time	Chloride (mg/L)	Specific conductance (µS/cm at 25 °C)
12/17/2008	13:45	1,100	4,360
1/20/2009	11:55	1,700	5,910
2/10/2009	10:10	540	2,253
2/10/2009	13:25	380	1,687
2/10/2009	19:25	500	2,097
2/11/2009	1:25	740	2,937
2/11/2009	11:25	1,000	3,660
2/11/2009	12:00	650	2,930
2/11/2009	15:30	380	1,610
2/12/2009	2:25	670	2,647
2/16/2009	12:20	980	3,737
3/7/2009	9:25	1,100	3,460
3/7/2009	10:25	400	1,300
3/7/2009	12:10	320	727
3/7/2009	16:05	270	520
3/7/2009	22:05	260	518
3/8/2009	14:25	170	354
3/9/2009	1:00	260	477
3/10/2009	0:50	610	704
3/10/2009	5:30	190	377
3/10/2009	9:30	240	354
3/10/2009	12:10	270	411
3/10/2009	12:15	280	411
3/24/2009	11:40	690	3,110
3/25/2009	1:20	240	809
3/25/2009	3:45	660	518
3/31/2009	16:15	510	2,110
3/31/2009	17:05	250	1,160
4/19/2009	17:10	430	2,050
4/19/2009	18:15	150	667
4/20/2009	2:30	86	429
4/20/2009	17:20	260	1,460
4/23/2009	10:45	460	2,340
4/25/2009	10:50	510	2,380
4/25/2009	12:40	34	196
4/25/2009	21:25	230	1,010
4/26/2009	2:25	74	391
4/26/2009	11:10	92	559
4/26/2009	15:30	69	417
4/26/2009	17:20	32	258
4/26/2009	20:25	90	591
5/13/2009	20:30	310	1,580
5/13/2009	20:50	59	281
5/13/2009	21:10	26	181
5/14/2009	0:55	17	190
5/14/2009	2:40	46	124
7/16/2009	11:00	190	1,050
8/7/2009	17:10	180	938
8/7/2009	20:20	27	241
8/7/2009	23:05	41	305
8/8/2009	9:10	24	179
8/8/2009	9:30	17	150
8/8/2009	19:55	140	715
8/10/2009	1:50	30	153
8/10/2009	4:10	11	181
8/19/2009	12:40	200	1,120
8/25/2009	20:55	270	1,360
8/28/2009	22:05	65	390
8/26/2009	4:05	34	276
9/15/2009	10:45	250	1,670
9/20/2009	20:20	240	1,240
9/20/2009	21:55	140	724
9/21/2009	3:55	59	431
9/22/2009	13:25	260	1,350
9/22/2009	14:05	31	237
9/22/2009	22:40	57	378
9/27/2009	20:20	120	533
9/27/2009	21:00	16	134
9/27/2009	23:35	23	182
9/28/2009	2:30	47	323
MINIMUM		**11**	**124**
MAXIMUM		**1,700**	**5,910**
MEAN		**297**	**1,150**
MEDIAN		**235**	**629**
STANDARD DEVIATION		**321**	**1,185**

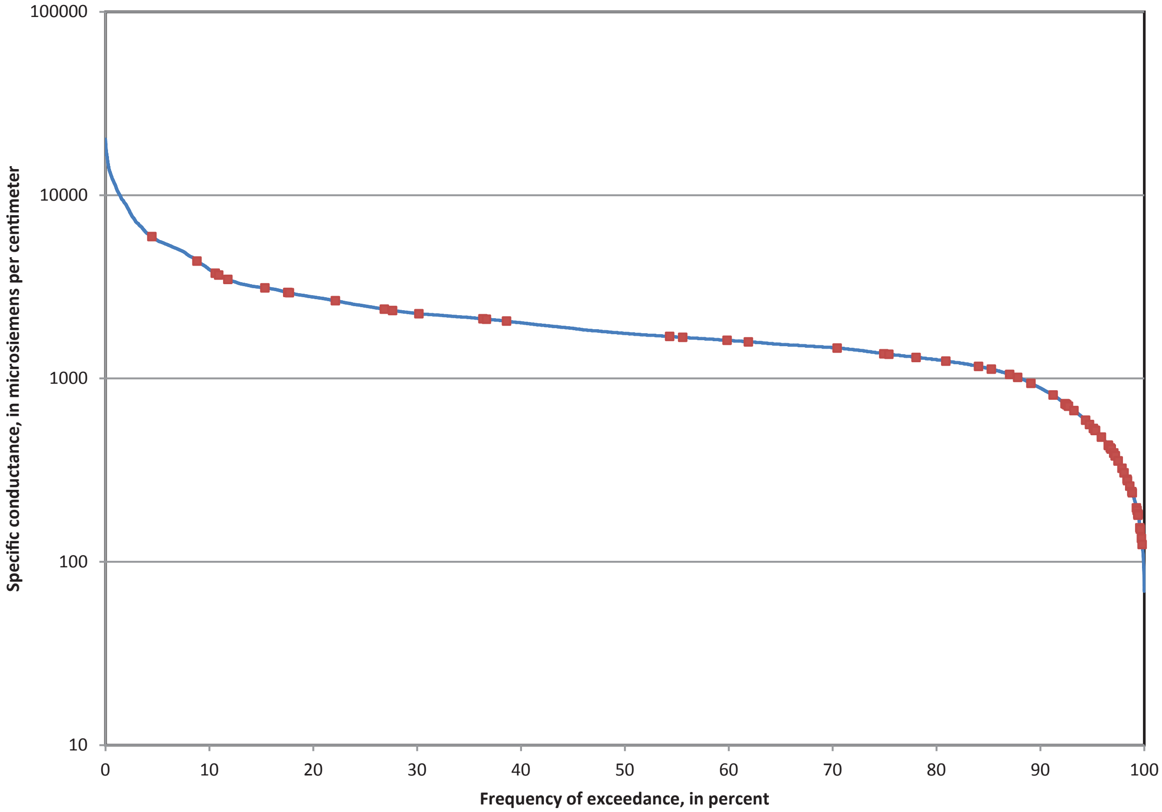


Figure 2-5. Duration curve for specific conductivity (November 2008–September 2010) and corresponding values associated with chloride concentration samples collected November 2008 to September 2009 at U.S.Geological Survey streamgage on Honey Creek at Wauwatosa, Wisconsin.

Chloride at Honey Creek at Wauwatosa, Wisconsin, November 2008–September 2009

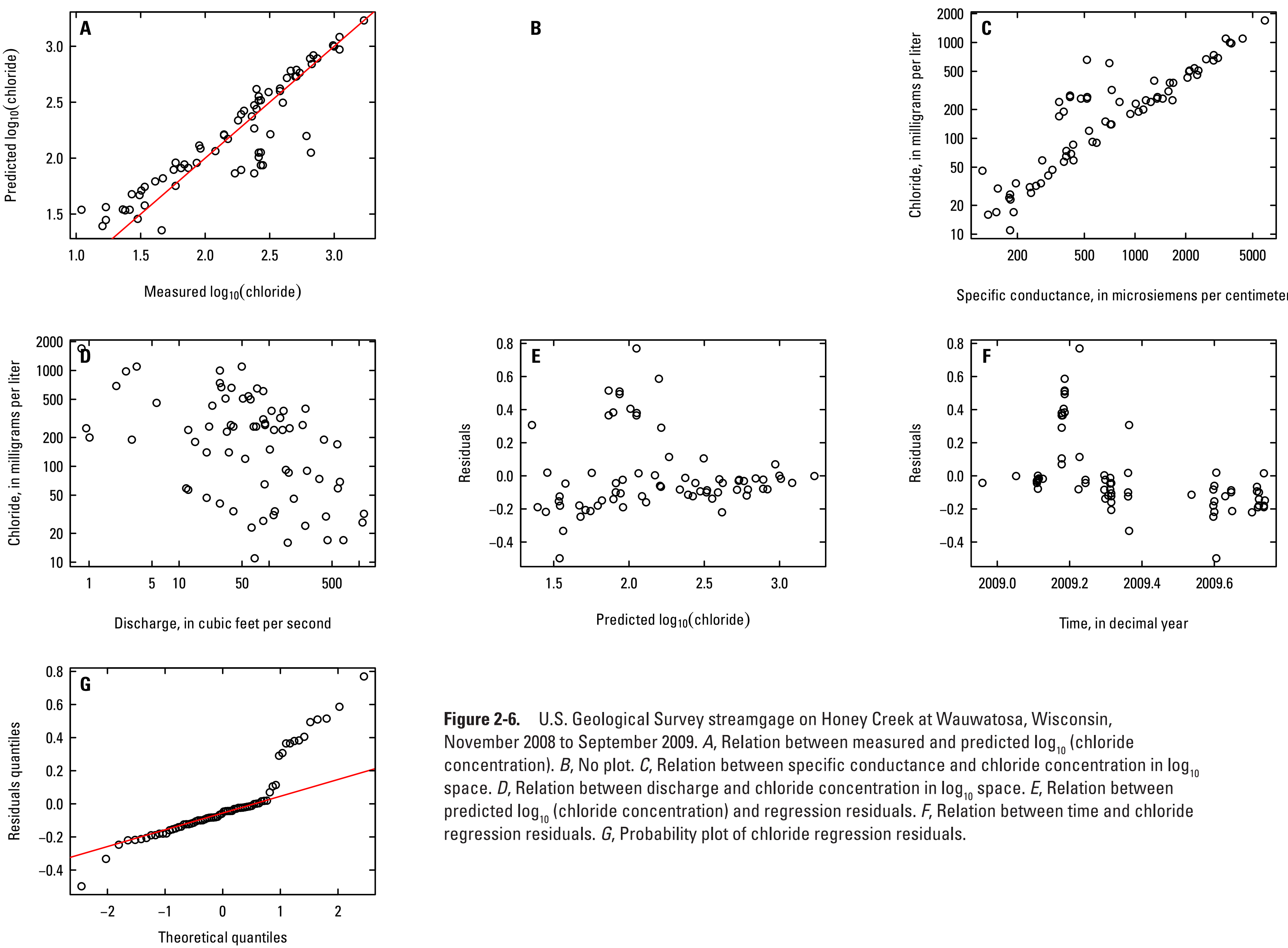


Figure 2-6. U.S. Geological Survey streamgage on Honey Creek at Wauwatosa, Wisconsin, November 2008 to September 2009. *A*, Relation between measured and predicted $\log_{10}$ (chloride concentration). *B*, No plot. *C*, Relation between specific conductance and chloride concentration in $\log_{10}$ space. *D*, Relation between discharge and chloride concentration in $\log_{10}$ space. *E*, Relation between predicted $\log_{10}$ (chloride concentration) and regression residuals. *F*, Relation between time and chloride regression residuals. *G*, Probability plot of chloride regression residuals.

Chloride at Menomonee River at Wauwatosa, WI (04087120)

MODEL SUMMARY—Summary of final regression results for estimating chloride concentrations at Menomonee River at Wauwatosa, WI.

$\log_{10}$ (Chloride) = -1.41 +1.23 $\log_{10}$ (SC),

Where:

Chloride = chloride concentration in mg/L
SC = Specific Conductance in µS/cm at 25^{o} C

***Model Information (in log units unless otherwise specified)*:**

Number of measurements = 101,
Root-mean-squared error (RMSE) = 0.115
Model standard percentage error (MPSE) = +30 and -23 percent
90-percent prediction intervals (based on units in mg/L) = +/- 47 percent
Adjusted coefficient of determination (Adj R^2) = 0.92
Sum of squared error = 1.30
PRESS = 1.35

***Coefficients*:**

	Coefficient	**Standard error**	**t statistic**	**p-value**
Intercept	**-1.41**	**0.111**	**-12.65**	**<0.0001**
$\log_{10}$ (SC)	**1.23**	**0.036**	**33.63**	**<0.0001**

Correlation matrix of coefficients:

	Intercept	**$\log_{10}$ (SC)**
Intercept	**1**	**-0.995**
$\log_{10}$ (SC)	**-0.995**	**1**

Duan's bias correction factor **= 1.03**

Table 2-4. Model-calibration dataset for Menomonee River at Wauwatosa, Wisconsin.

[mg/L, milligrams per liter; µS/cm, microsiemens per centimeter; °C, degrees Celsius]

Date	Time	Chloride (mg/L)	Specific conductance (µS/cm at 25 °C)	Date	Time	Chloride (mg/L)	Specific conductance (µS/cm at 25 °C)
11/20/2008	10:30	180	1,250	5/9/2009	0:30	180	992
12/17/2008	12:30	450	2,120	5/9/2009	9:30	150	825
12/27/2008	1:15	2,300	6,520	5/9/2009	15:50	150	807
12/27/2008	3:45	2,100	6,890	5/13/2009	20:40	140	816
12/27/2008	5:50	1,800	6,126	5/13/2009	21:05	110	673
12/27/2008	6:05	1,900	6,100	5/13/2009	22:00	85	513
12/27/2008	10:15	1,300	4,640	5/14/2009	3:15	85	525
12/27/2008	14:00	820	3,040	5/20/2009	11:15	190	1,150
12/27/2008	14:45	580	2,350	6/8/2009	3:10	210	1,090
12/28/2008	7:45	480	1,960	6/8/2009	4:00	150	944
1/20/2009	12:10	470	2,370	6/8/2009	4:15	150	778
2/7/2009	11:25	920	3,520	6/8/2009	6:45	46	288
2/7/2009	13:25	990	3,620	6/8/2009	10:15	80	481
2/7/2009	13:40	1,000	3,590	6/9/2009	4:15	130	734
2/7/2009	19:40	670	2,616	6/16/2009	11:50	240	1,320
2/8/2009	13:40	640	2,593	6/19/2009	9:15	110	319
2/9/2009	1:40	480	2,163	6/19/2009	18:15	39	361
2/9/2009	19:40	460	2,110	6/19/2009	21:20	35	269
2/9/2009	22:00	520	2,320	6/20/2009	3:10	54	496
2/9/2009	23:15	460	2,100	7/16/2009	11:45	220	1,160
2/10/2009	7:20	440	2,080	8/7/2009	18:00	240	1,180
2/10/2009	11:00	470	2,190	8/7/2009	20:40	230	1,230
2/10/2009	17:05	410	1,913	8/8/2009	0:55	120	699
2/10/2009	23:25	350	1,753	8/8/2009	8:50	100	598
2/16/2009	12:45	320	1,770	8/8/2009	9:45	62	402
2/26/2009	14:35	620	2,840	8/8/2009	19:50	77	485
2/26/2009	19:00	630	1,610	8/9/2009	19:50	170	861
2/26/2009	19:45	630	1,320	8/10/2009	2:00	130	739
2/26/2009	22:50	330	1,160	8/10/2009	4:20	68	457
2/27/2009	4:50	280	1,590	8/19/2009	12:20	47	1,370
3/2/2009	7:20	270	1,670	8/25/2009	20:50	82	623
3/10/2009	0:15	260	1,220	8/25/2009	21:25	99	643
3/10/2009	5:50	210	981	8/25/2009	21:30	150	944
3/10/2009	11:45	200	958	8/26/2009	3:30	95	577
3/10/2009	14:50	200	938	8/27/2009	3:35	94	587
3/11/2008	1:10	180	892	9/15/2009	11:00	290	1,520
3/24/2009	11:55	280	1,460	9/20/2009	21:40	210	1,080
3/25/2009	1:30	280	1,350	9/21/2009	3:40	140	740
3/31/2009	17:00	330	1,720	9/22/2009	13:30	140	889
3/31/2009	17:35	310	1,620	9/22/2009	13:40	82	848
4/1/2009	5:35	280	1,520	9/22/2009	21:50	120	470
4/19/2009	19:10	270	1,350	9/22/2009	23:10	120	675
4/20/2009	5:05	190	899	9/27/2009	20:35	100	666
4/21/2009	5:05	270	1,300	9/27/2009	21:05	140	758
4/23/2009	11:00	250	1,320	9/27/2009	21:20	96	508
4/25/2009	11:15	240	1,250	09/28/209	0:05	29	235
4/25/2009	12:40	160	813	9/28/2009	2:35	57	386
4/25/2009	21:35	140	735	9/28/2009	20:35	100	584
4/26/2009	2:35	120	637	**MINIMUM**		**29**	**235**
4/26/2009	14:35	130	725	**MAXIMUM**		**2,300**	**6,890**
4/26/2009	16:00	80	498	**MEAN**		**334**	**1,449**
4/26/2009	17:10	63	430	**MEDIAN**		**190**	**992**
4/27/2009	0:30	86	564	**STANDARD DEVIATION**		**418**	**1,308**

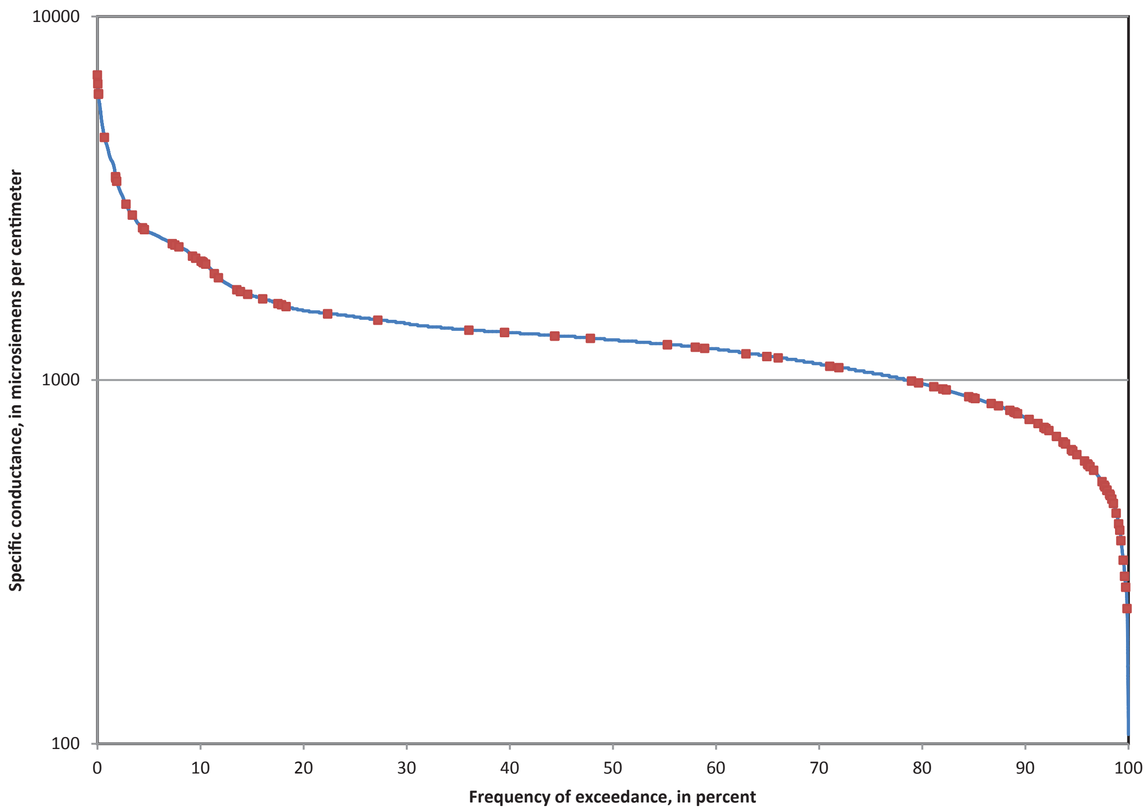


Figure 2-7. Duration curve for specific conductivity (November 2008–September 2010) and corresponding values associated with chloride concentration samples collected November 2008 to September 2009 at U.S.Geological Survey streamgage on Menomonee River at Wauwatosa, Wisconsin.

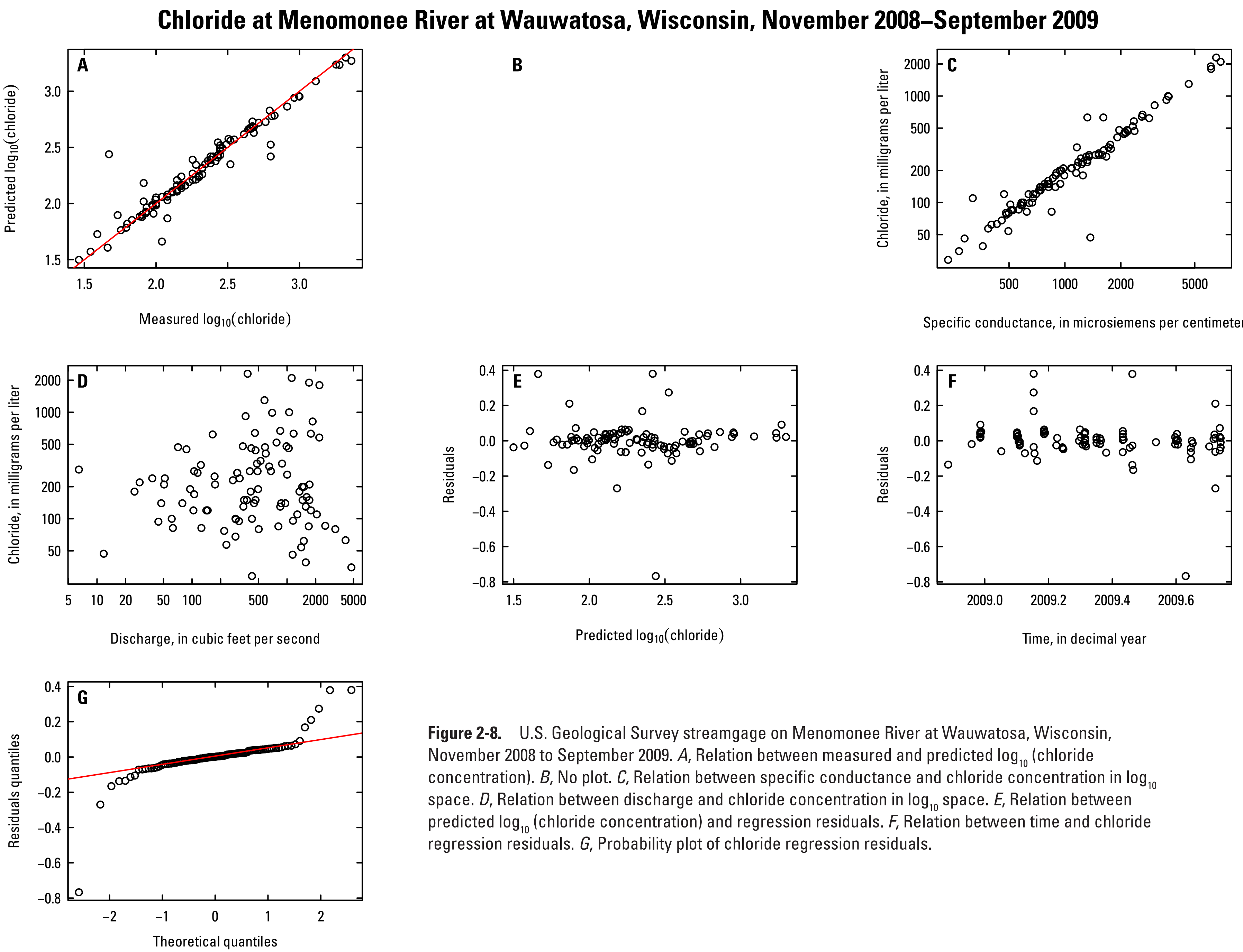


Figure 2-8. U.S. Geological Survey streamgage on Menomonee River at Wauwatosa, Wisconsin, November 2008 to September 2009. *A*, Relation between measured and predicted log_{10} (chloride concentration). *B*, No plot. *C*, Relation between specific conductance and chloride concentration in log_{10} space. *D*, Relation between discharge and chloride concentration in log_{10} space. *E*, Relation between predicted log_{10} (chloride concentration) and regression residuals. *F*, Relation between time and chloride regression residuals. *G*, Probability plot of chloride regression residuals.

Chloride at Menomonee River at 16th Street at Milwaukee, WI (04087142)

MODEL SUMMARY—Summary of final regression results for estimating chloride concentrations at Menomonee River at 16th Street at Milwaukee, WI.

$\log_{10}$ (Chloride) = -1.50 +1.26 $\log_{10}$ (SC),

Where:

Chloride = chloride concentration in mg/L

SC = Specific Conductance in µS/cm at 25° C

***Model Information (in log units unless otherwise specified)*:**

Number of measurements = 79,

Root-mean-squared error (RMSE) = 0.074

Model standard percentage error (MPSE) = +18 and -16 percent

90-percent prediction intervals (based on units in mg/L) = +/- 29 percent

Adjusted coefficient of determination (Adj R^2) = 0.97

Sum of squared error = 0.42

PRESS = 0.44

***Coefficients*:**

	Coefficient	**Standard error**	**t statistic**	**p-value**
Intercept	**-1.50**	**0.078**	**-19.25**	**<0.0001**
$\log_{10}$ (SC)	**1.26**	**0.026**	**47.86**	**<0.0001**

Correlation matrix of coefficients:

	Intercept	**$\log_{10}$ (SC)**
Intercept	**1**	**-0.994**
$\log_{10}$ (SC)	**-0.994**	**1**

Duan’s bias correction factor **= 1.01**

Table 2-5. Model-calibration dataset for Menomonee River at 16th Street at Milwaukee, Wisconsin.

[mg/L, milligrams per liter; µS/cm, microsiemens per centimeter; °C, degrees Celsius]

Date	Time	Chloride (mg/L)	Specific conductance (µS/cm at 25 °C)
11/20/2008	11:45	110	942
12/17/2008	14:15	520	2,480
12/27/2008	9:35	1,100	4,033
12/27/2008	12:35	1,400	4,763
12/27/2008	15:35	700	2,340
12/27/2008	21:35	510	2,053
12/28/2008	0:35	540	2,200
12/28/2008	6:35	520	2,130
1/20/2009	12:40	150	1,740
2/7/2009	11:40	250	1,493
2/7/2009	20:40	920	3,476
2/8/2009	5:40	730	2,880
2/8/2009	14:40	680	2,843
2/8/2009	23:40	690	2,753
2/9/2009	17:40	520	2,300
2/10/2009	5:40	480	2,210
2/11/2009	17:40	320	1,570
2/16/2009	13:40	360	1,873
2/26/2009	16:00	420	2,090
2/26/2009	19:00	480	2,110
2/26/2009	22:00	280	1,090
2/27/2009	4:00	300	1,240
2/27/2009	12:00	370	1,550
2/28/2009	12:00	320	1,860
3/7/2009	11:10	300	1,710
3/7/2009	14:10	270	1,420
3/7/2009	23:10	290	1,290
3/8/2009	12:10	280	1,300
3/8/2009	18:10	160	743
3/9/2009	0:10	240	1,100
3/10/2009	8:15	200	938
3/10/2009	12:55	210	1,020
3/10/2009	13:00	210	1,030
3/10/2009	20:30	200	991
3/11/2009	4:30	190	984
3/24/2009	12:25	270	1,334
4/1/2009	1:40	240	1,220
4/20/2009	3:05	180	866
4/20/2009	4:50	160	714
4/23/2009	11:15	240	1,220
4/25/2009	13:20	240	1,190
4/25/2009	20:00	120	611
4/26/2009	8:00	120	639
4/26/2009	14:00	120	680
4/26/2009	16:25	100	601
4/26/2009	17:10	74	450
4/26/2009	19:30	59	411
4/26/2009	19:35	59	414
5/13/2009	22:05	160	895
5/14/2009	0:35	51	374
5/14/2009	1:45	42	326
5/14/2009	3:35	49	378
5/20/2009	11:45	170	1,080
6/8/2009	12:40	66	395
6/8/2009	15:30	79	478
6/9/2009	2:35	95	566
6/9/2009	5:00	100	600
6/16/2009	13:00	150	974
6/19/2009	0:55	50	307
6/19/2009	1:10	18	174
6/19/2009	1:45	20	174
6/19/2009	9:35	47	379
6/19/2040	20:45	39	315
6/20/2009	2:25	56	471
7/16/2009	12:30	150	883
8/8/2009	22:30	56	361
8/9/2009	10:30	82	508
8/19/2009	13:30	120	775
8/26/2009	7:05	69	413
8/26/2009	17:00	84	522
8/26/2009	23:45	90	547
9/15/2009	11:30	96	725
9/23/2009	7:10	100	750
9/24/2009	7:00	110	710
9/28/2009	12:05	39	294
09/28/209	18:05	76	472
9/29/2009	0:05	72	481
9/29/2009	3:05	75	492
9/29/2009	5:00	72	541
MINIMUM		**18**	**174**
MAXIMUM		**1,400**	**4,763**
MEAN		**249**	**1,180**
MEDIAN		**160**	**938**
STANDARD DEVIATION		**254**	**910**

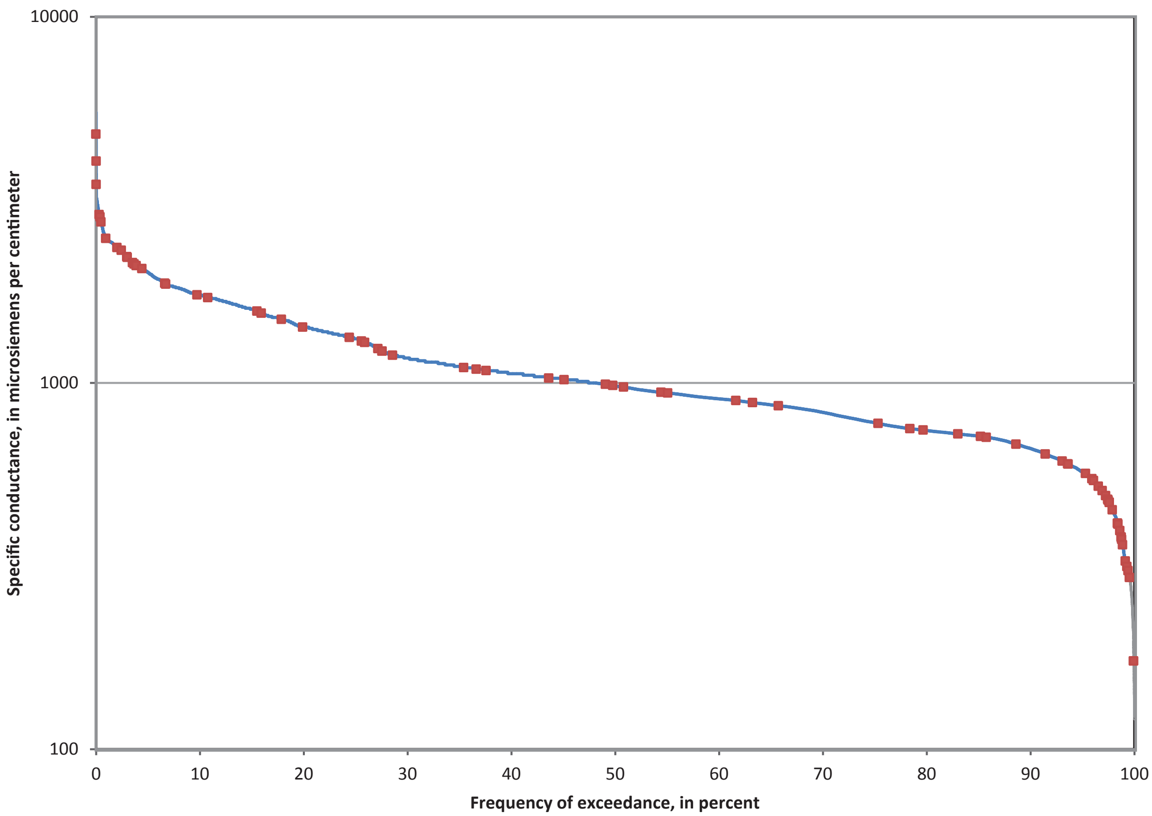
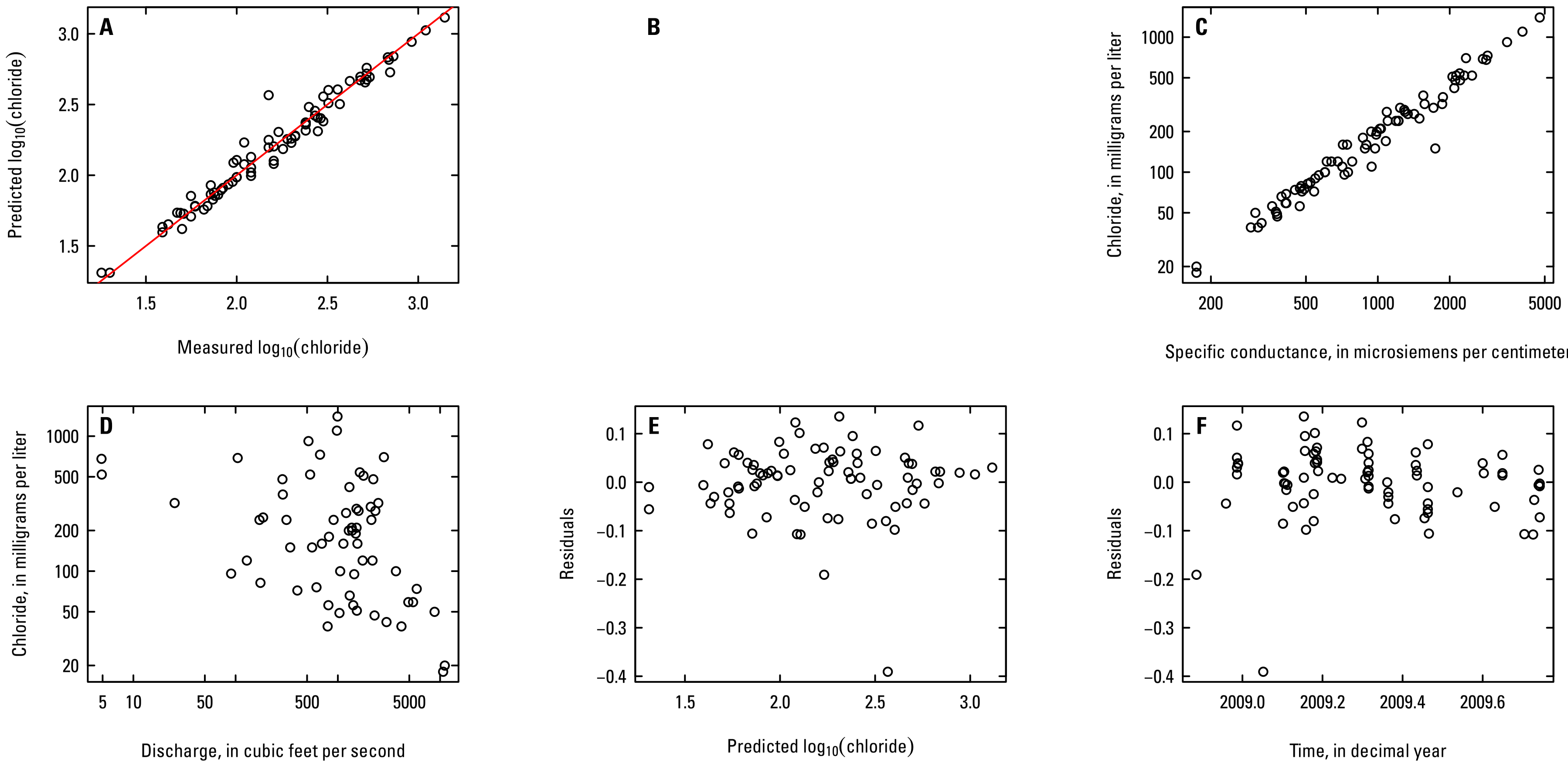


Figure 2-9. Duration curve for specific conductivity (November 2008–September 2010) and corresponding values associated with chloride concentration samples collected November 2008 to September 2009 at U.S.Geological Survey streamgage on Menomonee River at 16th Street at Milwaukee, Wisconsin.

Chloride at Menomonee River at 16th Street at Milwaukee, Wisconsin, November 2008–September 2009



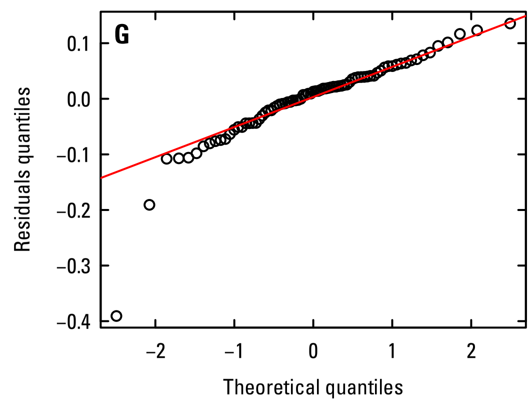


Figure 2-10. U.S. Geological Survey streamgage on Menomonee River at 16th Street at Milwaukee, Wisconsin, November 2008 to September 2009. *A*, Relation between measured and predicted $\log_{10}$ (chloride concentration). *B*, No plot. *C*, Relation between specific conductance and chloride concentration in $\log_{10}$ space. *D*, Relation between discharge and chloride concentration in $\log_{10}$ space. *E*, Relation between predicted $\log_{10}$ (chloride concentration) and regression residuals. *F*, Relation between time and chloride regression residuals. *G*, Probability plot of chloride regression residuals.

Appendix 3. Regression analysis results for estimating total suspended solids concentration

All data were collected using U.S. Geological Survey (USGS) protocols and are stored in the USGS National Water Information System (NWIS) database (*http://waterdata.usgs.gov/nwis*). The regression models are based on measurements of turbidity and concurrent total suspended solids samples collected from November 2008 to September 2009. Continuous water-quality data were collected at 5-minute intervals using a YSI model 6920 V2 multiparameter water-quality monitor with a 6560 specific conductance and water temperature sensor, and a 6136 optical turbidity sensor. Turbidity values are instantaneous unit values temporally corresponding to the collection of the total suspended solids samples. Samples were collected throughout the range of continuously observed hydrologic conditions. Summary statistics and the complete model-calibration dataset are provided. A comparison of cross-section mean and corresponding time-series monitor readings is archived at the Wisconsin Water Science Center and is available by request to Austin Baldwin (akbaldwi@usgs.gov).

Total suspended solids at Little Menomonee River near Freistadt, WI (04087050)

Samples collected on 2/26/2009 were not used in the regression analysis. From inspection of the scatter plots, these samples appear to be outliers.

MODEL SUMMARY—Summary of final regression results for estimating total suspended solids concentrations at Little Menomonee River near Freistadt, WI.

$\log_{10}$ (Suspended Solids) = 0.334 + 0.910 $\log_{10}$ (Turb),
Where:

Suspended Solids = total suspended solids concentration in mg/L
Turb = Turbidity (YSI 6136), in NTU

***Model Information (in log units unless otherwise specified)*:**
Number of measurements = 39,
Root-mean-squared error (RMSE) = 0.17
Model standard percentage error (MPSE) = +46 and -32 percent
90-percent prediction intervals (based on units in mg/L) = +/- 74 percent
Adjusted coefficient of determination (Adj R^2) = 0.94
Sum of squared error = 1.01
PRESS = 1.25

***Coefficients*:**

	Coefficient	**Standard error**	**t statistic**	**p-value**
Intercept	**0.334**	**0.063**	**5.31**	**<0.001**
$\log_{10}$ (Turb)	**0.910**	**0.038**	**23.84**	**<0.001**

Correlation matrix of coefficients:

	Intercept	**$\log_{10}$ (Turb)**
Intercept	**1**	**-0.908**
$\log_{10}$ (Turb)	**-0.908**	**1**

Duan's bias correction factor **= 1.08**

Table 3-1. Model-calibration dataset for Little Menomonee River near Freistadt, Wisconsin.

[mg/L, milligrams per liter; NTU, Nephelometric turbidity units]

Date	Time	Total suspended solids (mg/L)	Turbidity (NTU)
11/20/2008	9:45	2	1.2
12/17/2008	11:30	2	2.1
12/27/2008	13:05	13	11.2
12/28/2008	1:05	100	52.3
12/28/2008	7:15	42	45.0
1/20/2009	10:55	7	0.7
2/7/2009	18:50	37	19.7
2/9/2009	22:40	18	11.3
2/10/2009	10:45	67	38.0
2/10/2009	14:40	220	113.3
2/10/2009	20:40	92	46.0
2/11/2009	2:40	31	21.3
3/2/2009	7:10	5	4.2
3/7/2009	12:55	180	130.0
3/7/2009	18:05	410	220.0
3/8/2009	7:05	84	62.0
3/8/2009	19:00	320	210.0
3/9/2009	0:30	170	140.0
3/10/2009	3:20	100	68.0
03/10/209	8:15	160	94.0
3/10/2009	20:15	44	51.0
3/24/2009	10:40	9	2.8
4/23/2009	9:45	6	2.1
4/25/2009	15:10	130	100.0
4/26/2009	5:30	330	180.0
4/26/2009	19:30	310	200.0
4/27/2009	1:30	100	80.0
5/9/2009	7:25	110	81.0
5/9/2009	13:30	75	54.0
5/9/2009	19:30	24	15.0
5/14/2009	2:30	410	270.0
5/20/2009	9:00	14	4.5
6/8/2009	5:20	220	120.0
6/16/2009	8:45	18	12.0
6/19/2009	2:50	360	290.0
6/19/2009	8:50	160	89.0
7/16/2009	10:05	17	17.0
8/19/2009	10:00	10	17.0
9/15/2009	9:30	13	17.0
MINIMUM		**2**	**0.7**
MAXIMUM		**410**	**290.0**
MEAN		**113**	**74.2**
MEDIAN		**75**	**51.0**
STANDARD DEVIATION		**123**	**78.7**

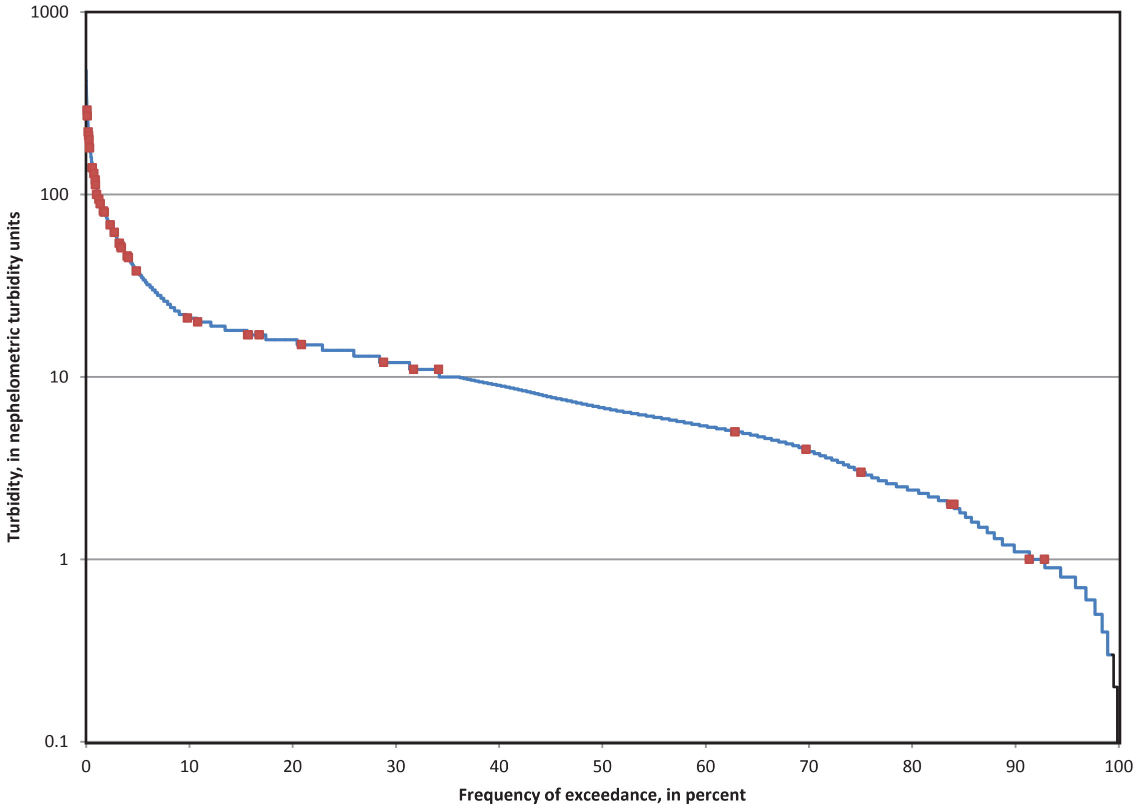
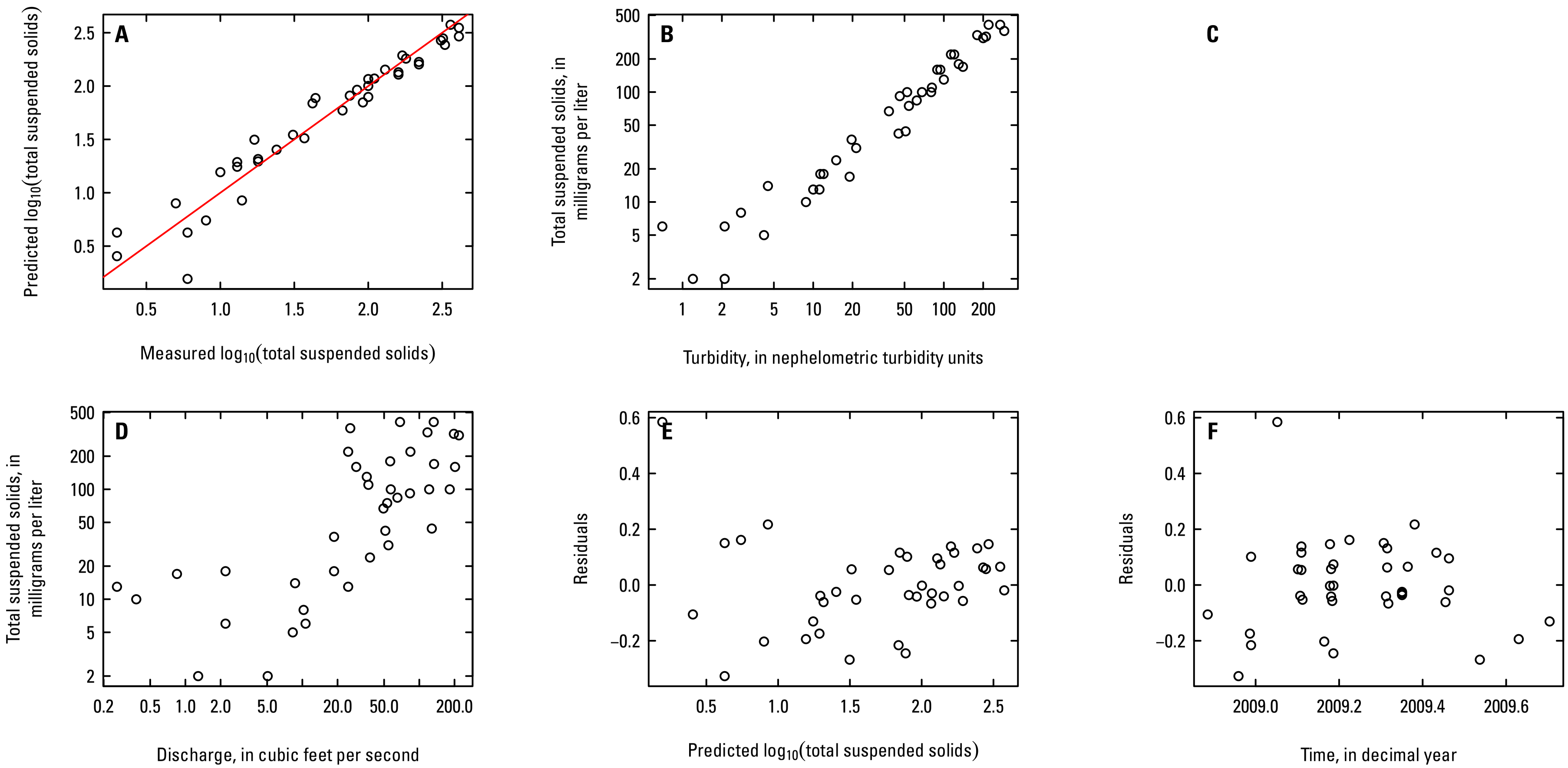


Figure 3-1. Duration curve for turbidity (November 2008–September 2010) and corresponding values associated with total suspended solids concentration samples collected November 2008 to September 2009 at U.S. Geological Survey streamgage on Little Menomonee River near Freistadt, Wisconsin.

Total suspended solids at Little Menomonee River near Freistadt, Wisconsin, November 2008–September 2009



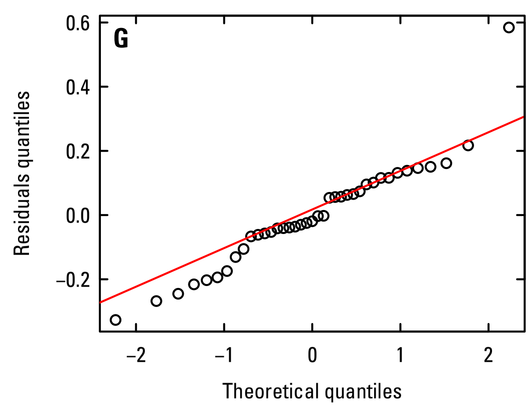


Figure 3-2. U.S. Geological Survey streamgage on Little Menomonee River near Freistadt, Wisconsin, November 2008 to September 2009. *A*, Relation between measured and predicted $\log_{10}$(total suspended solids concentration). *B*, Relation between turbidity and total suspended solids concentration in $\log_{10}$ space. *C*, No plot. *D*, Relation between discharge and total suspended solids concentration in $\log_{10}$ space. *E*, Relation between predicted $\log_{10}$ (total suspended solids concentration) and regression residuals. *F*, Relation between time and total suspended solids regression residuals. *G*, Probability plot of total suspended solids regression residuals.

Total suspended solids at Menomonee River at Menomonee Falls, WI (04087030)

MODEL SUMMARY—Summary of final regression results for estimating total suspended solids concentrations at Menomonee River at Menomonee Falls, WI.

$\log_{10}$ (Suspended Solids) = 0.256 + 0.953 $\log_{10}$ (Turb),

Where:

Suspended Solids = total suspended solids concentration in mg/L
Turb = Turbidity (YSI 6136), in NTU

***Model Information (in log units unless otherwise specified)*:**

Number of measurements = 59,
Root-mean-squared error (RMSE) = 0.16
Model standard percentage error (MPSE) = +43 and -30 percent
90-percent prediction intervals (based on units in mg/L) = +/- 69 percent
Adjusted coefficient of determination (Adj R^2) = 0.92
Sum of squared error = 1.40
PRESS = 1.54

***Coefficients*:**

	Coefficient	**Standard error**	**t statistic**	**p-value**
Intercept	**0.256**	**0.058**	**4.41**	**<0.0001**
$\log_{10}$ (Turb)	**0.953**	**0.038**	**25.19**	**<0.0001**

Correlation matrix of coefficients:

	Intercept	**$\log_{10}$ (Turb)**
Intercept	**1**	**-0.936**
$\log_{10}$ (Turb)	**-0.936**	**1**

Duan's bias correction factor **= 1.07**

Table 3-2. Model-calibration dataset for Menomonee River at Menomonee Falls, Wisconsin.

[mg/L, milligrams per liter; NTU, Nephelometric turbidity units]

Date	Time	Total suspended solids (mg/L)	Turbidity (NTU)
11/20/2008	9:15	6	3.6
12/17/2008	12:00	5	2.7
12/27/2008	0:35	18	18.0
12/27/2008	6:15	36	49.0
12/27/2008	14:20	110	100.7
12/27/2008	20:20	66	39.7
12/28/2008	8:20	37	45.3
1/20/2009	9:55	11	2.5
2/16/2009	11:00	5	3.1
2/26/2009	15:05	130	86.0
2/26/2009	18:15	110	81.0
2/27/2009	0:15	36	30.0
3/2/2009	7:15	22	3.2
3/7/2009	9:30	47	31.0
3/7/2009	15:30	48	29.0
3/8/2009	10:30	39	26.0
3/8/2009	14:00	130	69.0
3/9/2009	2:00	52	34.0
3/24/2009	10:00	9	4.1
3/25/2009	5:25	24	16.0
4/19/2009	23:00	46	23.0
4/20/2009	11:15	14	12.0
4/20/2009	23:15	13	11.0
4/23/2009	9:15	4	3.8
4/25/2009	10:50	120	71.0
4/25/2009	11:00	350	170.0
4/26/2009	5:00	44	27.0
4/26/2009	16:00	50	34.0
4/27/2009	4:00	38	23.0
5/9/2009	1:05	110	83.0
5/9/2009	1:15	210	110.0
5/9/2009	10:25	21	12.0
5/9/2009	22:25	24	14.0
5/10/2009	10:25	12	8.2
5/13/2009	23:00	120	81.0
05/20/209	9:30	11	6.3
6/8/2009	3:15	180	91.0
6/8/2009	3:25	500	220.0
6/8/2009	9:35	51	28.0
6/16/2009	10:15	20	13.0
6/19/2009	0:10	250	160.0
6/19/2009	0:50	200	110.0
6/19/2009	2:00	110	66.0
6/20/2009	2:00	28	21.0
7/16/2009	9:30	5	5.0
8/7/2009	19:35	76	46.0
8/8/2009	9:05	150	80.0
8/19/2009	9:00	4	3.2
8/25/2009	18:20	250	210.0
8/25/2009	18:45	120	85.0
8/26/2009	1:30	20	30.0
8/26/2009	1:55	50	48.0
9/15/2009	9:30	6	2.8
9/22/2009	13:15	88	62.0
9/22/2009	14:05	270	130.0
9/22/2009	15:20	36	21.0
9/27/2009	19:25	100	81.0
9/27/2008	21:30	99	51.0
9/28/2009	5:55	10	12.0
MINIMUM		**4**	**2.5**
MAXIMUM		**500**	**220.0**
MEAN		**81**	**49.8**
MEDIAN		**46**	**30.0**
STANDARD DEVIATION		**95**	**50.9**

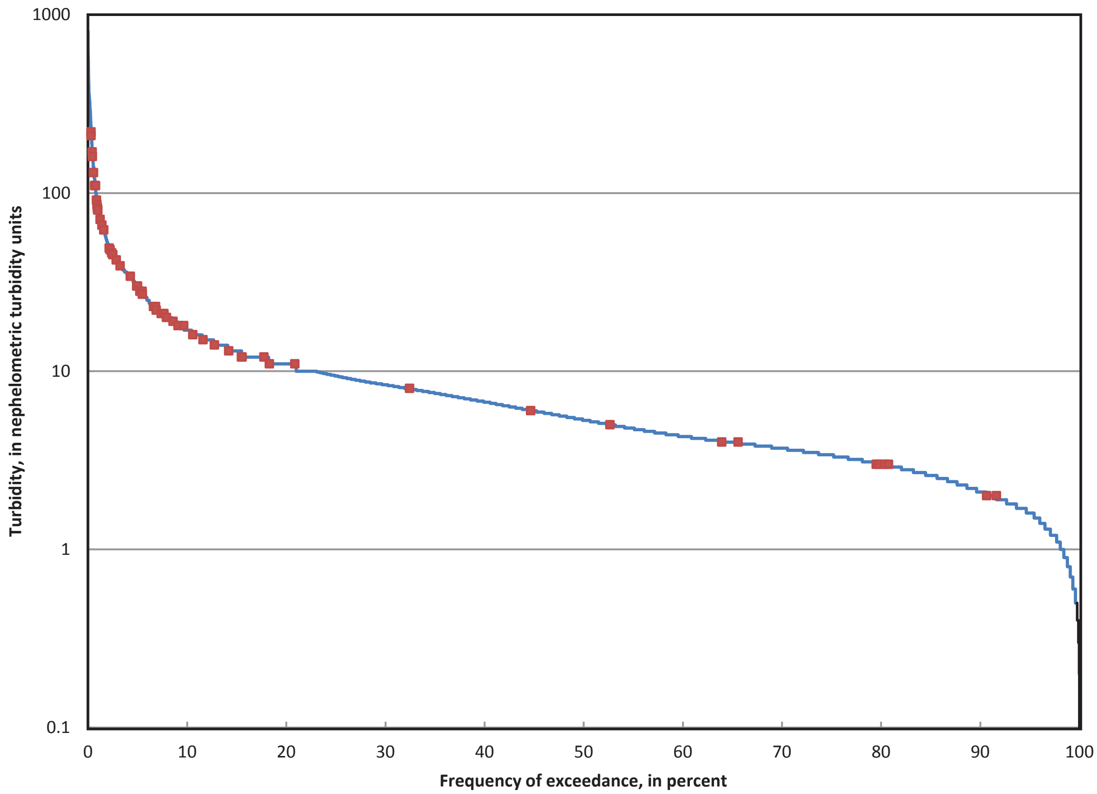
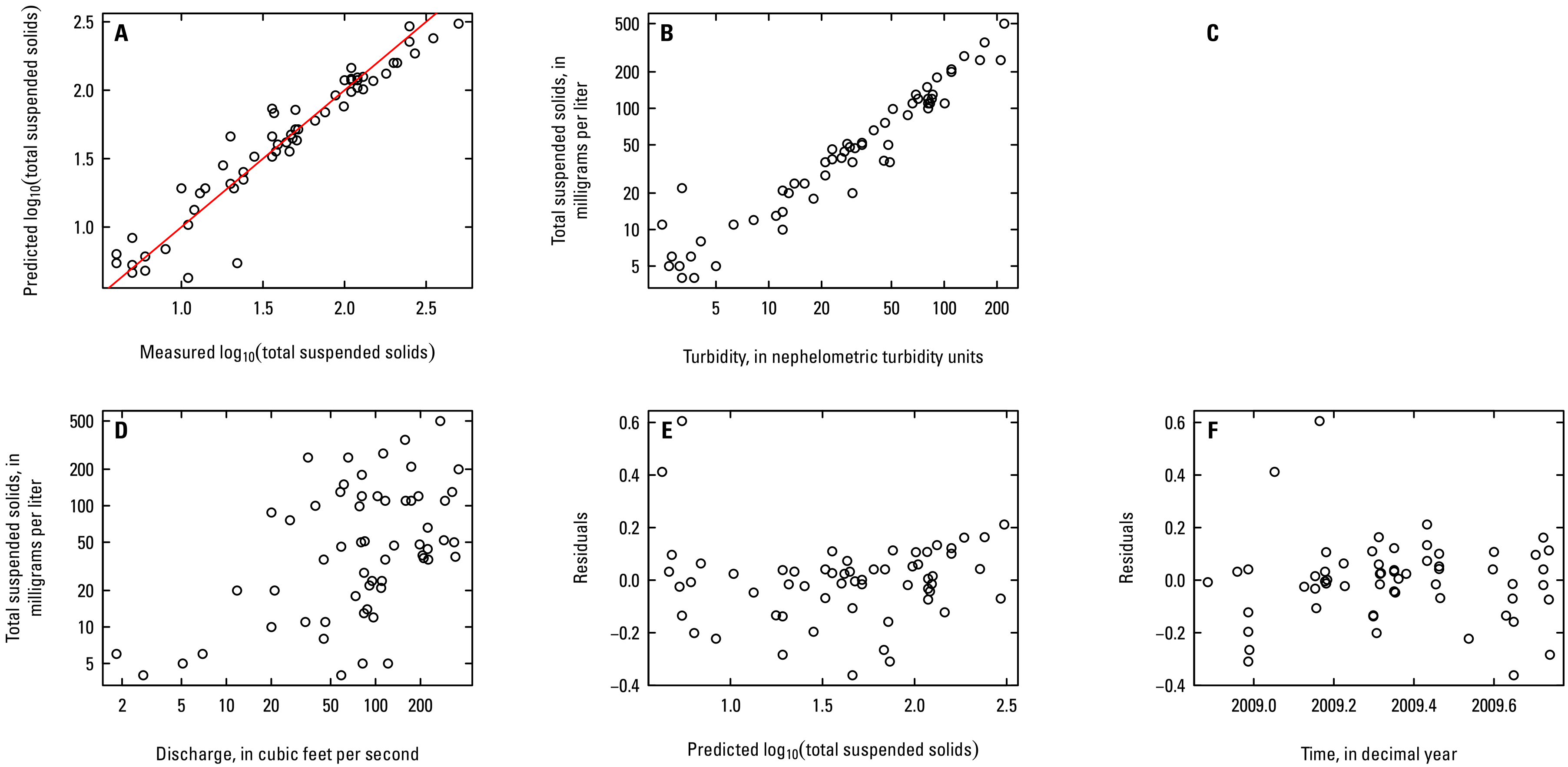


Figure 3-3. Duration curve for turbidity (November 2008–September 2010) and corresponding values associated with total suspended solids concentration samples collected November 2008 to September 2009 at U.S. Geological Survey streamgage on Menomonee River at Menomonee Falls, Wisconsin.

Total suspended solids at Menomonee River at Menomonee Falls, Wisconsin, November 2008–September 2009



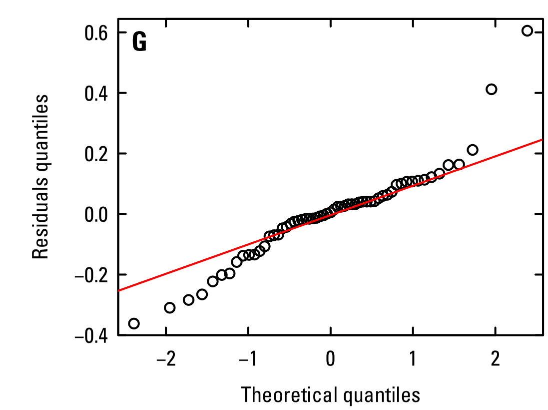


Figure 3-4. U.S. Geological Survey streamgage on Menomonee River at Menomonee Falls, Wisconsin, November 2008 to September 2009. *A*, Relation between measured and predicted log_{10} (total suspended solids concentration). *B*, Relation between turbidity and total suspended solids concentration in log_{10} space. *C*, No plot. *D*, Relation between discharge and total suspended solids concentration in log_{10} space. *E*, Relation between predicted log_{10} (total suspended solids concentration) and regression residuals. *F*, Relation between time and total suspended solids regression residuals. *G*, Probability plot of total suspended solids regression residuals.

Total suspended solids at Honey Creek at Wauwatosa, WI (04087119)

Sample data from 4/25/2009 at 12:40 through 4/26/2009, and sample data from 6/8/2009 were not used in the regression development because of excessive fouling of the data sonde. Sample data on 6/19/2009 were not used because of damage to the sonde and sampler line during an extreme flood event.

MODEL SUMMARY—Summary of final regression results for estimating total suspended solids concentrations at Honey Creek at Wauwatosa, WI.

$\log_{10}$ (Suspended Solids) = 0.160 + 0.967 $\log_{10}$ (Turb),
Where:

Suspended Solids = total suspended solids concentration in mg/L
Turb = Turbidity (YSI 6136), in NTU

***Model Information (in log units unless otherwise specified)*:**
Number of measurements = 66,
Root-mean-squared error (RMSE) = 0.25
Model standard percentage error (MPSE) = +77 and -44 percent
90-percent prediction intervals (based on units in mg/L) = +/- 128 percent
Adjusted coefficient of determination (Adj R^2) = 0.86
Sum of squared error = 3.94
PRESS = 4.25

***Coefficients*:**

	Coefficient	Standard error	t statistic	p-value
Intercept	**0.160**	**0.085**	**1.88**	**0.0643**
Log $_{10}$ (Turb)	**0.967**	**0.047**	**20.39**	**<0.0001**

Correlation matrix of coefficients:

	Intercept	$\log_{10}$ (Turb)
Intercept	**1**	**-0.934**
$\log_{10}$ (Turb)	**-0.934**	**1**

Duan's bias correction factor **= 1.16**

Table 3-3. Model-calibration dataset for Honey Creek at Wauwatosa, Wisconsin.

[mg/L, milligrams per liter; NTU, Nephelometric turbidity units]

Date	Time	Total suspended solids (mg/L)	Turbidity (NTU)
12/17/2008	13:45	1	1.8
1/20/2009	11:55	3	1.7
2/10/2009	10:10	31	46.0
2/10/2009	13:25	130	123.3
2/10/2009	19:25	100	82.0
2/11/2009	1:25	36	41.3
2/11/2009	11:25	12	21.3
2/11/2009	12:00	220	97.0
2/11/2009	15:30	230	210.0
2/12/2009	2:25	27	32.7
2/16/2009	12:20	41	53.3
3/7/2009	9:25	13	74.0
3/7/2009	10:25	310	210.0
3/7/2009	12:10	350	140.0
3/7/2009	16:05	110	71.0
3/7/2009	22:05	70	46.0
3/8/2009	14:25	180	140.0
3/9/2009	1:00	75	32.0
3/10/2009	0:50	36	40.0
3/10/2009	5:30	60	50.0
3/10/2009	9:30	46	55.0
3/10/2009	12:10	23	33.0
3/10/2009	12:15	21	31.0
3/24/2009	11:40	5	1.8
3/25/2009	1:20	230	280.0
3/25/2009	3:45	60	183.3
3/31/2009	16:15	75	61.0
3/31/2009	17:05	300	390.0
4/1/2009	3:00	24	27.0
4/19/2009	17:10	30	17.0
4/19/2009	18:15	200	117.5
4/20/2009	2:30	50	34.3
4/20/2009	17:20	10	18.5
4/23/2009	10:45	3	1.6
4/25/2009	10:50	37	21.0
5/13/2009	20:30	62	54.0
5/13/2009	20:50	440	280.0
5/13/2009	21:10	530	260.0
5/14/2009	0:55	170	130.0
5/14/2009	2:40	170	120.0
5/20/2009	11:00	5	2.7
6/16/2009	11:00	4	2.7
7/16/2009	11:00	8	4.0
8/7/2009	17:10	37	27.0
8/7/2009	20:20	340	170.0
8/7/2009	23:05	77	28.0
8/8/2009	9:10	460	240.0
8/8/2009	9:30	490	300.0
8/8/2009	19:55	29	59.0
8/10/2009	1:50	490	210.0
8/10/2009	4:10	170	100.0
8/19/2009	12:40	10	1.3
8/25/2009	20:55	120	63.0
8/28/2009	22:05	330	206.7
8/26/2009	4:05	120	34.0
9/15/2009	10:45	2	1.6
9/20/2009	20:20	53	44.0
9/20/2009	21:55	210	190.0
9/21/2009	3:55	41	34.0
9/22/2009	13:25	130	84.0
9/22/2009	14:05	370	210.0
9/22/2009	22:40	44	44.0
9/27/2009	20:20	140	110.0
9/27/2009	21:00	450	272.5
9/27/2009	23:35	280	99.0
9/28/2009	2:30	80	88.0
MINIMUM		**1**	**1.3**
MAXIMUM		**530**	**390.0**
MEAN		**136**	**94.8**
MEDIAN		**73**	**57.0**
STANDARD DEVIATION		**147**	**91.3**

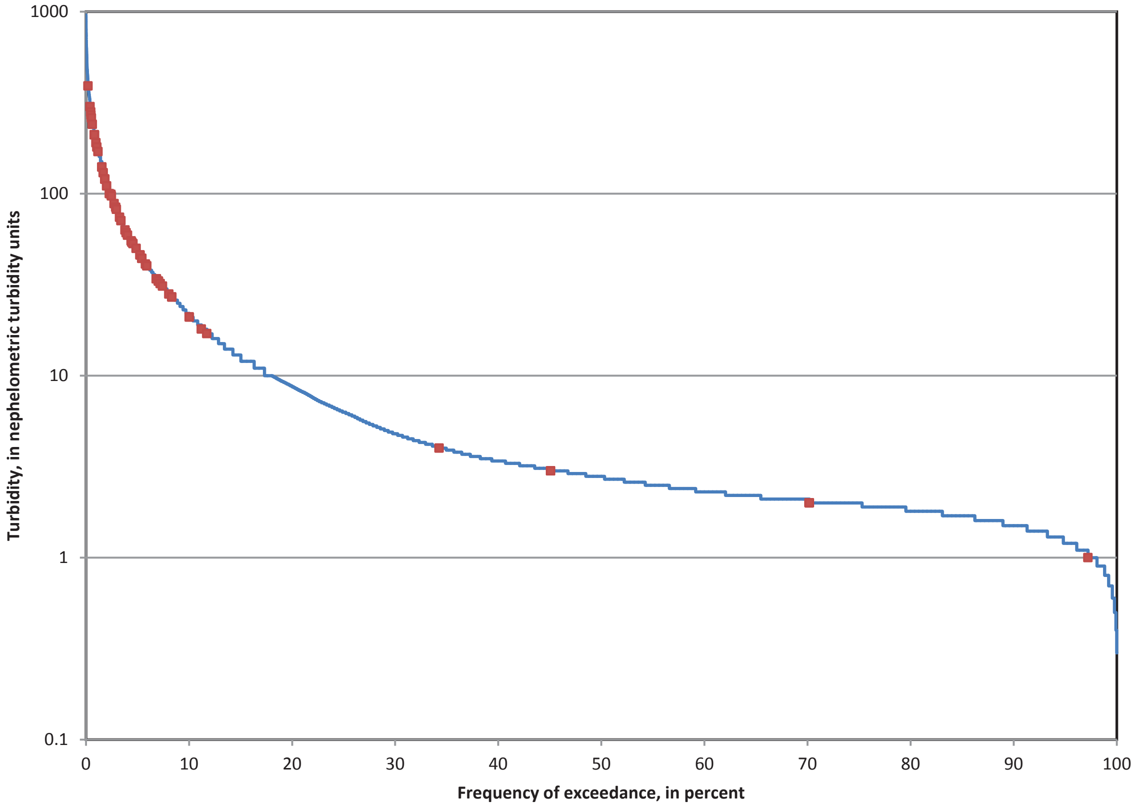


Figure 3-5. Duration curve for turbidity (November 2008–September 2010) and corresponding values associated with total suspended solids concentration samples collected November 2008 to September 2009 at U.S. Geological Survey streamgage on Honey Creek at Wauwatosa, Wisconsin.

Total suspended solids at Honey Creek at Wauwatosa, Wisconsin, November 2008–September 2009

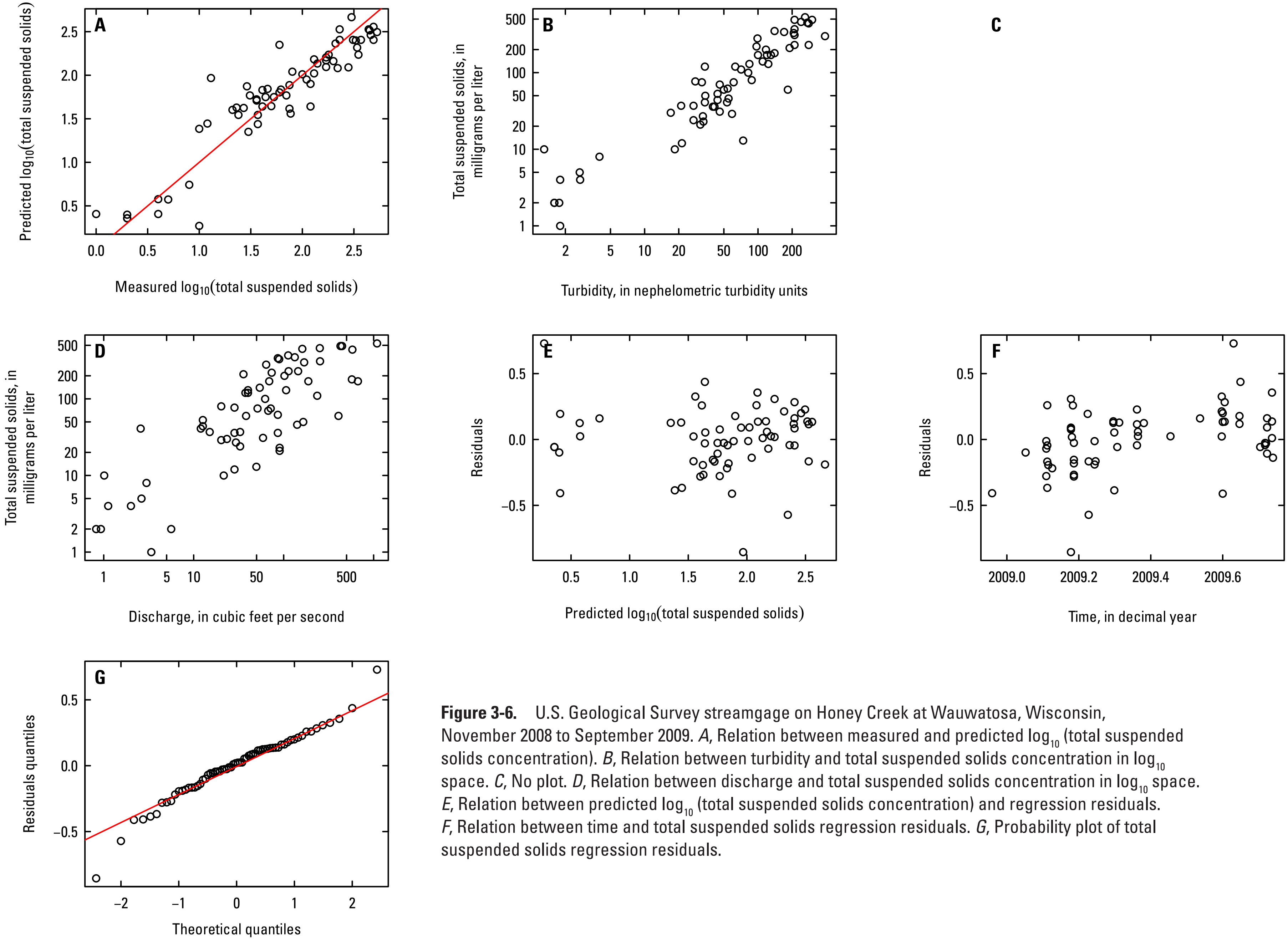


Figure 3-6. U.S. Geological Survey streamgage on Honey Creek at Wauwatosa, Wisconsin, November 2008 to September 2009. *A*, Relation between measured and predicted $\log_{10}$ (total suspended solids concentration). *B*, Relation between turbidity and total suspended solids concentration in $\log_{10}$ space. *C*, No plot. *D*, Relation between discharge and total suspended solids concentration in $\log_{10}$ space. *E*, Relation between predicted $\log_{10}$ (total suspended solids concentration) and regression residuals. *F*, Relation between time and total suspended solids regression residuals. *G*, Probability plot of total suspended solids regression residuals.

Total suspended solids at Menomonee River at Wauwatosa, WI (04087120)

Samples collected on 6/8-6/9 2009 were not used in the regression analysis because the turbidity sensor readings were spiking excessively and the data quality was thought to be poor.

MODEL SUMMARY—Summary of final regression results for estimating total suspended solids concentrations at Menomonee River at Wauwatosa, WI.

Log_{10} (Suspended Solids) = 0.567 + 0.779 log_{10} (Turb),
Where:

Suspended Solids = total suspended solids concentration in mg/L
Turb = Turbidity (YSI 6136), in NTU

***Model Information (in log units unless otherwise specified)*:**
Number of measurements = 95,
Root-mean-squared error (RMSE) = 0.22
Model standard percentage error (MPSE) = +67 and -40 percent
90-percent prediction intervals (based on units in mg/L) = +/- 110 percent
Adjusted coefficient of determination (Adj R^2) = 0.77
Sum of squared error = 4.59
PRESS = 4.92

***Coefficients*:**

	Coefficient	Standard error	t statistic	p-value
Intercept	**0.567**	**0.074**	**7.67**	**<0.0001**
Log_{10} (Turb)	**0.779**	**0.044**	**17.88**	**<0.0001**

Correlation matrix of coefficients:

	Intercept	log_{10} (Turb)
Intercept	**1**	**-0.951**
Log_{10} (Turb)	**-0.951**	**1**

Duan's bias correction factor **= 1.15**

Table 3-4. Model-calibration dataset for Menomonee River at Wauwatosa, Wisconsin.

[mg/L, milligrams per liter; NTU, Nephelometric turbidity units]

Date	Time	Total suspended solids (mg/L)	Turbidity (NTU)
11/20/2008	10:30	5	1.9
12/17/2008	12:30	5	6.8
12/27/2008	1:15	56	25.0
12/27/2008	3:45	78	46.0
12/27/2008	5:50	87	66.0
12/27/2008	6:05	94	63.0
12/27/2008	10:15	150	89.0
12/27/2008	14:00	260	180.0
12/27/2008	14:45	260	190.0
12/28/2008	7:45	51	36.0
1/20/2009	12:10	20	1.5
2/7/2009	11:25	92	72.3
2/7/2009	13:25	120	105.0
2/7/2009	13:40	230	110.0
2/7/2009	19:40	65	46.3
2/8/2009	13:40	22	26.0
2/9/2009	1:40	13	12.0
2/9/2009	19:40	140	64.0
2/9/2009	22:00	210	140.0
2/9/2009	23:15	110	140.0
2/10/2009	7:20	47	45.7
2/10/2009	11:00	230	100.0
2/10/2009	17:05	110	70.7
2/10/2009	23:25	42	41.3
2/16/2009	12:45	80	4.8
2/26/2009	14:35	36	66.0
2/26/2009	19:00	38	140.0
2/26/2009	19:45	130	170.0
2/26/2009	22:50	210	130.0
2/27/2009	4:50	230	70.0
3/2/2009	7:20	6	7.3
3/10/2009	0:15	31	34.0
3/10/2009	5:50	46	38.0
3/10/2009	11:45	38	38.0
3/10/2009	14:50	51	41.0
3/11/2008	1:10	28	45.5
3/24/2009	11:55	11	1.1
3/25/2009	1:30	57	38.0
3/31/2009	17:00	19	14.0
3/31/2009	17:35	38	33.0
4/1/2009	5:35	33	20.0
4/19/2009	19:10	26	17.0
4/20/2009	5:05	48	24.0
4/21/2009	5:05	12	7.1
4/23/2009	11:00	6	1.4
4/25/2009	11:15	41	22.0
4/25/2009	12:40	370	160.0
4/25/2009	21:35	100	77.0
4/26/2009	2:35	87	68.0
4/26/2009	14:35	50	36.0
4/26/2009	16:00	300	150.0
4/26/2009	17:10	360	190.0
4/27/2009	0:30	94	76.0
5/9/2009	0:30	66	37.0
5/9/2009	9:30	37	17.0
5/9/2009	15:50	21	15.0
5/13/2009	20:40	120	68.0
5/13/2009	21:05	250	150.0
5/13/2009	22:00	250	140.0
5/14/2009	3:15	110	86.0
5/20/2009	11:15	11	4.8
6/16/2009	11:50	17	9.6
6/19/2009	9:15	150	84.0
6/19/2009	18:15	75	52.0
6/19/2009	21:20	190	150.0
6/20/2009	3:10	120	45.0
7/16/2009	11:45	9	3.5
8/7/2009	18:00	57	32.0
8/7/2009	20:40	110	60.0
8/8/2009	0:55	59	37.0
8/8/2009	8:50	120	74.0
8/8/2009	9:45	390	210.0
8/8/2009	19:50	66	48.0
8/9/2009	19:50	51	39.0
8/10/2009	2:00	150	110.0
8/10/2009	4:20	77	99.0
8/19/2009	12:20	13	2.7
8/25/2009	20:50	120	68.0
8/25/2009	21:25	140	110.0
8/25/2009	21:30	170	96.0
8/26/2009	3:30	76	47.0
8/27/2009	3:35	20	18.0
9/15/2009	11:00	7	2.8
9/20/2009	21:40	120	69.0
9/21/2009	3:40	46	51.0
9/22/2009	13:30	97	56.0
9/22/2009	13:40	280	71.0
9/22/2009	21:50	260	56.0
9/22/2009	23:10	76	53.0
9/27/2009	20:35	160	100.0
9/27/2009	21:05	270	150.0
9/27/2009	21:20	330	180.0
09/28/209	0:05	110	70.0
9/28/2009	2:35	65	62.0
9/28/2009	20:35	55	25.0
MINIMUM		**5**	**1.1**
MAXIMUM		**390**	**210.0**
MEAN		**105**	**65.9**
MEDIAN		**76**	**53.0**
STANDARD DEVIATION		**93**	**52.1**

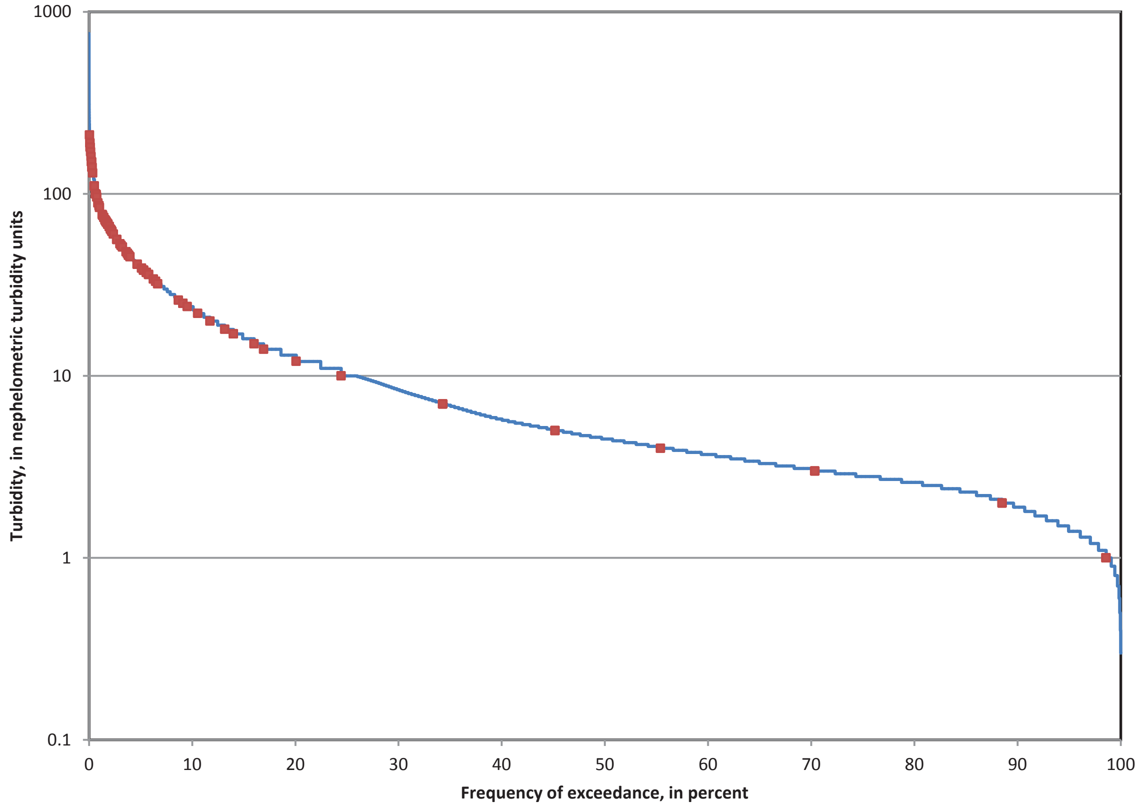


Figure 3-7. Duration curve for turbidity (November 2008–September 2010) and corresponding values associated with total suspended solids concentration samples collected November 2008 to September 2009 at U.S. Geological Survey streamgage on Menomonee River at Wauwatosa, Wisconsin.

Total suspended solids at Menomonee River at Wauwatosa, Wisconsin, November 2008–September 2009

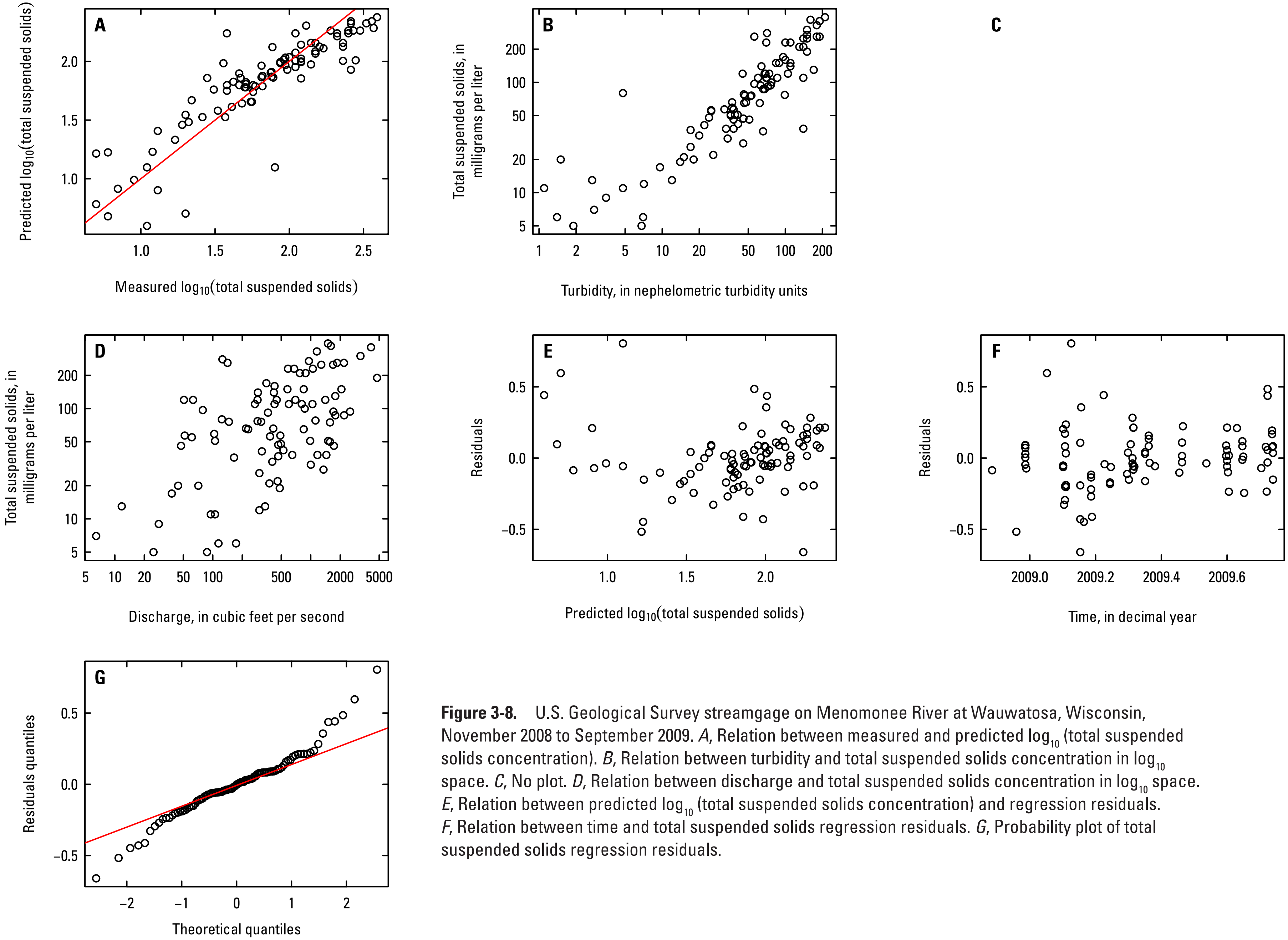


Figure 3-8. U.S. Geological Survey streamgage on Menomonee River at Wauwatosa, Wisconsin, November 2008 to September 2009. *A*, Relation between measured and predicted $\log_{10}$ (total suspended solids concentration). *B*, Relation between turbidity and total suspended solids concentration in $\log_{10}$ space. *C*, No plot. *D*, Relation between discharge and total suspended solids concentration in $\log_{10}$ space. *E*, Relation between predicted $\log_{10}$ (total suspended solids concentration) and regression residuals. *F*, Relation between time and total suspended solids regression residuals. *G*, Probability plot of total suspended solids regression residuals.

Total suspended solids at Menomonee River at 16th Street at Milwaukee, WI (04087142)

MODEL SUMMARY—Summary of final regression results for estimating total suspended solids concentrations at Menomonee River at 16th Street at Milwaukee, WI.

Log_{10} (Suspended Solids) = 0.108 + 0.974 log_{10} (Turb),
Where:

Suspended Solids = total suspended solids concentration in mg/L
Turb = Turbidity (YSI 6136), in NTU

***Model Information (in log units unless otherwise specified)*:**
Number of measurements = 79,
Root-mean-squared error (RMSE) = 0.21
Model standard percentage error (MPSE) = +62 and -38 percent
90-percent prediction intervals (based on units in mg/L) = +/- 100 percent
Adjusted coefficient of determination (Adj R^2) = 0.85
Sum of squared error = 3.39
PRESS = 3.61

***Coefficients*:**

	Coefficient	Standard error	t statistic	p-value
Intercept	**0.108**	**0.078**	**1.49**	**0.1416**
Log $_{10}$ (Turb)	**0.974**	**0.046**	**21.32**	**<0.0001**

Correlation matrix of coefficients:

	Intercept	log_{10} (Turb)
Intercept	**1**	**-0.946**
Log_{10} (Turb)	**-0.946**	**1**

Duan's bias correction factor **= 1.12**

Table 3-5. Model-calibration dataset for Menomonee River at 16th Street at Milwaukee, Wisconsin.

[mg/L, milligrams per liter; NTU, Nephelometric turbidity units]

Date	Time	Total suspended solids (mg/L)	Turbidity (NTU)
11/20/2008	11:45	6	3.1
12/17/2008	14:15	7	7.3
12/27/2008	9:35	22	20.0
12/27/2008	12:35	50	52.3
12/27/2008	15:35	260	153.3
12/27/2008	21:35	95	77.3
12/28/2008	0:35	84	58.7
12/28/2008	6:35	49	44.0
1/20/2009	12:40	8	5.4
2/7/2009	11:40	5	3.6
2/7/2009	20:40	68	78.7
2/8/2009	5:40	22	34.7
2/8/2009	14:40	16	28.3
2/8/2009	23:40	17	28.0
2/9/2009	17:40	30	12.7
2/10/2009	5:40	36	98.0
2/11/2009	17:40	78	69.3
2/16/2009	13:40	10	8.1
2/26/2009	16:00	12	8.2
2/26/2009	19:00	220	200.0
2/26/2009	22:00	170	130.0
2/27/2009	4:00	85	85.0
2/27/2009	12:00	13	51.0
2/28/2009	12:00	35	19.0
3/7/2009	11:10	97	19.0
3/7/2009	14:10	97	89.0
3/7/2009	23:10	58	54.0
3/8/2009	12:10	34	35.0
3/8/2009	18:10	120	90.0
3/9/2009	0:10	66	61.0
3/10/2009	8:15	60	47.0
3/10/2009	12:55	35	41.0
3/10/2009	13:00	38	42.0
3/10/2009	20:30	38	41.0
3/11/2009	4:30	23	29.0
3/24/2009	12:25	11	4.0
4/1/2009	1:40	30	34.0
4/20/2009	3:05	12	12.0
4/20/2009	4:50	12	14.0
4/23/2009	11:15	7	5.7
4/25/2009	13:20	26	30.0
4/25/2009	20:00	57	61.0
4/26/2009	8:00	48	48.0
4/26/2009	14:00	31	39.0
4/26/2009	16:25	190	82.0
4/26/2009	17:10	460	210.0
4/26/2009	19:30	340	210.0
4/26/2009	19:35	320	190.0
5/13/2009	22:05	42	35.0
5/14/2009	0:35	73	67.0
5/14/2009	1:45	93	93.0
5/14/2009	3:35	71	70.0
5/20/2009	11:45	11	5.0
6/8/2009	12:40	37	42.0
6/8/2009	15:30	37	50.0
6/9/2009	2:35	29	32.7
6/9/2009	5:00	24	31.3
6/16/2009	13:00	11	5.3
6/19/2009	0:55	1,800	530.0
6/19/2009	1:10	1,000	400.0
6/19/2009	1:45	820	340.0
6/19/2009	9:35	110	95.0
6/19/2040	20:45	230	160.0
6/20/2009	2:25	95	84.0
7/16/2009	12:30	12	4.9
8/8/2009	22:30	36	24.0
8/9/2009	10:30	19	17.0
8/19/2009	13:30	9	4.7
8/26/2009	7:05	15	15.0
8/26/2009	17:00	12	13.0
8/26/2009	23:45	15	14.0
9/15/2009	11:30	6	2.9
9/23/2009	7:10	12	7.1
9/24/2009	7:00	11	9.2
9/28/2009	12:05	22	28.0
09/28/209	18:05	22	30.0
9/29/2009	0:05	14	30.0
9/29/2009	3:05	11	17.0
9/29/2009	5:00	14	16.0
MINIMUM		**5**	**2.9**
MAXIMUM		**1,800**	**530.0**
MEAN		**105**	**63.8**
MEDIAN		**35**	**35.0**
STANDARD DEVIATION		**249**	**88.4**

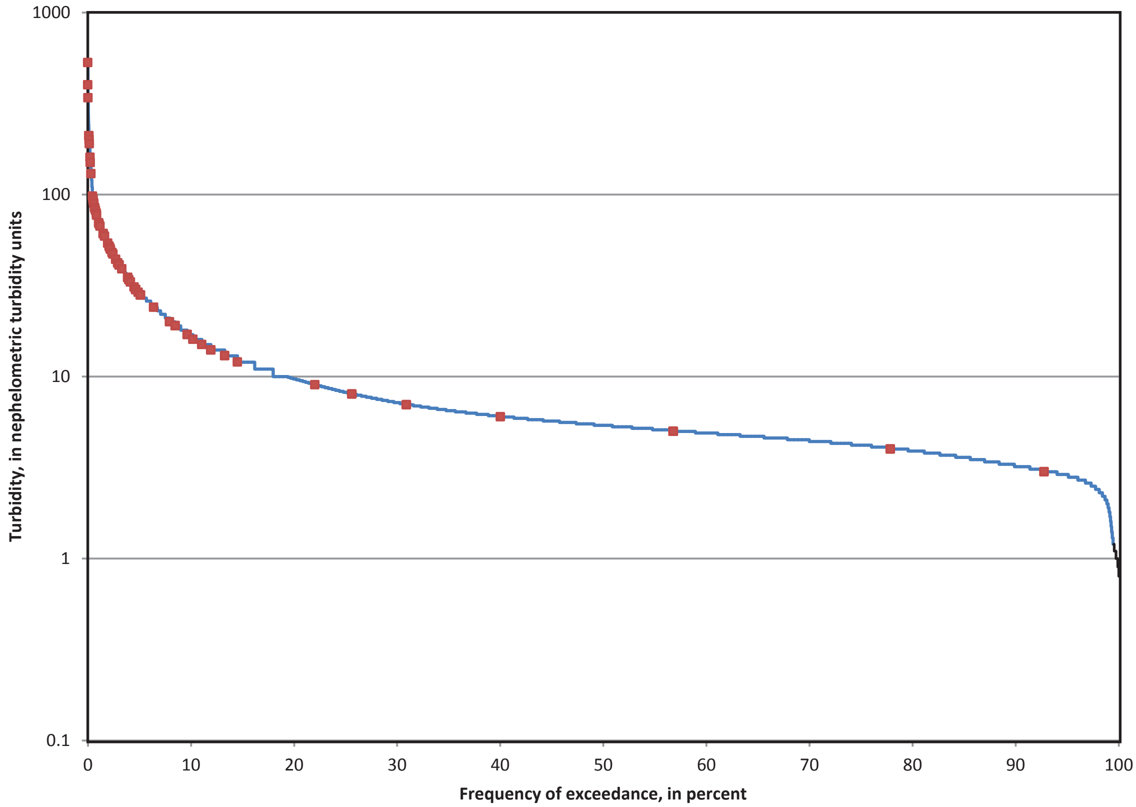
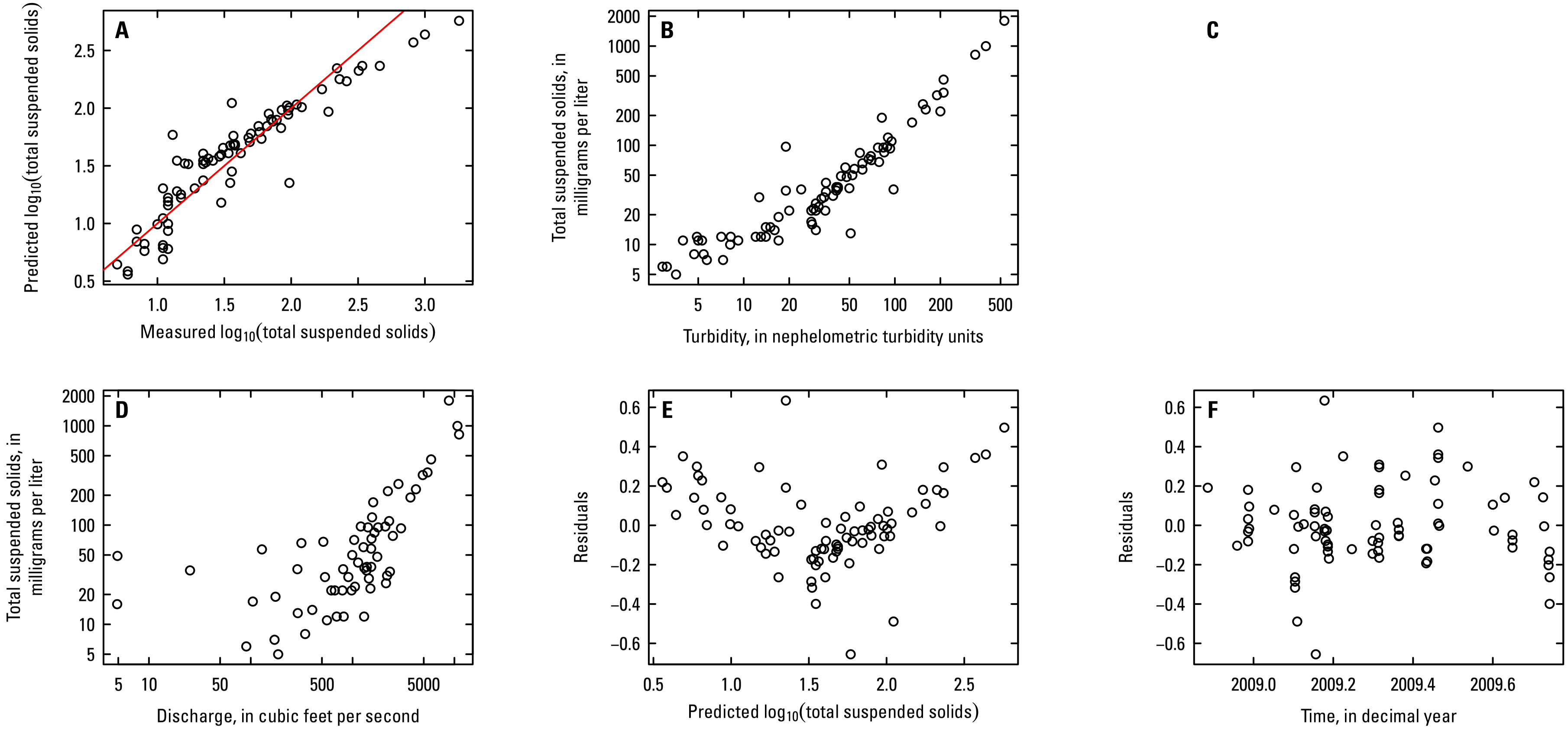


Figure 3-9. Duration curve for turbidity (November 2008–September 2010) and corresponding values associated with total suspended solids concentration samples collected November 2008 to September 2009 at U.S. Geological Survey streamgage on Menomonee River at 16th Street at Milwaukee, Wisconsin.

Total suspended solids at Menomonee River at 16th Street at Milwaukee, Wisconsin, November 2008–September 2009



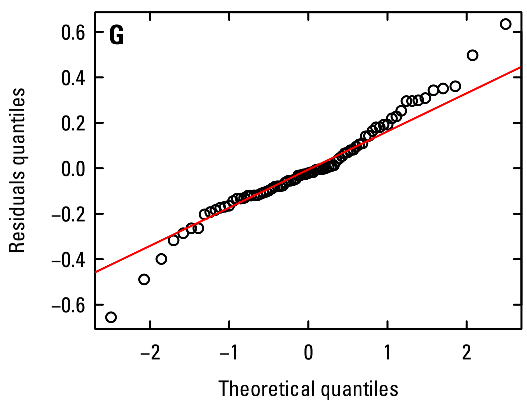


Figure 3-10. U.S. Geological Survey streamgage on Menomonee River at 16th Street at Milwaukee, Wisconsin, November 2008 to September 2009. *A*, Relation between measured and predicted $\log_{10}$ (total suspended solids concentration). *B*, Relation between turbidity and total suspended solids concentration in $\log_{10}$ space. *C*, No plot. *D*, Relation between discharge and total suspended solids concentration in $\log_{10}$ space. *E*, Relation between predicted $\log_{10}$ (total suspended solids concentration) and regression residuals. *F*, Relation between time and total suspended solids regression residuals. *G*, Probability plot of total suspended solids regression residuals.

Appendix 4. Regression analysis results for estimating total phosphorus concentration

All data were collected using U.S. Geological Survey (USGS) protocols and are stored in the USGS National Water Information System (NWIS) database (*http://waterdata.usgs.gov/nwis*). The regression models are based on measurements of turbidity and concurrent total phosphorus samples collected from November 2008 to September 2009. Continuous water-quality data were collected at 5-minute intervals using a YSI model 6920 V2 multiparameter water-quality monitor with a 6560 specific conductance and water temperature sensor, and a 6136 optical turbidity sensor. Turbidity values are instantaneous unit values temporally corresponding to the collection of the total phosphorus samples. Samples were collected throughout the range of continuously observed hydrologic conditions. Summary statistics and the complete model-calibration dataset are provided. A comparison of cross-section mean and corresponding time-series monitor readings is archived at the Wisconsin Water Science Center and is available by request to Austin Baldwin (akbaldwi@usgs.gov).

Total phosphorus at Little Menomonee River near Freistadt, WI (04087050)

MODEL SUMMARY—Summary of final regression results for estimating total phosphorus concentrations at Little Menomonee River near Freistadt, WI.

$\log_{10}$ (Total Phosphorus) = -1.37 + 0.486 $\log_{10}$ (Turb),
Where:

Total Phosphorus = total phosphorus concentration in mg/L
Turb = Turbidity, (YSI 6136), in NTU

***Model Information (in log units unless otherwise specified)*:**
Number of measurements = 39,
Root-mean-squared error (RMSE) = 0.19
Model standard percentage error (MPSE) = +56 and -36 percent
90-percent prediction intervals (based on units in mg/L) = +/- 94 percent
Adjusted coefficient of determination (Adj R^2) = 0.75
Sum of squared error = 1.40
PRESS = 1.75

***Coefficients*:**

	Coefficient	Standard error	t statistic	p-value
Intercept	**-1.37**	**0.074**	**-18.49**	**<.0001**
$\log_{10}$ (Turb)	**0.486**	**0.045**	**10.82**	**<.0001**

Correlation matrix of coefficients:

	Intercept	$\log_{10}$ (Turb)
Intercept	**1.00**	**-0.908**
$\log_{10}$ (Turb)	**-0.908**	**1.00**

Duan's bias correction factor **= 1.13**

Table 4-1. Model-calibration dataset for Little Menomonee River near Freistadt, Wisconsin.

[mg/L, milligrams per liter; NTU, Nephelometric turbidity units]

Date	Time	Total phosphorus (mg/L)	Turbidity (NTU)
11/20/2008	9:45	0.042	1.2
12/17/2008	11:30	0.044	2.1
12/27/2008	13:05	0.26	11.2
12/28/2008	1:05	0.52	52.3
12/28/2008	7:15	0.43	45.0
1/20/2009	10:55	0.21	0.7
2/7/2009	18:50	0.24	19.7
2/9/2009	22:40	0.12	11.3
2/10/2009	10:45	0.36	38.0
2/10/2009	14:40	0.57	113.3
2/10/2009	20:40	0.41	46.0
2/11/2009	2:40	0.28	21.3
3/2/2009	7:10	0.049	4.2
3/7/2009	12:55	0.37	130.0
3/7/2009	18:05	0.83	220.0
3/8/2009	7:05	0.35	62.0
3/8/2009	19:00	0.77	210.0
3/9/2009	0:30	0.56	140.0
3/10/2009	3:20	0.3	68.0
3/10/209	8:15	0.43	94.0
3/10/2009	20:15	0.25	51.0
3/24/2009	10:40	0.043	2.8
4/23/2009	9:45	0.038	2.1
4/25/2009	15:10	0.24	100.0
4/26/2009	5:30	0.55	180.0
4/26/2009	19:30	0.56	200.0
4/27/2009	1:30	0.32	80.0
5/9/2009	7:25	0.26	81.0
5/9/2009	13:30	0.23	54.0
5/9/2009	19:30	0.11	15.0
5/14/2009	2:30	0.68	270.0
5/20/2009	9:00	0.076	4.5
6/8/2009	5:20	0.32	120.0
6/16/2009	8:45	0.11	12.0
6/19/2009	2:50	0.56	290.0
6/19/2009	8:50	0.37	89.0
7/16/2009	10:05	0.14	19.0
8/19/2009	10:00	0.085	8.8
9/15/2009	9:30	0.066	10.0
MINIMUM		**0.04**	**0.7**
MAXIMUM		**0.83**	**290.0**
MEAN		**0.31**	**73.8**
MEDIAN		**0.28**	**51.0**
STANDARD DEVIATION		**0.21**	**79.0**

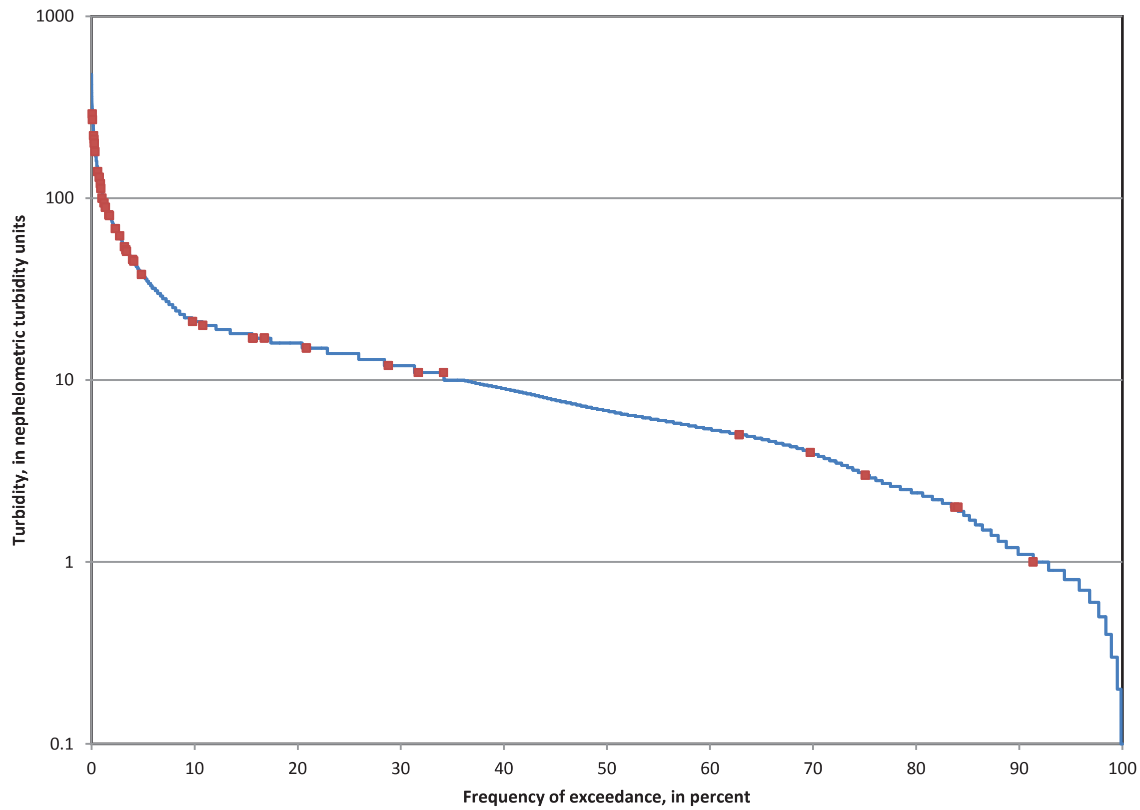


Figure 4-1. Duration curve for turbidity (November 2008–September 2010) and corresponding values associated with total phosphorus concentration samples collected November 2008 to September 2009 at U.S. Geological Survey streamgage on Little Menomonee River near Freistadt, Wisconsin.

Total phosphorus at Little Menomonee River near Freistadt, Wisconsin, November 2008–September 2009

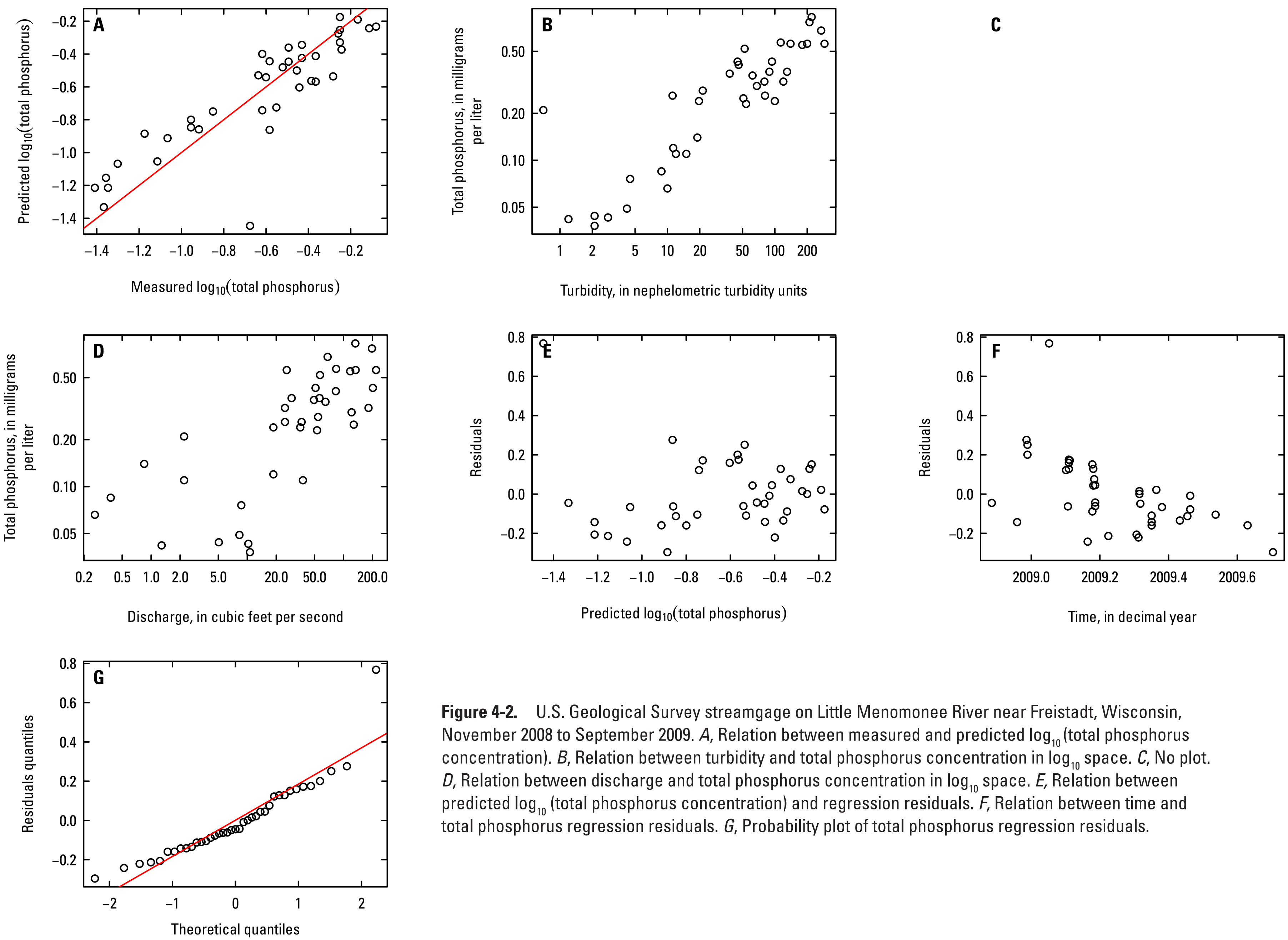


Figure 4-2. U.S. Geological Survey streamgage on Little Menomonee River near Freistadt, Wisconsin, November 2008 to September 2009. *A*, Relation between measured and predicted $\log_{10}$(total phosphorus concentration). *B*, Relation between turbidity and total phosphorus concentration in $\log_{10}$ space. *C*, No plot. *D*, Relation between discharge and total phosphorus concentration in $\log_{10}$ space. *E,* Relation between predicted $\log_{10}$ (total phosphorus concentration) and regression residuals. *F*, Relation between time and total phosphorus regression residuals. *G*, Probability plot of total phosphorus regression residuals.

Total phosphorus at Menomonee River at Menomonee Falls, WI (04087030)

MODEL SUMMARY—Summary of final regression results for estimating total phosphorus concentrations at Menomonee River at Menomonee Falls, WI.

$\log_{10}$ (Total Phosphorus) = -1.55 + 0.492 $\log_{10}$ (Turb),
Where:

Total Phosphorus = total phosphorus concentration in mg/L
Turb = Turbidity, (YSI 6136), in NTU

***Model Information (in log units unless otherwise specified)*:**
Number of measurements = 59,
Root-mean-squared error (RMSE) = 0.207
Model standard percentage error (MPSE) = +61 and -38 percent
90-percent prediction intervals (based on units in mg/L) = +/- 101 percent
Adjusted coefficient of determination (Adj R^2) = 0.62
Sum of squared error = 2.45
PRESS = 2.67

***Coefficients*:**

	Coefficient	Standard error	t statistic	p-value
Intercept	**-1.55**	**0.077**	**-20.20**	**<0.0001**
$\log_{10}$(Turb)	**0.492**	**0.050**	**9.83**	**<0.0001**

Correlation matrix of coefficients:

	Intercept	$\log_{10}$ (Turb)
Intercept	**1**	**-0.936**
$\log_{10}$(Turb)	**-0.936**	**1**

Duan's bias correction factor **= 1.14**

Table 4-2. Model-calibration dataset for Menomonee River at Menomonee Falls, Wisconsin.

[mg/L, milligrams per liter; NTU, Nephelometric turbidity units]

Date	Time	Total phosphorus (mg/L)	Turbidity (NTU)
11/20/2008	9:15	0.041	3.6
12/17/2008	12:00	0.036	2.7
12/27/2008	0:35	0.23	18.0
12/27/2008	6:15	0.27	49.0
12/27/2008	14:20	0.42	100.7
12/27/2008	20:20	0.35	39.7
12/28/2008	8:20	0.33	45.3
1/20/2009	9:55	0.24	2.5
2/16/2009	11:00	0.054	3.1
2/26/2009	15:05	0.22	86.0
2/26/2009	18:15	0.24	81.0
2/27/2009	0:15	0.17	30.0
3/2/2009	7:15	0.068	3.2
3/7/2009	9:30	0.13	31.0
3/7/2009	15:30	0.17	29.0
3/8/2009	10:30	0.18	26.0
3/8/2009	14:00	0.27	69.0
3/9/2009	2:00	0.2	34.0
3/24/2009	10:00	0.038	4.1
3/25/2009	5:25	0.057	16.0
4/19/2009	23:00	0.1	23.0
4/20/2009	11:15	0.043	12.0
4/20/2009	23:15	0.038	11.0
4/23/2009	9:15	0.034	3.8
4/25/2009	10:50	0.18	71.0
4/25/2009	11:00	0.38	170.0
4/26/2009	5:00	0.1	27.0
4/26/2009	16:00	0.12	34.0
4/27/2009	4:00	0.11	23.0
5/9/2009	1:05	0.17	83.0
5/9/2009	1:15	0.35	110.0
5/9/2009	10:25	0.077	12.0
5/9/2009	22:25	0.066	14.0
5/10/2009	10:25	0.053	8.2
5/13/2009	23:00	0.2	81.0
5/20/209	9:30	0.063	6.3
6/8/2009	3:15	0.32	91.0
6/8/2009	3:25	0.78	220.0
6/8/2009	9:35	0.096	28.0
6/16/2009	10:15	0.071	13.0
6/19/2009	0:10	0.55	160.0
6/19/2009	0:50	0.2	110.0
6/19/2009	2:00	0.1	66.0
6/20/2009	2:00	0.55	21.0
7/16/2009	9:30	0.082	5.0
8/7/2009	19:35	0.2	46.0
8/8/2009	9:05	0.21	80.0
8/19/2009	9:00	0.094	3.2
8/25/2009	18:20	0.36	210.0
8/25/2009	18:45	0.28	85.0
8/26/2009	1:30	0.11	30.0
8/26/2009	1:55	0.14	48.0
9/15/2009	9:30	0.06	2.8
9/22/2009	13:15	0.18	62.0
9/22/2009	14:05	0.4	130.0
9/22/2009	15:20	0.12	21.0
9/27/2009	19:25	0.23	81.0
9/27/2008	21:30	0.2	51.0
9/28/2009	5:55	0.088	12.0
MINIMUM		**0.03**	**2.5**
MAXIMUM		**0.78**	**220.0**
MEAN		**0.19**	**49.8**
MEDIAN		**0.17**	**30.0**
STANDARD DEVIATION		**0.15**	**50.9**

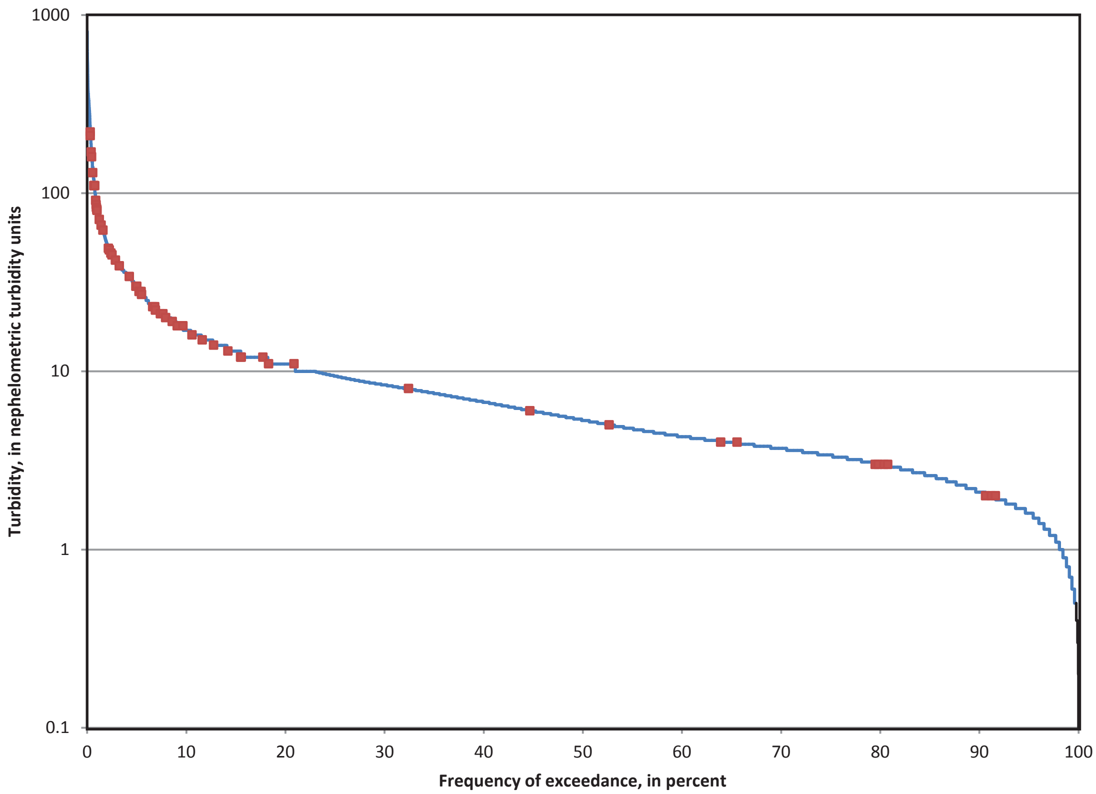


Figure 4-3. Duration curve for turbidity (November 2008–September 2010) and corresponding values associated with total phosphorus concentration samples collected November 2008 to September 2009 at U.S. Geological Survey streamgage on Menomonee River at Menomonee Falls, Wisconsin.

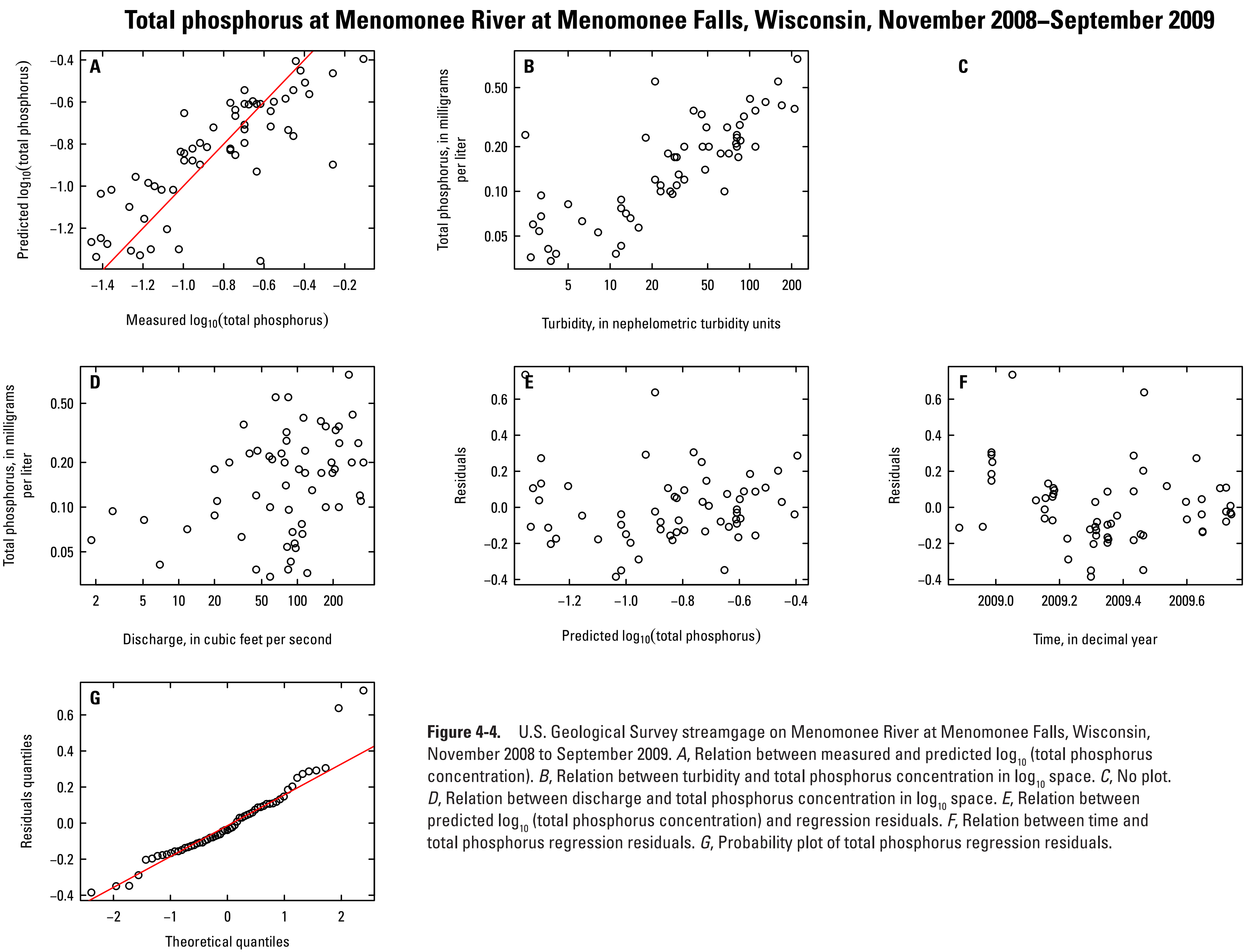


Figure 4-4. U.S. Geological Survey streamgage on Menomonee River at Menomonee Falls, Wisconsin, November 2008 to September 2009. *A*, Relation between measured and predicted log_{10} (total phosphorus concentration). *B*, Relation between turbidity and total phosphorus concentration in log_{10} space. *C*, No plot. *D*, Relation between discharge and total phosphorus concentration in log_{10} space. *E*, Relation between predicted log_{10} (total phosphorus concentration) and regression residuals. *F*, Relation between time and total phosphorus regression residuals. *G*, Probability plot of total phosphorus regression residuals.

Total phosphorus at Honey Creek at Wauwatosa, WI (04087119)

Sample data from 4/25/2009 at 12:40 through 4/26/2009, and sample data from 6/8/2009 were not used in the regression development because of excessive fouling of the data sonde. Sample data on 6/19/2009 were not used because of damage to the sonde and sampler line during an extreme flood event.

MODEL SUMMARY—Summary of final regression results for estimating total phosphorus concentrations at Honey Creek at Wauwatosa, WI.

Log_{10} (Total Phosphorus) = -1.45 + 0.451 $\log_{10}$ (Turb),
Where:

Total Phosphorus = total phosphorus concentration in mg/L
Turb = Turbidity, (YSI 6136), in NTU

***Model Information (in log units unless otherwise specified)*:**
Number of measurements = 66,
Root-mean-squared error (RMSE) = 0.22
Model standard percentage error (MPSE) = +66 and -40 percent
90-percent prediction intervals (based on units in mg/L) = +/- 108 percent
Adjusted coefficient of determination (Adj R^2) = 0.64
Sum of squared error = 3.08
PRESS = 3.35

***Coefficients*:**

	Coefficient	Standard error	t statistic	p-value
Intercept	**-1.45**	**0.075**	**-19.21**	**<.0001**
Log_{10} (Turb)	**0.451**	**0.042**	**10.74**	**<.0001**

Correlation matrix of coefficients:

	Intercept	$\log_{10}$ (Turb)
Intercept	**1.00**	**-0.934**
Log_{10} (Turb)	**-0.934**	**1.00**

Duan's bias correction factor **= 1.14**

Table 4-3. Model-calibration dataset for Honey Creek at Wauwatosa, Wisconsin.

[mg/L, milligrams per liter; NTU, Nephelometric turbidity units]

Date	Time	Total phosphorus (mg/L)	Turbidity (NTU)
12/17/2008	13:45	0.04	1.8
1/20/2009	11:55	0.26	1.7
2/10/2009	10:10	0.28	46.0
2/10/2009	13:25	0.37	123.3
2/10/2009	19:25	0.26	82.0
2/11/2009	1:25	0.18	41.3
2/11/2009	11:25	0.12	21.3
2/11/2009	12:00	0.37	97.0
2/11/2009	15:30	0.4	210.0
2/12/2009	2:25	0.15	32.7
2/16/2009	12:20	0.14	53.3
3/7/2009	9:25	0.074	74.0
3/7/2009	10:25	0.47	210.0
3/7/2009	12:10	0.41	140.0
3/7/2009	16:05	0.26	71.0
3/7/2009	22:05	0.22	46.0
3/8/2009	14:25	0.28	140.0
3/9/2009	1:00	0.22	32.0
3/10/2009	0:50	0.1	40.0
3/10/2009	5:30	0.15	50.0
3/10/2009	9:30	0.15	55.0
3/10/2009	12:10	0.12	33.0
3/10/2009	12:15	0.12	31.0
3/24/2009	11:40	0.041	1.8
3/25/2009	1:20	0.37	280.0
3/25/2009	3:45	0.14	183.3
3/31/2009	16:15	0.16	61.0
3/31/2009	17:05	0.39	390.0
4/1/2009	3:00	0.078	27.0
4/19/2009	17:10	0.081	17.0
4/19/2009	18:15	0.36	117.5
4/20/2009	2:30	0.12	34.3
4/20/2009	17:20	0.045	18.5
4/23/2009	10:45	0.03	1.6
4/25/2009	10:50	0.064	21.0
5/13/2009	20:30	0.17	54.0
5/13/2009	20:50	0.67	280.0
5/13/2009	21:10	0.66	260.0
5/14/2009	0:55	0.3	130.0
5/14/2009	2:40	0.28	120.0
5/20/2009	11:00	0.035	2.7
6/16/2009	11:00	0.051	2.7
7/16/2009	11:00	0.13	4.0
8/7/2009	17:10	0.3	27.0
8/7/2009	20:20	0.83	170.0
8/7/2009	23:05	0.27	28.0
8/8/2009	9:10	0.71	240.0
8/8/2009	9:30	0.7	300.0
8/8/2009	19:55	0.13	59.0
8/10/2009	1:50	0.49	210.0
8/10/2009	4:10	0.21	100.0
8/19/2009	12:40	0.086	1.3
8/25/2009	20:55	0.28	63.0
8/28/2009	22:05	0.51	206.7
8/26/2009	4:05	0.28	34.0
9/15/2009	10:45	0.054	1.6
9/20/2009	20:20	0.14	44.0
9/20/2009	21:55	0.88	190.0
9/21/2009	3:55	0.3	34.0
9/22/2009	13:25	0.33	84.0
9/22/2009	14:05	0.7	210.0
9/22/2009	22:40	0.16	44.0
9/27/2009	20:20	0.35	110.0
9/27/2009	21:00	0.6	272.5
9/27/2009	23:35	0.4	99.0
9/28/2009	2:30	0.16	88.0
MINIMUM		**0.03**	**1.3**
MAXIMUM		**0.88**	**390.0**
MEAN		**0.28**	**94.8**
MEDIAN		**0.24**	**57.0**
STANDARD DEVIATION		**0.21**	**91.3**

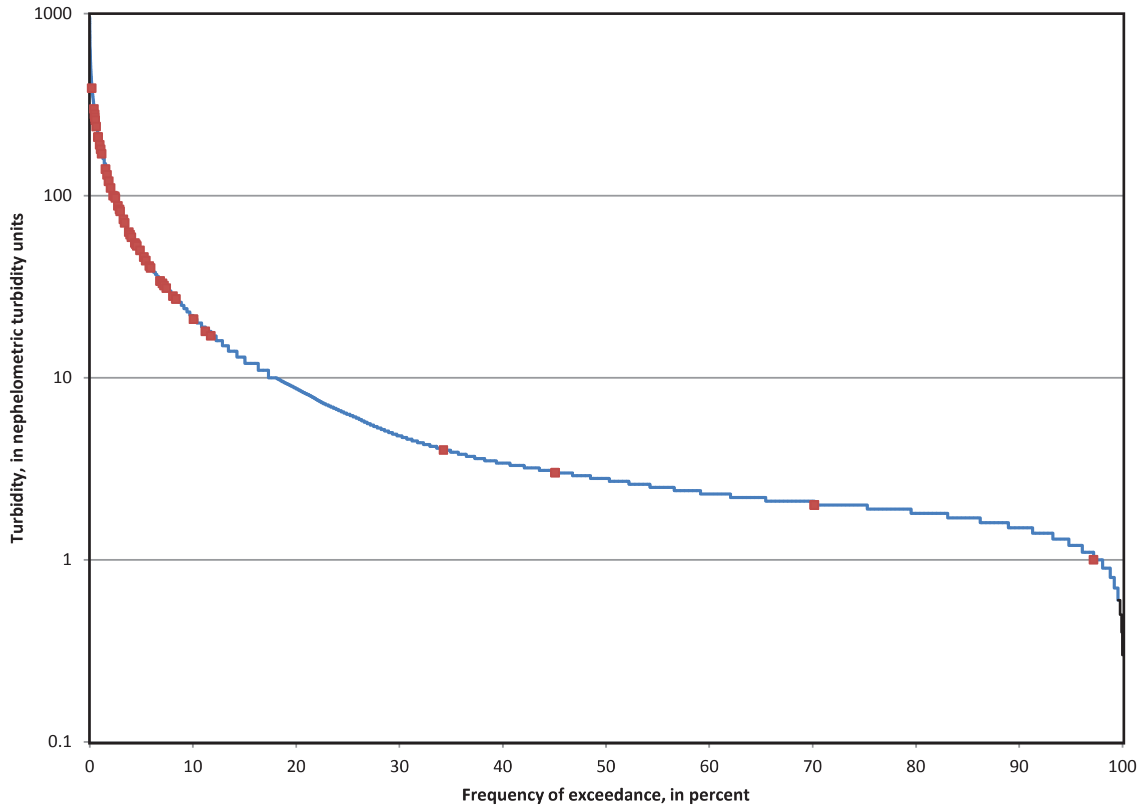
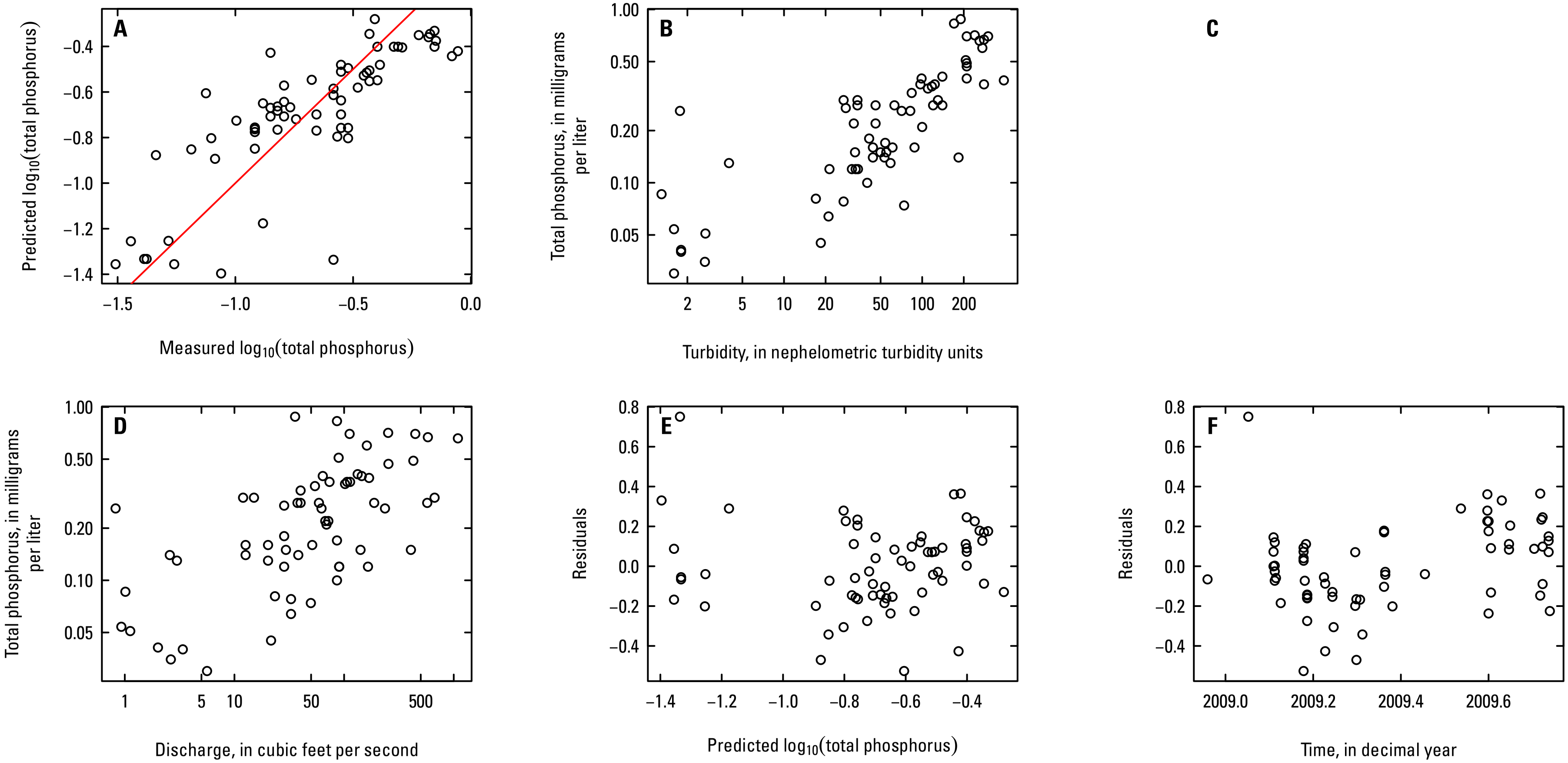


Figure 4-5. Duration curve for turbidity (November 2008–September 2010) and corresponding values associated with total phosphorus concentration samples collected November 2008 to September 2009 at U.S. Geological Survey streamgage on Honey Creek at Wauwatosa, Wisconsin.

Total phosphorus at Honey Creek at Wauwatosa, Wisconsin, November 2008–September 2009



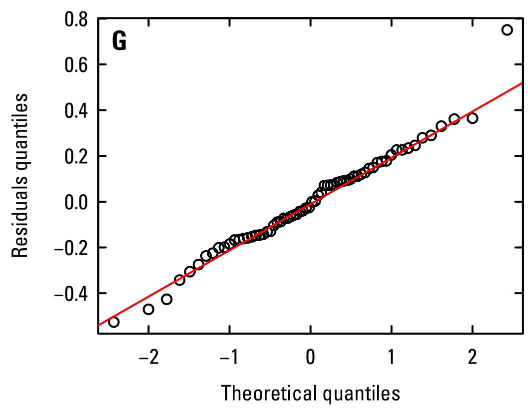


Figure 4-6. U.S. Geological Survey streamgage on Honey Creek at Wauwatosa, Wisconsin, November 2008 to September 2009. *A*, Relation between measured and predicted $\log_{10}$ (total phosphorus concentration). *B*, Relation between turbidity and total phosphorus concentration in $\log_{10}$ space. *C*, No plot. *D*, Relation between discharge and total phosphorus concentration in $\log_{10}$ space. *E*, Relation between predicted $\log_{10}$ (total phosphorus concentration) and regression residuals. *F*, Relation between time and total phosphorus regression residuals. *G*, Probability plot of total phosphorus regression residuals.

Total phosphorus at Menomonee River at Wauwatosa, WI (04087120)

Total phosphorus samples collected on 12/27/2008 at 06:05, 10:15, and 14:45, and on 12/28/2008 at 07:45 were not used in the regression analysis because the MMSD laboratory reported a qualified total phosphorus concentration of < 1.4 mg/L. Samples collected on 6/8-6/9 2009 were not used in the regression analysis because the turbidity sensor readings were spiking excessively and the data quality was thought to be poor.

MODEL SUMMARY—Summary of final regression results for estimating total phosphorus concentrations at Menomonee River at Wauwatosa, WI.

$\log_{10}$ (Total Phosphorus) = -1.42 + 0.431 $\log_{10}$ (Turb),
Where:

Total Phosphorus = total phosphorus concentration in mg/L
Turb = Turbidity, (YSI 6136), in NTU

***Model Information (in log units unless otherwise specified)*:**
Number of measurements = 91,
Root-mean-squared error (RMSE) = 0.204
Model standard percentage error (MPSE) = +60 and -38 percent
90-percent prediction intervals (based on units in mg/L) = +/- 97 percent
Adjusted coefficient of determination (Adj R^2) = 0.55
Sum of squared error = 3.72
PRESS = 3.96

***Coefficients*:**

	Coefficient	**Standard error**	**t statistic**	**p-value**
Intercept	**-1.42**	**0.068**	**-20.70**	**<0.0001**
$\log_{10}$ (Turb)	**0.431**	**0.041**	**10.63**	**<0.0001**

Correlation matrix of coefficients:

	Intercept	**$\log_{10}$ (Turb)**
Intercept	**1**	**-0.950**
$\log_{10}$ (Turb)	**-0.950**	**1**

Duan's bias correction factor **= 1.12**

Table 4-4. Model-calibration dataset for Menomonee River at Wauwatosa, Wisconsin.

[mg/L, milligrams per liter; NTU, Nephelometric turbidity units]

Date	Time	Total phosphorus (mg/L)	Turbidity (NTU)
11/20/2008	10:30	0.046	1.9
12/17/2008	12:30	0.053	6.8
12/27/2008	1:15	0.31	25.0
12/27/2008	3:45	0.34	46.0
12/27/2008	5:50	0.39	66.0
12/27/2008	14:00	0.66	180.0
1/20/2009	12:10	0.23	1.5
2/7/2009	11:25	0.33	72.3
2/7/2009	13:25	0.4	105.0
2/7/2009	13:40	0.54	110.0
2/7/2009	19:40	0.31	46.3
2/8/2009	13:40	0.22	26.0
2/9/2009	1:40	0.13	12.0
2/9/2009	19:40	0.34	64.0
2/9/2009	22:00	0.45	140.0
2/9/2009	23:15	0.3	140.0
2/10/2009	7:20	0.18	45.7
2/10/2009	11:00	0.39	100.0
2/10/2009	17:05	0.28	70.7
2/10/2009	23:25	0.17	41.3
2/16/2009	12:45	0.18	4.8
2/26/2009	14:35	0.093	66.0
2/26/2009	19:00	0.097	140.0
2/26/2009	19:45	0.26	170.0
2/26/2009	22:50	0.29	130.0
2/27/2009	4:50	0.36	70.0
3/2/2009	7:20	0.068	7.3
3/10/2009	0:15	0.13	34.0
3/10/2009	5:50	0.14	38.0
3/10/2009	11:45	0.15	38.0
3/10/2009	14:50	0.14	41.0
3/11/2008	1:10	0.13	45.5
3/24/2009	11:55	0.046	1.1
3/25/2009	1:30	0.11	38.0
3/31/2009	17:00	0.053	14.0
3/31/2009	17:35	0.092	33.0
4/1/2009	5:35	0.058	20.0
4/19/2009	19:10	0.085	17.0
4/20/2009	5:05	0.064	24.0
4/21/2009	5:05	0.042	7.1
4/23/2009	11:00	0.035	1.4
4/25/2009	11:15	0.082	22.0
4/25/2009	12:40	0.48	160.0
4/25/2009	21:35	0.17	77.0
4/26/2009	2:35	0.18	68.0
4/26/2009	14:35	0.098	36.0
4/26/2009	16:00	0.35	150.0
4/26/2009	17:10	0.37	190.0
4/27/2009	0:30	0.14	76.0
5/9/2009	0:30	0.15	37.0
5/9/2009	9:30	0.083	17.0
5/9/2009	15:50	0.065	15.0
5/13/2009	20:40	0.28	68.0
5/13/2009	21:05	0.46	150.0
5/13/2009	22:00	0.37	140.0
5/14/2009	3:15	0.2	86.0
5/20/2009	11:15	0.11	4.8
6/16/2009	11:50	0.089	9.6
6/19/2009	9:15	0.35	84.0
6/19/2009	18:15	0.17	52.0
6/19/2009	21:20	0.22	150.0
6/20/2009	3:10	0.18	45.0
7/16/2009	11:45	0.082	3.5
8/7/2009	18:00	0.26	32.0
8/7/2009	20:40	0.29	60.0
8/8/2009	0:55	0.2	37.0
8/8/2009	8:50	0.23	74.0
8/8/2009	9:45	0.56	210.0
8/8/2009	19:50	0.14	48.0
8/9/2009	19:50	0.19	39.0
8/10/2009	2:00	0.25	110.0
8/10/2009	4:20	0.16	99.0
8/19/2009	12:20	0.11	2.7
8/25/2009	20:50	0.3	68.0
8/25/2009	21:25	0.34	110.0
8/25/2009	21:30	0.37	96.0
8/26/2009	3:30	0.2	47.0
8/27/2009	3:35	0.11	18.0
9/15/2009	11:00	0.067	2.8
9/20/2009	21:40	0.41	69.0
9/21/2009	3:40	0.26	51.0
9/22/2009	13:30	0.31	56.0
9/22/2009	13:40	0.56	71.0
9/22/2009	21:50	0.49	56.0
9/22/2009	23:10	0.19	53.0
9/27/2009	20:35	0.37	100.0
9/27/2009	21:05	0.49	150.0
9/27/2009	21:20	0.54	180.0
09/28/209	0:05	0.22	70.0
9/28/2009	2:35	0.17	62.0
9/28/2009	20:35	0.16	25.0
MINIMUM		**0.04**	**1.1**
MAXIMUM		**0.66**	**210.0**
MEAN		**0.23**	**64.6**
MEDIAN		**0.20**	**52.0**
STANDARD DEVIATION		**0.15**	**51.4**

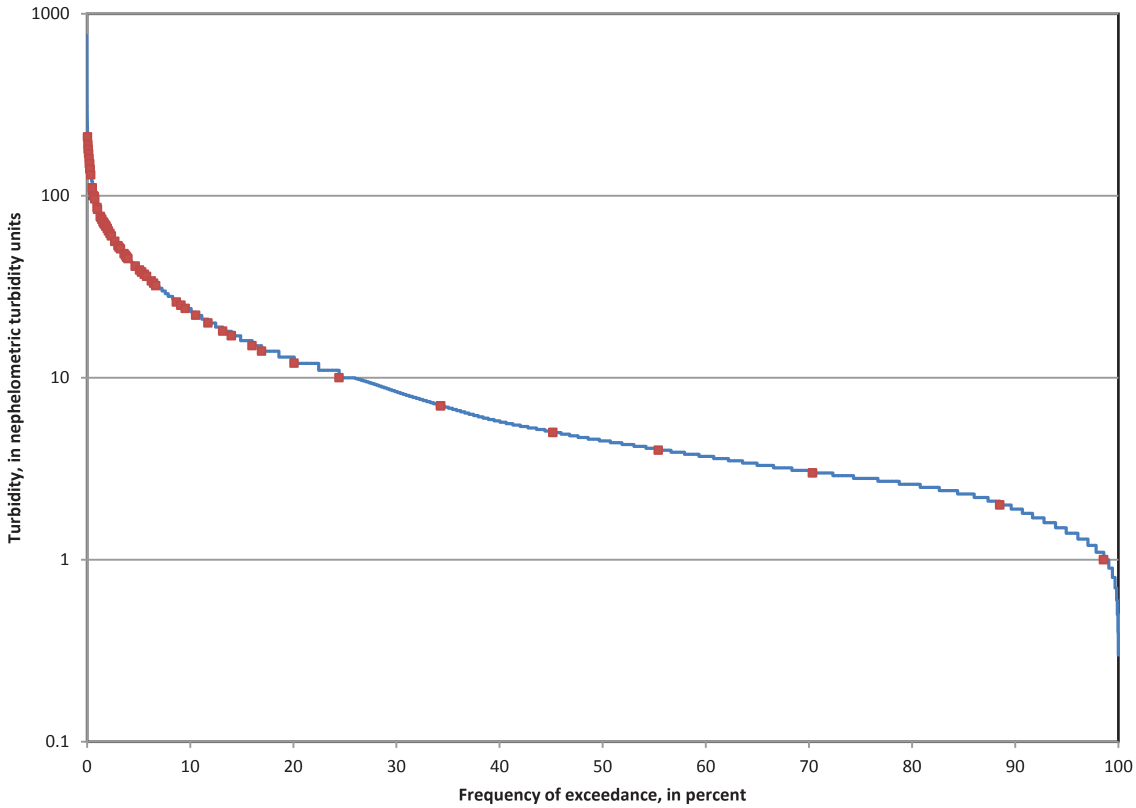


Figure 4-7. Duration curve for turbidity (November 2008–September 2010) and corresponding values associated with total phosphorus concentration samples collected November 2008 to September 2009 at U.S. Geological Survey streamgage on Menomonee River at Wauwatosa, Wisconsin.

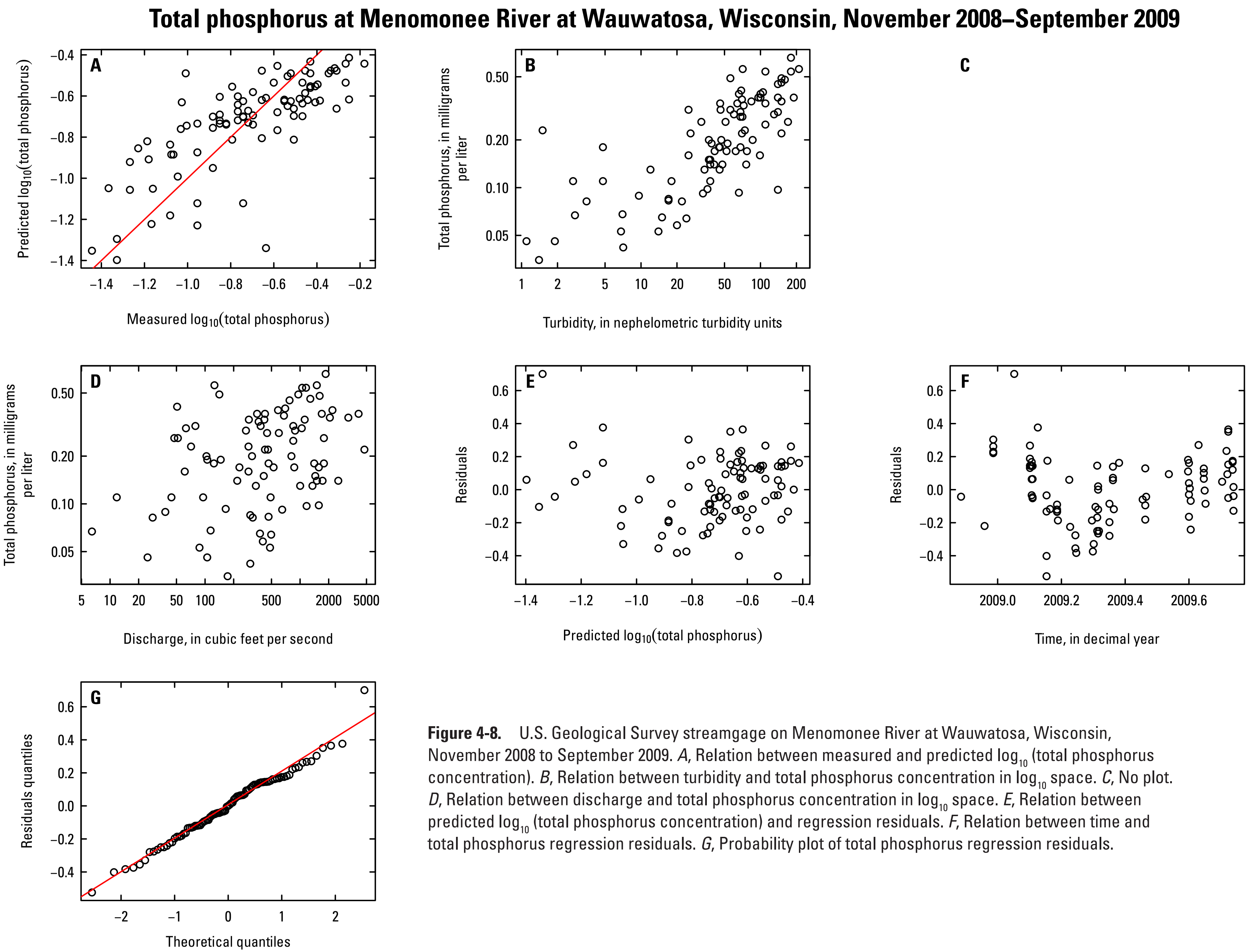


Figure 4-8. U.S. Geological Survey streamgage on Menomonee River at Wauwatosa, Wisconsin, November 2008 to September 2009. *A*, Relation between measured and predicted $\log_{10}$ (total phosphorus concentration). *B*, Relation between turbidity and total phosphorus concentration in $\log_{10}$ space. *C*, No plot. *D*, Relation between discharge and total phosphorus concentration in $\log_{10}$ space. *E*, Relation between predicted $\log_{10}$ (total phosphorus concentration) and regression residuals. *F*, Relation between time and total phosphorus regression residuals. *G*, Probability plot of total phosphorus regression residuals.

Total phosphorus at Menomonee River at 16th Street at Milwaukee, WI (04087142)

MODEL SUMMARY—Summary of final regression results for estimating total phosphorus concentrations at Menomonee River at 16th Street at Milwaukee, WI.

$\log_{10}$ (Total Phosphorus) = -1.51 + 0.462 $\log_{10}$ (Turb),
Where:

Total Phosphorus = total phosphorus concentration in mg/L
Turb = Turbidity, (YSI 6136), in NTU

***Model Information (in log units unless otherwise specified)*:**
Number of measurements = 77,
Root-mean-squared error (RMSE) = 0.192
Model standard percentage error (MPSE) = +56 and -36 percent
90-percent prediction intervals (based on units in mg/L) = +/- 89 percent
Adjusted coefficient of determination (Adj R^2) = 0.61
Sum of squared error = 2.76
PRESS = 2.97

***Coefficients*:**

	Coefficient	Standard error	t statistic	p-value
Intercept	**-1.51**	**0.067**	**-22.46**	**<0.0001**
$\log_{10}$ (Turb)	**0.462**	**0.042**	**10.93**	**<0.0001**

Correlation matrix of coefficients:

	Intercept	$\log_{10}$ (Turb)
Intercept	**1**	**-0.946**
$\log_{10}$ (Turb)	**-0.946**	**1**

Duan's bias correction factor **= 1.11**

Table 4-5. Model-calibration dataset for Menomonee River at 16th Street at Milwaukee, Wisconsin.

[mg/L, milligrams per liter; NTU, Nephelometric turbidity units]

Date	Time	Total phosphorus (mg/L)	Turbidity (NTU)
11/20/2008	11:45	0.051	3.1
12/17/2008	14:15	0.061	7.3
12/27/2008	9:35	0.26	20.0
12/27/2008	12:35	0.28	52.3
12/27/2008	21:35	0.38	77.3
12/28/2008	0:35	0.35	58.7
1/20/2009	12:40	0.26	5.4
2/7/2009	11:40	0.094	3.6
2/7/2009	20:40	0.34	78.7
2/8/2009	5:40	0.24	34.7
2/8/2009	14:40	0.19	28.3
2/8/2009	23:40	0.2	28.0
2/9/2009	17:40	0.18	12.7
2/10/2009	5:40	0.23	98.0
2/11/2009	17:40	0.28	69.3
2/16/2009	13:40	0.073	8.1
2/26/2009	16:00	0.096	8.2
2/26/2009	19:00	0.38	200.0
2/26/2009	22:00	0.3	130.0
2/27/2009	4:00	0.21	85.0
2/27/2009	12:00	0.12	51.0
2/28/2009	12:00	0.19	19.0
3/7/2009	11:10	0.1	19.0
3/7/2009	14:10	0.2	89.0
3/7/2009	23:10	0.17	54.0
3/8/2009	12:10	0.14	35.0
3/8/2009	18:10	0.25	90.0
3/9/2009	0:10	0.19	61.0
3/10/2009	8:15	0.15	47.0
3/10/2009	12:55	0.15	41.0
3/10/2009	13:00	0.14	42.0
3/10/2009	20:30	0.14	41.0
3/11/2009	4:30	0.12	29.0
3/24/2009	12:25	0.057	4.0
4/1/2009	1:40	0.083	34.0
4/20/2009	3:05	0.046	12.0
4/20/2009	4:50	0.044	14.0
4/23/2009	11:15	0.039	5.7
4/25/2009	13:20	0.073	30.0
4/25/2009	20:00	0.097	61.0
4/26/2009	8:00	0.1	48.0
4/26/2009	14:00	0.095	39.0
4/26/2009	16:25	0.26	82.0
4/26/2009	17:10	0.52	210.0
4/26/2009	19:30	0.38	210.0
4/26/2009	19:35	0.38	190.0
5/13/2009	22:05	0.14	35.0
5/14/2009	0:35	0.17	67.0
5/14/2009	1:45	0.21	93.0
5/14/2009	3:35	0.16	70.0
5/20/2009	11:45	0.12	5.0
6/8/2009	12:40	0.1	42.0
6/8/2009	15:30	0.12	50.0
6/9/2009	2:35	0.087	32.7
6/9/2009	5:00	0.088	31.3
6/16/2009	13:00	0.11	5.3
6/19/2009	0:55	1.8	530.0
6/19/2009	1:10	1.2	400.0
6/19/2009	1:45	0.96	340.0
6/19/2009	9:35	0.2	95.0
6/19/2040	20:45	0.27	160.0
6/20/2009	2:25	0.19	84.0
7/16/2009	12:30	0.1	4.9
8/8/2009	22:30	0.14	24.0
8/9/2009	10:30	0.1	17.0
8/19/2009	13:30	0.076	4.7
8/26/2009	7:05	0.11	15.0
8/26/2009	17:00	0.099	13.0
8/26/2009	23:45	0.1	14.0
9/15/2009	11:30	0.074	2.9
9/23/2009	7:10	0.11	7.1
9/24/2009	7:00	0.095	9.2
9/28/2009	12:05	0.11	28.0
09/28/209	18:05	0.12	30.0
9/29/2009	0:05	0.11	30.0
9/29/2009	3:05	0.1	17.0
9/29/2009	5:00	0.11	16.0
MINIMUM		**0.04**	**2.9**
MAXIMUM		**1.80**	**530.0**
MEAN		**0.21**	**62.9**
MEDIAN		**0.14**	**34.7**
STANDARD DEVIATION		**0.25**	**88.9**

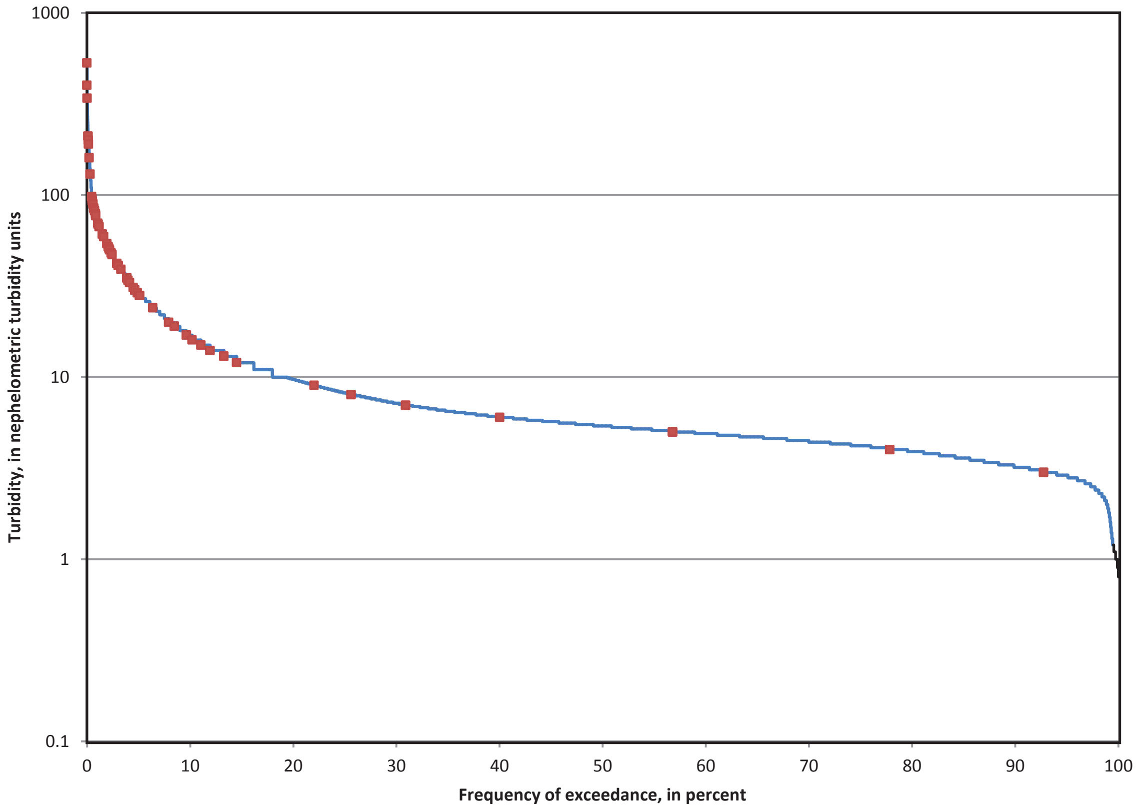
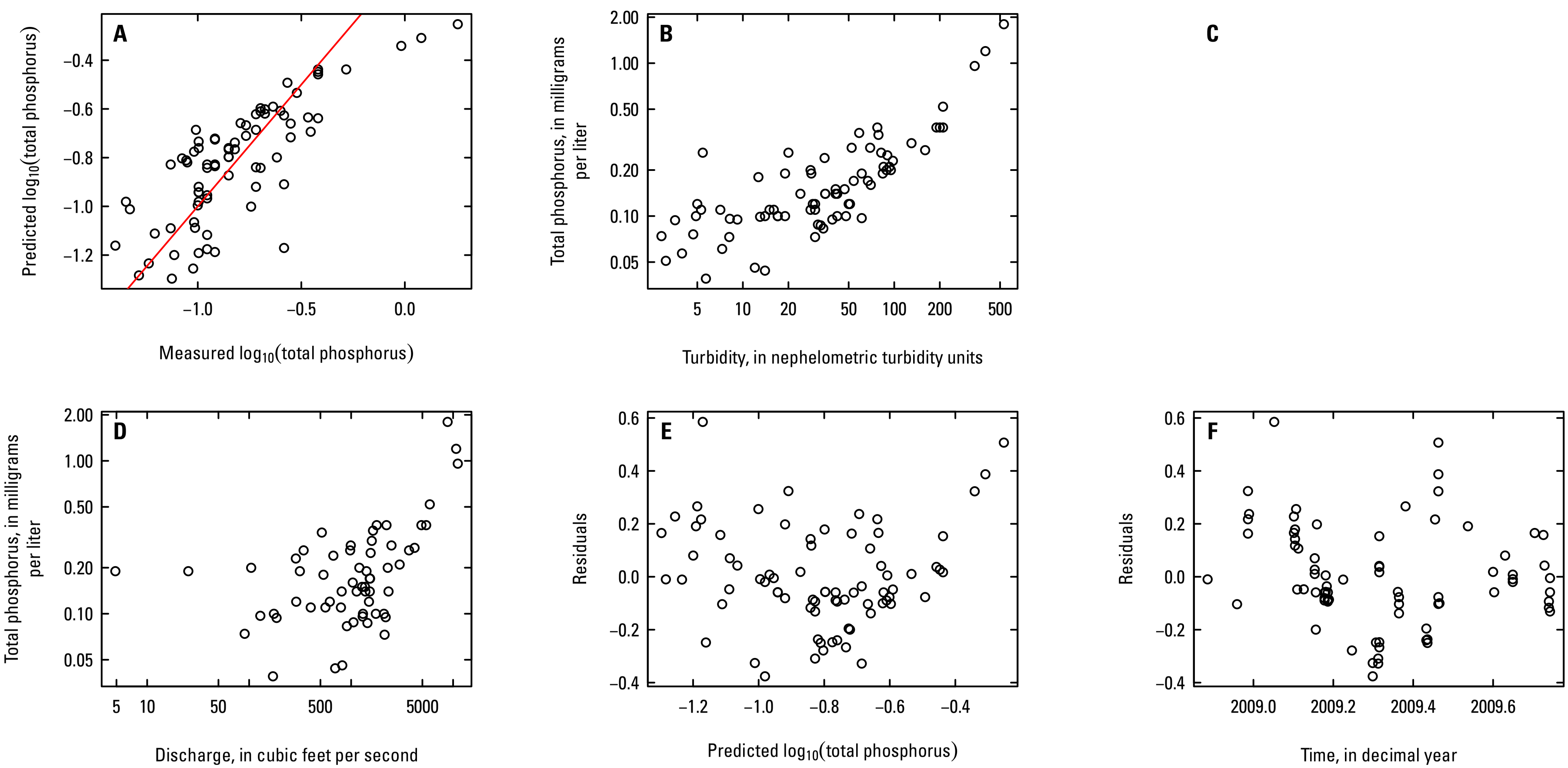


Figure 4-9. Duration curve for turbidity (November 2008–September 2010) and corresponding values associated with total phosphorus concentration samples collected November 2008 to September 2009 at U.S. Geological Survey streamgage on Menomonee River at 16th Street at Milwaukee, Wisconsin.

Total phosphorus at Menomonee River at 16th Street at Milwaukee, Wisconsin, November 2008–September 2009



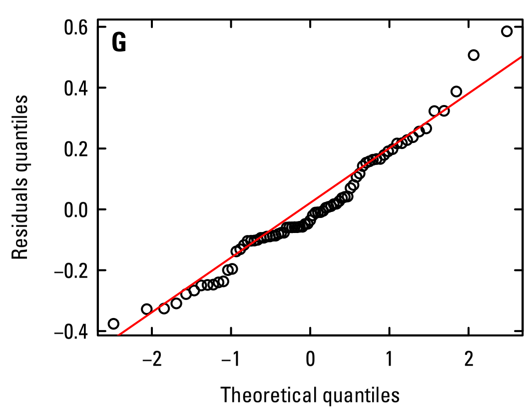


Figure 4-10. U.S. Geological Survey streamgage on Menomonee River at 16th Street at Milwaukee, Wisconsin, November 2008 to September 2009. *A*, Relation between measured and predicted $\log_{10}$ (total phosphorus concentration). *B*, Relation between turbidity and total phosphorus concentration in $\log_{10}$ space. *C*, No plot. *D*, Relation between discharge and total phosphorus concentration in $\log_{10}$ space. *E*, Relation between predicted $\log_{10}$ (total phosphorus concentration) and regression residuals. *F*, Relation between time and total phosphorus regression residuals. *G*, Probability plot of total phosphorus regression residuals.

Appendix 5. Regression analysis results for estimating *Escherichia coli* (*E. coli*) bacteria concentration

All data were collected using U.S. Geological Survey (USGS) protocols and are stored in the USGS National Water Information System (NWIS) database (*http://waterdata.usgs.gov/nwis*). The regression models are based on measurements of turbidity and water temperature and concurrent *E. coli* bacteria samples collected from November 2008 to September 2009. Continuous water-quality data were collected at 5-minute intervals using a YSI model 6920 V2 multiparameter water-quality monitor with a 6560 specific conductance and water temperature sensor, and a 6136 optical turbidity sensor. Turbidity and water temperature values are instantaneous unit values temporally corresponding to the collection of the *E. coli* bacteria samples. Samples were collected throughout the range of continuously observed hydrologic conditions. Summary statistics and the complete model-calibration dataset are provided. A comparison of cross-section mean and corresponding time-series monitor readings is archived at the Wisconsin Water Science Center and is available by request to Austin Baldwin (akbaldwi@usgs.gov).

Escherichia coli (*E. coli*) bacteria at Little Menomonee River near Freistadt, WI (04087050)

Sample data on 2/16/2009 were not used in the regression analysis because there was no sonde data. Sample data on 2/26/2010 was not used because it was believed the samples at 09:50 and 15:20 were switched and the concentration may be in error.

MODEL SUMMARY—Summary of final regression results for estimating *E. coli* concentrations at Little Menomonee River near Freistadt, WI.

$\log_{10}$ (*E. coli*) = 1.81 + 0.025 (WT) + 0.693 $\log_{10}$ (Turb),
Where:

E. coli = Most Probable Number of *E. coli* per 100 ml (MPN/100ml)
WT = Water Temperature in ^{o}C
Turb = Turbidity (YSI 6136), in NTU

***Model Information (in log units unless otherwise specified)*:**
Number of measurements = 37,
Root-mean-squared error (RMSE) = 0.45
Model standard percentage error (MPSE) = +182 and -65 percent
90-percent prediction intervals (based on units in MPN/100ml) = +/- 573 percent
Adjusted coefficient of determination (Adj R^2) = 0.58
Sum of squared error = 6.90
PRESS = 8.17

***Coefficients*:**

	Coefficient	**Standard error**	**t statistic**	**p-value**
Intercept	**1.81**	**0.182**	**9.91**	**<.0001**
WT	**0.025**	**0.012**	**2.12**	**0.041**
$\log_{10}$ (Turb)	**0.693**	**0.106**	**6.57**	**<.0001**

Correlation matrix of coefficients:

	Intercept	**WT**	**$\log_{10}$ (Turb)**
Intercept	**1.00**	**-0.296**	**-0.821**
WT	**-0.296**	**1.00**	**-0.125**
$\log_{10}$ (Turb)	**-0.821**	**-0.125**	**1.00**

Duan's bias correction factor **= 2.05**

Table 5-1. Model-calibration dataset for Little Menomonee River near Freistadt, Wisconsin.

[MPN/100 mL, most probable number per 100 milliliters; NTU, Nephelometric turbidity units; °C, degrees Celsius]

Date	Time	*Escherichia coli* (MPN/100 mL)	Turbidity (NTU)	Water temperature (°C)
11/20/2008	9:45	51	1.2	1.6
12/17/2008	11:30	120	2.1	0.0
12/28/2008	1:05	1,100	52.3	0.1
1/20/2009	10:55	10	0.7	0.1
2/7/2009	18:50	860	19.7	0.0
2/9/2009	22:40	1,700	11.3	0.2
2/10/2009	10:45	1,300	38.0	0.3
2/10/2009	14:40	830	113.3	0.5
2/10/2009	20:40	1,600	46.0	0.3
2/11/2009	2:40	15,000	21.3	0.2
3/2/2009	7:10	230	4.2	0.0
3/7/2009	12:55	400	130.0	1.8
3/7/2009	18:05	1,500	220.0	1.3
3/8/2009	7:05	760	62.0	1.0
3/8/2009	19:00	2,600	210.0	0.2
3/9/2009	0:30	1,500	140.0	0.3
3/10/2009	3:20	570	68.0	1.9
3/10/209	8:15	840	94.0	1.1
3/10/2009	20:15	610	51.0	2.2
3/24/2009	10:40	110	2.8	4.0
4/23/2009	9:45	610	2.1	6.4
4/25/2009	15:10	860	100.0	10.7
4/26/2009	5:30	4,500	180.0	7.1
4/26/2009	19:30	4,000	200.0	9.7
4/27/2009	1:30	2,200	80.0	9.6
5/9/2009	7:25	3,400	81.0	11.7
5/9/2009	13:30	8,700	54.0	11.6
5/9/2009	19:30	2,200	15.0	12.0
5/14/2009	2:30	6,000	270.0	13.8
5/20/2009	9:00	140	4.5	14.0
6/8/2009	5:20	3,800	120.0	11.5
6/16/2009	8:45	260	12.0	14.0
6/19/2009	2:50	9,600	290.0	17.4
6/19/2009	8:50	25,000	89.0	17.4
7/16/2009	10:05	1,100	19.0	16.2
8/19/2009	10:00	250	8.8	16.0
9/15/2009	9:30	730	10.0	16.5
MINIMUM		**10**	**0.7**	**0.0**
MAXIMUM		**25,000**	**290.0**	**17.4**
MEAN		**2,839**	**76.3**	**6.3**
MEDIAN		**1,100**	**52.3**	**2.2**
STANDARD DEVIATION		**4,870**	**80.3**	**6.4**

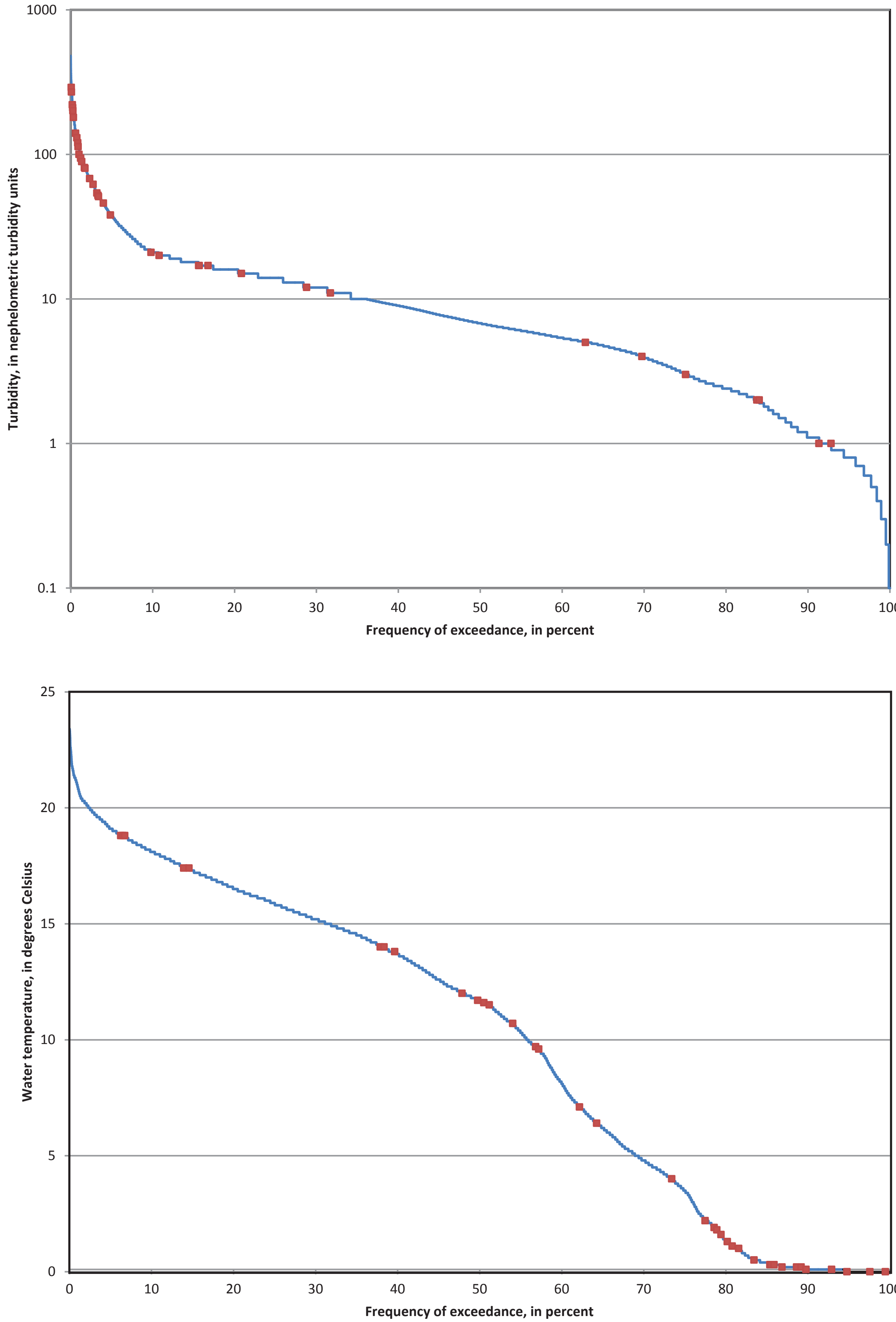
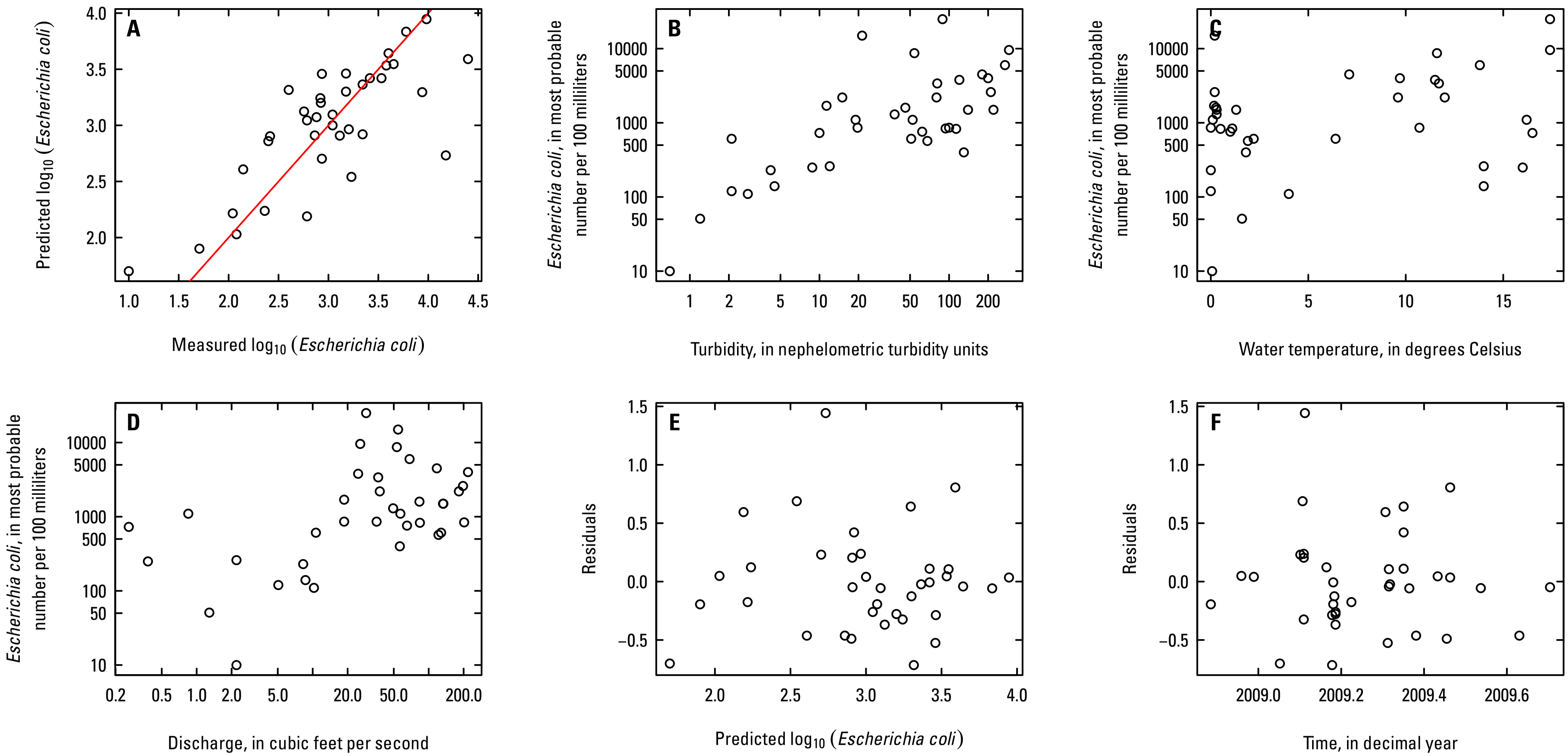


Figure 5-1. Duration curves for turbidity and water temperature (November 2008–September 2010) and corresponding values associated with *Escherichia coli* (*E. coli*) concentration samples collected November 2008 to September 2009 at U.S. Geological Survey streamgage on Little Menomonee River near Freistadt, Wisconsin.

Escherichia coli at Little Menomonee River near Freistadt, Wisconsin, November 2008–September 2009



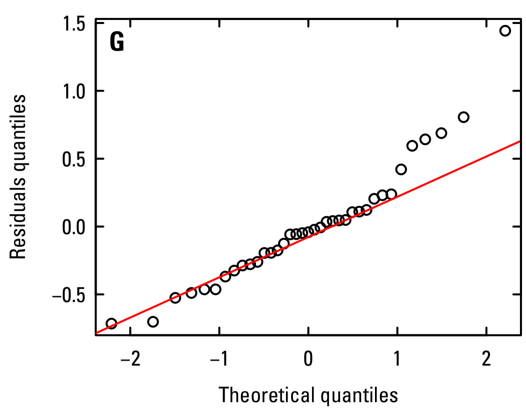


Figure 5-2. U.S. Geological Survey streamgage on Little Menomonee River near Freistadt, Wisconsin, November 2008 to September 2009. *A*, Relation between measured and predicted $\log_{10}$(*Escherichia coli* (*E. coli*) concentration). *B*, Relation between turbidity and *E. coli* concentration in $\log_{10}$ space. *C*, Relation between water temperature and *E. coli* concentration in $\log_{10}$ space. *D*, Relation between discharge and *E. coli* concentration in $\log_{10}$ space. *E*, Relation between predicted $\log_{10}$(*E. coli* concentration) and regression residuals. *F*, Relation between time and *E. coli* regression residuals. *G*, Probability plot of *E. coli* regression residuals.

Escherichia coli (*E. coli*) bacteria at Menomonee River at Menomonee Falls, WI (04087030)

MODEL SUMMARY—Summary of final regression results for estimating *E. coli* concentrations at Menomonee River at Menomonee Falls, WI.

$\log_{10}$ (*E. coli*) = 1.30 + 0.057 (WT) + 0.674 $\log_{10}$ (Turb),
Where:

E. coli = Most Probable Number of *E. coli* per 100 ml (MPN/100ml)
WT = Water Temperature in ^{o}C
Turb = Turbidity (YSI 6136), in NTU

***Model Information (in log units unless otherwise specified)*:**
Number of measurements = 55,
Root-mean-squared error (RMSE) = 0.556
Model standard percentage error (MPSE) = +259 and -72 percent
90-percent prediction intervals (based on units in MPN/100ml) = +/- 768 percent
Adjusted coefficient of determination (Adj R^2) = 0.60
Sum of squared error = 16.05
PRESS = 17.84

***Coefficients*:**

	Coefficient	**Standard error**	**t statistic**	**p-value**
Intercept	**1.30**	**0.213**	**6.13**	**<0.0001**
WT	**0.057**	**0.010**	**5.75**	**<0.0001**
$\log_{10}$ (Turb)	**0.674**	**0.143**	**4.73**	**<0.0001**

Correlation matrix of coefficients:

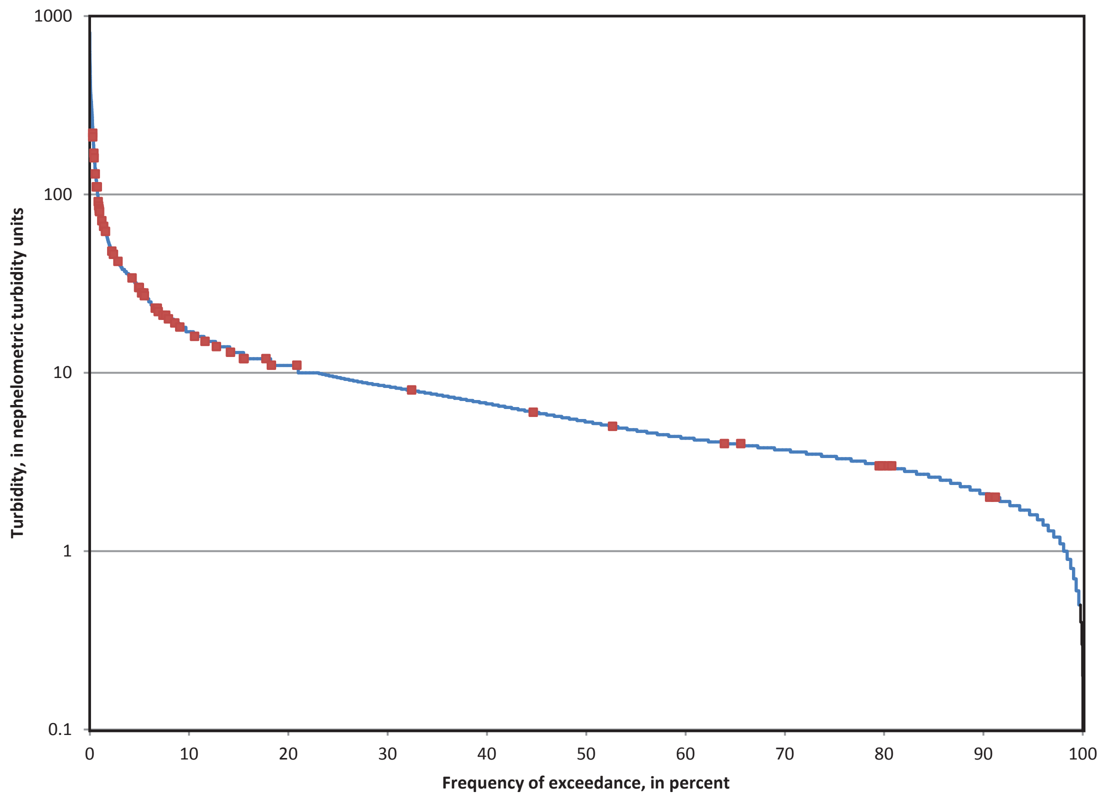
	Intercept	**WT**	**$\log_{10}$ (Turb)**
Intercept	**1**	**-0.250**	**-0.771**
WT	**-0.250**	**1**	**-0.326**
$\log_{10}$ (Turb)	**-0.771**	**-0.326**	**1**

Duan's bias correction factor **= 1.84**

Table 5-2. Model-calibration dataset for Menomonee River at Menomonee Falls, Wisconsin.

[MPN/100 mL, most probable number per 100 milliliters; NTU, Nephelometric turbidity units; °C, degrees Celsius]

Date	Time	*Escherichia coli* (MPN/100 mL)	Turbidity (NTU)	Water temperature (°C)
11/20/2008	9:15	63	3.6	1.1
12/17/2008	12:00	230	2.7	0.0
12/27/2008	14:20	490	100.7	0.1
1/20/2009	9:55	41	2.5	2.0
2/16/2009	11:00	50	3.1	0.2
2/26/2009	15:05	300	86.0	0.1
2/26/2009	18:15	730	81.0	0.2
2/27/2009	0:15	550	30.0	0.0
3/2/2009	7:15	70	3.2	0.0
3/7/2009	9:30	160	31.0	1.9
3/7/2009	15:30	160	29.0	2.0
3/8/2009	10:30	150	26.0	0.7
3/8/2009	14:00	370	69.0	0.8
3/9/2009	2:00	260	34.0	0.0
3/24/2009	10:00	190	4.1	4.1
3/25/2009	5:25	130	16.0	5.1
4/19/2009	23:00	410	23.0	10.5
4/20/2009	11:15	100	12.0	8.4
4/20/2009	23:15	200	11.0	8.3
4/23/2009	9:15	150	3.8	7.3
4/25/2009	10:50	750	71.0	14.6
4/25/2009	11:00	850	170.0	14.3
4/26/2009	5:00	410	27.0	8.9
4/26/2009	16:00	520	34.0	9.8
4/27/2009	4:00	520	23.0	10.2
5/9/2009	1:05	160	83.0	16.9
5/9/2009	1:15	1,000	110.0	16.7
5/9/2009	10:25	1,200	12.0	14.0
5/9/2009	22:25	400	14.0	13.5
5/10/2009	10:25	350	8.2	11.9
5/13/2009	23:00	2,300	81.0	15.8
5/20/209	9:30	10	6.3	16.5
6/8/2009	3:15	1,800	91.0	14.0
6/8/2009	3:25	12,000	220.0	13.5
6/8/2009	9:35	4,600	28.0	13.4
6/16/2009	10:15	70	13.0	19.1
6/19/2009	0:10	4,000	160.0	21.2
6/19/2009	0:50	4,000	110.0	21.1
6/19/2009	2:00	8,800	66.0	20.9
6/20/2009	2:00	3,600	21.0	20.1
7/16/2009	9:30	5,200	5.0	20.4
8/7/2009	19:35	20,000	46.0	20.2
8/8/2009	9:05	12,000	80.0	20.5
8/19/2009	9:00	430	3.2	20.1
8/25/2009	18:20	8,100	210.0	23.1
8/25/2009	18:45	34,000	85.0	23.1
8/26/2009	1:30	8,600	30.0	22.3
8/26/2009	1:55	6,300	48.0	22.4
9/15/2009	9:30	140	2.8	18.8
9/22/2009	13:15	18,000	62.0	18.9
9/22/2009	14:05	52,000	130.0	19.3
9/22/2009	15:20	19,000	21.0	18.4
9/27/2009	19:25	11,000	81.0	18.0
9/27/2008	21:30	12,000	51.0	17.1
9/28/2009	5:55	3,900	12.0	15.2
MINIMUM		**10**	**2.5**	**0.0**
MAXIMUM		**52,000**	**220.0**	**23.1**
MEAN		**4,778**	**50.7**	**11.9**
MEDIAN		**520**	**30.0**	**14.0**
STANDARD DEVIATION		**9,252**	**52.6**	**8.0**



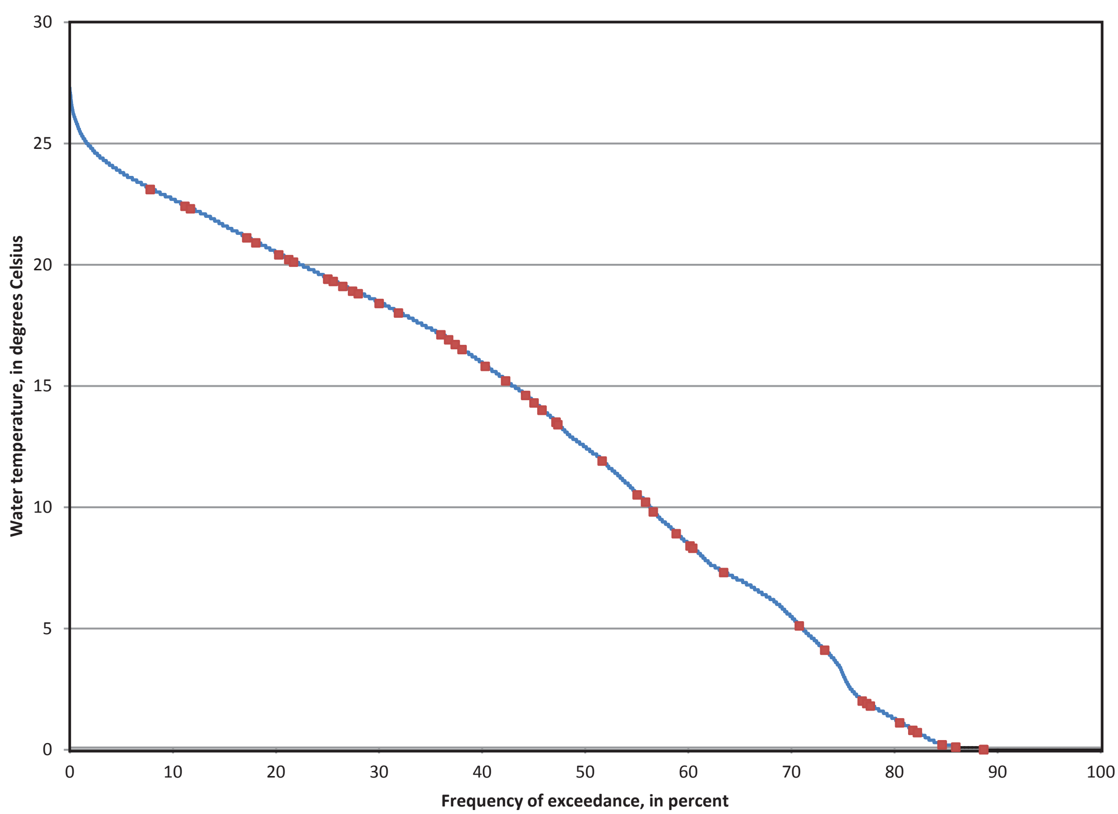


Figure 5-3. Duration curves for turbidity and water temperature (November 2008–September 2010) and corresponding values associated with *Escherichia coli* (*E. coli*) concentration samples collected November 2008 to September 2009 at U.S. Geological Survey streamgage on Menomonee River at Menomonee Falls, Wisconsin.

Escherichia coli at Menomonee River at Menomonee Falls, Wisconsin, November 2008–September 2009

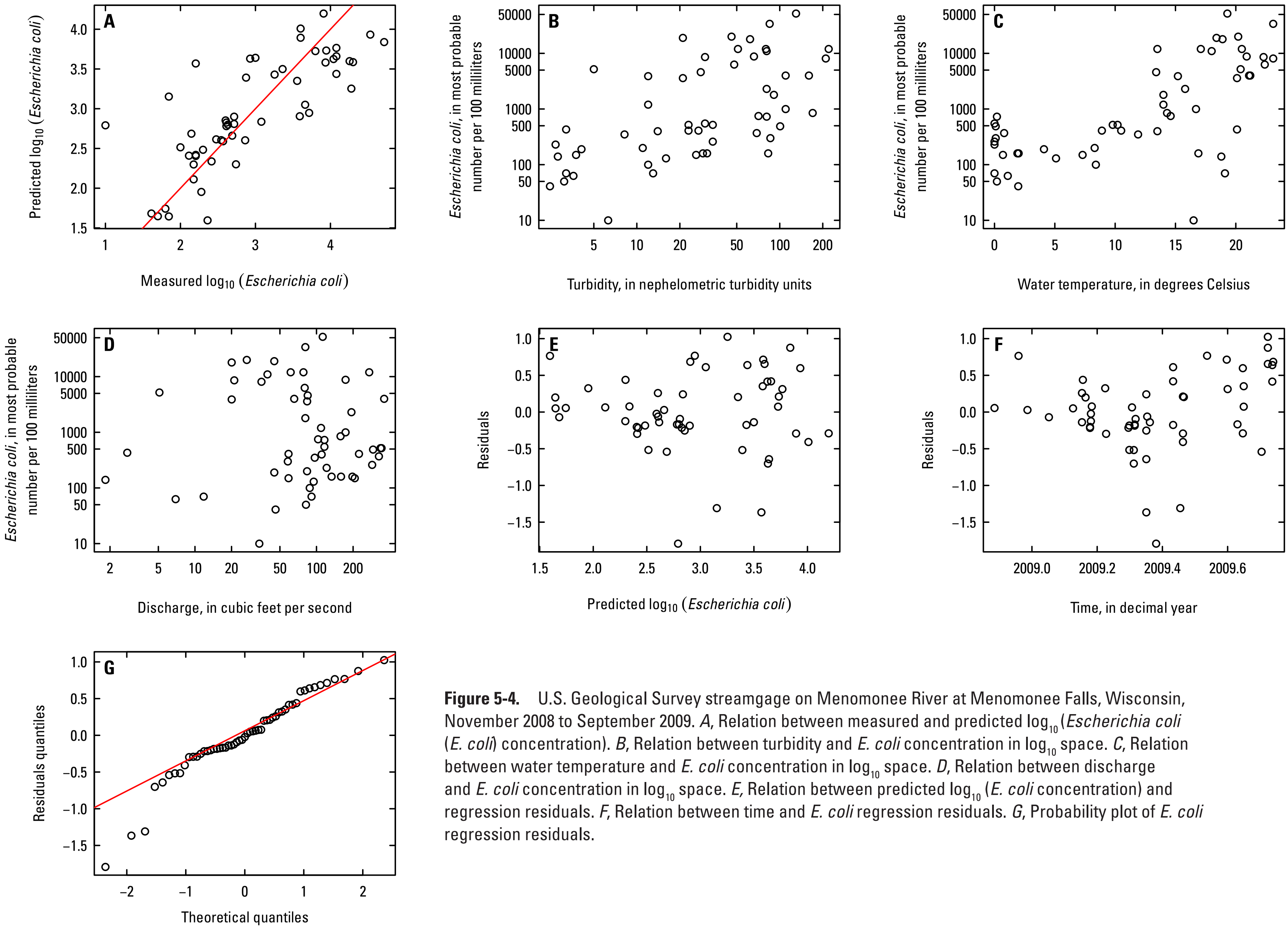


Figure 5-4. U.S. Geological Survey streamgage on Menomonee River at Menomonee Falls, Wisconsin, November 2008 to September 2009. *A*, Relation between measured and predicted $\log_{10}$(*Escherichia coli* (*E. coli*) concentration). *B*, Relation between turbidity and *E. coli* concentration in $\log_{10}$ space. *C*, Relation between water temperature and *E. coli* concentration in $\log_{10}$ space. *D*, Relation between discharge and *E. coli* concentration in $\log_{10}$ space. *E*, Relation between predicted $\log_{10}$(*E. coli* concentration) and regression residuals. *F*, Relation between time and *E. coli* regression residuals. *G*, Probability plot of *E. coli* regression residuals.

Escherichia coli (*E. coli*) bacteria at Honey Creek at Wauwatosa, WI (04087119)

Sample data from 4/25/2009 at 12:40 through 4/26/2009, and sample data from 6/8/2009 were not used in the regression development because of excessive fouling of the data sonde. Sample data on 6/19/2009 were not used because of damage to the sonde and sampler line during an extreme flood event.

MODEL SUMMARY—Summary of final regression results for estimating *E. coli* concentrations at Honey Creek at Wauwatosa, WI.

$\log_{10}$ (*E. coli*) = 1.68 + 0.071 (WT) + 0.626 $\log_{10}$ (Turb),
Where:

E. coli = Most Probable Number of *E. coli* per 100 ml (MPN/100ml)
WT = Water Temperature in ^{o}C
Turb = Turbidity (YSI 6136), in NTU

***Model Information (in log units unless otherwise specified)*:**
Number of measurements = 66,
Root-mean-squared error (RMSE) = 0.480
Model standard percentage error (MPSE) = +202 and -67 percent
90-percent prediction intervals (based on units in MPN/100ml) = +/- 610 percent
Adjusted coefficient of determination (Adj R^2) = 0.69
Sum of squared error = 14.50
PRESS = 16.22

***Coefficients*:**

	Coefficient	**Standard error**	**t statistic**	**p-value**
Intercept	**1.68**	**0.177**	**9.50**	**<0.0001**
WT	**0.071**	**0.008**	**9.12**	**<0.0001**
$\log_{10}$ (Turb)	**0.626**	**0.092**	**6.77**	**<0.0001**

Correlation matrix of coefficients:

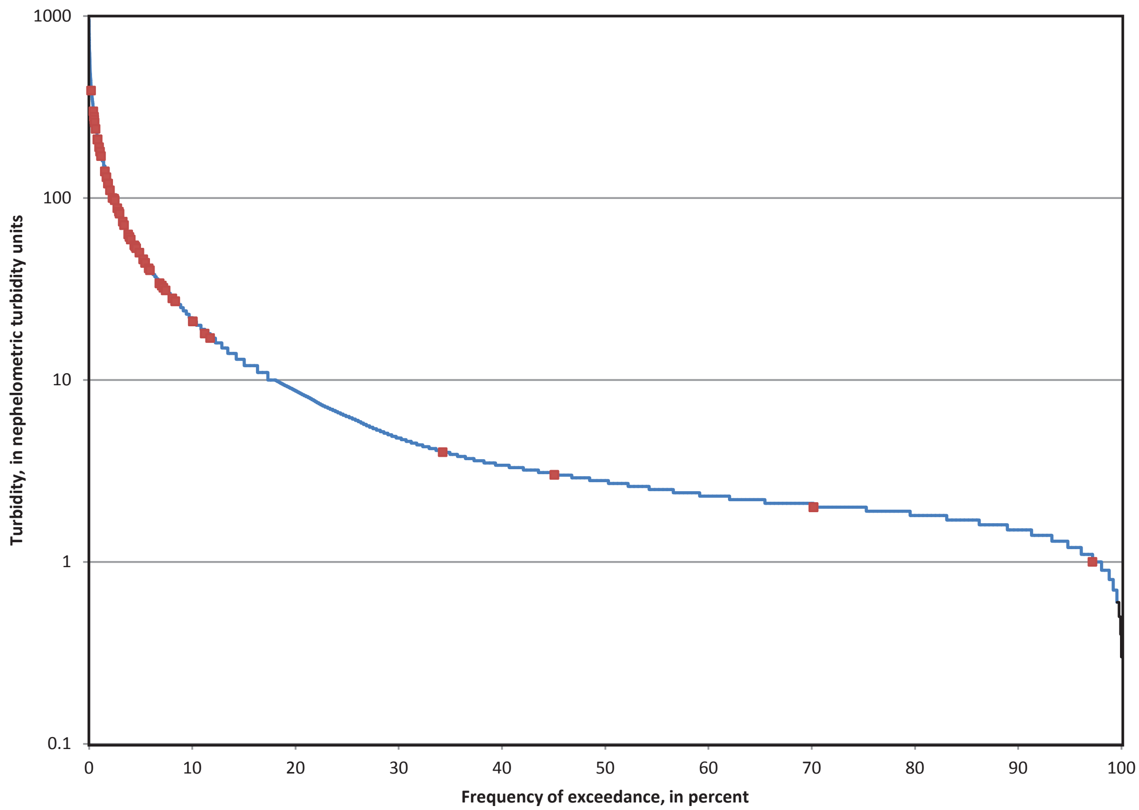
	Intercept	**WT**	**$\log_{10}$ (Turb)**
Intercept	**1**	**-0.367**	**-0.816**
WT	**-0.367**	**1**	**-0.124**
$\log_{10}$ (Turb)	**-0.816**	**-0.124**	**1**

Duan's bias correction factor **= 1.98**

Table 5-3. Model-calibration dataset for Honey Creek at Wauwatosa, Wisconsin.

[MPN/100 mL, most probable number per 100 milliliters; NTU, Nephelometric turbidity units; °C, degrees Celsius]

Date	Time	*Escherichia coli* (MPN/100 mL)	Turbidity (NTU)	Water temperature (°C)
12/17/2008	13:45	640	1.8	0.2
1/20/2009	11:55	500	1.7	0.0
2/10/2009	10:10	3,300	46.0	1.7
2/10/2009	13:25	1,400	123.3	2.5
2/10/2009	19:25	580	82.0	1.2
2/11/2009	1:25	750	41.3	1.9
2/11/2009	11:25	530	21.3	2.7
2/11/2009	12:00	1,100	97.0	2.9
2/11/2009	15:30	1,200	210.0	3.3
2/12/2009	2:25	690	32.7	2.3
2/16/2009	12:20	270	53.3	0.0
3/7/2009	9:25	1,200	74.0	3.2
3/7/2009	10:25	1,300	210.0	2.9
3/7/2009	12:10	680	140.0	3.0
3/7/2009	16:05	530	71.0	3.7
3/7/2009	22:05	400	46.0	3.0
3/8/2009	14:25	570	140.0	2.0
3/9/2009	1:00	600	32.0	2.0
3/10/2009	0:50	620	40.0	3.3
3/10/2009	5:30	260	50.0	2.6
3/10/2009	9:30	450	55.0	2.8
3/10/2009	12:10	1,300	33.0	3.1
3/10/2009	12:15	910	31.0	3.1
3/24/2009	11:40	310	1.8	4.6
3/25/2009	1:20	17,000	280.0	7.1
3/25/2009	3:45	9,200	183.3	7.1
3/31/2009	16:15	2,800	61.0	5.0
3/31/2009	17:05	2,400	390.0	5.0
4/1/2009	3:00	720	27.0	4.1
4/19/2009	17:10	2,300	17.0	9.1
4/19/2009	18:15	3,800	117.5	8.8
4/20/2009	2:30	310	34.3	8.3
4/20/2009	17:20	740	18.5	8.5
4/23/2009	10:45	250	1.6	7.6
4/25/2009	10:50	520	21.0	12.3
5/13/2009	20:30	3,900	54.0	14.0
5/13/2009	20:50	9,800	280.0	16.6
5/13/2009	21:10	11,000	260.0	16.9
5/14/2009	0:55	7,300	130.0	16.2
5/14/2009	2:40	9,800	120.0	15.2
5/20/2009	11:00	250	2.7	14.6
6/16/2009	11:00	620	2.7	15.4
7/16/2009	11:00	200	4.0	18.6
8/7/2009	17:10	24,000	27.0	18.3
8/7/2009	20:20	24,000	170.0	19.6
8/7/2009	23:05	24,000	28.0	19.5
8/8/2009	9:10	24,000	240.0	20.4
8/8/2009	9:30	10,000	300.0	20.7
8/8/2009	19:55	17,000	59.0	21.4
8/10/2009	1:50	24,000	210.0	21.9
8/10/2009	4:10	24,000	100.0	21.5
8/19/2009	12:40	300	1.3	18.9
8/25/2009	20:55	10,000	63.0	21.0
8/28/2009	22:05	21,000	206.7	21.9
8/26/2009	4:05	16,000	34.0	21.5
9/15/2009	10:45	510	1.6	19.0
9/20/2009	20:20	11,000	44.0	17.8
9/20/2009	21:55	87,000	190.0	17.8
9/21/2009	3:55	200,000	34.0	18.2
9/22/2009	13:25	98,000	84.0	17.0
9/22/2009	14:05	160,000	210.0	19.7
9/22/2009	22:40	46,000	44.0	19.4
9/27/2009	20:20	160,000	110.0	18.0
9/27/2009	21:00	130,000	272.5	17.4
9/27/2009	23:35	39,000	99.0	17.1
9/28/2009	2:30	17,000	88.0	16.4
MINIMUM		**200**	**1.3**	**0.0**
MAXIMUM		**200,000**	**390.0**	**21.9**
MEAN		**19,240**	**94.8**	**10.8**
MEDIAN		**1,850**	**57.0**	**9.0**
STANDARD DEVIATION		**41,203**	**91.3**	**7.7**



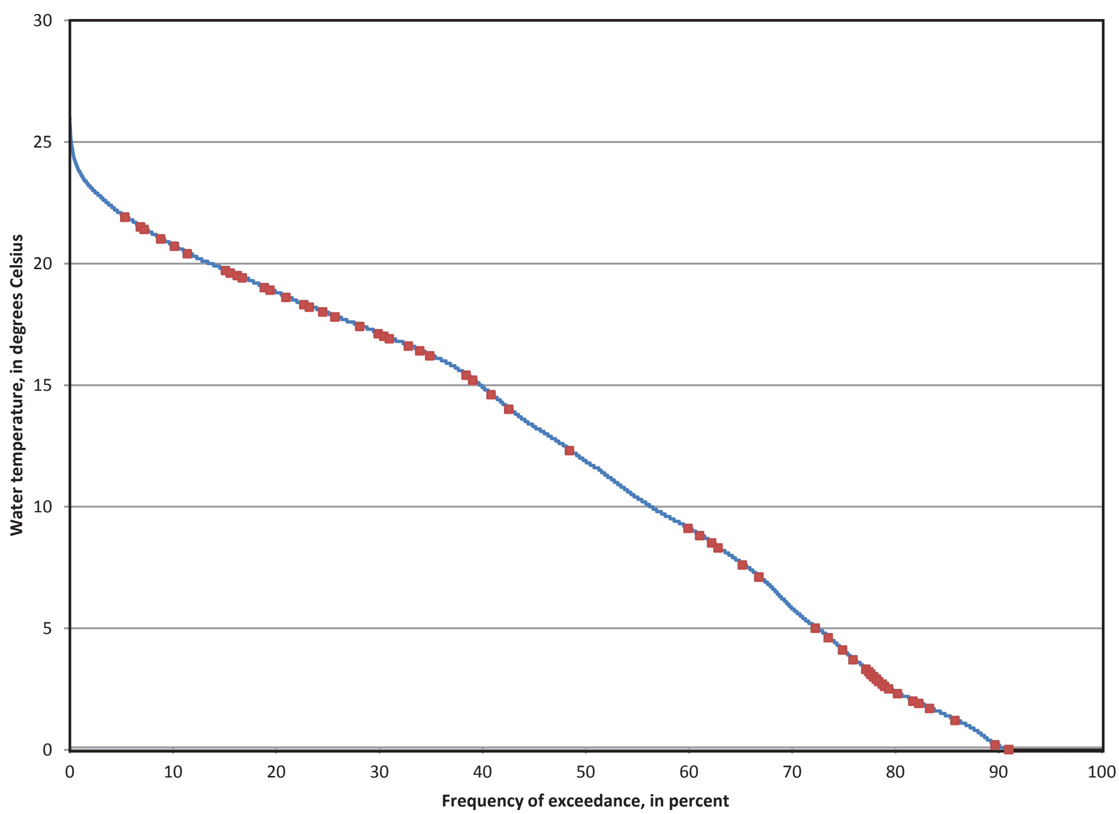


Figure 5-5. Duration curves for turbidity and water temperature (November 2008–September 2010) and corresponding values associated with *Escherichia coli* (*E. coli*) concentration samples collected November 2008 to September 2009 at U.S. Geological Survey streamgage on Honey Creek at Wauwatosa, Wisconsin.

Escherichia coli at Honey Creek at Wauwatosa, Wisconsin, November 2008–September 2009

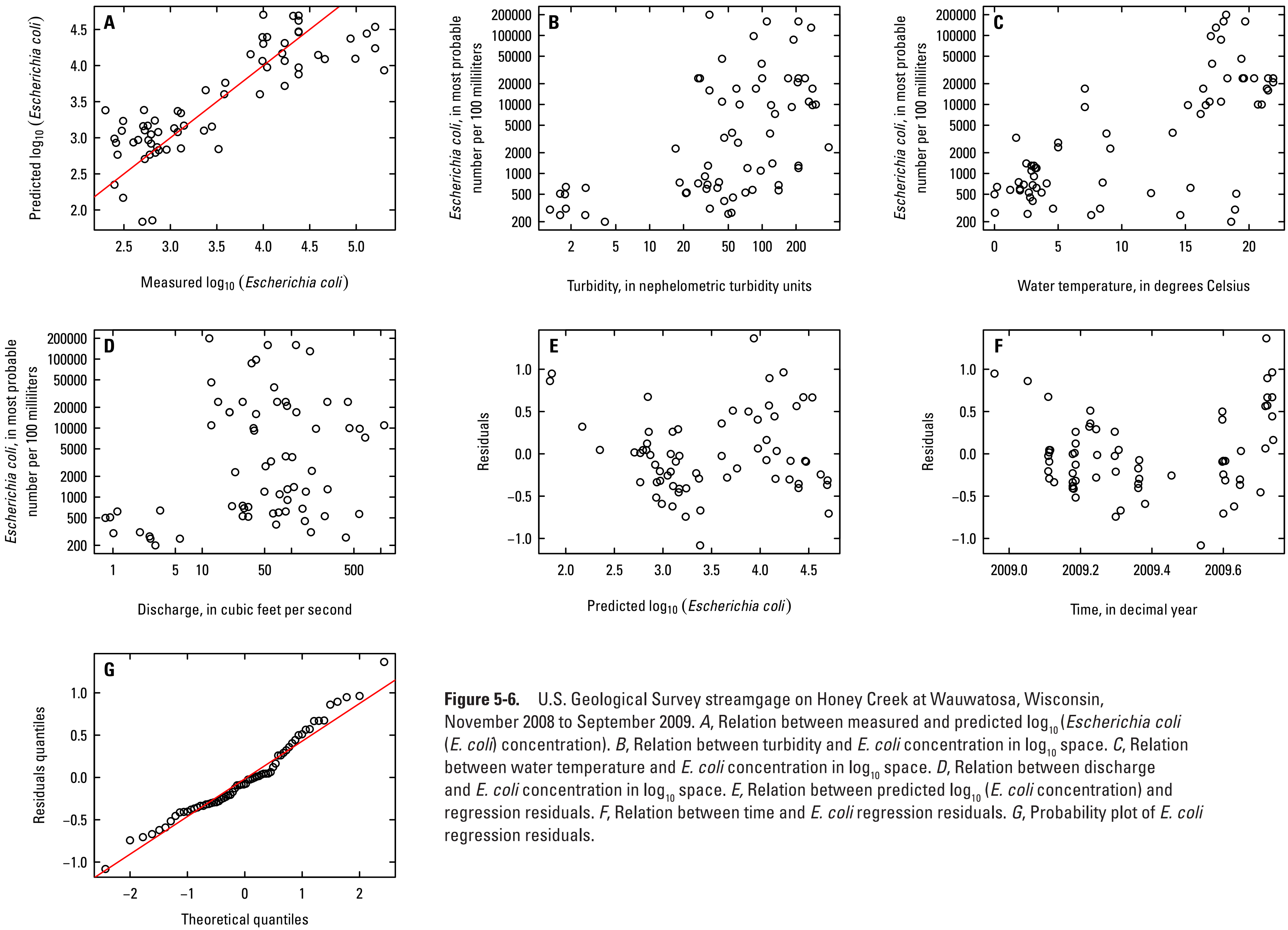


Figure 5-6. U.S. Geological Survey streamgage on Honey Creek at Wauwatosa, Wisconsin, November 2008 to September 2009. *A*, Relation between measured and predicted $\log_{10}$(*Escherichia coli* (*E. coli*) concentration). *B*, Relation between turbidity and *E. coli* concentration in $\log_{10}$ space. *C*, Relation between water temperature and *E. coli* concentration in $\log_{10}$ space. *D*, Relation between discharge and *E. coli* concentration in $\log_{10}$ space. *E*, Relation between predicted $\log_{10}$(*E. coli* concentration) and regression residuals. *F*, Relation between time and *E. coli* regression residuals. *G*, Probability plot of *E. coli* regression residuals.

Escherichia coli (*E. coli*) bacteria at Menomonee River at Wauwatosa, WI (04087120)

Samples collected on 4/21/2009, 6/08/2009 – 6/09/2009, 08/07/2009 - 8/8/2009 at 09:45, 8/09/2009, and 9/22/2009 at 13:40 were not used in the regression analysis because of extreme fouling or because the MMSD laboratory qualified the results.

MODEL SUMMARY—Summary of final regression results for estimating *E. coli* concentrations at Menomonee River at Wauwatosa, WI.

$\log_{10}$ (*E. coli*) = 1.28 + 0.063 (WT) + 0.884 $\log_{10}$ (Turb),
Where:

E. coli = Most Probable Number of *E. coli* per 100 ml (MPN/100ml)
WT = Water Temperature in ^{o}C
Turb = Turbidity (YSI 6136), in NTU

***Model Information (in log units unless otherwise specified)*:**
Number of measurements = 81,
Root-mean-squared error (RMSE) = 0.528
Model standard percentage error (MPSE) = +237 and -70 percent
90-percent prediction intervals (based on units in MPN/100ml) = +/- 807 percent
Adjusted coefficient of determination (Adj R^2) = 0.66
Sum of squared error = 21.74
PRESS = 23.37

***Coefficients*:**

	Coefficient	**Standard error**	**t statistic**	**p-value**
Intercept	**1.28**	**0.191**	**6.68**	**<0.0001**
WT	**0.063**	**0.007**	**9.07**	**<0.0001**
$\log_{10}$ (Turb)	**0.884**	**0.109**	**8.14**	**<0.0001**

Correlation matrix of coefficients:

	Intercept	**WT**	**$\log_{10}$ (Turb)**
Intercept	**1**	**-0.303**	**-0.878**
WT	**-0.303**	**1**	**-0.071**
$\log_{10}$ (Turb)	**-0.878**	**-0.071**	**1**

Duan's bias correction factor **= 2.18**

Table 5-4. Model-calibration dataset for Menomonee River at Wauwatosa, Wisconsin.

[MPN/100 mL, most probable number per 100 milliliters; NTU, Nephelometric turbidity units; °C, degrees Celsius]

Date	Time	*Escherichia coli* (MPN/100 mL)	Turbidity (NTU)	Water temperature (°C)
11/20/2008	10:30	74	1.9	2.2
12/17/2008	12:30	500	6.8	0.0
12/27/2008	10:15	1,700	89.0	0.0
12/28/2008	7:45	1,200	36.0	0.0
1/20/2009	12:10	86	1.5	0.0
2/7/2009	11:25	3,400	72.3	0.0
2/7/2009	13:25	1,800	105.0	0.0
2/7/2009	13:40	2,400	110.0	0.0
2/7/2009	19:40	1,200	46.3	0.0
2/8/2009	13:40	340	26.0	0.0
2/9/2009	1:40	430	12.0	0.0
2/9/2009	19:40	320	64.0	0.0
2/9/2009	22:00	1,500	140.0	0.0
2/9/2009	23:15	2,100	140.0	0.1
2/10/2009	7:20	760	45.7	0.0
2/10/2009	11:00	880	100.0	0.1
2/10/2009	17:05	750	70.7	0.5
2/10/2009	23:25	570	41.3	0.2
2/16/2009	12:45	60	4.8	0.3
2/26/2009	14:35	120	66.0	0.4
2/26/2009	19:00	320	140.0	0.7
2/26/2009	19:45	1,900	170.0	0.7
2/26/2009	22:50	1,700	130.0	0.6
2/27/2009	4:50	1,100	70.0	0.0
3/2/2009	7:20	220	7.3	0.0
3/10/2009	0:15	290	34.0	2.3
3/10/2009	5:50	200	38.0	2.1
3/10/2009	11:45	370	38.0	1.9
3/10/2009	14:50	240	41.0	1.9
3/11/2008	1:10	150	45.5	2.2
3/24/2009	11:55	62	1.1	4.9
3/25/2009	1:30	2,200	38.0	6.2
3/31/2009	17:00	2,000	14.0	5.1
3/31/2009	17:35	1,900	33.0	5.2
4/1/2009	5:35	610	20.0	4.3
4/19/2009	19:10	1,300	17.0	11.4
4/20/2009	5:05	1,400	24.0	9.1
4/23/2009	11:00	85	1.4	8.2
4/25/2009	11:15	1,100	22.0	14.2
4/25/2009	12:40	3,700	160.0	13.8
4/25/2009	21:35	1,200	77.0	11.1
4/26/2009	2:35	2,200	68.0	9.6
4/26/2009	14:35	850	36.0	8.9
4/26/2009	16:00	1,300	150.0	10.0
4/26/2009	17:10	1,800	190.0	10.5
4/27/2009	0:30	1,600	76.0	10.2
5/9/2009	0:30	700	37.0	16.6
5/9/2009	9:30	990	17.0	14.6
5/9/2009	15:50	510	15.0	14.7
5/13/2009	20:40	2,400	68.0	15.2
5/13/2009	21:05	8,700	150.0	15.6
5/13/2009	22:00	5,500	140.0	15.9
5/14/2009	3:15	2,800	86.0	15.4
5/20/2009	11:15	73	4.8	17.4
6/16/2009	11:50	130	9.6	18.8
6/19/2009	9:15	9,600	84.0	19.6
6/19/2009	18:15	12,000	52.0	20.4
6/19/2009	21:20	9,300	150.0	20.5
6/20/2009	3:10	9,300	45.0	19.7
7/16/2009	11:45	2,600	3.5	21.8
8/8/2009	19:50	24,000	48.0	21.8
8/10/2009	2:00	24,000	110.0	22.3
8/10/2009	4:20	17,000	99.0	21.4
8/19/2009	12:20	320	2.7	21.9
8/25/2009	20:50	87,000	68.0	22.3
8/25/2009	21:25	32,000	110.0	22.4
8/25/2009	21:30	20,000	96.0	21.9
8/26/2009	3:30	34,000	47.0	21.5
8/27/2009	3:35	3,500	18.0	20.0
9/15/2009	11:00	130	2.8	20.0
9/20/2009	21:40	92,000	69.0	18.0
9/21/2009	3:40	200,000	51.0	17.8
9/22/2009	13:30	200,000	56.0	18.3
9/22/2009	21:50	200,000	56.0	19.5
9/22/2009	23:10	49,000	53.0	19.0
9/27/2009	20:35	46,000	100.0	17.8
9/27/2009	21:05	37,000	150.0	18.0
9/27/2009	21:20	69,000	180.0	18.1
9/28/209	0:05	55,000	70.0	17.1
9/28/2009	2:35	22,000	62.0	16.4
9/28/2009	20:35	8,000	25.0	14.8
MINIMUM		**60**	**1.1**	**0.0**
MAXIMUM		**200,000**	**190.0**	**22.4**
MEAN		**16,476**	**63.7**	**10.1**
MEDIAN		**1,700**	**52.0**	**10.2**
STANDARD DEVIATION		**40,762**	**49.6**	**8.5**

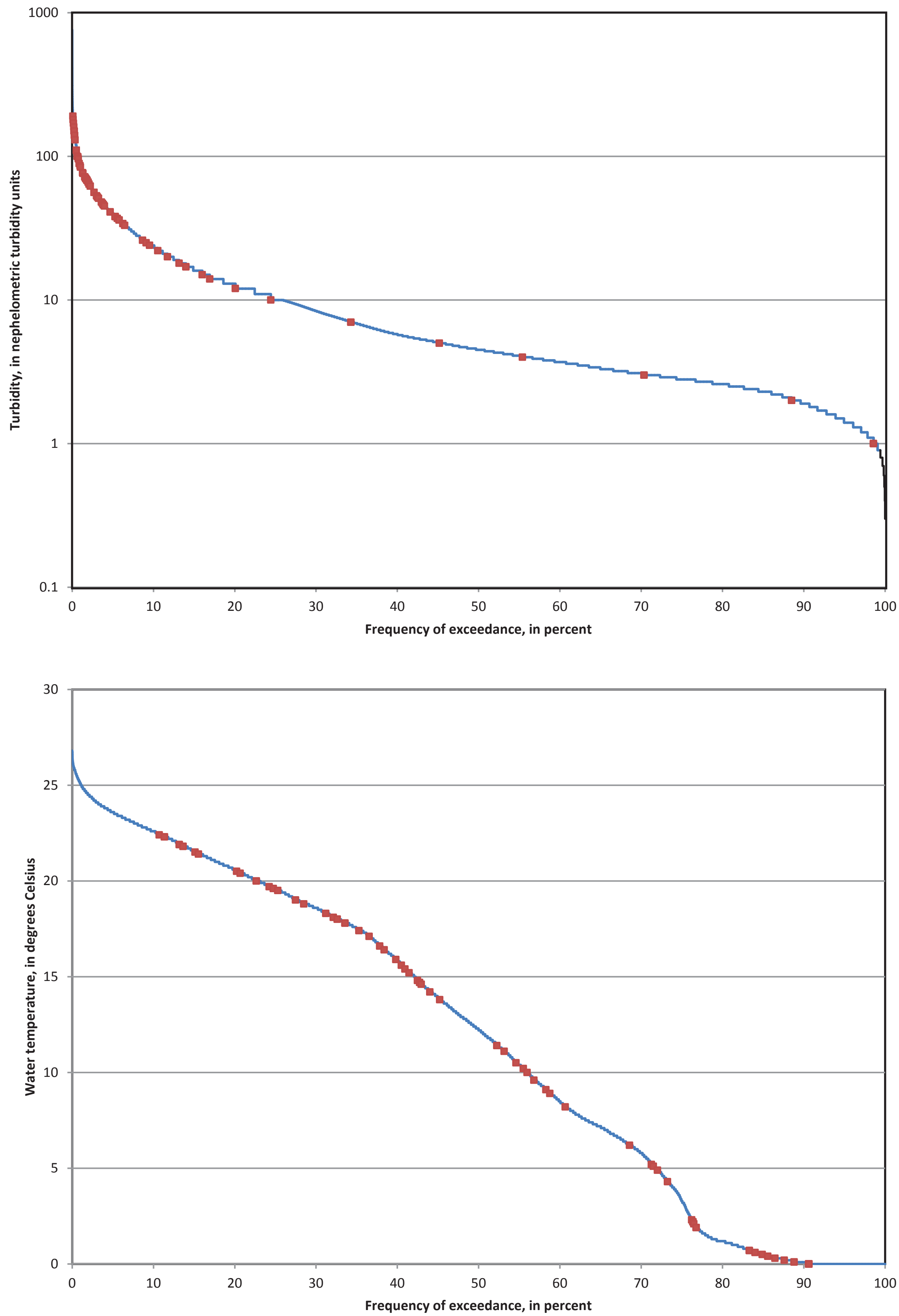


Figure 5-7. Duration curves for turbidity and water temperature (November 2008–September 2010) and corresponding values associated with *Escherichia coli* (*E. coli*) concentration samples collected November 2008 to September 2009 at U.S. Geological Survey streamgage on Menomonee River at Wauwatosa, Wisconsin.

Escherichia coli at Menomonee River at Wauwatosa, Wisconsin, November 2008–September 2009

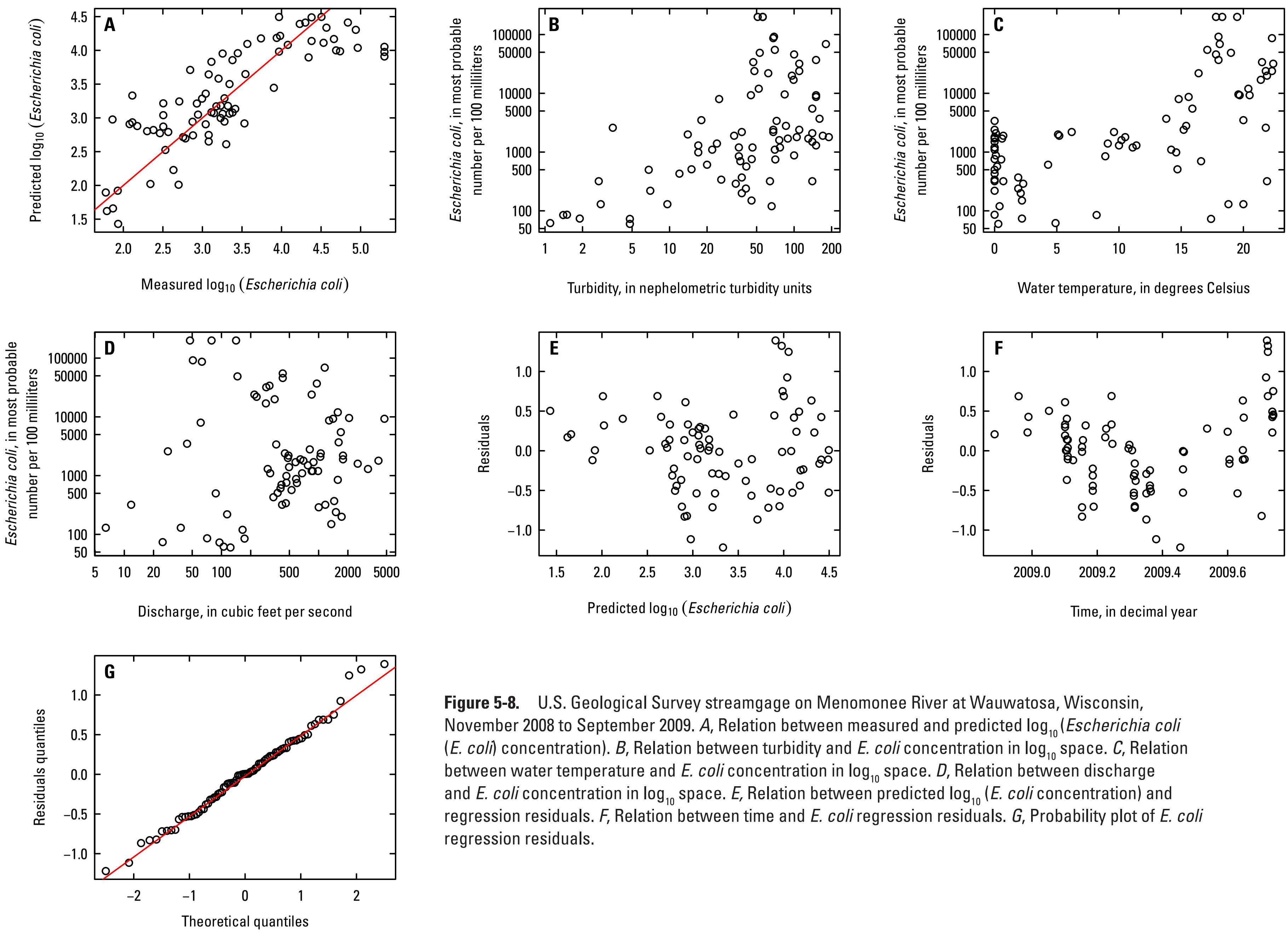


Figure 5-8. U.S. Geological Survey streamgage on Menomonee River at Wauwatosa, Wisconsin, November 2008 to September 2009. *A*, Relation between measured and predicted $\log_{10}$(*Escherichia coli* (*E. coli*) concentration). *B*, Relation between turbidity and *E. coli* concentration in $\log_{10}$ space. *C*, Relation between water temperature and *E. coli* concentration in $\log_{10}$ space. *D*, Relation between discharge and *E. coli* concentration in $\log_{10}$ space. *E*, Relation between predicted $\log_{10}$(*E. coli* concentration) and regression residuals. *F*, Relation between time and *E. coli* regression residuals. *G*, Probability plot of *E. coli* regression residuals.

Escherichia coli (*E. coli*) bacteria at Menomonee River at 16th Street at Milwaukee, WI (04087142)

MODEL SUMMARY—Summary of final regression results for estimating *E. coli* concentrations at Menomonee River at 16th Street at Milwaukee, WI.

$$\log_{10}(E.\ coli) = 1.29 + 0.059\,(WT) + 0.886\,\log_{10}(Turb),$$

Where:

E. coli = Most Probable Number of *E. coli* per 100 ml (MPN/100ml)
WT = Water Temperature in °C
Turb = Turbidity (YSI 6136), in NTU

***Model Information (in log units unless otherwise specified)*:**

Number of measurements = 76,
Root-mean-squared error (RMSE) = 0.542
Model standard percentage error (MPSE) = +248 and -71 percent
90-percent prediction intervals (based on units in MPN/100ml) = +/- 926 percent
Adjusted coefficient of determination (Adj R^2) = 0.54
Sum of squared error = 21.45
PRESS = 24.05

***Coefficients*:**

	Coefficient	Standard error	t statistic	p-value
Intercept	1.29	0.222	5.82	<0.0001
WT	0.059	0.008	7.78	<0.0001
$\log_{10}$ (Turb)	0.886	0.122	7.26	<0.0001

Correlation matrix of coefficients:

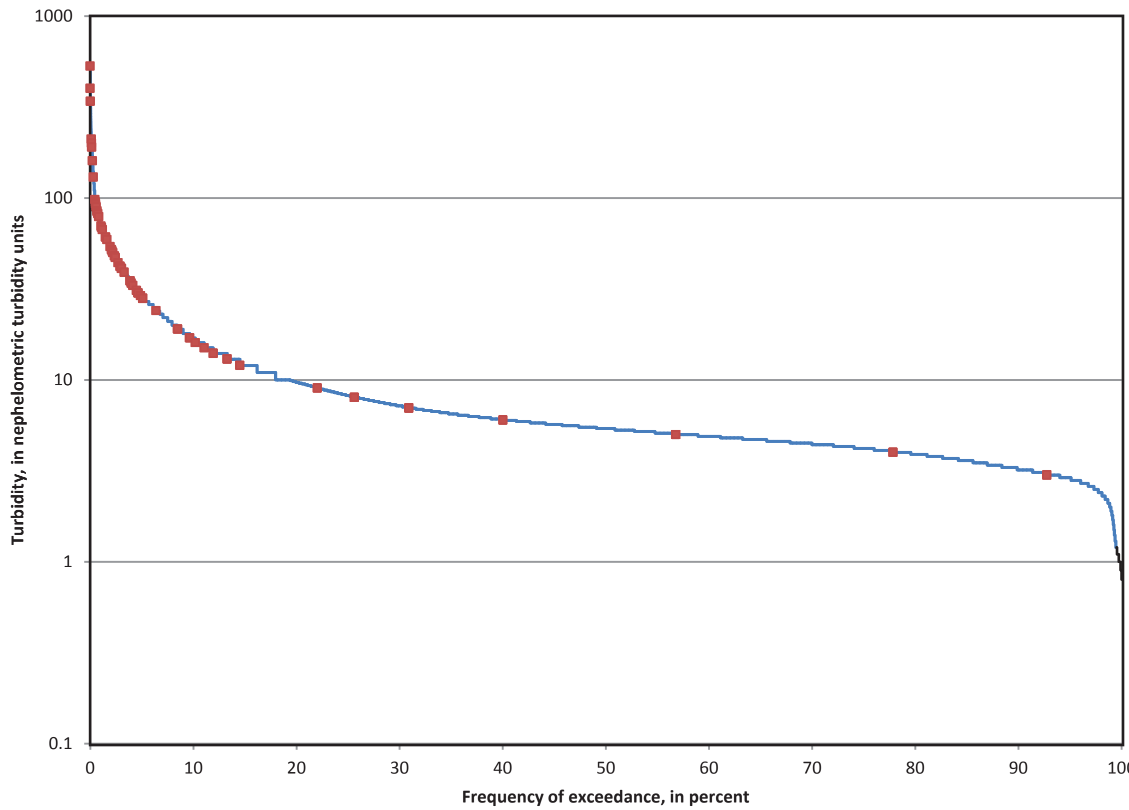
	Intercept	WT	$\log_{10}$ (Turb)
Intercept	1	-0.513	-0.895
WT	-0.513	1	0.191
$\log_{10}$ (Turb)	-0.895	0.191	1

Duan's bias correction factor **= 2.34**

Table 5-5. Model-calibration dataset for Menomonee River at 16th Street at Milwaukee, Wisconsin.

[MPN/100 mL, most probable number per 100 milliliters; NTU, Nephelometric turbidity units; °C, degrees Celsius]

Date	Time	*Escherichia coli* (MPN/100 mL)	Turbidity (NTU)	Water temperature (°C)
11/20/2008	11:45	160	3.1	9.7
12/17/2008	14:15	440	7.3	0.0
12/27/2008	12:35	1,500	52.3	0.3
12/28/2008	0:35	2,400	58.7	1.5
12/28/2008	6:35	930	44.0	0.5
1/20/2009	12:40	63	5.4	8.2
2/7/2009	11:40	52	3.6	5.7
2/7/2009	20:40	1,500	78.7	0.0
2/8/2009	5:40	1,100	34.7	0.0
2/8/2009	14:40	730	28.3	0.8
2/8/2009	23:40	1,100	28.0	0.0
2/9/2009	17:40	780	12.7	0.1
2/10/2009	5:40	1,100	98.0	0.0
2/11/2009	17:40	1,100	69.3	1.5
2/16/2009	13:40	70	8.1	0.1
2/26/2009	16:00	610	8.2	8.9
2/26/2009	19:00	3,300	200.0	0.2
2/26/2009	22:00	1,500	130.0	0.7
2/27/2009	4:00	1,400	85.0	0.6
2/27/2009	12:00	210	51.0	0.1
2/28/2009	12:00	990	19.0	0.0
3/7/2009	11:10	460	19.0	2.9
3/7/2009	14:10	1,200	89.0	2.9
3/7/2009	23:10	360	54.0	2.6
3/8/2009	12:10	430	35.0	1.2
3/8/2009	18:10	1,000	90.0	1.6
3/9/2009	0:10	570	61.0	0.9
3/10/2009	8:15	380	47.0	2.3
3/10/2009	12:55	280	41.0	2.1
3/10/2009	13:00	400	42.0	2.1
3/10/2009	20:30	160	41.0	2.2
3/11/2009	4:30	170	29.0	2.0
3/24/2009	12:25	63	4.0	12.0
4/1/2009	1:40	1,900	34.0	5.1
4/20/2009	3:05	520	12.0	10.9
4/20/2009	4:50	1,700	14.0	9.6
4/23/2009	11:15	110	5.7	12.5
4/25/2009	13:20	2,000	30.0	14.2
4/25/2009	20:00	2,400	61.0	11.8
4/26/2009	8:00	1,600	48.0	8.8
4/26/2009	14:00	980	39.0	8.8
4/26/2009	16:25	11,000	82.0	9.6
4/26/2009	17:10	16,000	210.0	10.3
4/26/2009	19:30	3,700	210.0	10.9
4/26/2009	19:35	3,200	190.0	10.9
5/13/2009	22:05	3,300	35.0	15.2
5/14/2009	0:35	5,200	67.0	16.4
5/14/2009	1:45	3,100	93.0	16.4
5/14/2009	3:35	4,100	70.0	16.0
5/20/2009	11:45	120	5.0	18.4
6/8/2009	12:40	3,600	42.0	13.1
6/8/2009	15:30	3,100	50.0	13.6
6/9/2009	2:35	5,200	32.7	14.3
6/9/2009	5:00	7,100	31.3	14.3
6/16/2009	13:00	60	5.3	22.7
6/19/2009	0:55	27,000	530.0	20.1
6/19/2009	1:10	16,000	400.0	20.0
6/19/2009	1:45	26,000	340.0	20.1
6/19/2009	9:35	18,000	95.0	19.6
6/19/2040	20:45	24,000	160.0	21.1
6/20/2009	2:25	20,000	84.0	19.8
7/16/2009	12:30	11,000	4.9	24.4
8/8/2009	22:30	17,000	24.0	21.6
8/9/2009	10:30	8,700	17.0	22.1
8/19/2009	13:30	240	4.7	22.1
8/26/2009	7:05	98,000	15.0	21.6
8/26/2009	17:00	16,000	13.0	22.0
8/26/2009	23:45	7,500	14.0	21.8
9/15/2009	11:30	41	2.9	26.3
9/23/2009	7:10	140,000	7.1	24.3
9/24/2009	7:00	18,000	9.2	23.7
9/28/2009	12:05	17,000	28.0	16.3
09/28/209	18:05	12,000	30.0	15.6
9/29/2009	0:05	7,000	30.0	15.1
9/29/2009	3:05	6,200	17.0	16.8
9/29/2009	5:00	7,000	16.0	17.2
MINIMUM		**41**	**2.9**	**0.0**
MAXIMUM		**140,000**	**530.0**	**26.3**
MEAN		**7,937**	**63.0**	**10.4**
MEDIAN		**1,550**	**34.8**	**10.6**
STANDARD DEVIATION		**19,897**	**89.4**	**8.4**



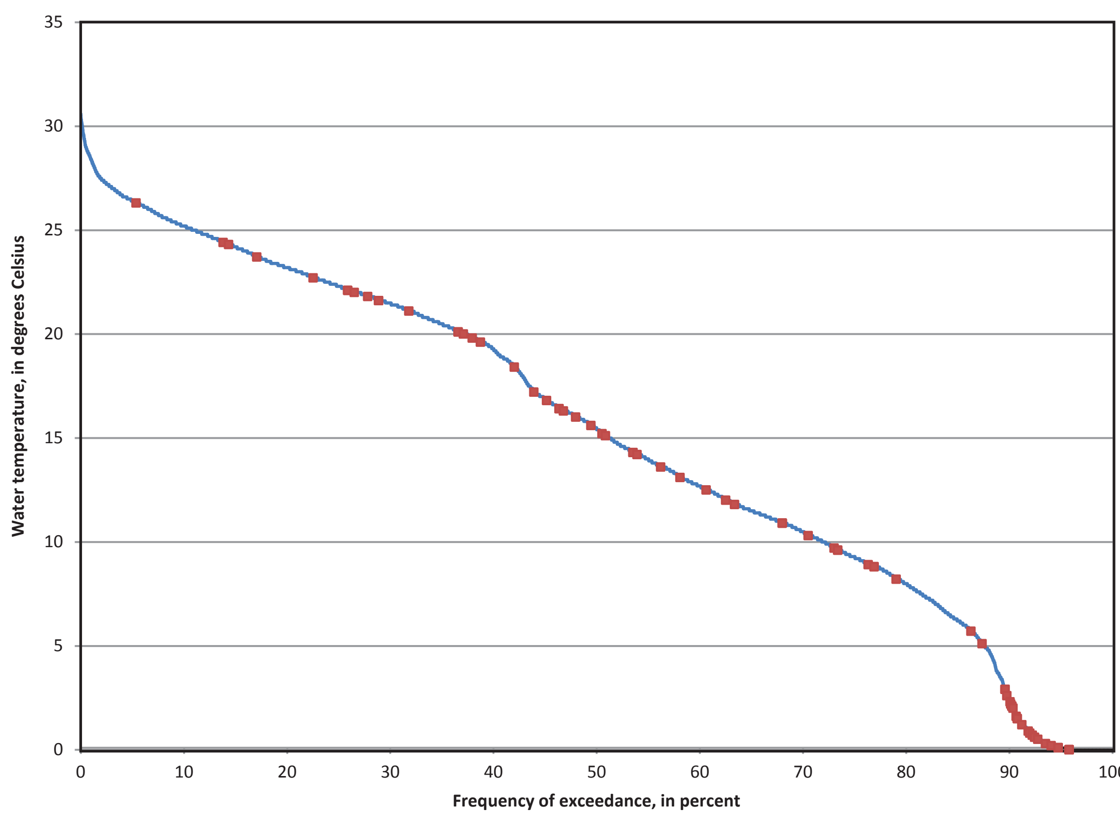


Figure 5-9. Duration curves for turbidity and water temperature (November 2008–September 2010) and corresponding values associated with *Escherichia coli* (*E. coli*) concentration samples collected November 2008 to September 2009 at U.S. Geological Survey streamgage on Menomonee River at 16th Street at Milwaukee, Wisconsin.

Escherichia coli at Menomonee River at 16th Street at Milwaukee, Wisconsin, November 2008–September 2009

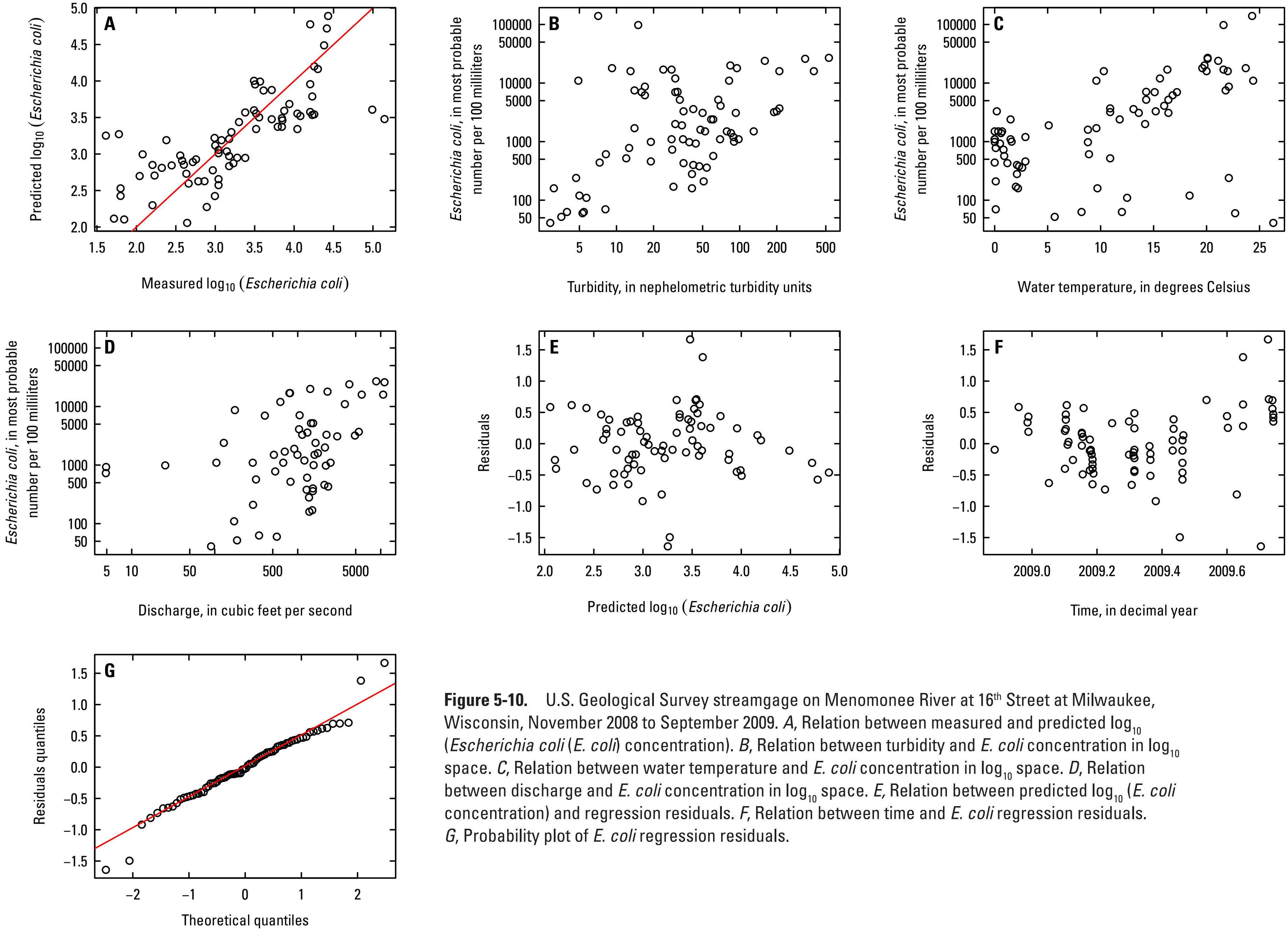


Figure 5-10. U.S. Geological Survey streamgage on Menomonee River at 16th Street at Milwaukee, Wisconsin, November 2008 to September 2009. *A*, Relation between measured and predicted $\log_{10}$ (*Escherichia coli* (*E. coli*) concentration). *B*, Relation between turbidity and *E. coli* concentration in $\log_{10}$ space. *C*, Relation between water temperature and *E. coli* concentration in $\log_{10}$ space. *D*, Relation between discharge and *E. coli* concentration in $\log_{10}$ space. *E*, Relation between predicted $\log_{10}$ (*E. coli* concentration) and regression residuals. *F*, Relation between time and *E. coli* regression residuals. *G*, Probability plot of *E. coli* regression residuals.

Appendix 6. Regression analysis results for estimating fecal coliform bacteria concentration

All data were collected using U.S. Geological Survey (USGS) protocols and are stored in the USGS National Water Information System (NWIS) database (*http://waterdata.usgs.gov/nwis*). The regression models are based on measurements of turbidity and water temperature and concurrent fecal coliform bacteria samples collected from November 2008 to September 2009. Continuous water-quality data were collected at 5-minute intervals using a YSI model 6920 V2 multiparameter water-quality monitor with a 6560 specific conductance and water temperature sensor, and a 6136 optical turbidity sensor. Turbidity and water temperature values are instantaneous unit values temporally corresponding to the collection of the fecal coliform bacteria samples. Samples were collected throughout the range of continuously observed hydrologic conditions. Summary statistics and the complete model-calibration dataset are provided. A comparison of cross-section mean and corresponding time-series monitor readings is archived at the Wisconsin Water Science Center and is available by request to Austin Baldwin (akbaldwi@usgs.gov).

Fecal coliform bacteria at Little Menomonee River near Freistadt, WI (04087050)

Sample data on 2/16/2009 was not used in the regression development because there was a program change and the sonde data was lost.

MODEL SUMMARY—Summary of final regression results for estimating fecal coliform concentrations at Little Menomonee River near Freistadt, WI.

Log_{10} (fecal coliform) = 1.49 + 0.035 (WT) + 0.777 $\log_{10}$ (Turb),
Where:

fecal coliform = colony forming units of fecal coliform per 100 ml (CFU/100ml)
WT = Water Temperature in ^{o}C
Turb = Turbidity (YSI 6136), in NTU

***Model Information (in log units unless otherwise specified)*:**
Number of measurements = 32,
Root-mean-squared error (RMSE) = 0.51
Model standard percentage error (MPSE) = +221 and -69 percent
90-percent prediction intervals (based on units in CFU/100ml) = +/- 639 percent
Adjusted coefficient of determination (Adj R^2) = 0.58
Sum of squared error = 7.45
PRESS = 8.97

***Coefficients*:**

	Coefficient	**Standard error**	**t statistic**	**p-value**
Intercept	**1.49**	**0.231**	**6.46**	**<0.0001**
WT	**0.035**	**0.014**	**2.48**	**0.019**
Log_{10} (Turb)	**0.777**	**0.130**	**5.97**	**<0.0001**

Correlation matrix of coefficients:

	Intercept	**WT**	**Log_{10}(Turb)**
Intercept	**1**	**-0.348**	**-0.808**
WT	**-0.348**	**1**	**-0.114**
Log_{10} (Turb)	**-0.808**	**-0.114**	**1**

Duan's bias correction factor **= 1.79**

Table 6-1. Model-calibration dataset for Little Menomonee River near Freistadt, Wisconsin.

[CFU/100 mL, colony forming units per 100 milliliters; NTU, Nephelometric turbidity units; °C, degrees Celsius]

Date	Time	Fecal coliform bacteria (CFU/100 mL)	Water temperature (°C)	Turbidity (NTU)
11/20/2008	9:45	16	1.6	1.2
1/20/2009	10:55	10	0.1	0.7
2/7/2009	18:50	590	0.0	19.7
2/9/2009	22:40	720	0.2	11.3
2/10/2009	10:45	760	0.3	38.0
2/10/2009	14:40	570	0.5	113.3
2/10/2009	20:40	950	0.3	46.0
2/11/2009	2:40	4,000	0.2	21.3
3/7/2009	12:55	71	1.8	130.0
3/7/2009	18:05	1,400	1.3	220.0
3/8/2009	7:05	2,800	1.0	62.0
3/9/2009	0:30	1,200	0.3	140.0
3/10/2009	3:20	330	1.9	68.0
3/10/2009	20:15	580	2.2	51.0
3/24/2009	10:40	95	4.0	2.8
4/23/2009	9:45	320	6.4	2.1
4/25/2009	15:10	370	10.7	100.0
4/26/2009	5:30	5,200	7.1	180.0
4/26/2009	19:30	4,000	9.7	200.0
4/27/2009	1:30	1,700	9.6	80.0
5/9/2009	7:25	4,600	11.7	81.0
5/9/2009	13:30	6,800	11.6	54.0
5/9/2009	19:30	1,800	12.0	15.0
5/14/2009	2:30	8,600	13.8	270.0
5/20/2009	9:00	100	14.0	4.5
6/8/2009	5:20	5,600	11.5	120.0
6/16/2009	8:45	240	14.0	12.0
6/19/2009	2:50	8,200	17.4	290.0
6/19/2009	8:50	30,000	17.4	89.0
7/16/2009	10:05	690	16.2	19.0
8/19/2009	10:00	300	16.0	8.8
9/15/2009	9:30	580	16.5	10.0
MINIMUM		**10**	**0.0**	**0.7**
MAXIMUM		**30,000**	**17.4**	**290.0**
MEAN		**2,912**	**7.2**	**76.9**
MEDIAN		**740**	**6.8**	**52.5**
STANDARD DEVIATION		**5,534**	**6.4**	**80.9**

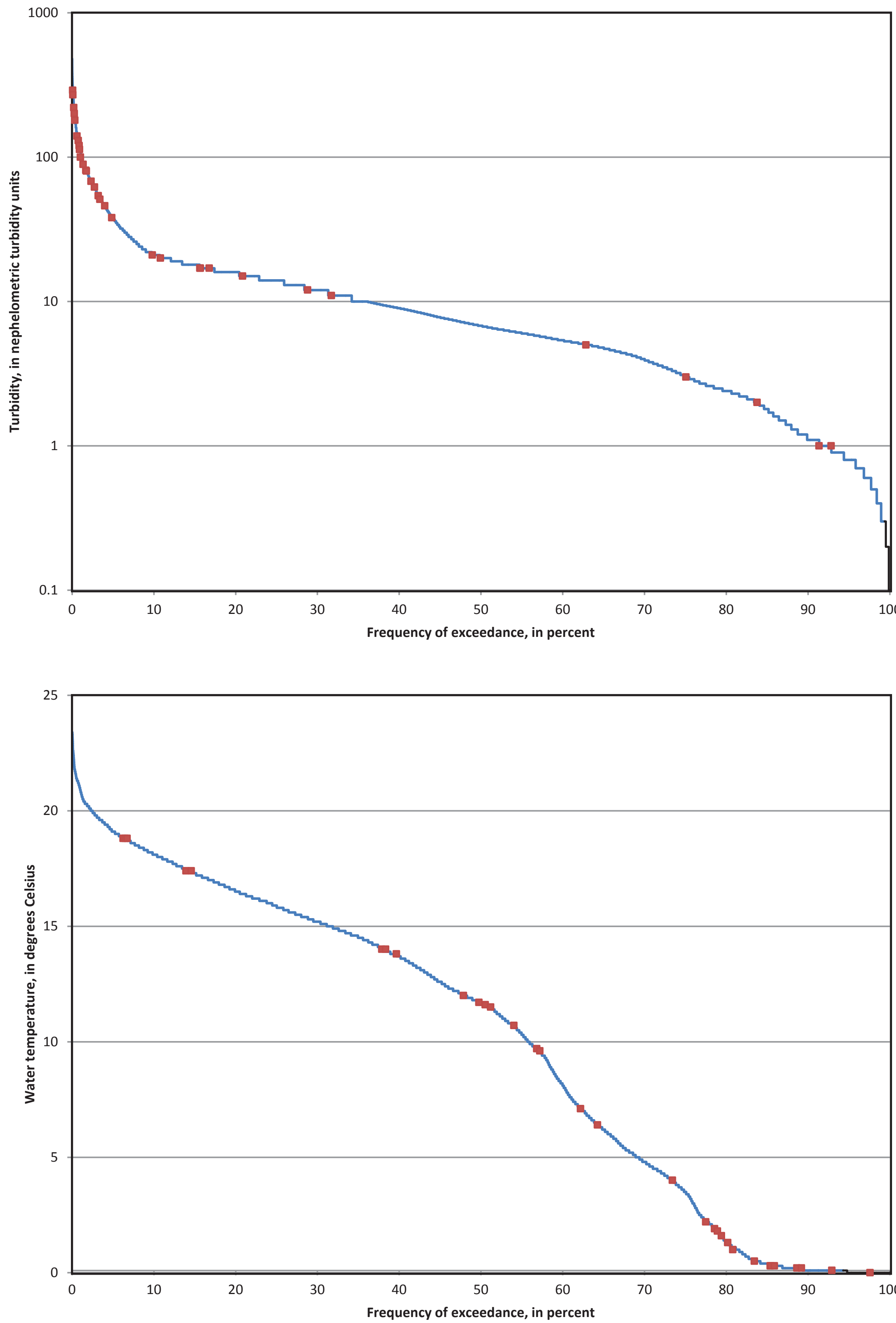


Figure 6-1. Duration curves for turbidity and water temperature (November 2008–September 2010) and corresponding values associated with fecal coliform bacteria concentration samples collected November 2008 to September 2009 at U.S. Geological Survey streamgage on Little Menomonee River near Freistadt, Wisconsin.

Fecal Coliform Bacteria at Little Menomonee River near Freistadt, Wisconsin, November 2008–September 2009

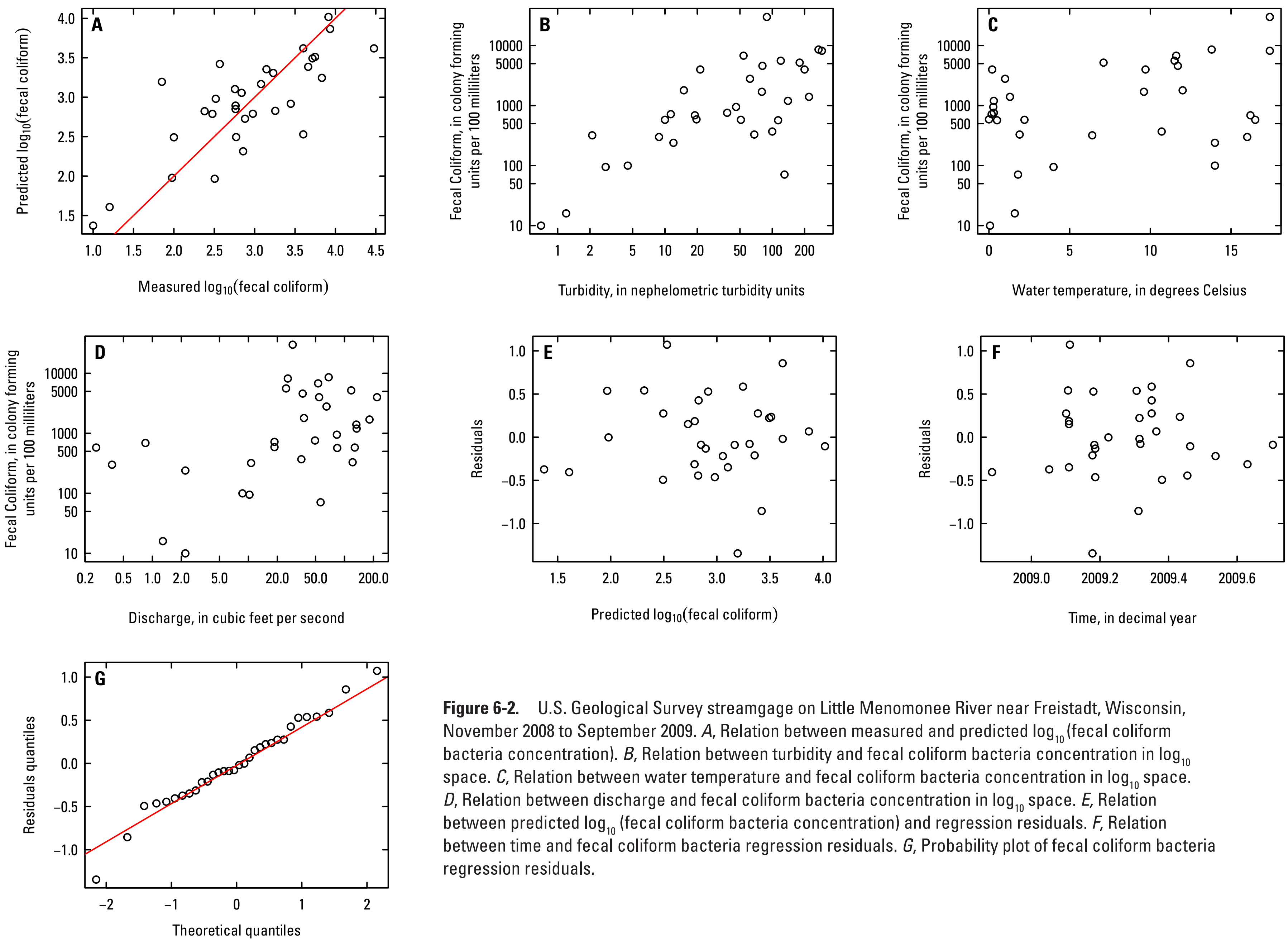


Figure 6-2. U.S. Geological Survey streamgage on Little Menomonee River near Freistadt, Wisconsin, November 2008 to September 2009. *A*, Relation between measured and predicted $\log_{10}$(fecal coliform bacteria concentration). *B*, Relation between turbidity and fecal coliform bacteria concentration in $\log_{10}$ space. *C*, Relation between water temperature and fecal coliform bacteria concentration in $\log_{10}$ space. *D*, Relation between discharge and fecal coliform bacteria concentration in $\log_{10}$ space. *E*, Relation between predicted $\log_{10}$ (fecal coliform bacteria concentration) and regression residuals. *F*, Relation between time and fecal coliform bacteria regression residuals. *G*, Probability plot of fecal coliform bacteria regression residuals.

Fecal coliform bacteria at Menomonee River at Menomonee Falls, WI (04087030)

MODEL SUMMARY—Summary of final regression results for estimating fecal coliform concentrations at Menomonee River at Menomonee Falls, WI.

$\log_{10}$ (fecal coliform) = 1.07 + 0.063 (WT) + 0.834 $\log_{10}$ (Turb),
Where:

fecal coliform = colony forming units of fecal coliform per 100 ml (CFU/100ml)
WT = Water Temperature in ^{o}C
Turb = Turbidity (YSI 6136), in NTU

***Model Information (in log units unless otherwise specified)*:**
Number of measurements = 49,
Root-mean-squared error (RMSE) = 0.540
Model standard percentage error (MPSE) = +246 and -71 percent
90-percent prediction intervals (based on units in CFU/100ml) = +/- 716 percent
Adjusted coefficient of determination (Adj R^2) = 0.68
Sum of squared error = 13.39
PRESS = 14.99

***Coefficients*:**

	Coefficient	Standard error	t statistic	p-value
Intercept	**1.07**	**0.222**	**4.81**	**<0.0001**
WT	**0.063**	**0.010**	**6.26**	**<0.0001**
$\log_{10}$ (Turb)	**0.834**	**0.144**	**5.79**	**<0.0001**

Correlation matrix of coefficients:

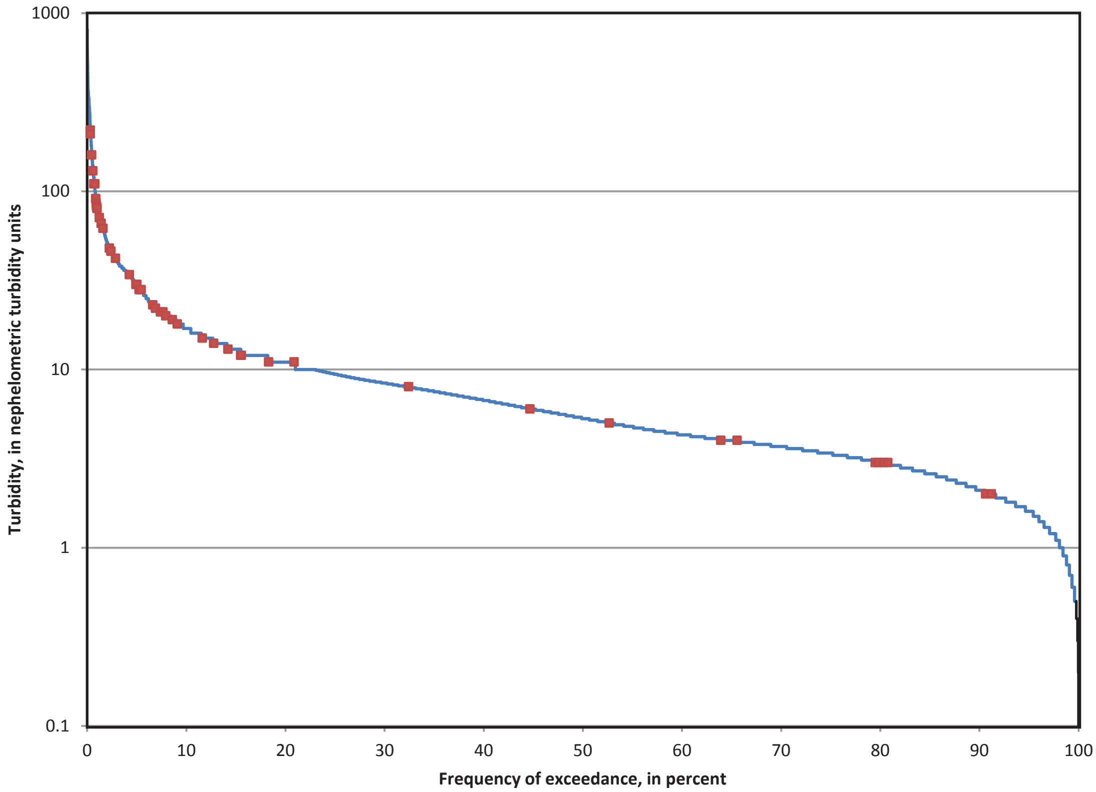
	Intercept	WT	$\log_{10}$ (Turb)
Intercept	**1**	**-0.296**	**-0.764**
WT	**-0.296**	**1**	**0.293**
$\log_{10}$ (Turb)	**-0.764**	**0.293**	**1**

Duan’s bias correction factor **= 1.80**

Table 6-2. Model-calibration dataset for Menomonee River at Menomonee Falls, Wisconsin.

[CFU/100 mL, colony forming units per 100 milliliters; NTU, Nephelometric turbidity units; °C, degrees Celsius]

Date	Time	Fecal coliform bacteria (CFU/100 mL)	Water temperature (°C)	Turbidity (NTU)
11/20/2008	9:15	87	1.1	3.6
12/17/2008	12:00	190	0.0	2.7
12/27/2008	14:20	520	0.1	100.7
1/20/2009	9:55	10	2.0	2.5
2/16/2009	11:00	32	0.2	3.1
2/26/2009	15:05	320	0.1	86.0
2/26/2009	18:15	550	0.2	81.0
2/27/2009	0:15	210	0.0	30.0
3/7/2009	9:30	170	1.9	31.0
3/7/2009	15:30	130	2.0	29.0
3/8/2009	14:00	540	0.8	69.0
3/9/2009	2:00	270	0.0	34.0
3/24/2009	10:00	170	4.1	4.1
3/25/2009	5:25	100	5.1	16.0
4/19/2009	23:00	720	10.5	23.0
4/20/2009	23:15	250	8.3	11.0
4/23/2009	9:15	210	7.3	3.8
4/25/2009	10:50	570	14.6	71.0
4/26/2009	16:00	1,000	9.8	34.0
5/9/2009	1:05	150	16.9	83.0
5/9/2009	1:15	1,200	16.7	110.0
5/9/2009	10:25	810	14.0	12.0
5/9/2009	22:25	380	13.5	14.0
5/10/2009	10:25	280	11.9	8.2
5/13/2009	23:00	2,800	15.8	81.0
05/20/2009	9:30	87	16.5	6.3
6/8/2009	3:15	4,300	14.0	91.0
6/8/2009	3:25	10,000	13.5	220.0
6/8/2009	9:35	4,600	13.4	28.0
6/16/2009	10:15	100	19.1	13.0
6/19/2009	0:10	6,200	21.2	160.0
6/19/2009	0:50	16,000	21.1	110.0
6/19/2009	2:00	23,000	20.9	66.0
6/20/2009	2:00	4,200	20.1	21.0
7/16/2009	9:30	210	20.4	5.0
8/7/2009	19:35	20,000	20.2	46.0
8/8/2009	9:05	10,000	20.5	80.0
8/19/2009	9:00	270	20.1	3.2
8/25/2009	18:20	7,600	23.1	210.0
8/25/2009	18:45	46,000	23.1	85.0
8/26/2009	1:30	28,000	22.3	30.0
8/26/2009	1:55	44,000	22.4	48.0
9/15/2009	9:30	160	18.8	2.8
9/22/2009	13:15	20,000	18.9	62.0
9/22/2009	14:05	43,000	19.3	130.0
9/22/2009	15:20	19,000	18.4	21.0
9/27/2009	19:25	9,400	18.0	81.0
9/27/2008	21:30	9,200	17.1	51.0
9/28/2009	5:55	4,800	15.2	12.0
MINIMUM		**10**	**0.0**	**2.5**
MAXIMUM		**46,000**	**23.1**	**220.0**
MEAN		**6,975**	**12.5**	**51.5**
MEDIAN		**570**	**14.6**	**31.0**
STANDARD DEVIATION		**11,911**	**8.1**	**51.9**



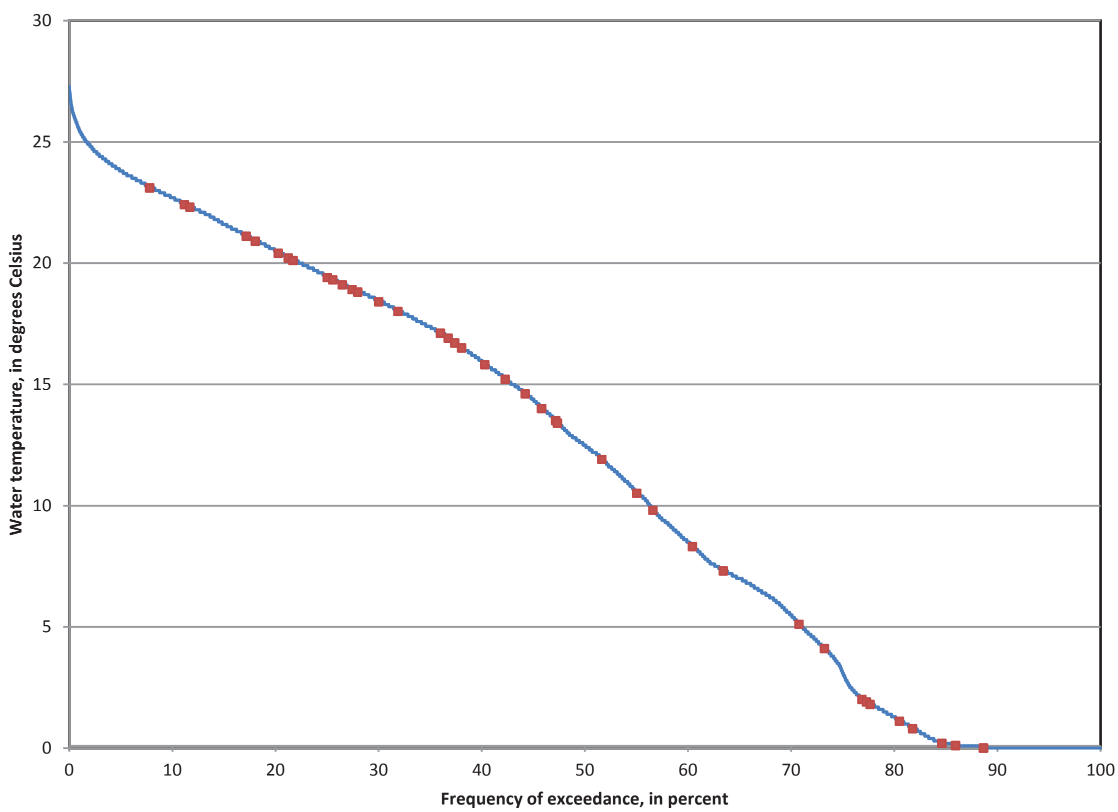


Figure 6-3. Duration curves for turbidity and water temperature (November 2008–September 2010) and corresponding values associated with fecal coliform bacteria concentration samples collected November 2008 to September 2009 at U.S. Geological Survey streamgage on Menomonee River at Menomonee Falls, Wisconsin.

Fecal Coliform Bacteria at Menomonee River at Menomonee Falls, Wisconsin, November 2008–September 2009

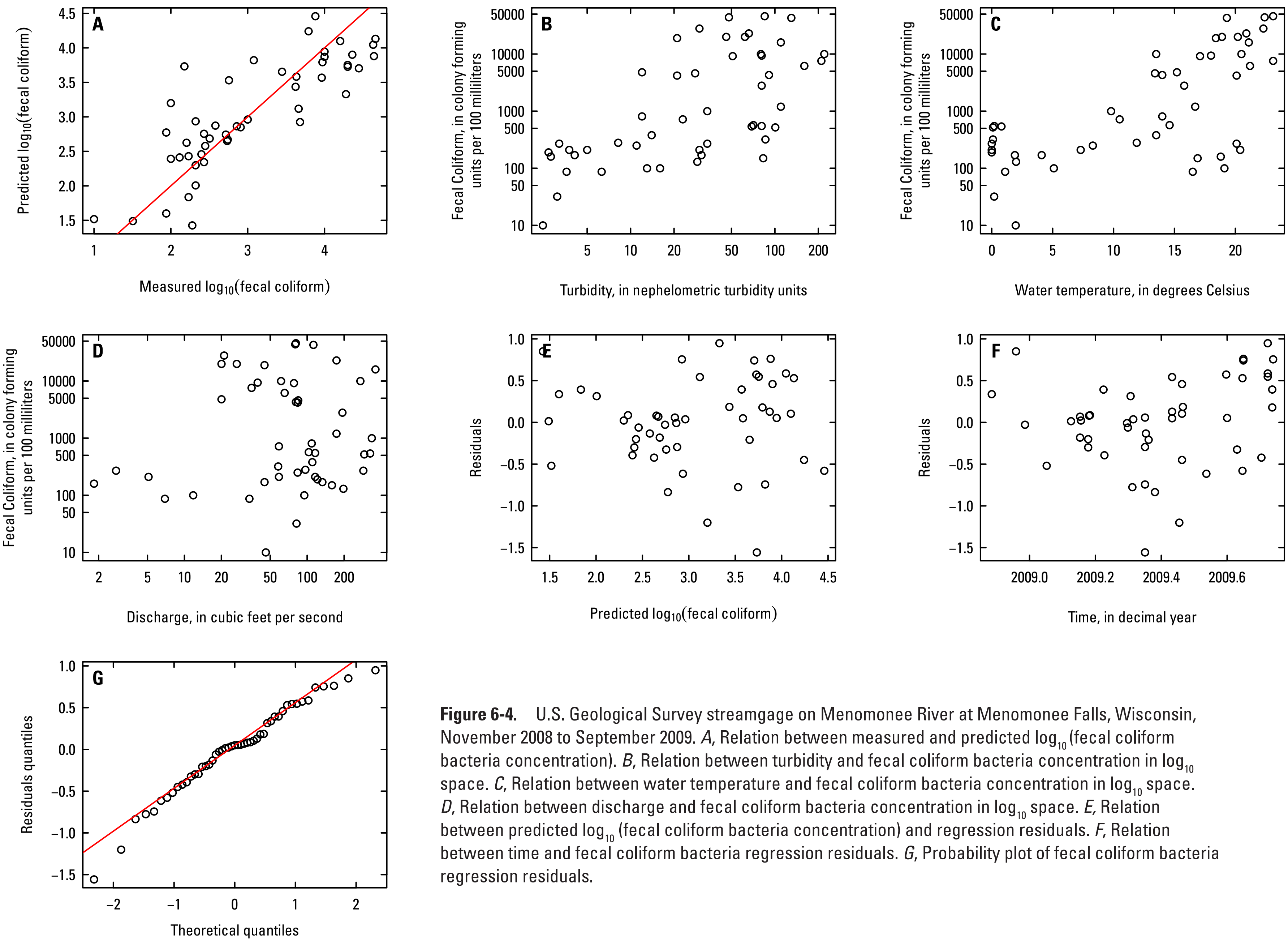


Figure 6-4. U.S. Geological Survey streamgage on Menomonee River at Menomonee Falls, Wisconsin, November 2008 to September 2009. *A*, Relation between measured and predicted $\log_{10}$(fecal coliform bacteria concentration). *B*, Relation between turbidity and fecal coliform bacteria concentration in $\log_{10}$ space. *C*, Relation between water temperature and fecal coliform bacteria concentration in $\log_{10}$ space. *D*, Relation between discharge and fecal coliform bacteria concentration in $\log_{10}$ space. *E*, Relation between predicted $\log_{10}$ (fecal coliform bacteria concentration) and regression residuals. *F*, Relation between time and fecal coliform bacteria regression residuals. *G*, Probability plot of fecal coliform bacteria regression residuals.

Fecal coliform bacteria at Honey Creek at Wauwatosa, WI (04087119)

Sample data from 4/25/2009 at 12:40 through 4/26/2009, and sample data from 6/8/2009 were not used in the regression development because of excessive fouling of the data sonde. Sample data on 6/19/2009 were not used because of damage to the sonde and sampler line during an extreme flood event.

MODEL SUMMARY—Summary of final regression results for estimating fecal coliform concentrations at Honey Creek at Wauwatosa, WI.

Log_{10} (fecal coliform) = 1.46 + 0.089 (WT) + 0.648 $\log_{10}$ (Turb),
Where:

fecal coliform = colony forming units of fecal coliform per 100 ml (CFU/100ml)
WT = Water Temperature in ^{o}C
Turb = Turbidity (YSI 6136), in NTU

***Model Information (in log units unless otherwise specified)*:**
Number of measurements = 65,
Root-mean-squared error (RMSE) = 0.504
Model standard percentage error (MPSE) = +219 and -69 percent
90-percent prediction intervals (based on units in CFU/100ml) = +/- 687 percent
Adjusted coefficient of determination (Adj R^2) = 0.74
Sum of squared error = 15.77
PRESS = 17.81

***Coefficients*:**

	Coefficient	**Standard error**	**t statistic**	**p-value**
Intercept	**1.46**	**0.187**	**7.79**	**<0.0001**
WT	**0.089**	**0.008**	**10.88**	**<0.0001**
Log_{10} (Turb)	**0.648**	**0.097**	**6.66**	**<0.0001**

Correlation matrix of coefficients:

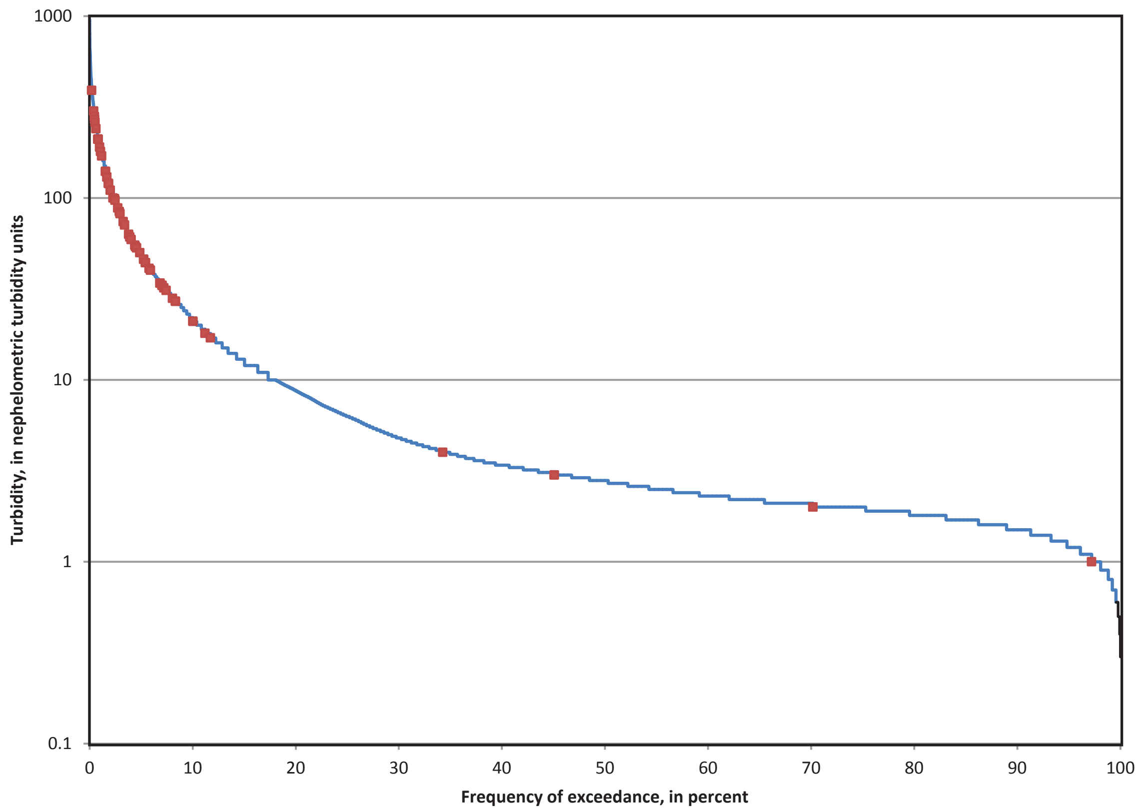
	Intercept	**WT**	**$\log_{10}$ (Turb)**
Intercept	**1**	**-0.368**	**-0.815**
WT	**-0.368**	**1**	**-0.123**
Log_{10} (Turb)	**-0.815**	**-0.123**	**1**

Duan's bias correction factor **= 2.02**

Table 6-3. Model-calibration dataset for Honey Creek at Wauwatosa, Wisconsin.

[CFU/100 mL, colony forming units per 100 milliliters; NTU, Nephelometric turbidity units; °C, degrees Celsius]

Date	Time	Fecal coliform bacteria (CFU/100 mL)	Water temperature (°C)	Turbidity (NTU)
12/17/2008	13:45	570	0.2	1.8
1/20/2009	11:55	400	0.0	1.7
2/10/2009	10:10	1,300	1.7	46.0
2/10/2009	13:25	760	2.5	123.3
2/10/2009	19:25	410	1.2	82.0
2/11/2009	1:25	1,500	1.9	41.3
2/11/2009	11:25	530	2.7	21.3
2/11/2009	12:00	840	2.9	97.0
2/11/2009	15:30	1,300	3.3	210.0
2/12/2009	2:25	610	2.3	32.7
2/16/2009	12:20	130	0.0	53.3
3/7/2009	9:25	210	3.2	74.0
3/7/2009	10:25	210	2.9	210.0
3/7/2009	12:10	720	3.0	140.0
3/7/2009	16:05	420	3.7	71.0
3/7/2009	22:05	400	3.0	46.0
3/8/2009	14:25	680	2.0	140.0
3/9/2009	1:00	480	2.0	32.0
3/10/2009	0:50	500	3.3	40.0
3/10/2009	5:30	180	2.6	50.0
3/10/2009	9:30	420	2.8	55.0
3/10/2009	12:10	1,600	3.1	33.0
3/10/2009	12:15	1,200	3.1	31.0
3/24/2009	11:40	190	4.6	1.8
3/25/2009	1:20	4,000	7.1	280.0
3/25/2009	3:45	22,000	7.1	183.3
3/31/2009	16:15	1,700	5.0	61.0
3/31/2009	17:05	1,600	5.0	390.0
4/1/2009	3:00	340	4.1	27.0
4/19/2009	17:10	2,300	9.1	17.0
4/19/2009	18:15	2,900	8.8	117.5
4/20/2009	17:20	880	8.5	18.5
4/23/2009	10:45	95	7.6	1.6
4/25/2009	10:50	840	12.3	21.0
5/13/2009	20:30	2,900	14.0	54.0
5/13/2009	20:50	16,000	16.6	280.0
5/13/2009	21:10	11,000	16.9	260.0
5/14/2009	0:55	6,200	16.2	130.0
5/14/2009	2:40	9,800	15.2	120.0
5/20/2009	11:00	120	14.6	2.7
6/16/2009	11:00	440	15.4	2.7
7/16/2009	11:00	400	18.6	4.0
8/7/2009	17:10	140,000	18.3	27.0
8/7/2009	20:20	27,000	19.6	170.0
8/7/2009	23:05	56,000	19.5	28.0
8/8/2009	9:10	93,000	20.4	240.0
8/8/2009	9:30	120,000	20.7	300.0
8/8/2009	19:55	35,000	21.4	59.0
8/10/2009	1:50	20,000	21.9	210.0
8/10/2009	4:10	67,000	21.5	100.0
8/19/2009	12:40	500	18.9	1.3
8/25/2009	20:55	12,000	21.0	63.0
8/28/2009	22:05	46,000	21.9	206.7
8/26/2009	4:05	28,000	21.5	34.0
9/15/2009	10:45	380	19.0	1.6
9/20/2009	20:20	7,600	17.8	44.0
9/20/2009	21:55	170,000	17.8	190.0
9/21/2009	3:55	160,000	18.2	34.0
9/22/2009	13:25	67,000	17.0	84.0
9/22/2009	14:05	140,000	19.7	210.0
9/22/2009	22:40	45,000	19.4	44.0
9/27/2009	20:20	120,000	18.0	110.0
9/27/2009	21:00	120,000	17.4	272.5
9/27/2009	23:35	38,000	17.1	99.0
9/28/2009	2:30	21,000	16.4	88.0
MINIMUM		**95**	**0.0**	**1.3**
MAXIMUM		**170,000**	**21.9**	**390.0**
MEAN		**25,116**	**10.8**	**95.7**
MEDIAN		**1,600**	**9.1**	**59.0**
STANDARD DEVIATION		**44,561**	**7.7**	**91.7**



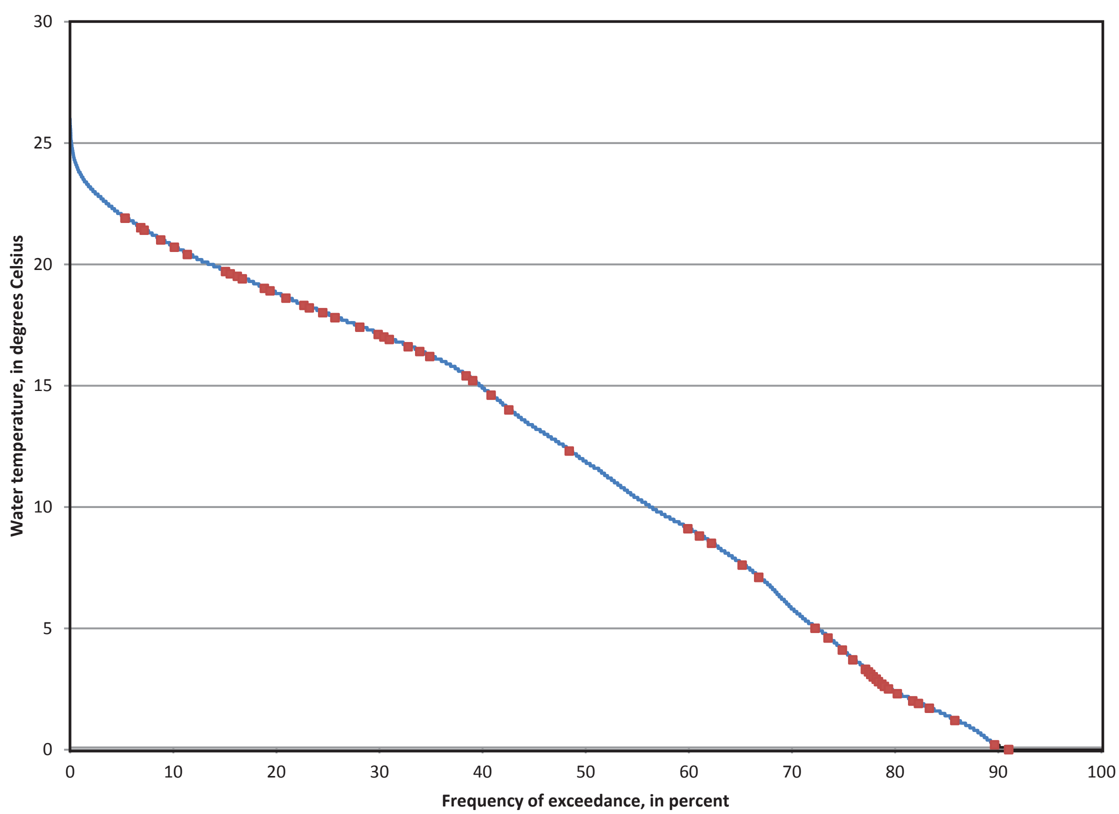


Figure 6-5. Duration curves for turbidity and water temperature (November 2008–September 2010) and corresponding values associated with fecal coliform bacteria concentration samples collected November 2008 to September 2009 at U.S. Geological Survey streamgage on Honey Creek at Wauwatosa, Wisconsin.

Fecal Coliform Bacteria at Honey Creek at Wauwatosa, Wisconsin, November 2008–September 2009

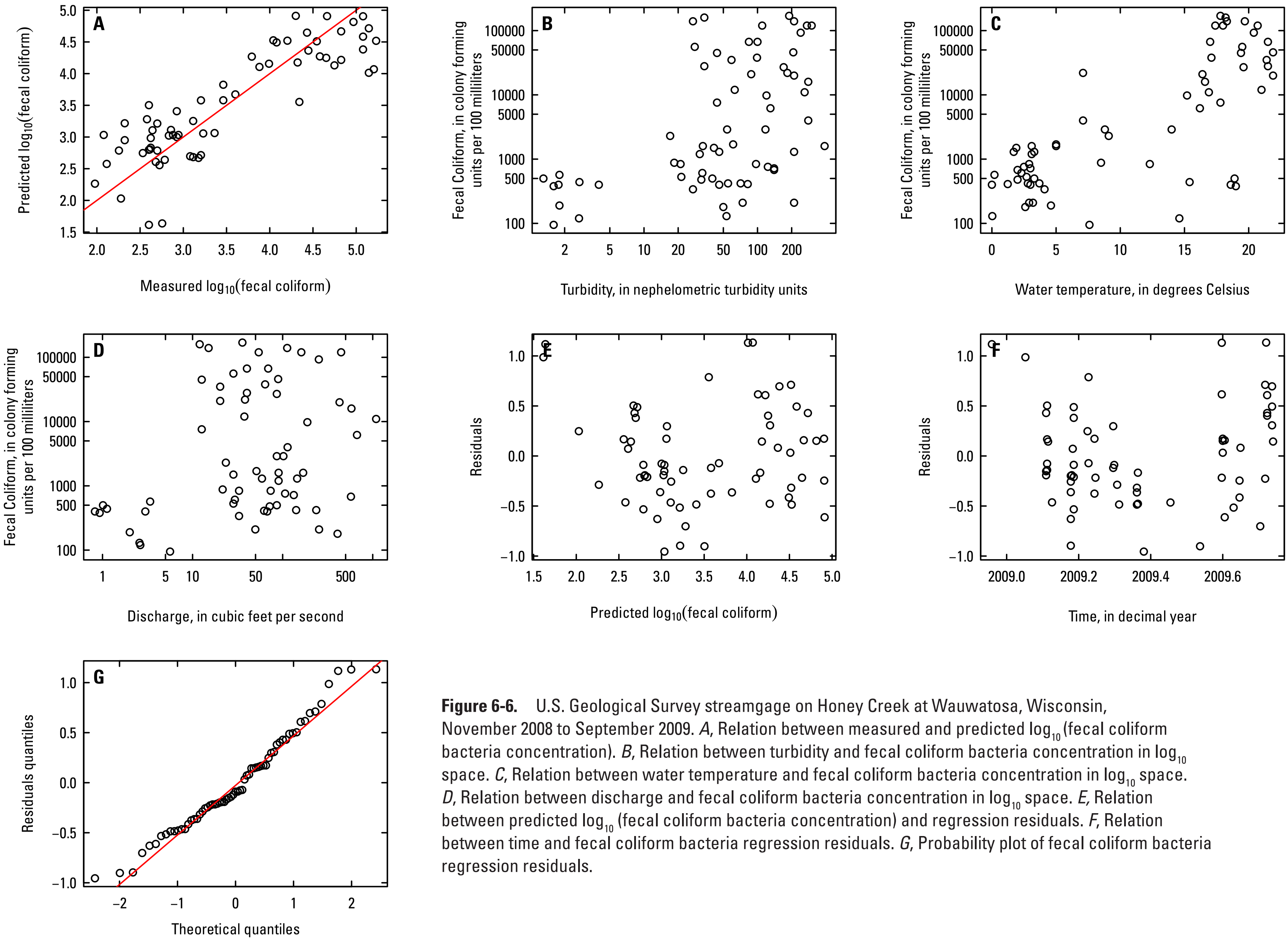


Figure 6-6. U.S. Geological Survey streamgage on Honey Creek at Wauwatosa, Wisconsin, November 2008 to September 2009. *A*, Relation between measured and predicted $\log_{10}$(fecal coliform bacteria concentration). *B*, Relation between turbidity and fecal coliform bacteria concentration in $\log_{10}$ space. *C*, Relation between water temperature and fecal coliform bacteria concentration in $\log_{10}$ space. *D*, Relation between discharge and fecal coliform bacteria concentration in $\log_{10}$ space. *E*, Relation between predicted $\log_{10}$ (fecal coliform bacteria concentration) and regression residuals. *F*, Relation between time and fecal coliform bacteria regression residuals. *G*, Probability plot of fecal coliform bacteria regression residuals.

Fecal coliform bacteria at Menomonee River at Wauwatosa, WI (04087120)

Samples collected on 6/08/2009 – 6/09/2009, and 8/09/2009, were not used in the regression analysis because of extreme fouling or because the MMSD laboratory qualified the results.

MODEL SUMMARY—Summary of final regression results for estimating fecal coliform concentrations at Menomonee River at Wauwatosa, WI.

$\log_{10}$ (fecal coliform) = 1.38 + 0.078 (WT) + 0.79 $\log_{10}$ (Turb),
Where:

fecal coliform = colony forming units of fecal coliform per 100 ml (CFU/100ml)
WT = Water Temperature in ^{o}C
Turb = Turbidity (YSI 6136), in NTU

***Model Information (in log units unless otherwise specified)*:**
Number of measurements = 68,
Root-mean-squared error (RMSE) = 0.492
Model standard percentage error (MPSE) = +211 and -68 percent
90-percent prediction intervals (based on units in CFU/100ml) = +/- 553 percent
Adjusted coefficient of determination (Adj R^2) = 0.74
Sum of squared error = 15.75
PRESS = 17.10

***Coefficients*:**

	Coefficient	**Standard error**	**t statistic**	**p-value**
Intercept	**1.38**	**0.203**	**6.81**	**<0.0001**
WT	**0.078**	**0.007**	**10.90**	**<0.0001**
$\log_{10}$ (Turb)	**0.79**	**0.114**	**6.95**	**<0.0001**

Correlation matrix of coefficients:

	Intercept	**WT**	**$\log_{10}$ (Turb)**
Intercept	**1**	**-0.277**	**-0.861**
WT	**-0.276**	**1**	**-0.155**
$\log_{10}$ (Turb)	**-0.861**	**-0.155**	**1**

Duan's bias correction factor **= 1.70**

Table 6-4. Model-calibration dataset for Menomonee River at Wauwatosa, Wisconsin.

[CFU/100 mL, colony forming units per 100 milliliters; NTU, Nephelometric turbidity units; °C, degrees Celsius]

Date	Time	Fecal coliform bacteria (CFU/100 mL)	Water temperature (°C)	Turbidity (NTU)
11/20/2008	10:30	110	2.2	1.9
12/27/2008	10:15	1,000	0.0	89.0
1/20/2009	12:10	64	0.0	1.5
2/7/2009	11:25	2,100	0.0	72.3
2/7/2009	13:25	2,400	0.0	105.0
2/7/2009	13:40	2,400	0.0	110.0
2/7/2009	19:40	840	0.0	46.3
2/8/2009	13:40	300	0.0	26.0
2/9/2009	22:00	910	0.0	140.0
2/9/2009	23:15	1,300	0.1	140.0
2/10/2009	11:00	1,300	0.1	100.0
2/10/2009	17:05	800	0.5	70.7
2/26/2009	14:35	140	0.4	66.0
2/26/2009	19:00	260	0.7	140.0
2/26/2009	19:45	2,000	0.7	170.0
2/26/2009	22:50	1,200	0.6	130.0
2/27/2009	4:50	720	0.0	70.0
3/2/2009	7:20	270	0.0	7.3
3/10/2009	0:15	340	2.3	34.0
3/24/2009	11:55	71	4.9	1.1
3/25/2009	1:30	2,100	6.2	38.0
3/31/2009	17:00	1,700	5.1	14.0
3/31/2009	17:35	1,000	5.2	33.0
4/1/2009	5:35	480	4.3	20.0
4/19/2009	19:10	1,200	11.4	17.0
4/21/2009	5:05	380	7.7	7.1
4/23/2009	11:00	48	8.2	1.4
4/25/2009	11:15	800	14.2	22.0
4/25/2009	12:40	3,300	13.8	160.0
4/26/2009	14:35	2,400	8.9	36.0
4/26/2009	17:10	3,300	10.5	190.0
5/9/2009	0:30	500	16.6	37.0
5/9/2009	9:30	730	14.6	17.0
5/13/2009	20:40	1,900	15.2	68.0
5/13/2009	21:05	3,500	15.6	150.0
5/13/2009	22:00	5,600	15.9	140.0
5/14/2009	3:15	4,600	15.4	86.0
5/20/2009	11:15	56	17.4	4.8
6/19/2009	9:15	9,000	19.6	84.0
6/19/2009	18:15	19,000	20.4	52.0
6/19/2009	21:20	18,000	20.5	150.0
6/20/2009	3:10	42,000	19.7	45.0
7/16/2009	11:45	4,200	21.8	3.5
8/7/2009	18:00	29,000	19.6	32.0
8/7/2009	20:40	38,000	19.8	60.0
8/8/2009	0:55	60,000	19.3	37.0
8/8/2009	8:50	47,000	19.8	74.0
8/8/2009	9:45	70,000	20.1	210.0
8/8/2009	19:50	41,000	21.8	48.0
8/10/2009	2:00	27,000	22.3	110.0
8/10/2009	4:20	25,000	21.4	99.0
8/25/2009	20:50	83,000	22.3	68.0
8/25/2009	21:25	46,000	22.4	110.0
8/25/2009	21:30	35,000	21.9	96.0
8/26/2009	3:30	41,000	21.5	47.0
8/27/2009	3:35	5,400	20.0	18.0
9/20/2009	21:40	90,000	18.0	69.0
9/21/2009	3:40	180,000	17.8	51.0
9/22/2009	13:30	130,000	18.3	56.0
9/22/2009	13:40	140,000	18.4	71.0
9/22/2009	21:50	93,000	19.5	56.0
9/22/2009	23:10	42,000	19.0	53.0
9/27/2009	20:35	32,000	17.8	100.0
9/27/2009	21:05	43,000	18.0	150.0
9/27/2009	21:20	46,000	18.1	180.0
09/28/209	0:05	42,000	17.1	70.0
9/28/2009	2:35	23,000	16.4	62.0
9/28/2009	20:35	8,300	14.8	25.0
MINIMUM		**48**	**0.0**	**1.1**
MAXIMUM		**180,000**	**22.4**	**210.0**
MEAN		**22,956**	**11.9**	**71.3**
MEDIAN		**3,300**	**15.3**	**64.0**
STANDARD DEVIATION		**36,566**	**8.5**	**52.5**

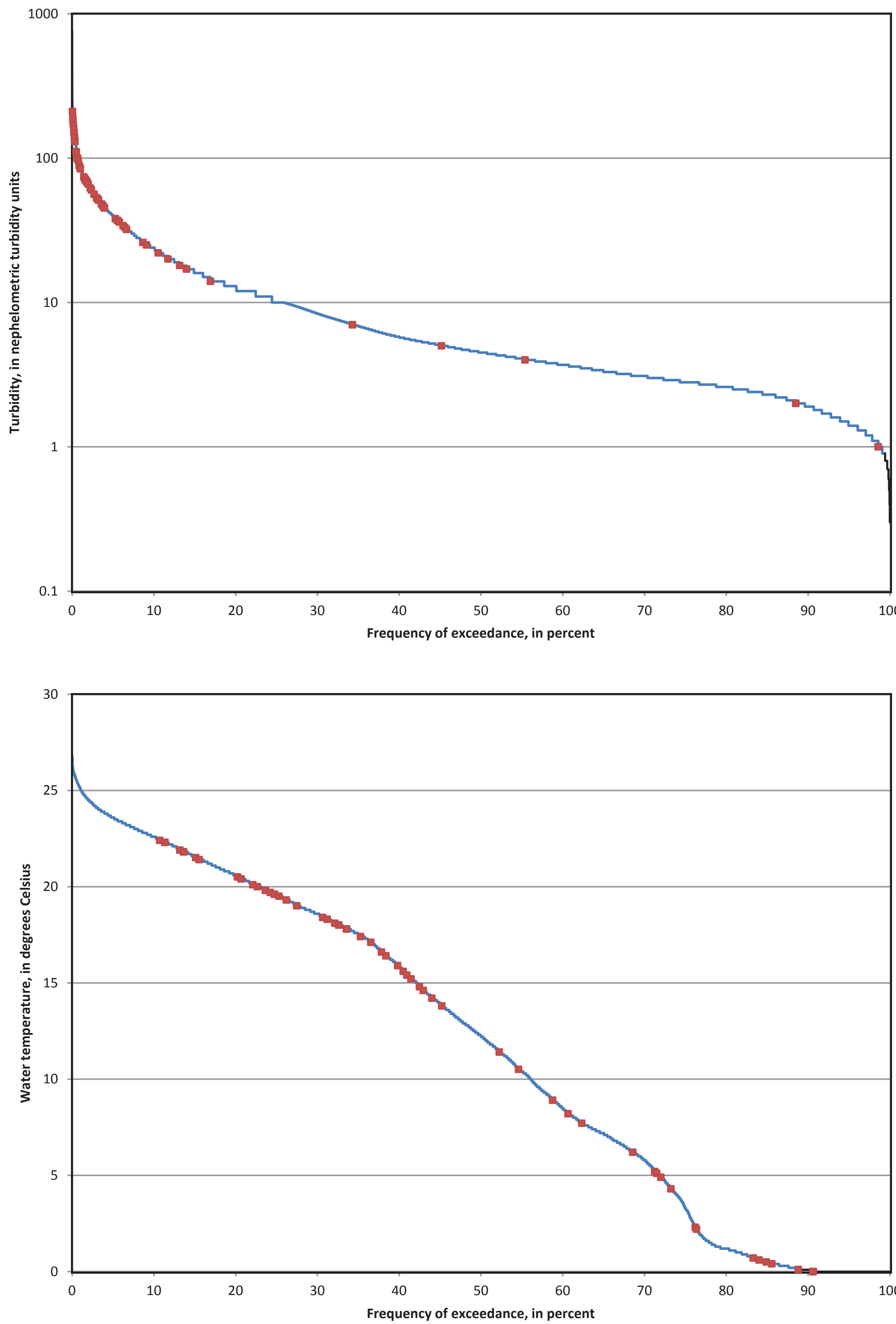


Figure 6-7. Duration curves for turbidity and water temperature (November 2008–September 2010) and corresponding values associated with fecal coliform bacteria concentration samples collected November 2008 to September 2009 at U.S. Geological Survey streamgage on Menomonee River at Wauwatosa, Wisconsin.

Fecal Coliform Bacteria at Menomonee River at Wauwatosa, Wisconsin, November 2008–September 2009

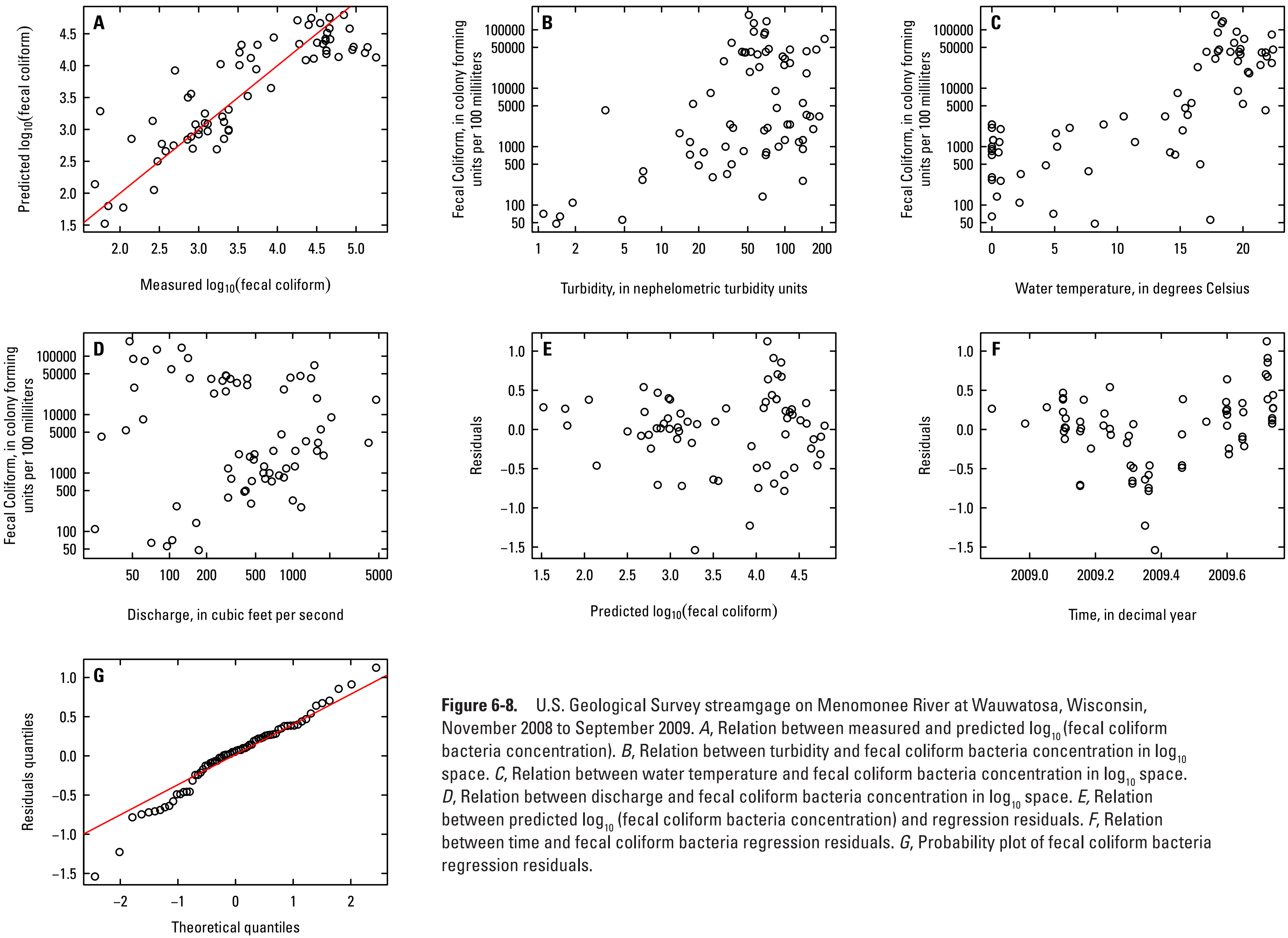


Figure 6-8. U.S. Geological Survey streamgage on Menomonee River at Wauwatosa, Wisconsin, November 2008 to September 2009. *A*, Relation between measured and predicted $\log_{10}$(fecal coliform bacteria concentration). *B*, Relation between turbidity and fecal coliform bacteria concentration in $\log_{10}$ space. *C*, Relation between water temperature and fecal coliform bacteria concentration in $\log_{10}$ space. *D*, Relation between discharge and fecal coliform bacteria concentration in $\log_{10}$ space. *E*, Relation between predicted $\log_{10}$ (fecal coliform bacteria concentration) and regression residuals. *F*, Relation between time and fecal coliform bacteria regression residuals. *G*, Probability plot of fecal coliform bacteria regression residuals.

Fecal coliform bacteria at Menomonee River at 16th Street at Milwaukee, WI (04087142)

MODEL SUMMARY—Summary of final regression results for estimating fecal coliform concentrations at Menomonee River at 16th Street at Milwaukee, WI.

Log_{10} (fecal coliform) = 1.07 + 0.062 (WT) + 1.00 $\log_{10}$ (Turb),
Where:

fecal coliform = colony forming units of fecal coliform per 100 ml (CFU/100ml)
WT = Water Temperature in ^{o}C
Turb = Turbidity (YSI 6136), in NTU

***Model Information (in log units unless otherwise specified)*:**
Number of measurements = 56,
Root-mean-squared error (RMSE) = 0.652
Model standard percentage error (MPSE) = +348 and -77 percent
90-percent prediction intervals (based on units in CFU/100ml) = +/- 1585 percent
Adjusted coefficient of determination (Adj R^2) = 0.54
Sum of squared error = 22.50
PRESS = 25.56

***Coefficients*:**

	Coefficient	**Standard error**	**t statistic**	**p-value**
Intercept	**1.07**	**0.296**	**3.62**	**0.0007**
WT	**0.062**	**0.011**	**5.71**	**<0.0001**
Log_{10} (Turb)	**1.001**	**0.159**	**6.31**	**<0.0001**

Correlation matrix of coefficients:

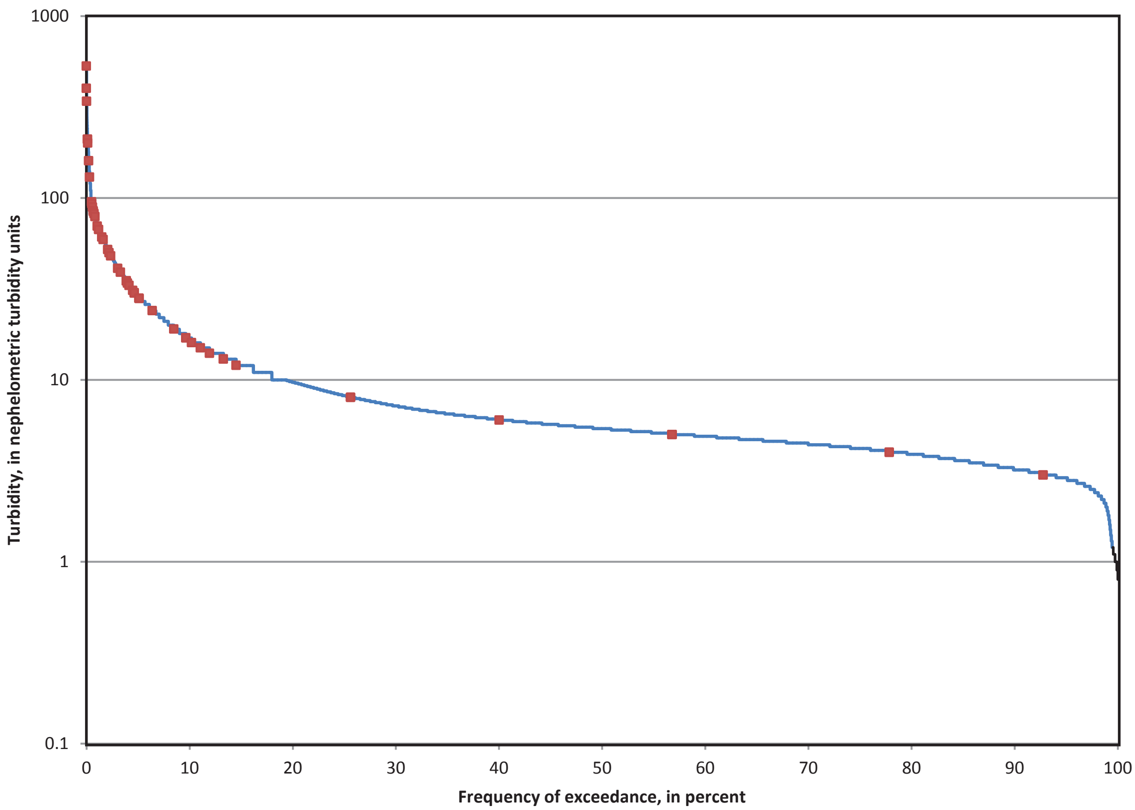
	Intercept	**WT**	**$\log_{10}$ (Turb)**
Intercept	**1**	**-0.522**	**-0.852**
WT	**-0.522**	**1**	**0.108**
$\log_{10}$ (Turb)	**-0.852**	**0.108**	**1**

Duan's bias correction factor **= 2.60**

Table 6-5. Model-calibration dataset for Menomonee River at 16th Street at Milwaukee, Wisconsin.

[CFU/100 mL, colony forming units per 100 milliliters; NTU, Nephelometric turbidity units; °C, degrees Celsius]

Date	Time	Fecal coliform bacteria (CFU/100 mL)	Water temperature (°C)	Turbidity (NTU)
11/20/2008	11:45	110	9.7	3.1
12/27/2008	12:35	840	0.3	52.3
12/28/2008	0:35	2,100	1.5	58.7
1/20/2009	12:40	24	8.2	5.4
2/7/2009	11:40	71	5.7	3.6
2/7/2009	20:40	1,800	0.0	78.7
2/8/2009	5:40	900	0.0	34.7
2/8/2009	14:40	870	0.8	28.3
2/8/2009	23:40	400	0.0	28.0
2/9/2009	17:40	1,000	0.1	12.7
2/16/2009	13:40	48	0.1	8.1
2/26/2009	16:00	32	8.9	8.2
2/26/2009	19:00	1,100	0.2	200.0
2/26/2009	22:00	1,700	0.7	130.0
2/27/2009	4:00	1,300	0.6	85.0
3/7/2009	11:10	270	2.9	19.0
3/7/2009	14:10	800	2.9	89.0
3/9/2009	0:10	720	0.9	61.0
3/10/2009	20:30	280	2.2	41.0
3/24/2009	12:25	71	12.0	4.0
4/1/2009	1:40	1,500	5.1	34.0
4/20/2009	3:05	1,700	10.9	12.0
4/23/2009	11:15	56	12.5	5.7
4/25/2009	13:20	2,200	14.2	30.0
4/26/2009	8:00	2,400	8.8	48.0
4/26/2009	14:00	2,700	8.8	39.0
4/26/2009	16:25	12,000	9.6	82.0
4/26/2009	17:10	17,000	10.3	210.0
4/26/2009	19:30	2,400	10.9	210.0
5/13/2009	22:05	2,000	15.2	35.0
5/14/2009	0:35	4,000	16.4	67.0
5/14/2009	1:45	5,800	16.4	93.0
5/14/2009	3:35	3,500	16.0	70.0
5/20/2009	11:45	130	18.4	5.0
6/8/2009	15:30	5,800	13.6	50.0
6/9/2009	2:35	9,200	14.3	32.7
6/9/2009	5:00	6,200	14.3	31.3
6/16/2009	13:00	340	22.7	5.3
6/19/2009	0:55	50,000	20.1	530.0
6/19/2009	1:10	36,000	20.0	400.0
6/19/2009	1:45	37,000	20.1	340.0
6/19/2009	9:35	110	19.6	95.0
6/19/2040	20:45	63,000	21.1	160.0
6/20/2009	2:25	60,000	19.8	84.0
7/16/2009	12:30	41,000	24.4	4.9
8/8/2009	22:30	97,000	21.6	24.0
8/9/2009	10:30	4,600	22.1	17.0
8/26/2009	7:05	110,000	21.6	15.0
8/26/2009	17:00	34,000	22.0	13.0
8/26/2009	23:45	6,000	21.8	14.0
9/15/2009	11:30	71	26.3	2.9
9/28/2009	12:05	19,000	16.3	28.0
09/28/209	18:05	9,600	15.6	30.0
9/29/2009	0:05	6,400	15.1	30.0
9/29/2009	3:05	5,600	16.8	17.0
9/29/2009	5:00	6,400	17.2	16.0
MINIMUM		**24**	**0.0**	**2.9**
MAXIMUM		**110,000**	**26.3**	**530.0**
MEAN		**12,128**	**11.7**	**68.4**
MEDIAN		**2,150**	**13.1**	**32.0**
STANDARD DEVIATION		**23,421**	**8.1**	**100.8**



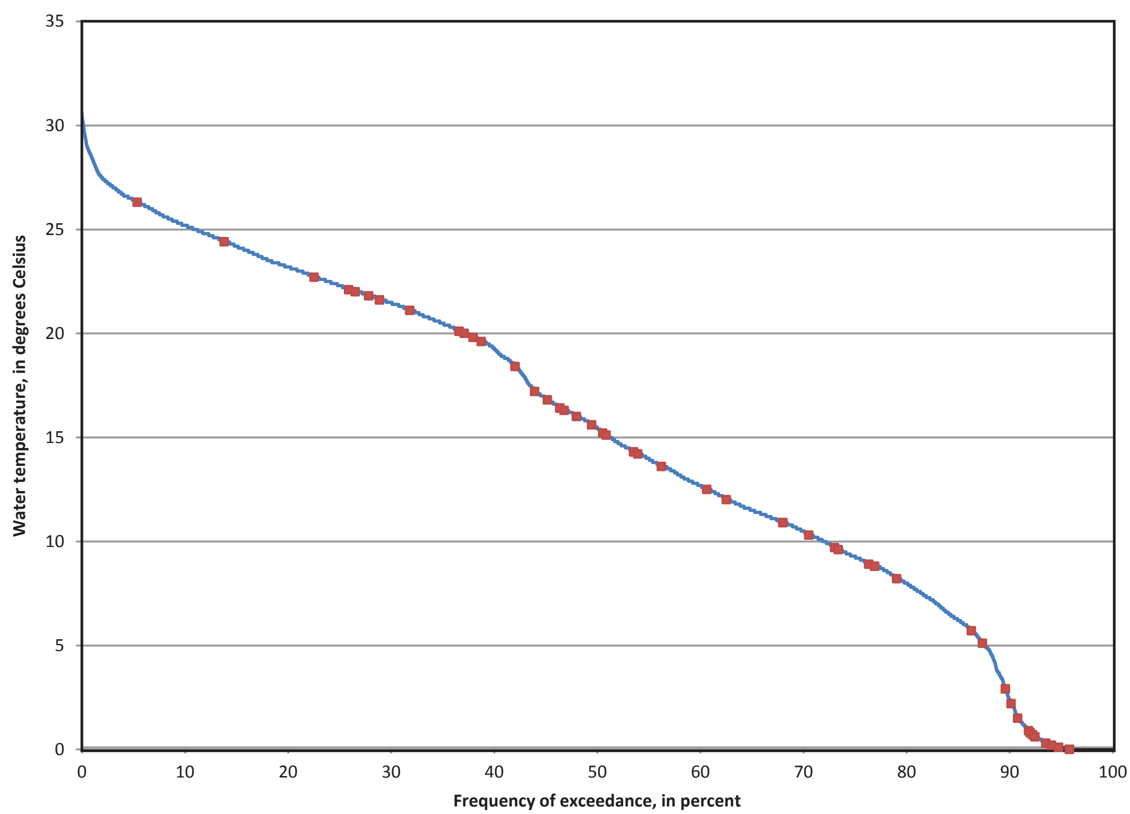
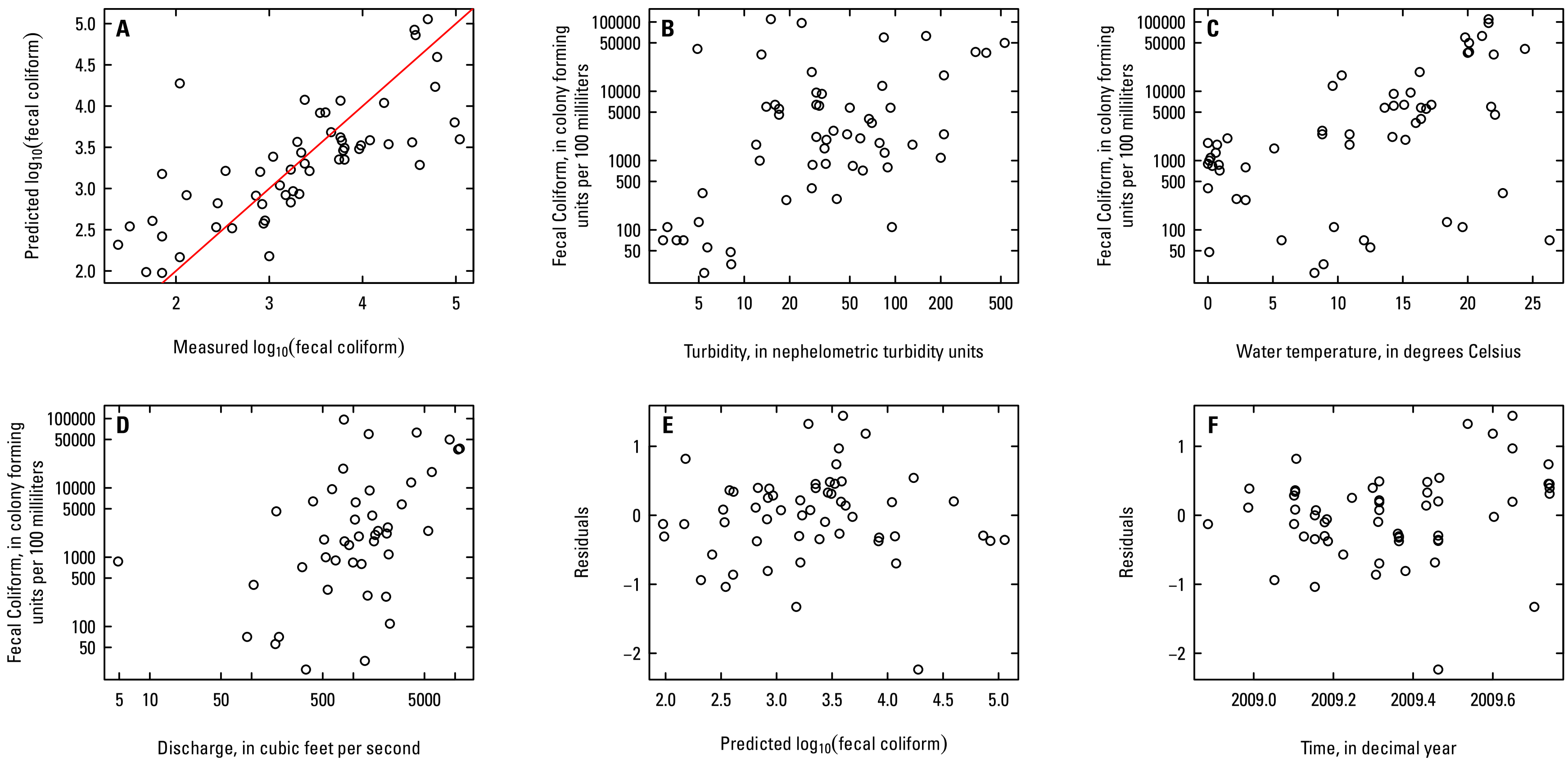


Figure 6-9. Duration curves for turbidity and water temperature (November 2008–September 2010) and corresponding values associated with fecal coliform bacteria concentration samples collected November 2008 to September 2009 at U.S. Geological Survey streamgage on Menomonee River at 16th Street at Milwaukee, Wisconsin.

Fecal Coliform Bacteria at Menomonee River at 16th Street at Milwaukee, Wisconsin, November 2008–September 2009



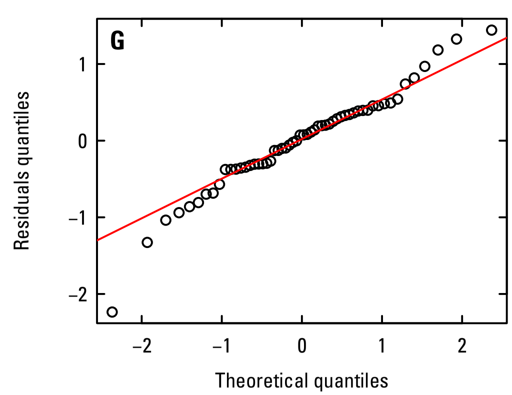


Figure 6-10. U.S. Geological Survey streamgage on Menomonee River at 16th Street at Milwaukee, Wisconsin, November 2008 to September 2009. *A*, Relation between measured and predicted $\log_{10}$ (fecal coliform bacteria concentration). *B*, Relation between turbidity and fecal coliform bacteria concentration in $\log_{10}$ space. *C*, Relation between water temperature and fecal coliform bacteria concentration in $\log_{10}$ space. *D*, Relation between discharge and fecal coliform bacteria concentration in $\log_{10}$ space. *E*, Relation between predicted $\log_{10}$ (fecal coliform bacteria concentration) and regression residuals. *F*, Relation between time and fecal coliform bacteria regression residuals. *G*, Probability plot of fecal coliform bacteria regression residuals.

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Baldwin and others—**Real-Time Monitoring of Select Constituents, Menomonee River, Wisconsin, 2008–9**—Scientific Investigations Report 2012–5064