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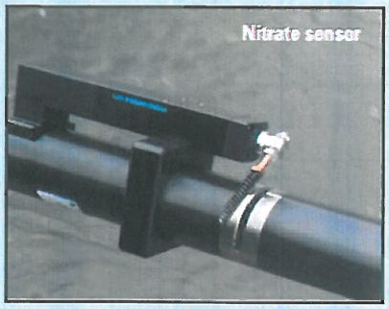
Real-Time, Continuous Water-Quality Monitoring in Indiana and Kentucky

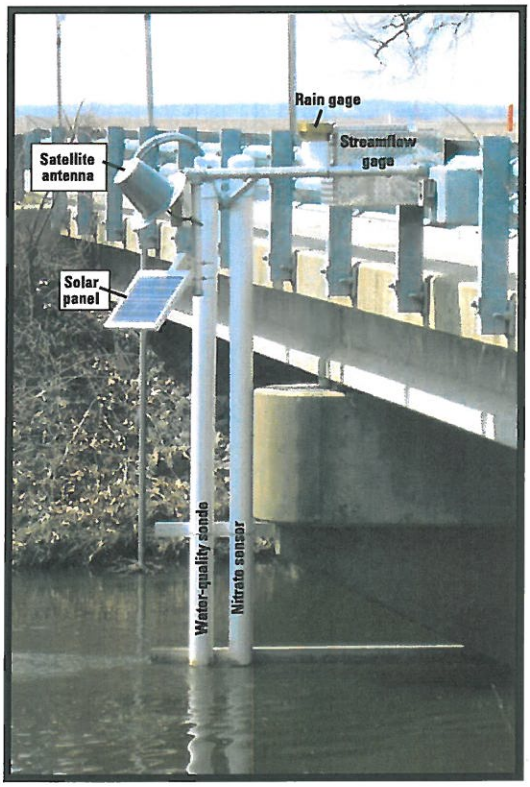
Water-quality "sentry" gages provide real-time, continuous measurements of constituent concentrations at or near selected USGS streamgages in Indiana and Kentucky. A sentry gage includes streamflow and water-quality instrumentation, representative stream sample collection for laboratory analysis, and statistical surrogate models relating instrument values to analyzed constituent concentrations. Real-time, continuous and laboratory-analyzed constituent concentration and load data are publicly accessible on USGS web pages.



Water-quality is measured at a sentry gage with one or more of the above instruments immersed in the stream.

How does a water-quality sentry gage operate?

Like a sentry keeping watch around the clock, a continuous water-quality gage uses in-stream instruments to measure streamflow, water-quality characteristics, nitrate, and phosphate many times a day and throughout the year. Traditional, intermittent water samples can miss changes in water quality that happen at night, during storms, and when it is not practical or affordable for a sample team to operate. By combining continuous and intermittent water sample data in a statistical model at sentry gages, constituent concentrations and loads (such as pounds per day) can be continuously computed. Operation of a sentry gage has the following components:



Continuous water-quality characteristics measured by sentry gage sensors are recorded and transmitted at USGS streamgage, Kankakee River at Davis, IN.

- **Measurement of stream stage and streamflow.** An instrument continuously measures gage height (also known as stream stage), which is related to routine measurements of stream velocity in order to compute instantaneous stream discharge (also known as streamflow) in cubic feet per second. Some water-quality constituent concentrations increase due to overland runoff during high streamflow conditions, while others can be diluted during high streamflow. Understanding flow conditions and constituent response is important to overall understanding of stream water-quality.
- **Measurement of water-quality characteristics and nutrients.** An in-stream water-quality sonde can continuously measure turbidity, dissolved oxygen, specific conductance, pH, and water temperature and records values four times per hour. Some sentry gages include an ultraviolet-absorbance sensor used to measure nitrate plus nitrite, and a chemical-reaction light-absorbance analyzer used to measure phosphate. Table 1 lists instrument reporting limits. An on-site data logger stores measurements and satellite telemetry transmit the data hourly to publicly-accessible USGS web pages.
- **Routine quality control.** USGS field teams routinely visit a sentry gage to clean and check calibration of in-stream instruments. Measurement drift from biofouling is quantified and independent meters calibrated daily and solutions of known concentration are used to verify the accuracy of the in-stream instruments. For quality control, mathematical corrections are applied to selected data if needed. Standard USGS procedures are documented in Pellerin and other (2013), Wagner and others (2006), and the National Field Manual (U.S. Geological Survey, variously dated).
- **Representative stream samples.** Stream width- and depth- integrated samples are routinely collected at a sentry gage and the samples are analyzed at a laboratory for constituents in table 1. Constituent concentrations such as nitrate or phosphate are used for comparison with the in-stream sensor and analyzer.
- **Statistical surrogate models.** Constituent concentrations from laboratory analysis and corresponding values from in-stream instruments are combined to develop a statistical surrogate model. The model computes real-time concentrations of a constituent based on continuous in-stream sensor readings. Turbidity is commonly used as a surrogate for suspended sediment concentration. Daily, monthly, and annual loads can be computed and compared to understand seasonal and annual variability.

Table 1. Water-quality parameters for analysis of USGS water samples at a sentry gage

[mg/l, milligram per liter; FNU, Formazin Nephelometric Unit ; oC, degree Celsius; su, standard unit; ms/cm, microsiemen per centimeter at 25 oC]

Parameters	Reporting Limit	Units	Determination	Method
Turbidity	0.1	FNU	sensor	optical
Dissolved oxygen	0.01	mg/L	sensor	optical
Specific conductance	1	µs/cm	sensor	electrical
pH	0.1	su	sensor	electrode
Water temperature	0.1	°C	sensor	thermistor
Nitrate plus nitrite	0.01	mg/L	sensor	optical
Phosphate	0.001	mg/L	analyzer	colorimetry
Suspended sediment, sand-fine break	1	mg/L	laboratory	filtration
Dissolved ammonia nitrogen	0.01	mg/L	laboratory	colorimetry
Dissolved nitrite nitrogen	0.001	mg/L	laboratory	colorimetry
Dissolved nitrite and nitrate nitrogen	0.04	mg/L	laboratory	alkaline persulfate
Total nitrogen*	0.05	mg/L	laboratory	colorimetry
Dissolved orthophosphate	0.004	mg/L	laboratory	colorimetry
Whole water phosphorus	0.004	mg/L	laboratory	colorimetry

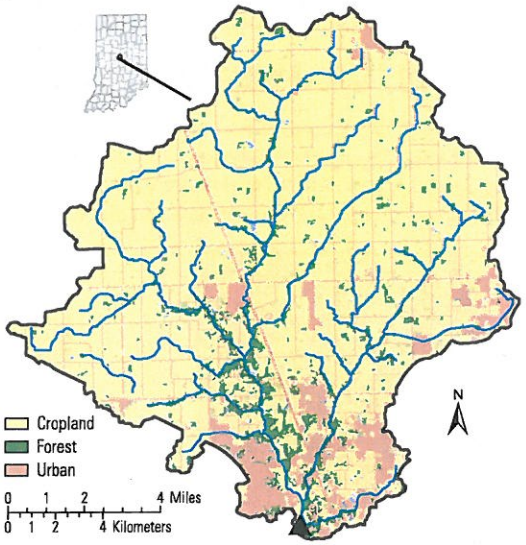
*Includes ammonia, nitrite, nitrate, organic nitrogen

Lower Green River, Kentucky Nitrate Monitoring

The Lower Green River Basin is a highly agricultural area in Kentucky that was selected as a priority basin for the Mississippi River Basin Healthy Watershed Initiative (MRBI) led by the Natural Resources Conservation Service (Natural Resources Conservation Service, 2008). The goal of the MRBI is to improve water quality while maintaining agricultural productivity. Since 2013, the USGS, in cooperation with the Kentucky Governor's Office of Agricultural Policy, has been measuring continuous nitrate concentrations and computing nitrate loads discharged from the Lower Green River to the Ohio River, a major tributary to the Mississippi River. This data is critical for evaluating the effectiveness of agricultural nutrient management plans and strategies implemented in the Basin.

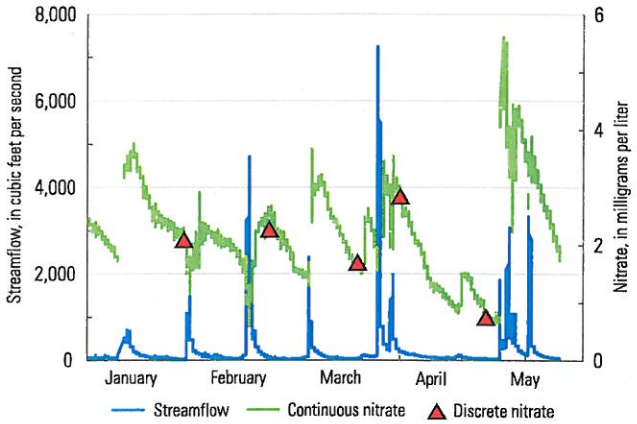
Lower Green River near Spottsville, Kentucky

Eagle Creek, Indiana Demonstration Sentry Gage



Eagle Creek at Zionsville, IN

Eagle Creek flows through the town of Zionsville in southeast Boone County north of Indianapolis. The USGS has operated a sentry gage on Eagle Creek since 2010 as a demonstration and test site. Water-quality instruments, a weather station, soil moisture probes, and a remote video camera have been used to showcase the wide variety of real time, continuous data that can be served at a sentry gage. The site has also been used by USGS to test different types of water-quality instruments such as nitrate sensors and analyzers. Eagle Creek at Zionsville is an important sentry gage for understanding the effects of land use on water quality. Since 2000, the town has more than tripled in size and the watershed is transitioning from agricultural to suburban land use. Eagle Creek is the major tributary to Eagle Creek Reservoir, a water source for the Indianapolis public water supply that has episodic algal blooms from nutrient enrichment.



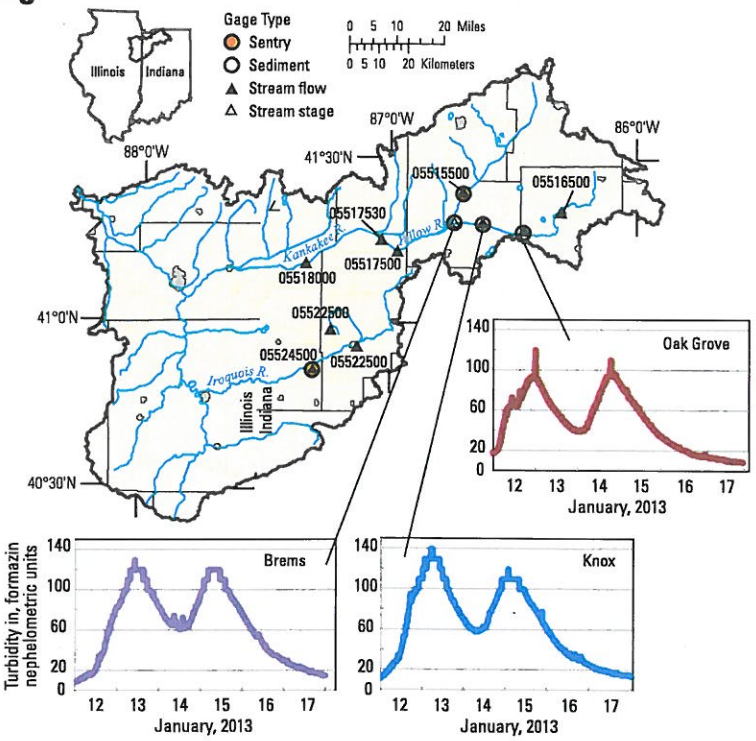
The sentry gage on Eagle Creek at Zionsville measures continuous streamflow and nitrate concentrations. Continuous nitrate concentrations respond to changes in streamflow. These responses in nitrate may not be detected with discrete samples alone.

Kankakee River Sediment and Nutrient Monitoring

The Kankakee River Basin in northwestern Indiana drains 2,989 square miles and includes the Kankakee River and Iroquois River that flow into the Illinois River west of the Indiana-Illinois border. The Kankakee River Basin Commission (KRBC) coordinates management activities for flood control, recreation, water quality, and soil conservation in Indiana (KRBC, 2014). The Grand Kankakee Marsh was drained in the past century and the Kankakee River and many of its tributaries were channelized to promote drainage for agricultural land.

Starting in 2012, the USGS in cooperation with KRBC, has measured continuous turbidity and stream discharge at three sentry gages to understand the concentrations and loads of suspended sediment transported in the Yellow River, a major tributary of the Kankakee River (map on the top right). Statistical surrogate models were developed to relate continuous turbidity measurements to analyzed concentrations of suspended sediment sampled at these gages. An example comparing the changes in turbidity at the three gages on the Yellow River is shown in the graphs to the right.

The USGS operates two other sentry gages in the Basin as of 2015, the Kankakee River at Davis, IN (05515500) and the Iroquois River at Foresman, IN (05524500), shown on the map on the top right. These sentry gages record continuous values of water-quality characteristics, nitrate concentrations, and streamflow to document changes in response to land management

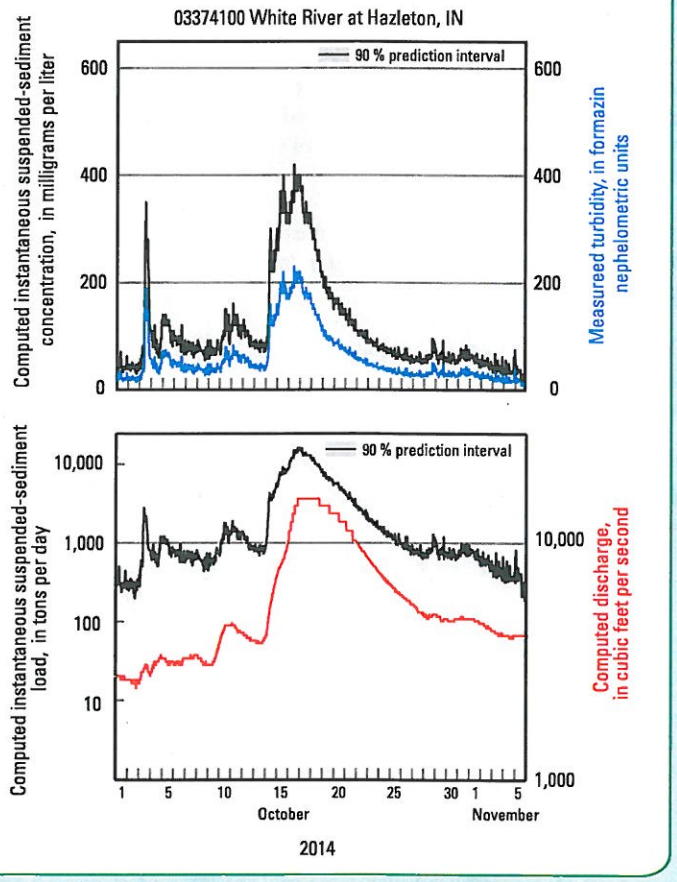


Graphs show the increase in turbidity from suspended sediment during storm runoff and high streamflow measured at three sentry gages in the Yellow River watershed. The greatest increase in turbidity occurs between the sites Oak Grove and Knox and high levels persist downstream to the site near Brems, IN

Statistical Surrogate Models to Compute Constituent Concentrations and Loads

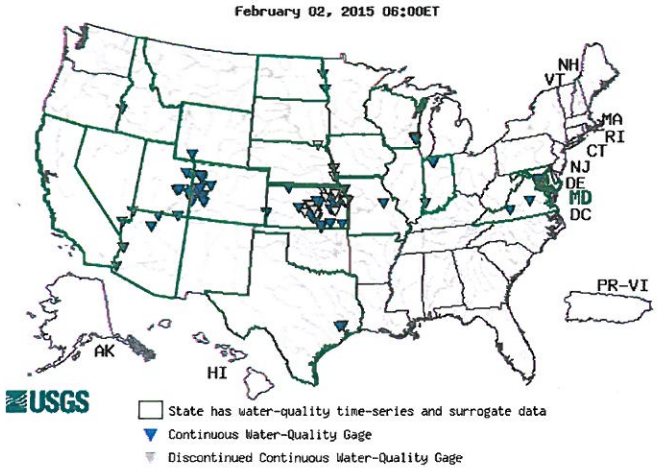
Concentrations of water-quality constituents.in routine water samples are determined by laboratory analysis. Laboratory analyzed concentrations are then compared to constituents measured by continuous in-stream instruments operating at the same time samples were collected. USGS hydrologists develop and refine statistical regression models for selected constituents using data collected at a sentry gage during a range of streamflow conditions and constituent concentrations. The in-stream continuous sensor values act as a surrogate to compute continuous constituent concentrations. As an example, turbidity, the clarity of water in a stream, is often used as a surrogate for suspended sediment (top graph on right). The relation between suspended sediment and turbidity is site specific, but is usually consistent and definable (Rasmussen and Ziegler, 2008). Surrogate models, as described above, can be developed for various constituents including instream nitrate sensor data as a surrogate for total nitrogen, instream phosphate analyzer data for total phosphorus, or turbidity and streamflow data combined for total phosphorus.

At sentry gages, instantaneous constituent loads are computed as the product of the concentrations and streamflow (bottom graph on right), typically recorded four times an hour each day. Daily, monthly, and annual summary loads are computed as sums of the instantaneous loads, such as pounds per day or tons per year. Watershed yields are computed by dividing summary loads by drainage area, such as pounds per square mile per year.



How to Access Data

USGS continuous water-quality data and models are located on the USGS National Real-Time Water Quality website, http://nrtwq.usgs.gov



The website features:

- Interactive maps of states with real-time, continuous water-quality monitoring gages, with lists of the constituents measured and links to the data for each gage.
- Links to maps of states with gages that have surrogate models to predict constituent concentrations that are not measured directly with in-stream instruments.
- Links to published methods used to develop surrogate models through statistical regression and site specific information.
- Surrogate model data available as a plot or a table, with the 90 percent confidence interval for calculated values.

The USGS water-quality sentry gages in Indiana and Kentucky are part of a national network.

Quality Control

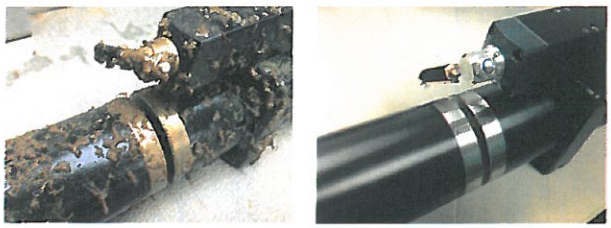
The USGS uses quality-control protocols to insure that data are accurate, representative of stream conditions, reproducible, and consistently collected.

- A USGS scientist visits each sentry gage regularly to clean and, if necessary, recalibrate water-quality sensors according to USGS-approved methods. Information collected during site visits is used to quality assure the continuous data record and to provide a data quality rating for each time period.

- Daily review of the real-time data for each sentry gage determines that instruments are operating correctly and that malfunctions are resolved promptly.

- Representative water-quality samples and cross-stream water-quality profiles are used to verify that sentry gage instruments are accurately portraying in-stream conditions.

- Surrogate models are developed following USGS guidelines (Rasmussen and Zeigler, 2008) and undergo a thorough review process.



Biofouling of in-stream nitrate sensors is managed by regular cleaning and inspection.

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For additional information contact:

Indiana-Kentucky Water Science Center (URL for INKY sentry gage website)
Indianapolis office: 317-290-3333 (http://in.water.usgs.gov/)
Louisville office: 502-493-1900 (http://ky.water.usgs.gov/)

Authors:

Megan E. Shoda, Timothy R. Lathrop, Martin R. Risch