Uncertainty in Measured Streamflow and Water Quality Data for Small Watersheds

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Attention on Measured Data Uncertainty

- Intensified disputes about point, nonpoint source contribution
- Increased use of H/WQ models to guide decision-making, TMDLs

wacotrib.com

"Lake Waco Study Still Finds Dairy Waste Big Problem"
Wednesday, March 1, 2006

- Data uncertainty often highlighted in introduction of water quality publications, especially related to H/WQ modeling, but…
  - almost always ignored in data analysis and conclusions
  - "accounted for" with arbitrary margins of safety in TMDLs
  - in spite of need for rigorous, scientific uncertainty analysis

Reasons for Lack of Scientific Uncertainty Analysis

- Scientists have not established an adequate understanding of uncertainty in measured flow and water quality data
  - previous research produced valuable information on uncertainty related to various sampling procedures, but…
    - comparative data are limited
    - no complete uncertainty (error propagation) analysis has been conducted on resulting data

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Objectives

- Provide fundamental scientific estimates of uncertainty in measured streamflow and water quality data for small watersheds
- Present a methodology for subsequent uncertainty analysis
- With hopes of improving
  - data collection QA/QC - focus on significant sources of uncertainty
  - H/WQ modeling - quantify “quality” of calibration and evaluation data to more realistically judge model performance

Methods

- Compiled published uncertainty data
  - flow, TSS, N, and P
  - small watersheds

- Established four procedural categories
  - streamflow measurement
  - sample collection
  - sample preservation/storage
  - laboratory analysis

Procedural Category 1: Flow Measurement

- Steps/sources of uncertainty:
  - individual flow measurements
  - stage discharge relationship
  - continuous stage measurement
  - effect of streambed condition

Procedural Category 2: Sample collection

- Steps/sources of uncertainty:
  - sample collection method
    - manual sampling
      - integrated (EWI, EDI)
      - grab sampling
    - automated sampling
      - single intake
      - time- or flow-interval sampling
  - define storm (minimum flow threshold)

Procedural Category 3: Storage/Preservation

- Steps/sources of uncertainty:
  - container characteristics
  - storage environment
  - sample preservation
  - filtration methodology

Procedural Category 4: Laboratory Analysis

- Steps/sources of uncertainty:
  - sample handling
  - reagent and standard preparation
  - analytical method
  - analytical instrument

Methods

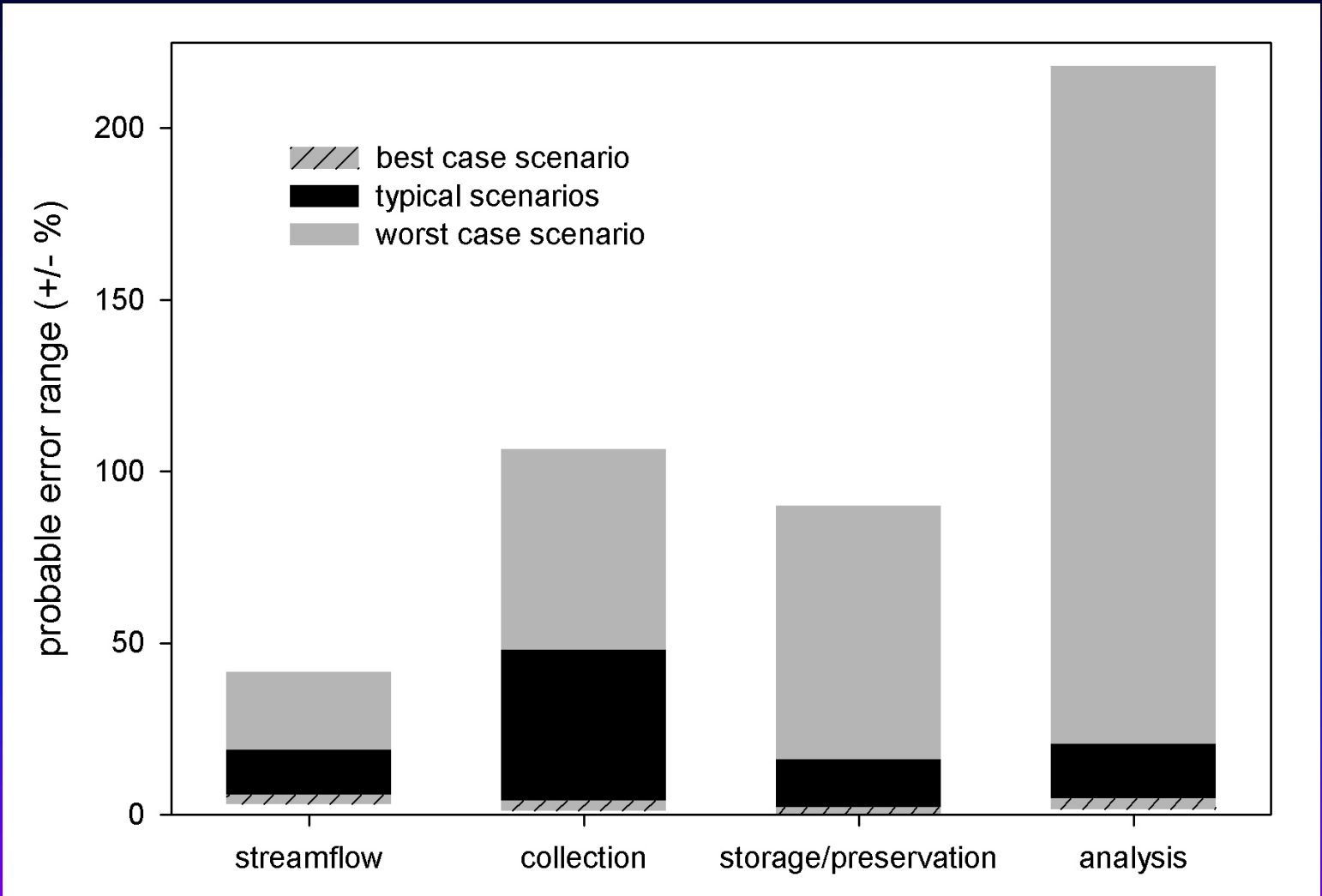
- Created several arbitrary “data quality” scenarios
  - best case – dedicated QA/QC, unlimited resources, ideal conditions
  - worst case – minimal QA/QC, few resources, difficult conditions
  - typical – moderate QA/QC, typical resources and conditions
- For each scenario
  - compared uncertainty introduced by each procedural category
  - calculated cumulative uncertainty in resulting data

Methods

- Root mean square error propagation method (Topping, 1972)
  - includes all steps required to measure flow and water quality data
  - widely-accepted error propagation method
    - previously used for discharge, pesticides
  - combines all potential errors to produce realistic estimates of overall error (cumulative probable uncertainty)
  - assumes potential errors are bi-directional and non-additive

$$E_P = \sqrt{\sum_{i=1}^{n}\left(E_1^{\,2} + E_2^{\,2} + E_3^{\,2} + \ldots + E_n^{\,2}\right)}$$

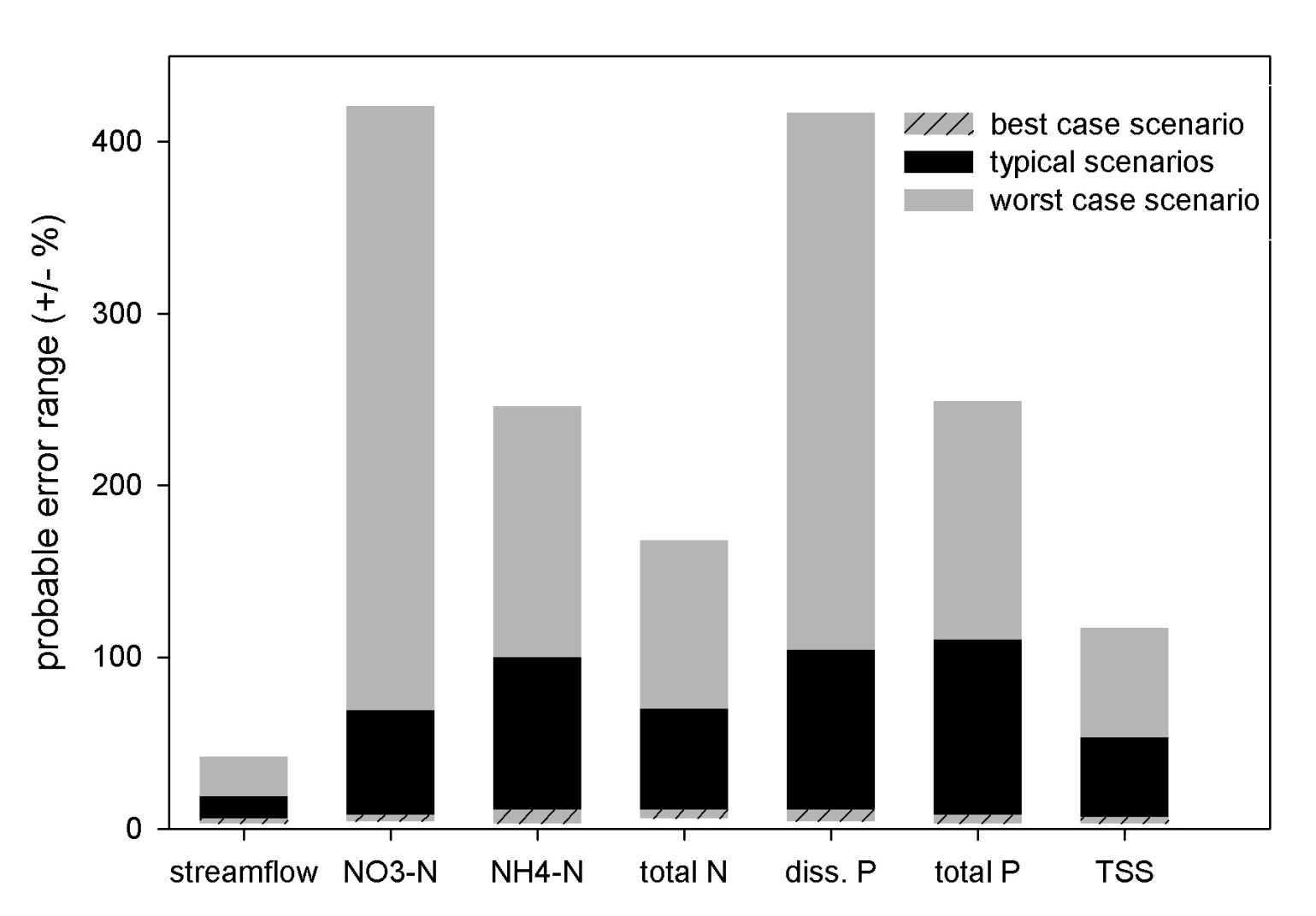
Results and Discussion



Results and Discussion

- Changes in current QA/QC methodology needed
  - sample preservation/storage and lab analysis typically emphasized
  - flow measurement and sample collection should not be ignored
  - in fact, sample collection may introduce the most uncertainty in typical scenarios
- Martin et al. (1992) made a similar observation
  - recognized the relative lack of discussion on sample collection methodology in publications that address standard methods for evaluating water quality

Results and Discussion



Results and Discussion

- Uncertainty in measured storm loads (kg/ha)
  - flow measurement, sample collection, preservation/storage, analysis
- Uncertainty in measured storm concentrations (mg/l)
  - sample collection, preservation/storage, lab analysis
  - <10% reduction
- Uncertainty in measured baseflow concentrations (mg/l)
  - preservation/storage, lab analysis
  - 3-35% reductions for typical scenarios

Conclusions – Related to H/WQ Modeling

- It is hoped that this research will improve H/WQ modeling
  - quantify the "quality" of calibration and evaluation data
    - use (±%) presented uncertainty estimates -or-
    - use methodology to make site- or project specific estimates
  - judge model performance (calibration, validation, evaluation) realistically based on "data quality"
    - "typical" data - model output within ± 30% may be appropriate
    - "best case" data – models held to a higher standard (±5%)
    - "worst case" data - little value for modeling

General Conclusions – Related to Data Uncertainty

- Important for all hydrology and water quality professionals to understand that…
  - measured streamflow and water quality data are uncertain
  - uncertainty increases dramatically without dedicated QA/QC
  - collection of high quality data requires considerable time, expense, personnel commitment
  - little value in poor quality data
  - no longer acceptable to acknowledge measured data uncertainty but fail to consider it in data analysis and decision making

Any Questions??

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