Quantifying uncertainties in watershed nutrient loads: apportionment of uncertainty sources

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Monitoring water quality in agricultural watersheds

N Flux, [N]?
P Flux, [P]?
others...?
Sources of uncertainties when measuring nutrient loads

- Uncertainties on flow rates and cumulated flow
- Uncertainties associated with infrequent sampling
- Uncertainties due to the sampling location in the water column
- Uncertainties due to sample degradation between sampling and analysis
- Uncertainties of laboratory analyses

Optimizing Monitoring

- What should I be particularly careful about to lower uncertainties on loads and improve confidence in my results?
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In a perfect world, perfect continuous data...

\[ L = K \int_{t_0}^{T} q(t)c(t) \, dt \]
Video: daily sampling interval

Sampling interval: 6 days
Sampling interval: 10 days

\[ L = K \int_{0}^{T} c(t) dt \]

\[ \hat{L} = KQ_{\text{cum}} \frac{\sum_{i=1}^{n} c_i q_i}{\sum_{i=1}^{n} q_i} \]
Flow weighted average: least bad method

Uncertainties on flow

- Difficult to fully estimate
- Approach chosen:
  - Flow estimated using rating curves
  - Errors due to
    - number of gauged points,
    - hysteresis of the stage discharge relationship
    - Mathematical relationship chosen as rating curve
Video: 10 gauging points

Video

Video: 26 gauging points

Video
Calculating cumulative uncertainty

\[ E_P = \sqrt{\sum_{i=1}^{n} (E_i^2 + E_2^2 + E_3^2 + \ldots + E_n^2)} \]

Global Sensitivity Analysis (GSA)
Global Sensitivity/Uncertainty Analysis

WHY/WHEN?

Apportions output variance into input factors

GLOBAL SENSITIVITY ANALYSIS

INPUT FACTORS

MODEL

OUTPUTS

UNCERTAINTY ANALYSIS

Propagates input factor variability into output

HOW MUCH?

Step 1: Screening (Morris Method)

• qualitative measure of importance ($\mu^*$) and interaction ($\sigma$) of input factors

• Used as a screening method to reduce number of important factors

Very important factor. Its importance depends some on the values of other parameters

Less important parameter. Its importance depends heavily on the values of other parameters
Step 2: Variance Decomposition

\[ V(Y) = V_1 + V_2 + \ldots + V_k + R \]

V(Y) – variance of output, \( V_i \) – variance due input factor \( X_i \),
k – nr of uncertain factors, R - residual

Simulations

• Reference data with continuous Q and WQ
• Errors on annual loads
• Variables
  o \( \text{NO}_3, \) TP
  o Sampling frequency
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- Variables
  - NO$_3$, TP
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  - Number of gauged points
  - Type of rating curve
Simulations

- Reference data with continuous Q and WQ
- Errors on annual loads
- Variables
  - NO₃, TP
  - Sampling frequency
  - Number of gauged points
  - Type of rating curve
  - Lab errors: systematic (e.g. +5%) or random (e.g. ±5%)
Results – nitrate

Results – TP
Conclusion

• The GSA approach very useful tool for uncertainties on nutrient loads
• Random lab errors weigh little on the overall uncertainties
• Errors due to the number of gauged points small
• Rating curve type very important
• Results may vary dramatically with watersheds and nutrients

Thank you for your attention!

Questions?