Continuous Nitrate Monitoring in Agricultural Watersheds

Leveraging the Hach NT3100sc UV Nitrate Sensor for Data-Driven Nutrient Management

Challenge

- Agencies require continuous environmental water quality data to support watershed management and public safety.
- Nitrate transport in agricultural watersheds is highly dynamic and event driven.

Solution

- The Hach NT3100sc UV Nitrate Sensor provides continuous, reagent-free nitrate monitoring.
- Reliable online measurements accurately capture rapid changes in nitrate concentrations.

Result

- Continuous monitoring improves nitrate load estimation and captures event-driven variability.
- Supports more informed, data-driven watershed management decisions.

Photo 1: Hach SC4500 Digital Controller and NT3100sc UV Nitrate sensor (5mm path length configuration)

Background and Application Overview

Agricultural watersheds are a dominant source of nitrate loading to rivers, reservoirs, and downstream drinking water supplies. Because nitrate transport is highly dynamic and event driven, traditional grab sampling often fails to capture peak loading conditions and short-duration runoff events.

The Hach NT3100sc UV Nitrate Sensor provides continuous, reagent-free nitrate monitoring, enabling high-resolution measurement of nitrate concentrations in streams, rivers, and edge-of-field applications. When combined with other hydrological data via connectivity provided by the SC4500 digital controller, the NT3100sc supports accurate nutrient load calculations, real-time event detection, and defensible watershed management decisions.

Monitoring Challenges in Agricultural Watersheds

Event-Driven Nitrate Transport

In agricultural systems, nitrate losses can occur through surface runoff following precipitation, subsurface tile drainage (networks of perforated pipes buried beneath the soil surface to remove excess groundwater and lower the water table), groundwater discharge to streams and seasonal fertilizer application cycles.

Nitrate is very soluble in water and is stable over a wide range of environmental conditions. It is readily transported in groundwater and streams and can contribute to eutrophication, rapid cyanobacteria growth and a range of threats to human and aquatic ecosystem health.[1]

Photo 2: Fast-moving freshwater stream and wetlands areas at valley floors are prone to agricultural runoff and occasional flooding from seasonal rainfall, contributing to surface water eutrophication, cyanobacteria growth and harmful algal blooms. (Credit: Adobe Stock #266367985)

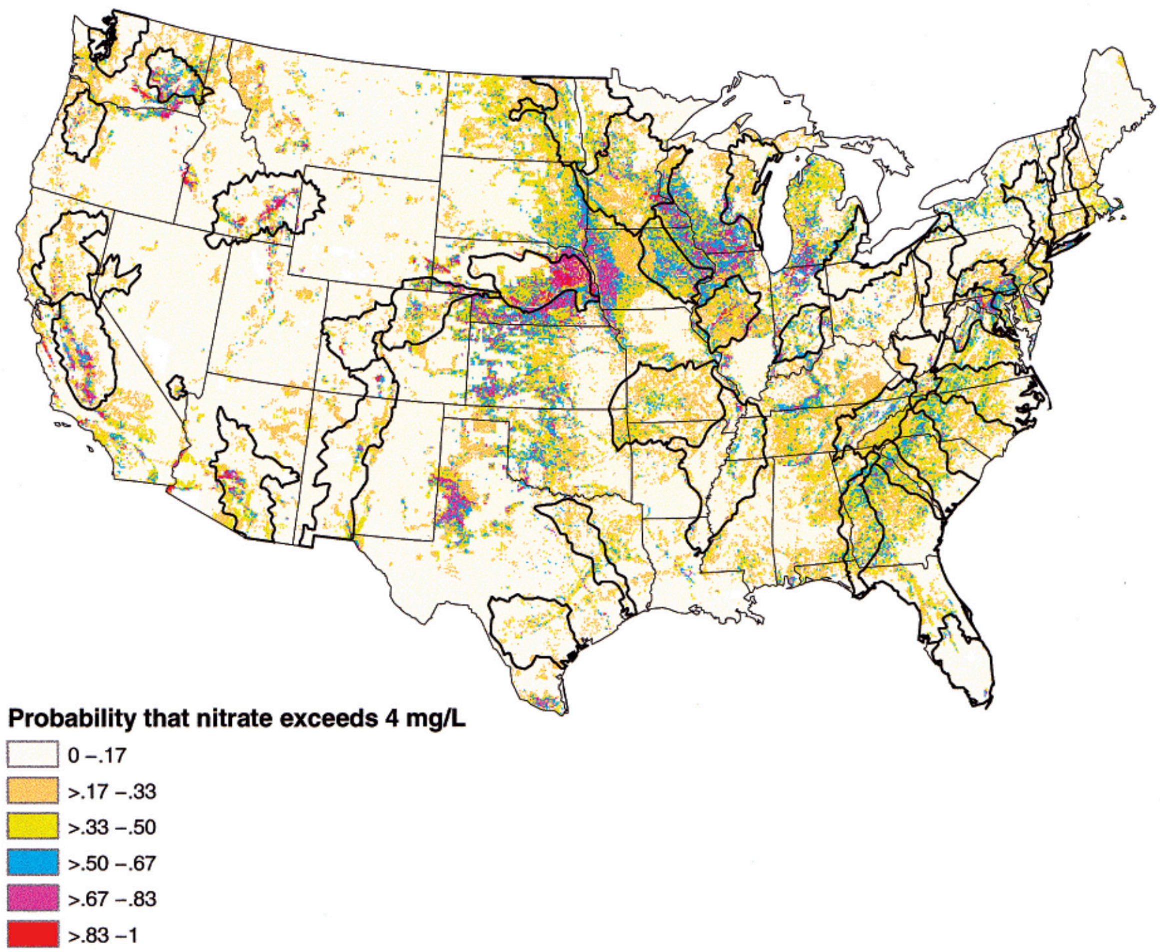

Figure 1: Probability that nitrate exceeds 4 mg/L in shallow groundwaters of the United States.[4]
(Credit: U.S. Geological Survey research study, 2002)

UV Nitrate Monitoring in Natural Waterways

The NT3100sc sensor represents the latest generation of Hach's reagent-free ultraviolet (UV) absorbance technologies for nitrate monitoring and is a direct replacement for previous generations, including Nitratax Plus. The NT3100sc features an integrated wiper system, a dual-wavelength optical configuration that compensates for turbidity and suspended solids interference, and low-level detection capabilities over previous models.[2]

While the platform was designed primarily for wastewater treatment plant environments, hydrologic and environmental professionals have also successfully adapted it for deployment into natural waterways for monitoring agricultural runoff within several watersheds in the United States. This application was first evaluated in a study supervised by the United States Geological Survey (USGS) Hydrologic Instrumentation Facility (HIF) which compared five UV spectrophotometric nitrate measurement instruments in both laboratory and field conditions.

The conclusion emphasized Hach instrument reliability and accuracy in low ranges as well as in conditions with high sediment loading.[3] In addition, the NT3100sc sensor is more cost effective than other environmental sonde solutions designed for long-term deployment in oceanic and high-salinity environments.

The USGS study results preceded a series of environmental deployments in Iowa, Minnesota and Tennessee, which incorporate sensor immersion from bridges and riparian zones into rivers as well as use of data logger and cellular gateway equipment to facilitate real-time public access to sensor information. The NT3100sc 5mm path length configuration is well suited for surface water monitoring with a wide measurement range of 0.02 to 25.0 mg/L as NO_3–N.

NT3100sc User Experience Spotlight

Iowa Water Quality Information System (IWQIS)

The IWQIS program seasonally deploys a fleet of several dozen Hach nitrate sensors into natural waterways across the state, alongside sensors operated by the U.S. Department of Agriculture and the U.S. Geological Survey. The resulting deployment coverage represents one of the largest water quality sensor network in the country.[5]

This information is aggregated with other hydrologic parameters including pH, dissolved oxygen concentration, discharge rates and temperature. Data are incorporated into models maintained by the University of Iowa's IIHR—Hydroscience and Engineering and the Center for Health Effects of Environmental Contamination. These models support evaluation of nutrient reduction strategies under Iowa's Nutrient Reduction Strategy framework.[6]

The data collected by nitrate sensors are also made available in real-time on a public website to help researchers, agencies, and landowners directly monitor the impact of land-use strategies/ changes on downstream water quality. This enables watershed stakeholders to understand the fate and transport of nutrients in the state's waterways.[7]

The University of Iowa staff periodically adjust deployed nitrate sensor depth based on water level and remove sensors between December and March to avoid damage from freezing temperatures. During this period the sensor fleet is scheduled for certified bench preventative maintenance through partnership with the Hach service center, centrally located in Ames to ensure reliable operation prior to each springtime redeployment.

University staff also validate measurements of operational nitrate sensors periodically using a side-by-side comparison with a calibrated portable sensor. Mounting methods immerse sensors into surface water from off-bank structures. Most mounting approaches consist of a 10-foot-long section of 4-inch diameter PVC pipe fastened to extruded aluminum rails and are immersed into streams and rivers.

The team scouts the monitoring sites prior to seasonal installation to determine river depth, ease of access and possible issues with wildlife damaging the equipment. Deployed depth of the sensor head is generally between 1 and 2 feet above the river bottom to avoid accumulation of clay and other sediments.

Monitoring stations incorporate photovoltaic solar panels and outdoor-rated cabinet enclosures to station Hach digital controllers, marine batteries, data loggers and cellular gateways for each deployed sensor.

Photo 3: Depiction of an open monitoring station enclosure cabinet with photovoltaic solar panel, marine battery and portable NT3100sc nitrate sensor visible on the river bank, prior to seasonal deployment of a sensor in-situ. (Credit: IWQIS)

Photo 4: Example pipe deployment of optical nitrate sensor into environmental waters from the bank of a river. (Credit: U.S. Geological Survey report, 2013)

Minnesota Pollution Control Agency (MPCA)

The Minnesota Pollution Control Agency has installed a network of Hach nitrate sensors in areas of the state where elevated nitrate concentrations and nutrient loading have historically been observed. Sensors are typically deployed between February and November each year. Water quality data collected through the Continuous Nitrate Sensor Network is publicly available through collaborative efforts among state and federal agencies, providing stakeholders with a valuable tool to identify, monitor, and manage sources of elevated nutrient loading in surface waters.

MPCA staff utilize custom-fabricated mounting systems to deploy and immerse sensors into surface water while allowing for seasonal depth adjustments as water levels change throughout the year. In addition to the NT3100sc sensor's integrated automated wiper system for debris removal, operators routinely perform maintenance, cleaning, and calibration checks on the nitrate sensor. Cleaning solutions include water, diluted vinegar solution, and diluted acid solutions as part of regular field servicing procedures. Calibration checks are performed using factory standards, and the freshly maintained sensor is verified against a portable field meter in the river to confirm proper operation and accuracy.

Monitoring stations are powered using either photovoltaic solar panels or AC electrical service. Solar-powered installations also incorporate marine batteries within the gage house enclosure to support continuous operation of Hach controllers, data loggers, and cellular communication gateways. Data logging and telemetry management are coordinated by the Minnesota Department of Natural Resources, Minnesota Department of Agriculture, or the MPCA, with data transmitted via GOES satellite telemetry or cellular communications.

Collected data is processed through a continuous monitoring database before being published online for public access and stakeholder use.

Tennessee (United States Geological Survey)

The USGS monitors nitrate in two locations along the Harpeth River in Tennessee. The river flows through the Franklin metropolitan area before meeting the Cumberland River which provides drinking water to over 2 million people in the Nashville metropolitan area.

The Harpeth River is used primarily as a recreational area for boating and fishing; the presence of agricultural land within the river's watershed drives stakeholder interest in nutrient monitoring.[9]

The NT3100sc sensors are mounted horizontally from the riverbank, and staff adjust the positioning to ensure even mixing through the deepest portion of the river channel. Nitrate is monitored along with dissolved oxygen, conductivity and temperature.

Nitrate concentration (as NO_3+NO_2) rises immediately and proportionally following each spike in the river's gage height and trends with changes in conductivity and river flow. While measured nitrate concentration and conductivity levels shift with changes in river stage they do not trend together.

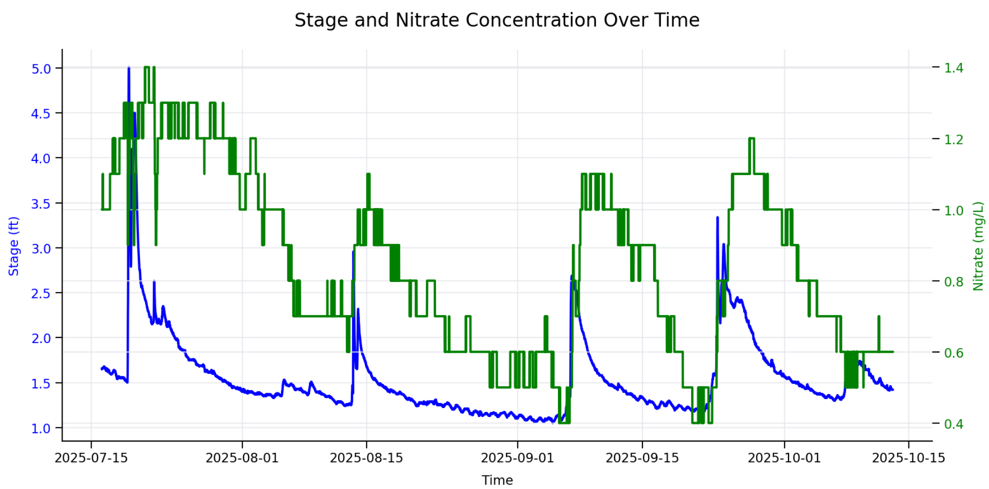

Figure 2: Correlation of measured nitrate concentration (mg/L, in green) obtained by Hach NT3100sc sensor with surface water stage (ft, in blue) on Harpeth river between July and October 2025. (Credit: U.S. Geological Survey, 2026).

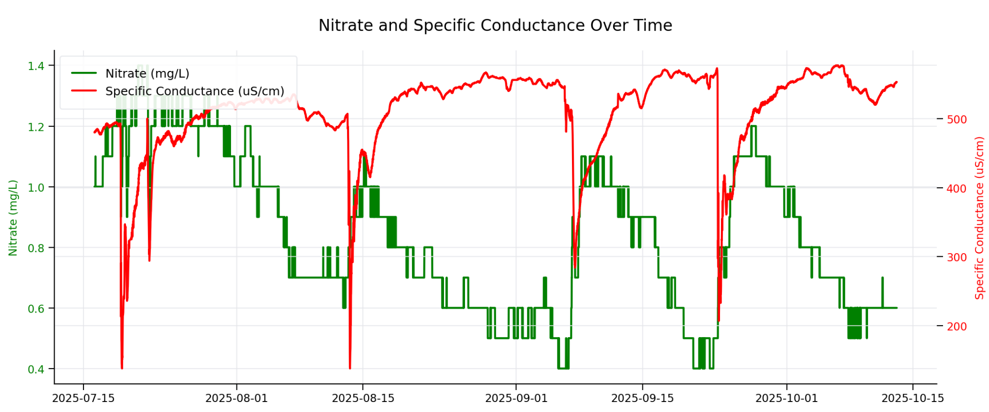

Figure 3: Correlation of measured nitrate concentration (mg/L, in green) with specific conductance (uS/cm, in red) on Harpeth River between July and October 2025. (Credit: U.S. Geological Survey, 2026)

Conclusion

While nitrate does occur naturally in groundwater, concentrations greater than 3 mg/L generally indicate contamination[10] and a more recent nationwide study found that concentrations over 1 mg/L nitrate indicate human activity.[11] The United States Environmental Protection Agency's maximum contaminant level (MCL) for nitrate set to protect against acute health effects such as blue-baby syndrome is 10 mg/L.[12]

Remote watershed locations for agricultural monitoring present challenges from limited power availability, riparian zone access restrictions, variable river flow conditions, biofouling, damage from wildlife and unpredictable weather conditions. The NT3100sc sensor's rugged, in-situ design makes it well suited for long-term river deployment with field installations and monitoring networks across many locations. Continuous nitrate monitoring allows researchers to determine point source nutrient pathways and detect trends to manage environmental strategies. These data-driven strategies enhance long-term sustainability for environmental cooperation within the community and industry.

For watershed managers and environmental agencies, continuous nitrate monitoring is no longer optional; it is essential.

References

1 *Nutrients and Eutrophication, 2019. U.S. Geological Survey. (https://www.usgs.gov/mission-areas/water-resources/science/nutrients-and-eutrophication)*

2 *Hach Company, NT3100sc UV Nitrate Sensor, Technical Data Specification Sheet. Publication DOC053.53.35333. (https://cdn.hach.com/7FYZVWYB/at/362cq8wm67kkrwf5k6vvm9wc/DOC0535335333-NT3X00sc.pdf)*

3 *Snazelle, T. 2015. Results from laboratory and field testing of nitrate measuring spectrophotometers. Open-File Report 2015-1065. U.S. Geological Survey Publications Warehouse, Reston, Virginia. (https://pubs.usgs.gov/of/2015/1065/pdf/ofr2015-1065.pdf)*

4 *Nolan, B., Hitt, K. and Ruddy, B. 2002. Probability of Nitrate Contamination of Recently Recharged Groundwaters in the Conterminous United States, Research Report. U.S. Geological Survey Publications Warehouse, Reston, Virginia. (https://water.usgs.gov/nawqa/nutrients/pubs/est_v36_no10/est_v36_no10.pdf)*

5 *Iowa Nutrient Research Center, 2026. Maxwell Stanley Hydraulics Laboratory, Iowa City, Iowa. (https://iihr.uiowa.edu/research/centers-and-programs)*

6 *Rivers, Watersheds, & the Landscape, 2026. (https://iihr.uiowa.edu/research/rivers-watersheds-and-landscape)*

7 *Iowa Water Quality Information System, 2026. (https://iwqis.iowawis.org/about.html)*

8 *Minnesota Pollution Control Network, 2026. (https://www.pca.state.mn.us/air-water-land-climate/24-hour-nitrate-network)*

9 *National Water Information System Web Interface, USGS 03433500 Harpeth River at Bellevue, TN, 2026. (https://waterdata.usgs.gov/nwis/uv?site_no=03433500&legacy=1&agency_cd=USGS)*

10 *Madisson, R. J., & Brunett, J. D. (1985). Overview of the Occurrences of Nitrate in Groundwater of the United States (pp. 93-105). US Geological Survey, Water Supply Paper 2275. (https://www.scirp.org/reference/referencespapers?referenceid=3848787)*

11 *Dubrovsky, N.M., and Hamilton, P.A., 2010, Nutrients in the nation's streams and groundwater: National findings and implications: U.S. Geological Survey Fact Sheet 2010-3078, 6 p., (https://doi.org/10.3133/fs20103078)*

12 *Estimated Nitrate Concentrations in Groundwater Used for Drinking, 2026. (https://www.epa.gov/nutrientpollution/estimated-nitrate-concentrations-groundwater-used-drinking)*

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