Stream monitoring

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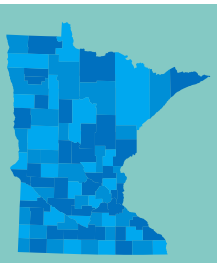
Continuous Nitrate Sensor Network: Standard operating procedures and guidance

MINNESOTA POLLUTION CONTROL AGENCY



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Foreword

The Minnesota Pollution Control Agency's Continuous Nitrate Sensor Network (CNSN) staff should follow the Standard Operating Procedures and Guidance (SOPG) outlined in this manual. This SOPG will be updated as needed. CNSN staff should be consulted with any questions regarding sampling methods used in the CNSN program.

Contents

1 Scope and application

1.1 Purpose

This Standard Operating Procedures and Guidance (SOPG) document describes the methods followed by the Minnesota Pollution Control Agency (MPCA) Continuous Nitrate Sensor Network (CNSN) staff and participating partners for the deployment, operation, calibration, maintenance, and documentation of continuous nitrate + nitrite (NO_2+NO_3) sensors, as well as the collection management of the data.

2 Program overview

2.1 Continuous nitrate monitoring

In-stream nitrate sensors provide continuous, real-time monitoring of NO_2+NO_3 concentrations in rivers and streams. At each site, 15-minute time series data is collected, providing high-resolution data that exceeds the temporal coverage of traditional intermittent grab sampling. Continuous monitoring allows for improved tracking of progress toward Minnesota's Nutrient Reduction Strategy goals and supports more effective allocation of resources toward nutrient reduction practices.

Real-time sensor data also facilitate collaboration with downstream states through data sharing, strengthening coordinated nutrient management efforts. Additionally, these data support advanced water-quality modeling and the evaluation and implementation of best management practices aimed at reducing nutrient pollution. Overall, the integration of continuous nitrate sensors represents a significant advancement in addressing water-quality challenges and achieving long-term environmental goals.

2.2 Site selection

Monitoring sites are selected based on the following criteria.

2.2.1 Historic water-quality relevance

Sites are prioritized based on historically elevated nitrate loads, using calculated yields and loads. Preference is given to locations with documented, persistent nutrient concerns or where nitrate inputs are expected to be significant.

2.2.2 Hydrologic monitoring requirement

Each site must have an existing streamflow monitoring gage or be located where a monitoring gage represents the stream flow at the monitoring location. Co-location of water-quality sensors with streamflow measurements is required to support accurate nutrient load calculations.

2.2.3 Power availability

Sites with access to Alternating Current (AC) power are preferred to ensure reliable, long-term operation. Where AC power is unavailable, sites must have sufficient solar exposure, including minimal shading and suitable mounting locations, to support solar-powered systems.

2.2.4 Sensor location

Sensors should be deployed in locations that protect them from damage during high-flow conditions. This is often achieved by placing sensors behind bridge pilings, piers, or other structures that reduce exposure to debris and strong currents.

Sensors must be oriented to minimize the likelihood of catching debris that could block or damage the sensor.

Sensors should also be placed where they accurately represent overall stream conditions. This will be confirmed through a cross-sectional survey as described in Section 6.0.

2.2.5 Common infrastructure and accessibility

Bridge-mounted locations are preferred because they:

- Provide protection from floating debris.
- Allow safe, efficient, and repeatable installation and access for maintenance and calibration at nearly all river stages.
- Offer stable mounting points for sensors, enclosures, and power systems.

Shore-mounted configurations may be used when bridge mounting is not feasible. Acceptable configurations include:

Track and carriage systems

- Used when no bridge is present or when bridge mounting cannot be implemented.
- Site must be well mixed.
- Channel depth must be sufficient to keep the sensor submerged during low-flow conditions.
- Channel morphology (erosion and deposition) must be considered and adapted to over time.
- Commonly used at sites with existing water quality sensors.

Plastic pipe with shuttle

- Used at sites where simple, low-profile installations are required.
- Must meet the same mixing and depth requirements as other shore-mounted configurations.

Concrete block on stream bed

- Used when no bridge is present or when other options are not feasible.
- Typically used in very small streams .
- Sensor is attached to block and placed in stream securely (typically secured with posts or rebar).
- The sensor may not be assessable at all stream flows/levels.

2.2.6 Hydrodynamic and mixing characteristics

Selected sites should exhibit well-mixed and uniform water chemistry both horizontally across the channel and vertically within the water column. This minimizes sampling bias and ensures point measurements are representative of overall stream conditions.

2.2.7 Sensor accessibility

Whenever feasible, sensors should be installed in locations that allow access under all streamflow conditions to support routine maintenance, calibration, and data quality assurance.

3 Calibration of sensors

Calibration solutions must be selected at one concentration level higher than the expected maximum nitrate + nitrite (NO_3 + NO_2) concentration at the monitoring site. Common calibration standard concentrations include 5.56, 11.3, 22.6, and 45.2 milligrams per liter (mg/L).

All calibration activities must follow manufacturer guidance.

All calibration and maintenance activities must be documented in the GoCanvas application. Upon submission, measured values from the completed forms must be uploaded to the WISKI database for quality assurance/quality control (QA/QC) review, verification, and correction as necessary. Completed forms must be archived for reference as needed

3.1 Calibration procedures

Calibration must be performed in accordance with manufacturer instructions.

Sensor readings must meet the following acceptance criteria.

3.2 Expected sensor readings

Open air:

- 0 mg/L

Certified 0 mg/L water:

- 0 mg/L

Calibration standards (80-120% Percent Recovery):

The formula used to calculate percent recovery, where %R is percent recovery.

$$\%R = \frac{Measured\ Value}{Known\ Value} \times 100$$

- 5.56 mg/L → acceptable range: 4.49–6.67 mg/L
- 11.30 mg/L → acceptable range: 9.04–13.56 mg/L
- 22.60 mg/L → acceptable range: 18.08–27.12 mg/L
- 45.20 mg/L → acceptable range: 36.16–54.24 mg/L

If any calibration adjustment or correction is performed, the sensor slope, offset, and pre- and post-calibration values must be recorded in the GoCanvas calibration form and/or calibration sheet.

3.2.1 Troubleshooting

If sensor readings fall outside the thresholds defined in Section 3.2, the sensor must be recleaned and recalibrated. If the sensor continues to produce measurements that do not meet acceptance criteria, it must be returned to the manufacturer for repair.

4 Deployment of sensors

4.1 Timing of deployment

Sensors should be deployed as close to ice-out or spring thaw as practicable. By this time, sensors are expected to have been serviced by factory technicians and be in optimal working condition. Despite factory servicing, a calibration check must be performed prior to deployment as an additional quality assurance/quality control (QA/QC) measure.

4.2 Side-by-side sensor comparison

A side-by-side sensor comparison is required during every calibration or maintenance visit to support QA/QC verification. The portable field sensor used should be calibrated to the same concentration of the site sensor.

4.2.1 Pre-cleaning comparison

- Position the field (portable) sensor as close as possible to the site (installed) sensor without interfering with normal operation.
- Allow both sensors to stabilize.
- Record pre-cleaning comparison values for both sensors in the GoCanvas application and/or calibration sheet.
    - This pre-cleaning value taken from the portable field sensor is used in WISKI for data corrections at the end of the season.

4.2.2 Post-cleaning comparison

- After all cleaning, calibration, and maintenance activities are complete, reposition the field sensor as close as possible to the site sensor without interfering with normal operation.
- Allow both sensors to stabilize.
- Record post-cleaning comparison values for both the field and site sensors in the GoCanvas application.

4.2.3 Troubleshooting

These comparisons are required to verify sensor performance before and after maintenance activities. If sensor readings fall outside the thresholds of 20% relative percent difference (RPD), the sensor must be recleaned and recalibrated. If the sensor continues to produce measurements that do not meet acceptance criteria, it must be returned to the manufacturer for repair.

5 Monthly maintenance

5.1 Monthly maintenance

Monitoring sites must be visited frequently to ensure the collection of high-quality data. Although cleaning and calibration are not required at every site visit, they must be performed every 4–6 weeks to maintain data quality. These activities must include a calibration check, sensor cleaning, and side-by-side sensor comparisons conducted both before and after cleaning.[1]

If a site is visited and cleaning and calibration are not completed, a GoCanvas Survey must still be completed to document the visit and include notes on why the visit was conducted.

Other tasks that may or may not be included during monthly maintenance site visits include data downloads, record battery voltage (if applicable), clock verification, confirmation or configuration settings, completion of a general site visit form and collection of grab samples in accordance with the Watershed Pollutant Load Monitoring Network (WPLMN) SOPG.[2]

5.1.1 Pre-cleaning documentation

- Perform a pre-cleaning side-by-side sensor comparison (as described in section 4.2.1 above).
- The recorded portable sensor field value taken prior to the site sensor cleaning and calibration is used in data corrections in WISKI.
- Remove the sensor from the stream.
- Prior to cleaning, photograph the sensor body in its field-condition state.
- Upload the photograph to the **"Before Cleaning – Body"** section of the GoCanvas application or calibration form.

5.1.2 Cleaning the sensor body

Clean the exterior sensor body using an appropriate combination of the following materials, as needed:

- soft bristle brush
- scrub pads
- rags
- distilled, purified or tap water
- vinegar or vinegar solution
- mild non-corrosive household detergents
- <5% hydrochloric acid (HCl) solutions

[1] USGS. 2013. Optical Techniques for the Determination of Nitrate in Environmental Waters. Techniques and Methods 1-D5

[2] MPCA. 2019. Watershed Pollutant Load Monitoring Network (WPLMN): Standard operating procedures and guidance (SOPG). wq-cm1-02.

Remove stains, algae, calcium buildup, and other debris until the exterior surface is restored to a like-new condition.

5.2 Lens area – pre-cleaning documentation

- After the exterior body is clean, carefully disassemble the sensor to expose the lens area by removing appropriate screws or fasteners.
- Photograph the lens area prior to cleaning.
- Upload the photograph to the **"Before Cleaning – Lens"** section of the GoCanvas application.

5.3 Lens and wiper cleaning

Clean the lens area using approved materials, which may include:

- soft bristle brush
- cotton swabs
- rags
- lint free lens wipes
- deionized, purified, tap or stream water
- vinegar solution
- mild non-corrosive household detergents
- <5% Hydrochloric acid solution

Use extreme care to avoid scratching or damaging the optical lens. Remove, clean, and inspect the wiper to ensure it is in like-new working condition.

All cleaning waste and solutions must be disposed of properly in accordance with applicable safety and environmental requirements.

Any use of chemical cleaners is always followed by a distilled or deionized water rinse.[3]

5.4 Post-cleaning documentation – lens

- Photograph the cleaned lens area.
- Upload the photograph to the **"After Cleaning – Lens"** field in the GoCanvas application.

5.5 Reassembly

- Reassemble the sensor, ensuring all screws and fasteners are properly secured.
- Do not overtighten or leave fasteners loose.

[3] USGS. 2000. Guidelines and Standard Procedures for Continuous Water-Quality Monitors: Site Selection, Field Operation, Calibration, Record Computation, and Reporting. Water-Resources Investigations Report 00-4252.

5.6 Post-cleaning documentation – body

- Photograph the fully reassembled and cleaned sensor body.
- Upload the photograph to the **"After Cleaning – Body"** section of the GoCanvas application.

5.7 Calibration

A calibration check must be performed any time the sensor is redeployed into the waterbody. Calibration procedures must follow **Section 3.1 Calibration procedures**.

5.8 Redeployment

After maintenance or calibration, the sensor must be redeployed in the stream using the same installation method and orientation that was used prior to maintenance or calibration.

5.9 Post-cleaning comparison

A post-cleaning comparison must be conducted in accordance with Section 4.2.2.

6 Cross section concentration analysis

6.1 Cross section concentration surveys

A horizontal cross-sectional survey of the stream is conducted at least three times per year and is designed to encompass a range of flow conditions, including high-flow, moderate-flow, and baseflow periods. These surveys are performed using a calibrated portable nitrate sensor.

The purpose of the horizontal cross-sectional survey is to evaluate lateral variability in nitrate concentrations across the stream channel. Results from these surveys indicate whether nitrate concentrations are relatively uniform across the stream width and whether the permanently deployed site sensor is measuring a concentration that is representative of overall stream conditions. Confirming lateral uniformity supports the validity of continuous nitrate data collected at the monitoring site.

Criteria for categorizing high-flow, moderate-flow, and baseflow conditions are established through analysis of the site-specific period of record for streamflow, supplemented by professional judgment. This approach ensures that surveys are conducted under hydrologic conditions that reflect the range of variability observed at each site. Flow percentiles (Q80, Q50, and Q10) represent the percentage of time that discharge exceeds a given value.

- Baseflow – Slow, sustained flow primarily derived from groundwater contributions; less than Q80 of the total streamflow record.
- Moderate flow – Flow conditions approximately equal to Q50 of the total streamflow record.
- High flow – Bank full stage or greater than Q10 of the total streamflow record.

6.1.1 Procedure

1. Divide the stream cross section into 10 equal subsections (USGS 2) using the calculator within the GoCanvas application or as described in Section 6.2.
2. Collect a nitrate + nitrite measurement within each subsection using a calibrated field meter.
3. The sensor should be positioned at mid-depth within the water column whenever possible.
4. Under high-velocity conditions where mid-depth placement is unsafe or impractical, a surface measurement is acceptable.
5. **Cross-section comparison**

   Compare nitrate concentrations measured at the Right Edge of Water (REW) and Left Edge of Water (LEW), defined while facing downstream. The difference between the minimum and maximum nitrate concentrations measured across the entire cross section must not exceed 15% relative percent difference (RPD).

6. **Troubleshooting**

   If the cross-section's minimum and maximum nitrate concentrations exceed 15% RPD, the cause of the difference must be evaluated. If the variation is determined to be a characteristic of the monitoring location, the site may be relocated, or appropriate data correction methods may be applied. Professional judgment should be used when determining whether the observed difference is acceptable, especially in cases of low (<2mg/L) nitrate + nitrite values.

These surveys verify that the fixed sensor location provides representative measurements of overall stream conditions and help identify spatial variability in water quality.

6.2 Stream sectioning formula

A standardized formula should be used to calculate subsection locations and sampling points.

6.2.1 Spacing (distance in feet between stations)

This formula calculates the uniform distance between each measurement point.

$$Spacing = \frac{(REW - LEW)}{10}$$

- Spacing: The distance between any two adjacent stations.
- REW and LEW: Location of Right Edge Wetted/Location of Left Edge Wetted, representing the boundary measurements of the stream section you are dividing. The expression REW – LEW represents the total length of the reach being studied.
- 10: The number of equal sections desired.

6.2.2 Location of section 1 (station 1)

This formula is used to locate the first station.

$$Location1 = \frac{Spacing}{2} + Starting\ Point$$

6.2.3 General station locations

This formula allows you to calculate the location of subsequent stations by adding the fixed spacing to the previous station's location.

$$Location1 + Spacing$$

6.2.4 QA/QC threshold

15% RPD between any of the 10 measurements.

6.2.5 Troubleshooting

If any of the concentrations fall outside the 15% threshold, they should be handled in accordance with the policies outlined in the WISKI User's Manual. Previous data collected may be rejected, corrected, or assigned a lower quality code.

7 Sensor retrieval

7.1 Seasonal sensor removal

After October 31 of each year, the in-stream sensor must be removed from the site. Sensors must be removed prior to ice-in.

Prior to probe removal, a side-by-side comparison must be conducted using a calibrated field meter. The comparison results must be recorded in the GoCanvas application.

No probe calibration or cleaning is required at the time of sensor retrieval. The probe will be cleaned, serviced, and calibrated during off-season maintenance or prior to redeployment, in accordance with manufacturer recommendations.

8 Post-season sensor maintenance

8.1 Sensor cleaning and service

After seasonal retrieval, sensors must be cleaned and prepared for shipment to Hach Bench Services.

At Hach Bench Services, sensors are:

- disassembled
- cleaned
- maintained according to factory specifications
- updated with the latest software and firmware
- repaired or replaced if any components are damaged or worn
- refurbished with replacement of common wear parts and seals

This post-season maintenance ensures sensors remain in optimal working condition and are ready for redeployment during the subsequent monitoring season.

9 Data management

At each site visit, the latest data is downloaded to a USB drive, SD Card or personal computer.

Data is then uploaded and managed in WISKI in accordance with the WISKI Policy and Procedures Manuals.

10 Health and safety

All health and safety measures should be conducted in accordance with the WPLMN SOPG

Reference documents

USGS. 2013. Optical Techniques for the Determination of Nitrate in Environmental Waters. Techniques and Methods 1-D5

MPCA. 2019. Watershed Pollutant Load Monitoring Network (WPLMN): Standard operating procedures and guidance (SOPG). wq-cm1-02.

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