Uncertainty in Measured Streamflow and Water Quality Data for Small Watersheds

Daren Harmel, Rick Haney, Jeff Arnold – USDA-ARS, Temple, TX
Richard Cooper – Macaulay Institute, Aberdeen, Scotland
Raymond Slade – USGS retired, Austin, TX

Agricultural Research Service

Grassland Soil and Water Research Laboratory, Temple, TX

THE MACAULAY INSTITUTE

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

Agricultural Research Service

Grassland Soil and Water Research Laboratory, Temple, TX

THE MACAULAY INSTITUTE

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**

Agricultural
Research
Service

Grassland Soil and Water Research Laboratory, Temple, TX

THE MACAULAY INSTITUTE

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

Agricultural Research Service

THE MACAULAY INSTITUTE

Procedural Category 4: Laboratory Analysis

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

Methods

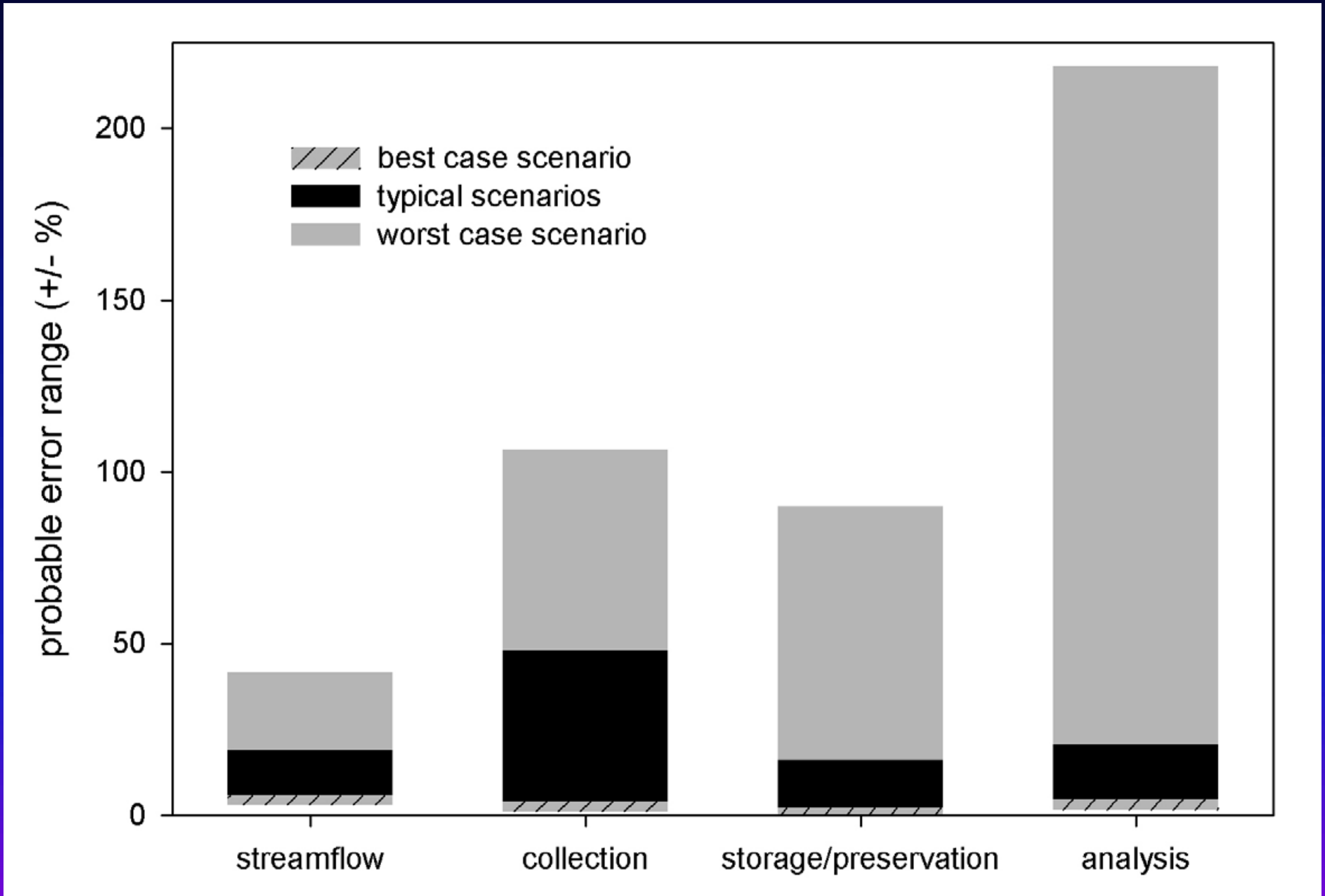
- Created several arbitrary "data quality" scenarios
  - best case – dedicated QA/QC, unlimited resources, ideal conditions
  - worst case – minimal QA/QC, few resources, difficult conditions
  - typical – moderate QA/QC, typical resources and conditions
- For each scenario
  - compared uncertainty introduced 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

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

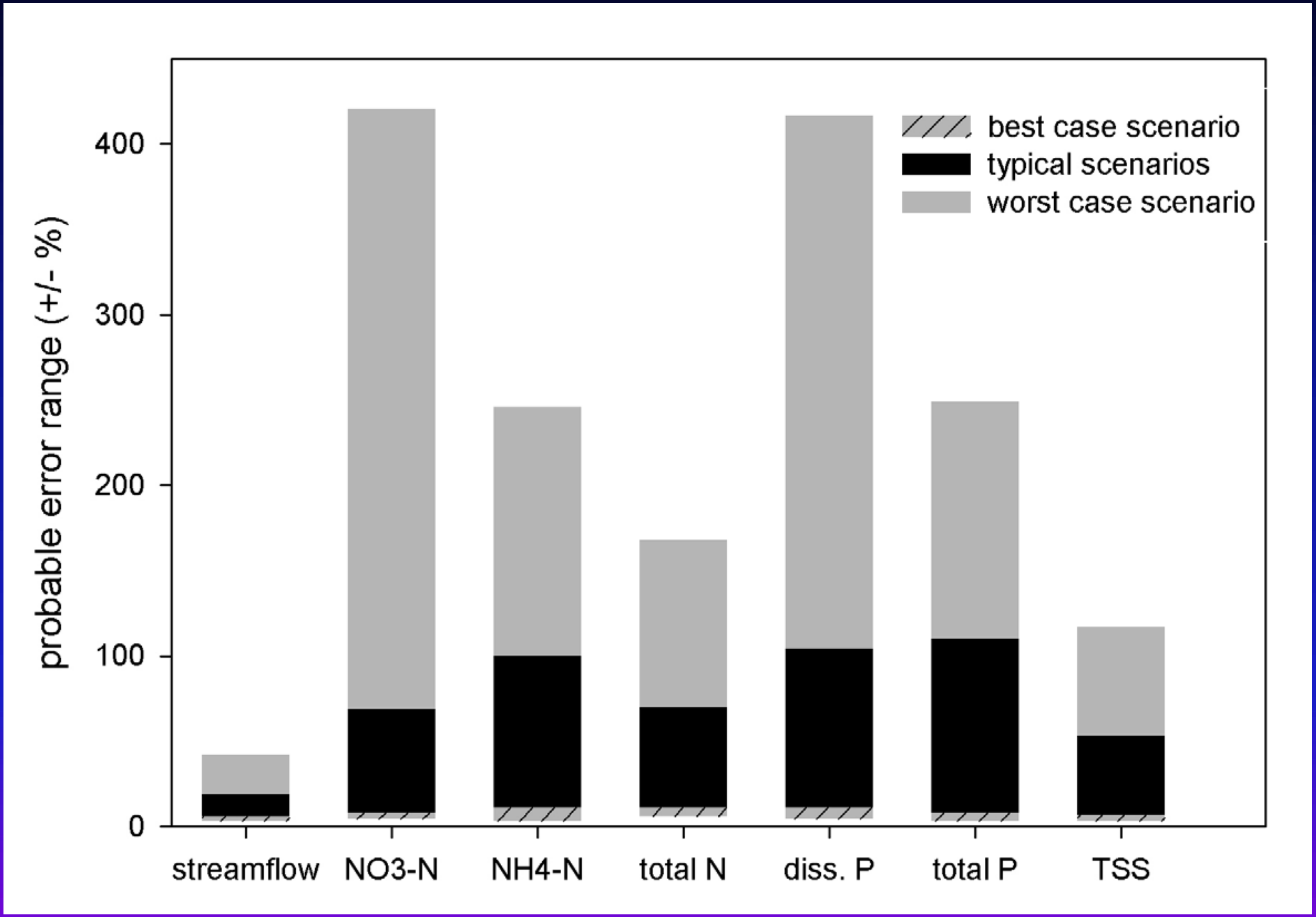
Results and Discussion



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

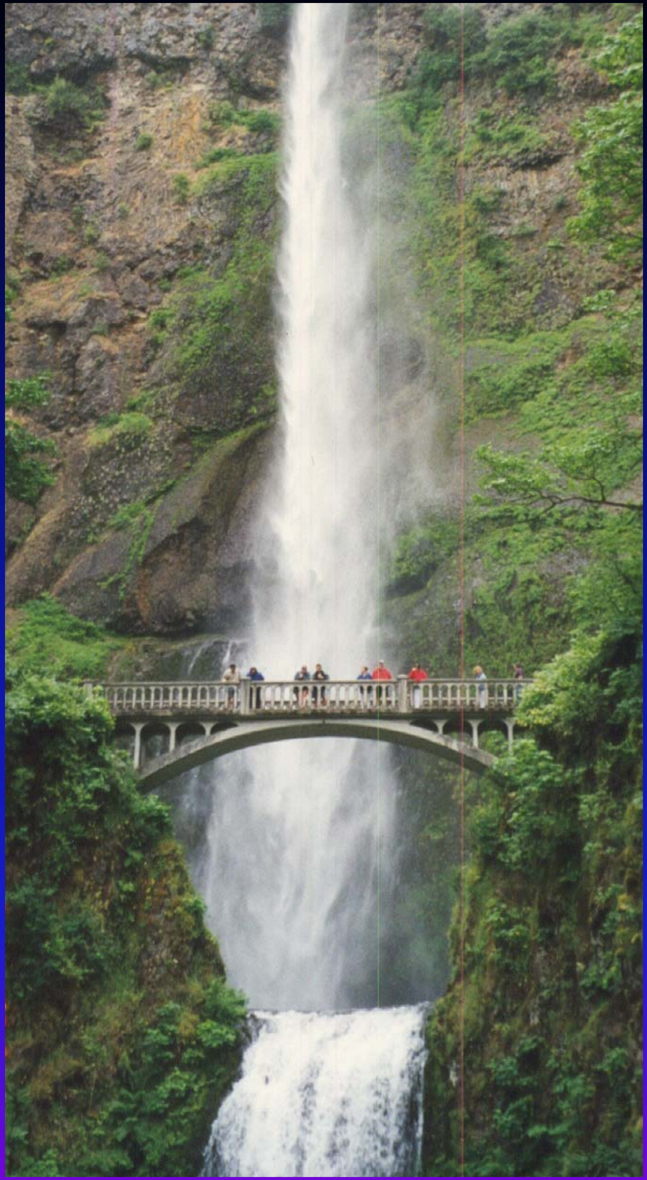
- Uncertainty in measured storm loads (kg/ha)
  - flow measurement, sample collection, preservation/storage, analysis
- Uncertainty in measured storm concentrations (mg/l)
  - sample collection, preservation/storage, lab analysis
  - <10% reduction
- Uncertainty in measured baseflow concentrations (mg/l)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

Daren Harmel, PhD
USDA-ARS
808 E. Blackland Rd.
Temple, TX

(254) 770-6521
dharmel@spa.ars.usda.gov
http://www.ars.usda.gov