Data Uncertainty Estimation Tool for Hydrology and Water Quality (DUET-H/WQ):

Estimating Measurement Uncertainty for Monitoring and Modeling Applications

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Objectives

- Present background information on uncertainty in flow and water quality data
- Describe the Data Uncertainty Estimation Tool for Hydrology and Water Quality (DUET- H/WQ)
- Present results of DUET- H/WQ application to measured data
- Briefly discuss relevance to model calibration and validation

Introduction

"Should it not be required that every… (field and modeling study) …attempt to evaluate the uncertainty in the results?" Beven (2006)

"The use of uncertainty estimation… (should be)…routine in hydrological and hydraulic science." Pappenberger, Beven (2006)

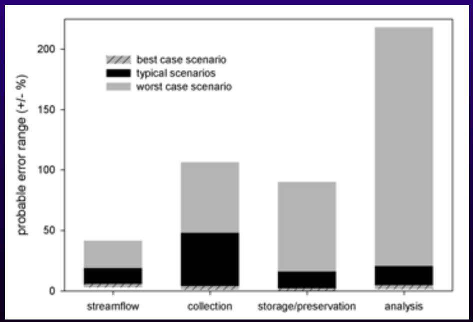
- **Data uncertainty is almost always ignored in analysis and reporting of H/WQ data**
  - **In spite of such calls for uncertainty analysis.**
  - **In spite of the fact that all measurements are inherently uncertain.**

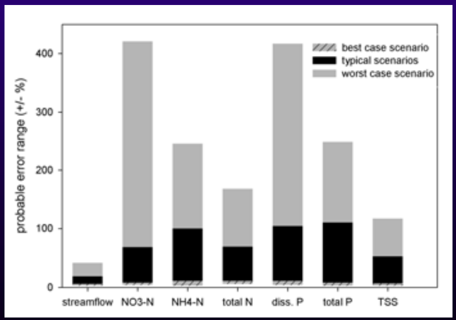
Introduction

- **Why is data uncertainty typically ignored?? Until recently…**
  - **An adequate understanding of H/WQ measurement uncertainty had not been established.**
  - **No complete uncertainty (error propagation) analysis had been conducted on measured H/WQ data.**
  - **No easy-to-use tool was available to assist with uncertainty estimation in H/WQ.**

Uncertainty Estimation Framework (2006)

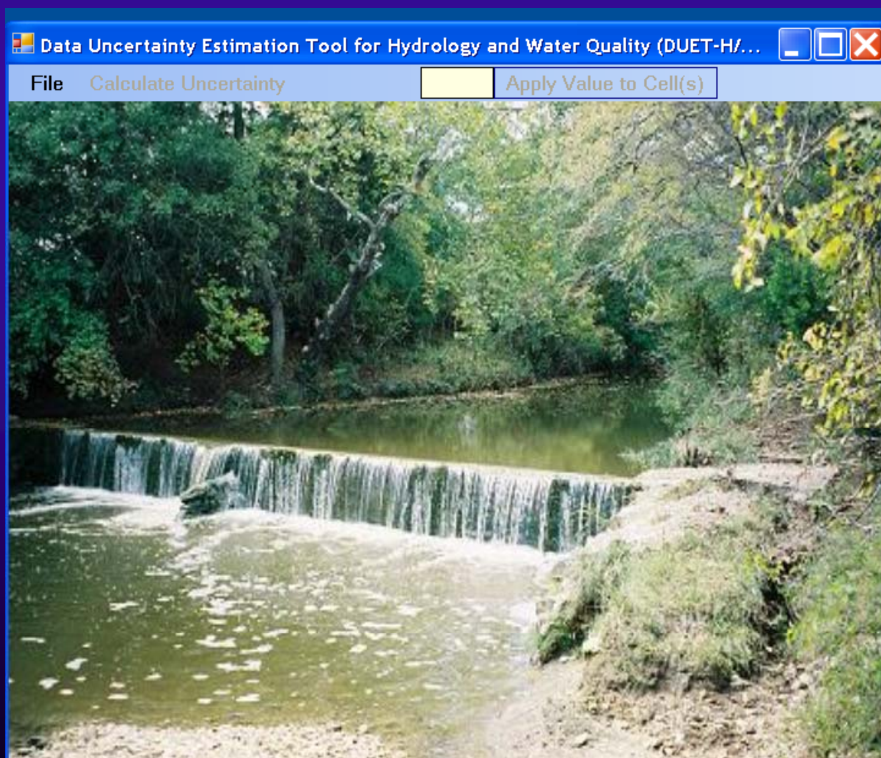
- Focused on Q, TSS, N, and P data for small watersheds
- Provided published uncertainty estimates for data collection steps within each of four procedural categories
  - discharge measurement, sample collection, sample preservation/storage, laboratory analysis
- For arbitrary "data quality" scenarios (best, typical, worst)
  - compared uncertainty introduced by each procedural category
  - calculated cumulative uncertainty in resulting data

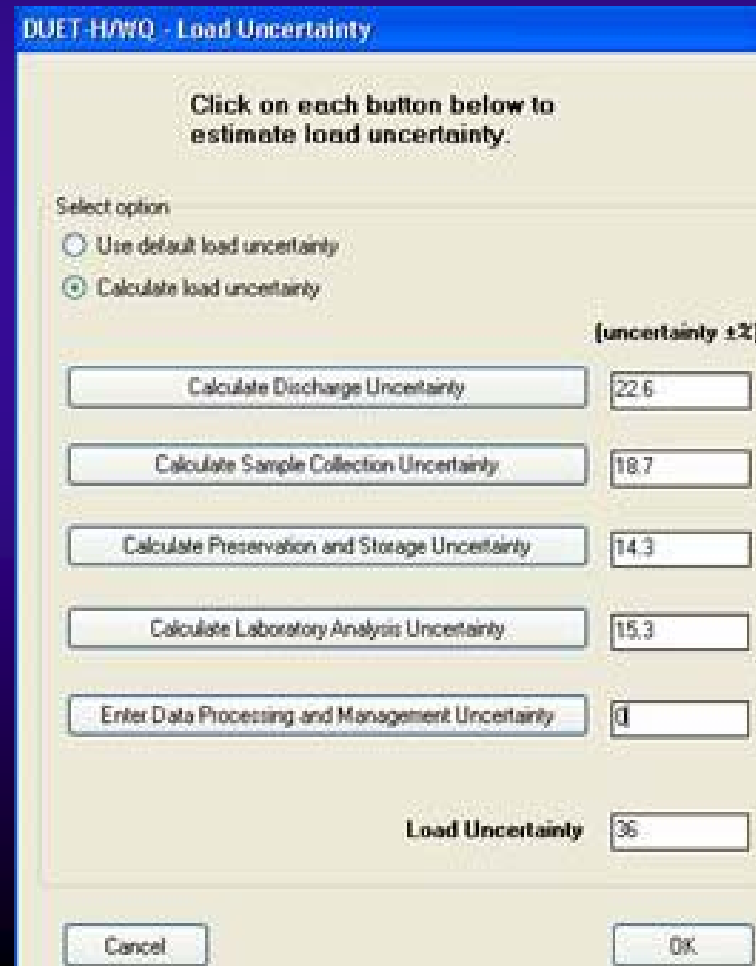




DUET- H/WQ (2009)

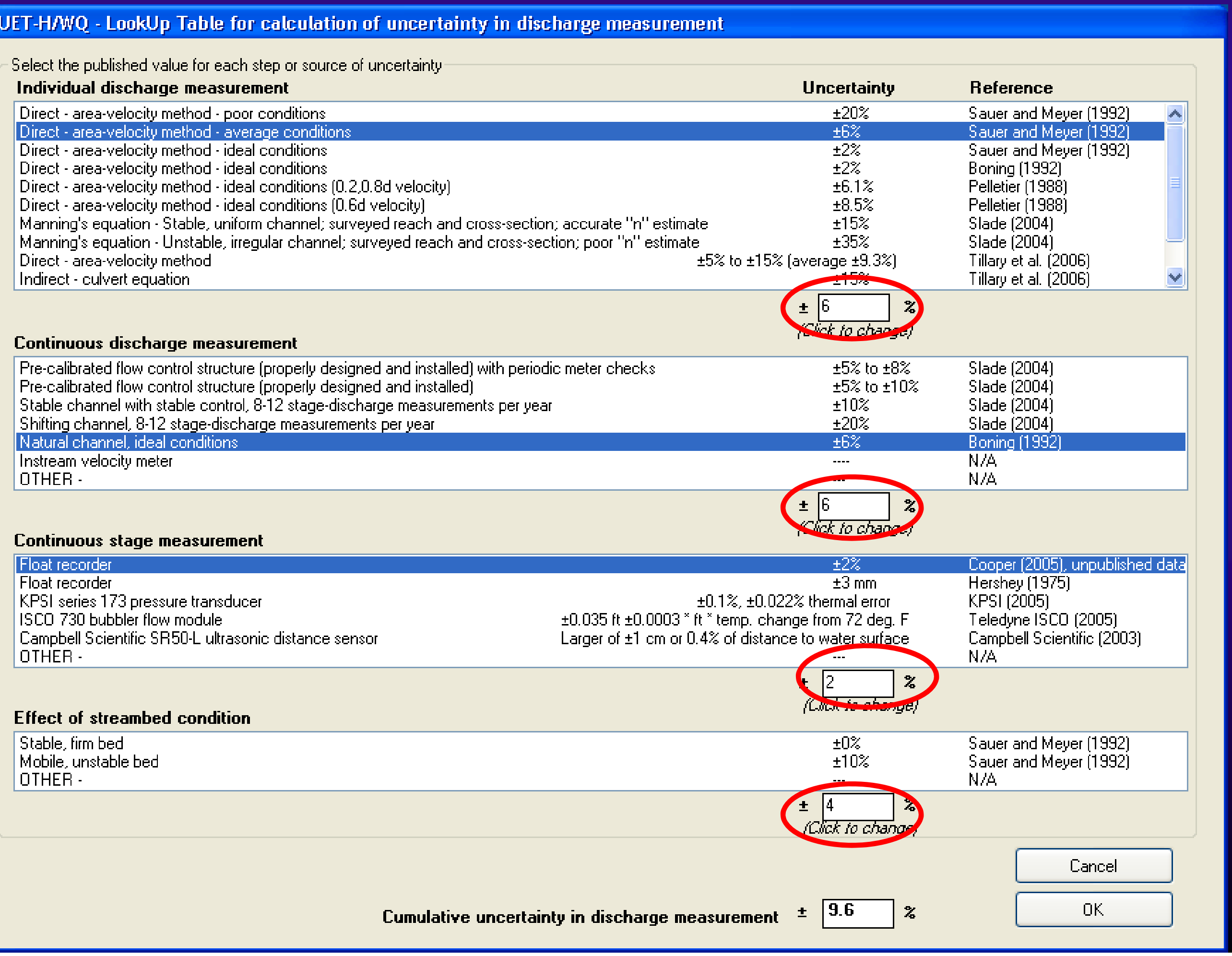
- Based on 2006 framework
- Added "data processing and management" procedural category





DUET- H/WQ

- **Uses the RMSE method to determine uncertainty**
  - **within each procedural category**



$$E_Q = \sqrt{\sum \left({E_{Q1}}^2 + {E_{Q2}}^2 + {E_{Q3}}^2 + {E_{Q4}}^2 \right)}$$

DUTET- H/WQ

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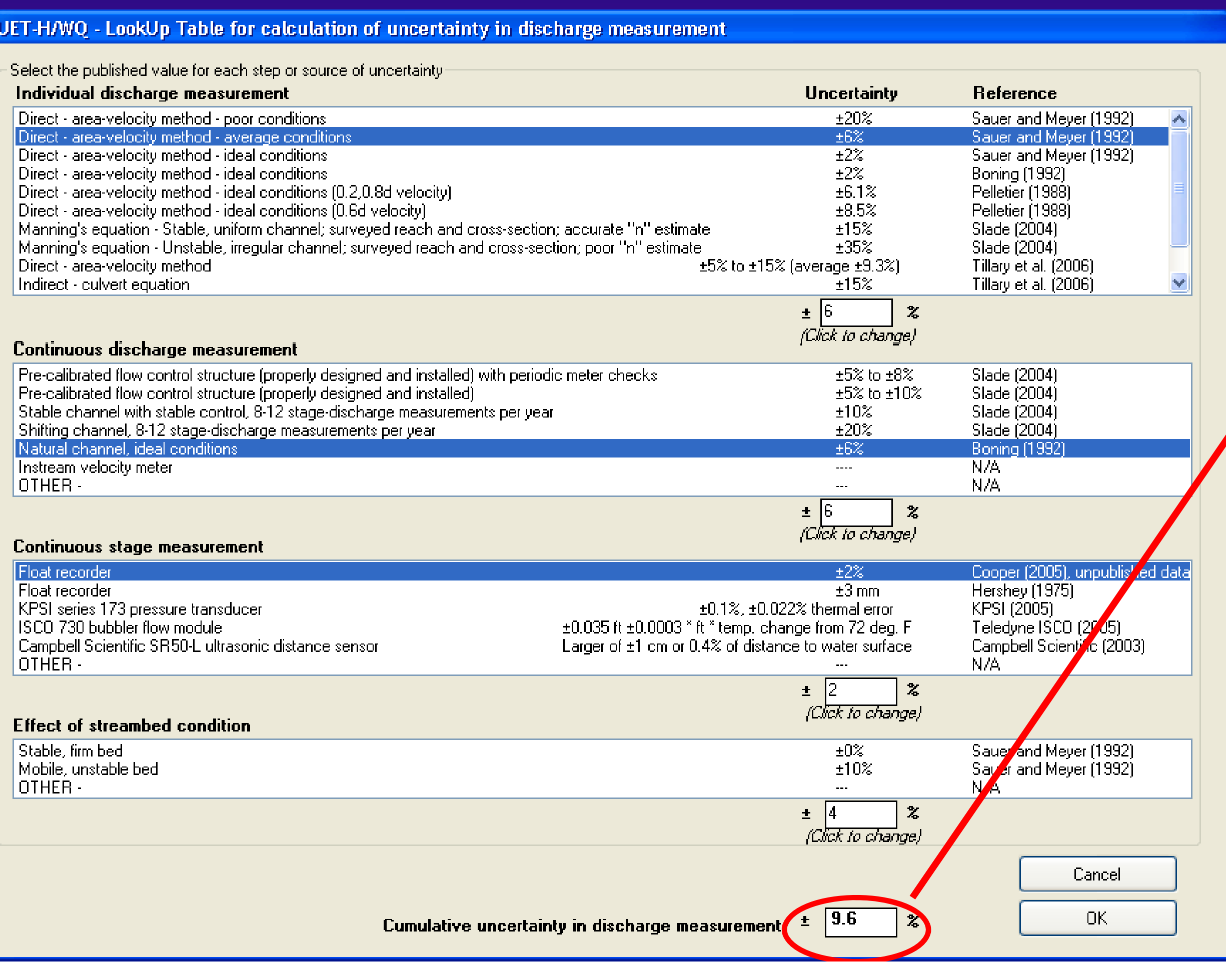
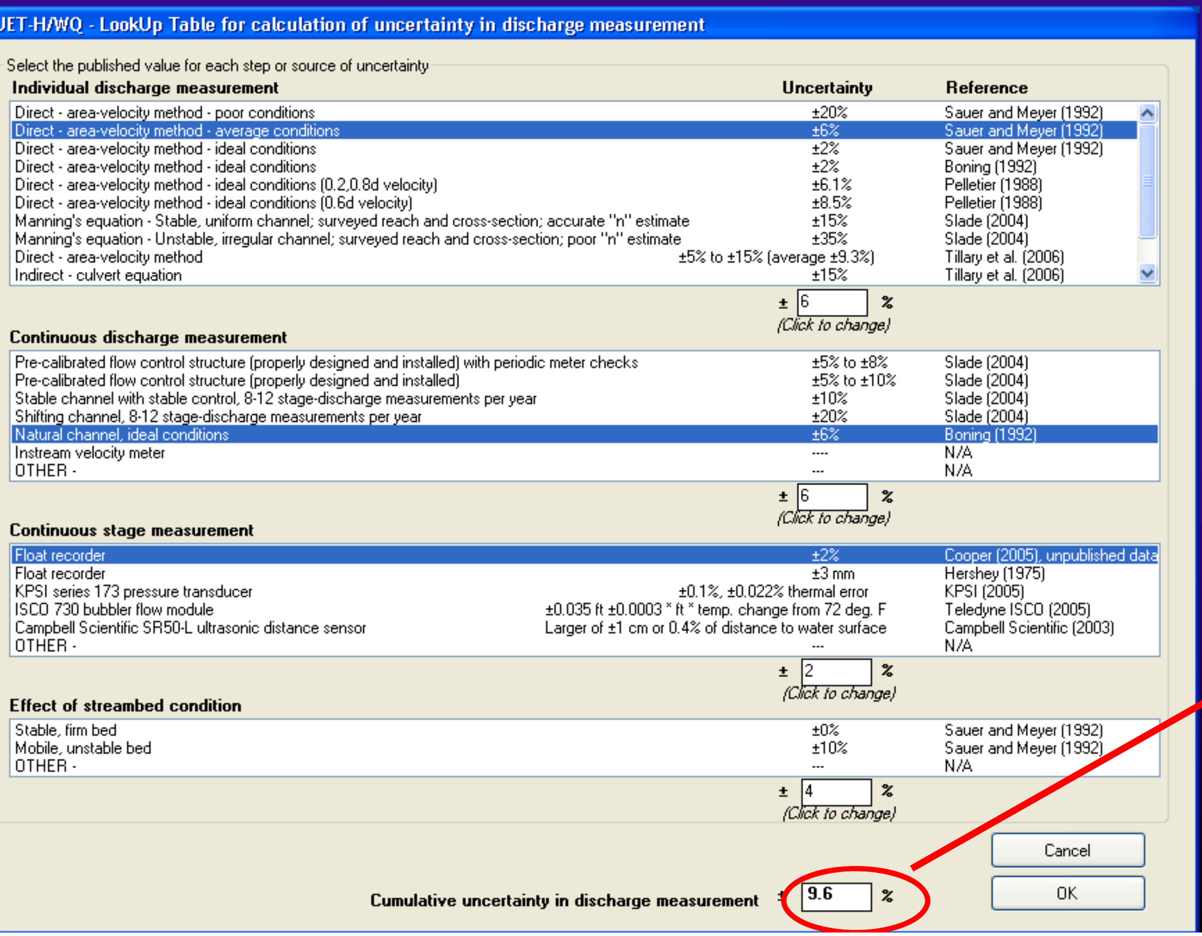


$$E_Q = \sqrt{\sum \left(E_{Q1}^{\ 2} + E_{Q2}^{\ 2} + E_{Q3}^{\ 2} + E_{Q4}^{\ 2} \right)}$$

DUET- H/WQ

- **Uses the RMSE method to determine uncertainty**
  - **within each procedural category**
  - **for individual measured discharge, concentration, load values**



JET-H/WQ - LookUp Table for calculation of uncertainty in discharge measurement

Select the published value for each step or source of uncertainty

Individual discharge measurement

Individual discharge measurement	Uncertainty	Reference
Direct - area-velocity method - poor conditions	±20%	Sauer and Meyer (1992)
Direct - area-velocity method - average conditions	±6%	Sauer and Meyer (1992)
Direct - area-velocity method - ideal conditions	±2%	Sauer and Meyer (1992)
Direct - area-velocity method - ideal conditions	±2%	Boning (1992)
Direct - area-velocity method - ideal conditions (0.2,0.8d velocity)	±6.1%	Pelletier (1988)
Direct - area-velocity method - ideal conditions (0.6d velocity)	±8.5%	Pelletier (1988)
Manning's equation - Stable, uniform channel; surveyed reach and cross-section; accurate "n" estimate	±15%	Slade (2004)
Manning's equation - Unstable, irregular channel; surveyed reach and cross-section; poor "n" estimate	±35%	Slade (2004)
Direct - area-velocity method	±5% to ±15% (average ±9.3%)	Tillary et al. (2006)
Indirect - culvert equation	±15%	Tillary et al. (2006)

± 6 % (Click to change)

Continuous discharge measurement

Pre-calibrated flow control structure (properly designed and installed) with periodic meter checks	±5% to ±8%	Slade (2004)
Pre-calibrated flow control structure (properly designed and installed)	±5% to ±10%	Slade (2004)
Stable channel with stable control, 8-12 stage-discharge measurements per year	±10%	Slade (2004)
Shifting channel, 8-12 stage-discharge measurements per year	±20%	Slade (2004)
Natural channel, ideal conditions	±6%	Boning (1992)
Instream velocity meter	----	N/A
OTHER -	---	N/A

± 6 % (Click to change)

Continuous stage measurement

Float recorder	±2%	Cooper (2005), unpublished data
Float recorder	±3 mm	Hershey (1975)
KPSI series 173 pressure transducer	±0.1%, ±0.022% thermal error	KPSI (2005)
ISCO 730 bubbler flow module	±0.035 ft ±0.0003 * ft * temp. change from 72 deg. F	Teledyne ISCO (2005)
Campbell Scientific SR50-L ultrasonic distance sensor	Larger of ±1 cm or 0.4% of distance to water surface	Campbell Scientific (2003)
OTHER -	---	N/A

± 2 % (Click to change)

Effect of streambed condition

Stable, firm bed	±0%	Sauer and Meyer (1992)
Mobile, unstable bed	±10%	Sauer and Meyer (1992)
OTHER -	---	N/A

± 4 % (Click to change)

Cancel

OK

Cumulative uncertainty in discharge measurement ± 9.6 %

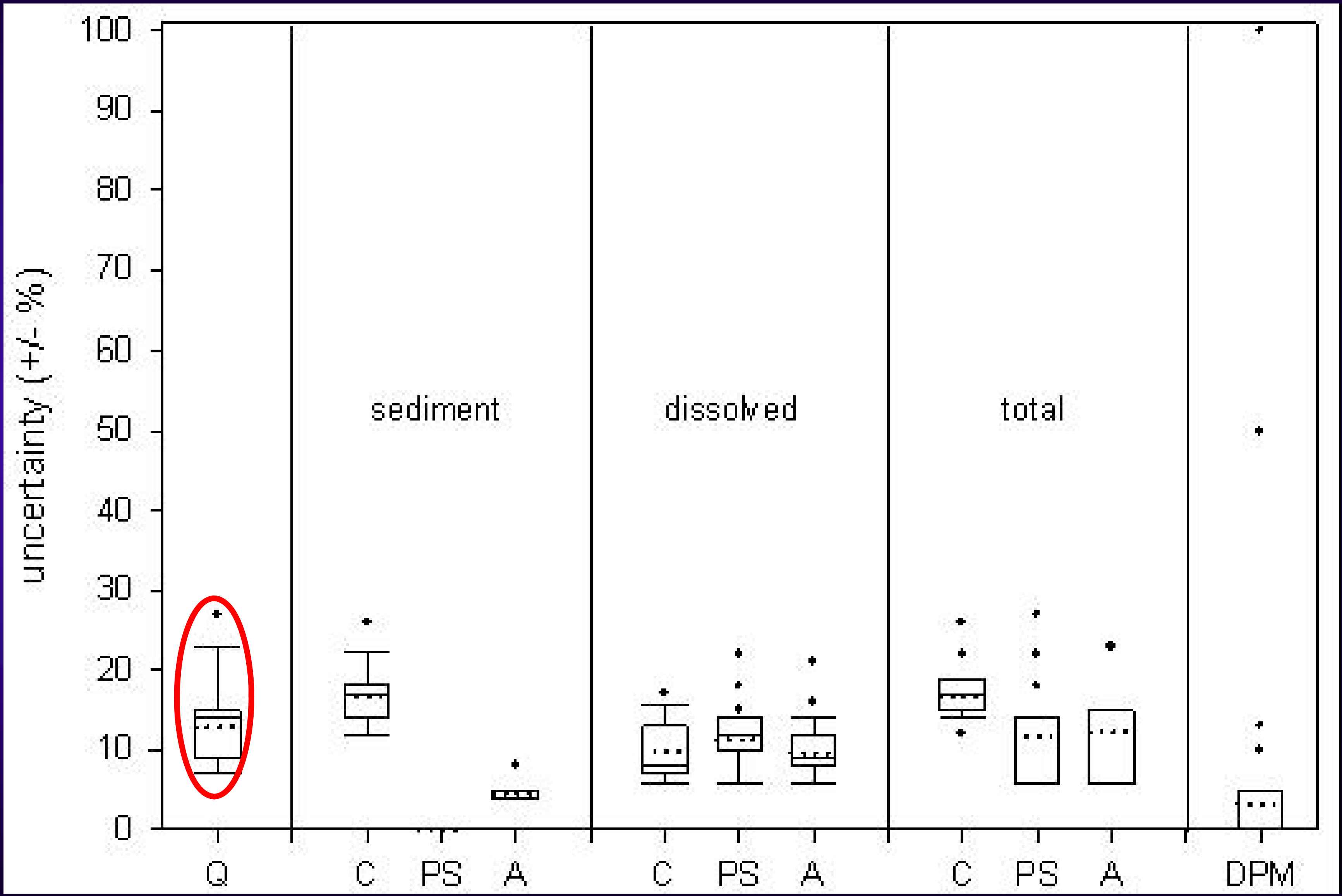
$$EP = \sqrt{\sum \left(E_Q{}^2 + E_C{}^2 + E_{PS}{}^2 + E_A{}^2 + E_{DPM}{}^2 \right)}$$

DUET- H/WQ Application

- Applied to real-world data sets from five monitoring projects
  - various hydrologic settings, land uses, watershed sizes, and field and laboratory techniques

- Estimated uncertainty in measured Q, TSS, NO_3-N, PO_4-P, total N, and total P data
  - 131 storm events

DUET- H/WQ Application Results



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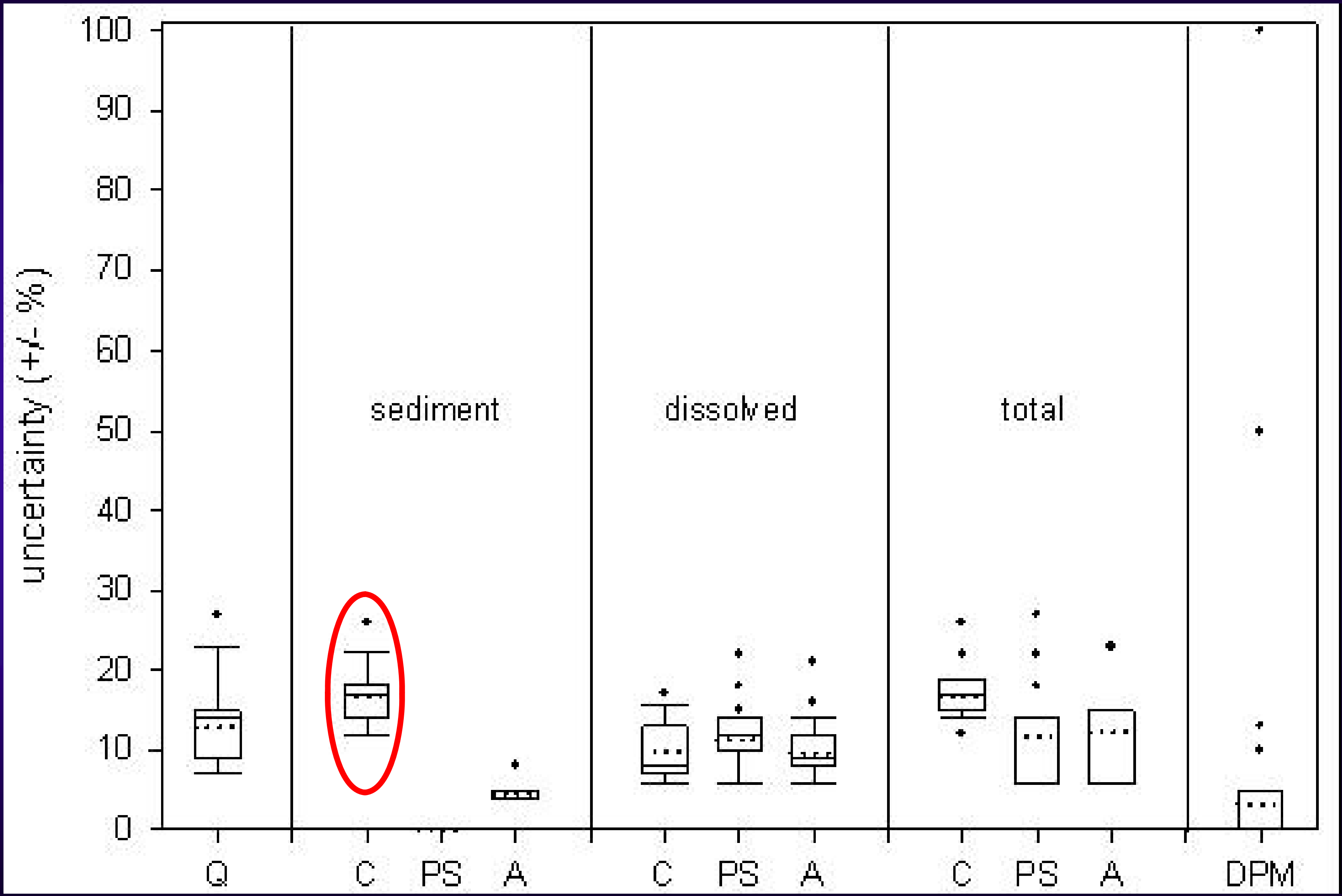

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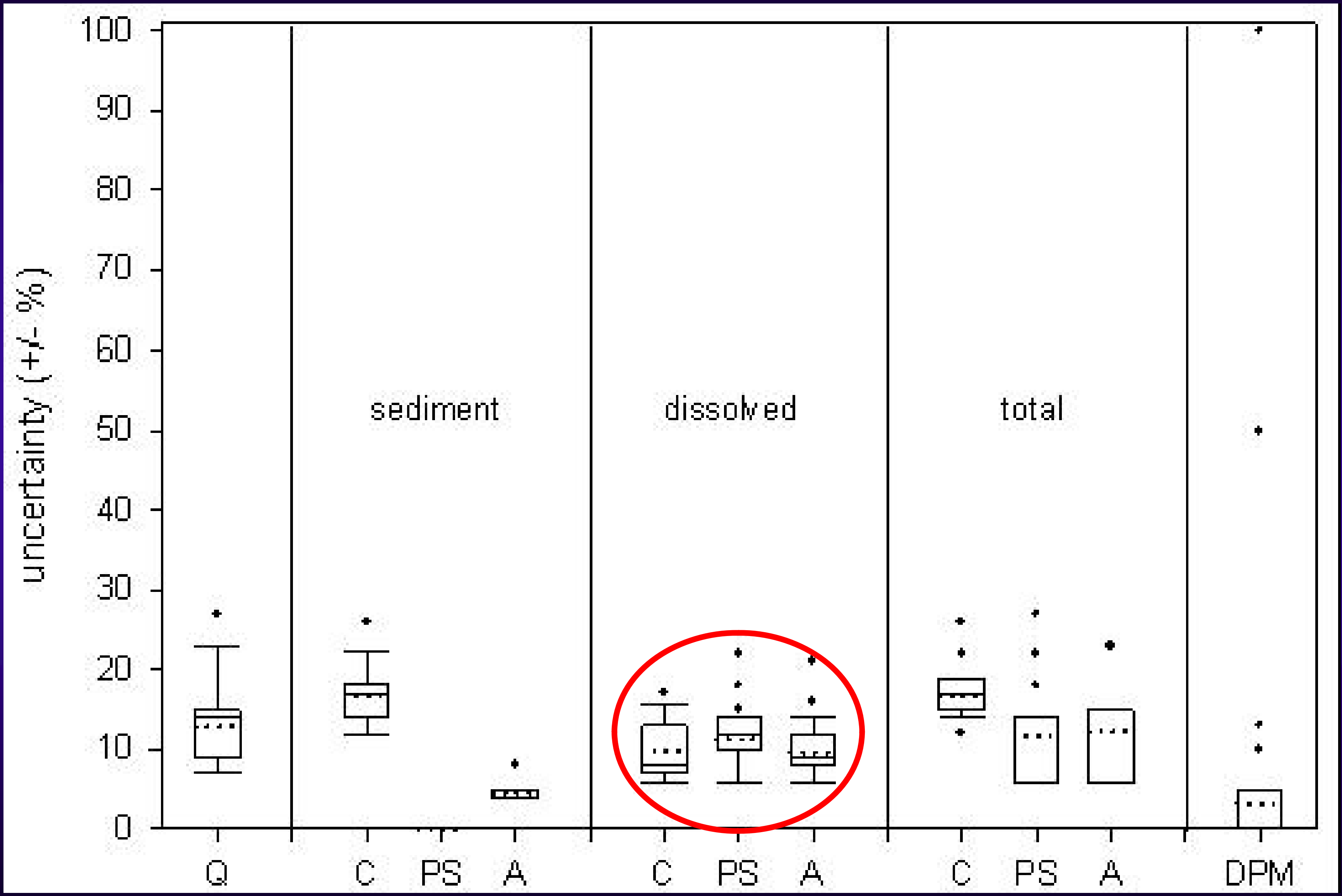

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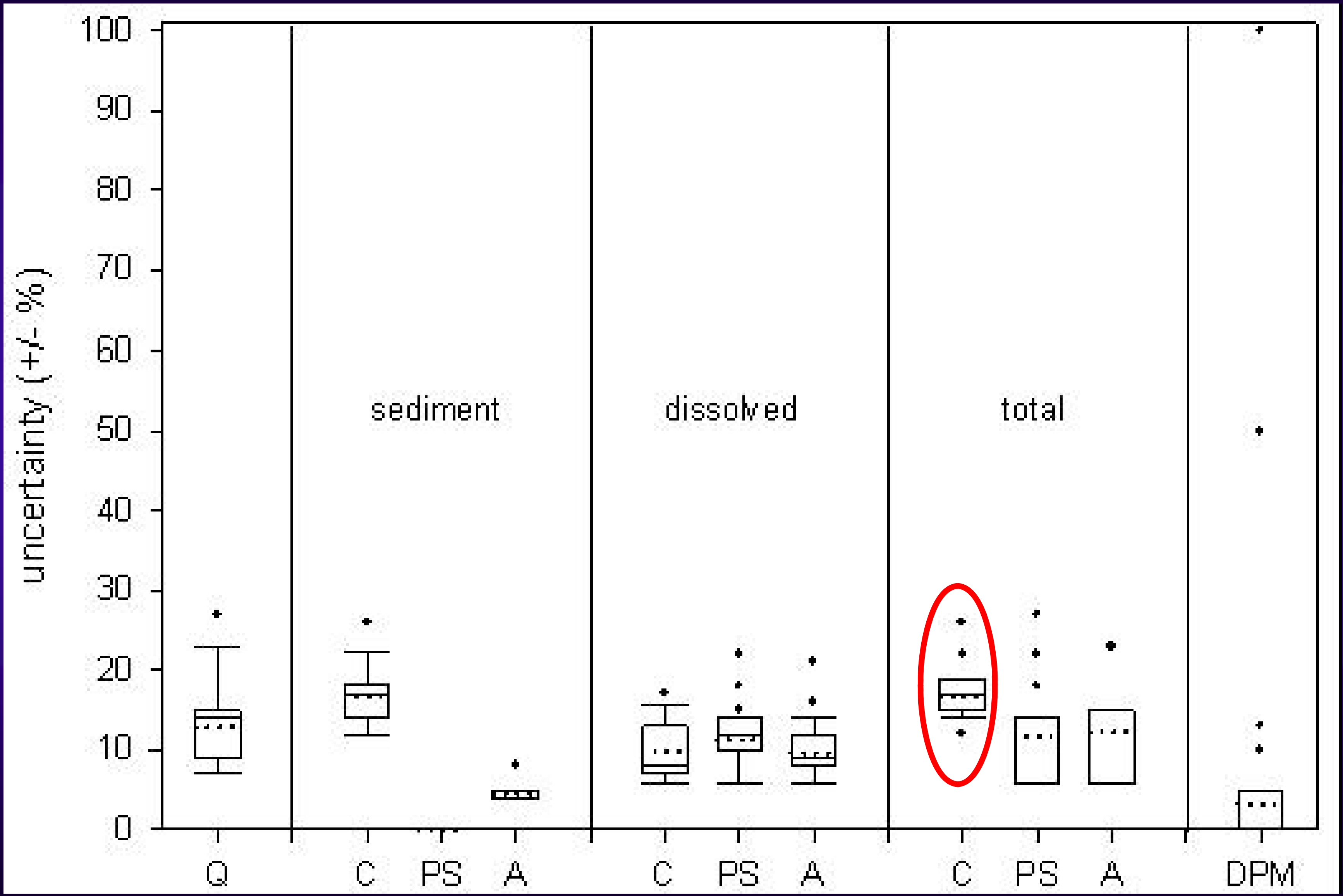

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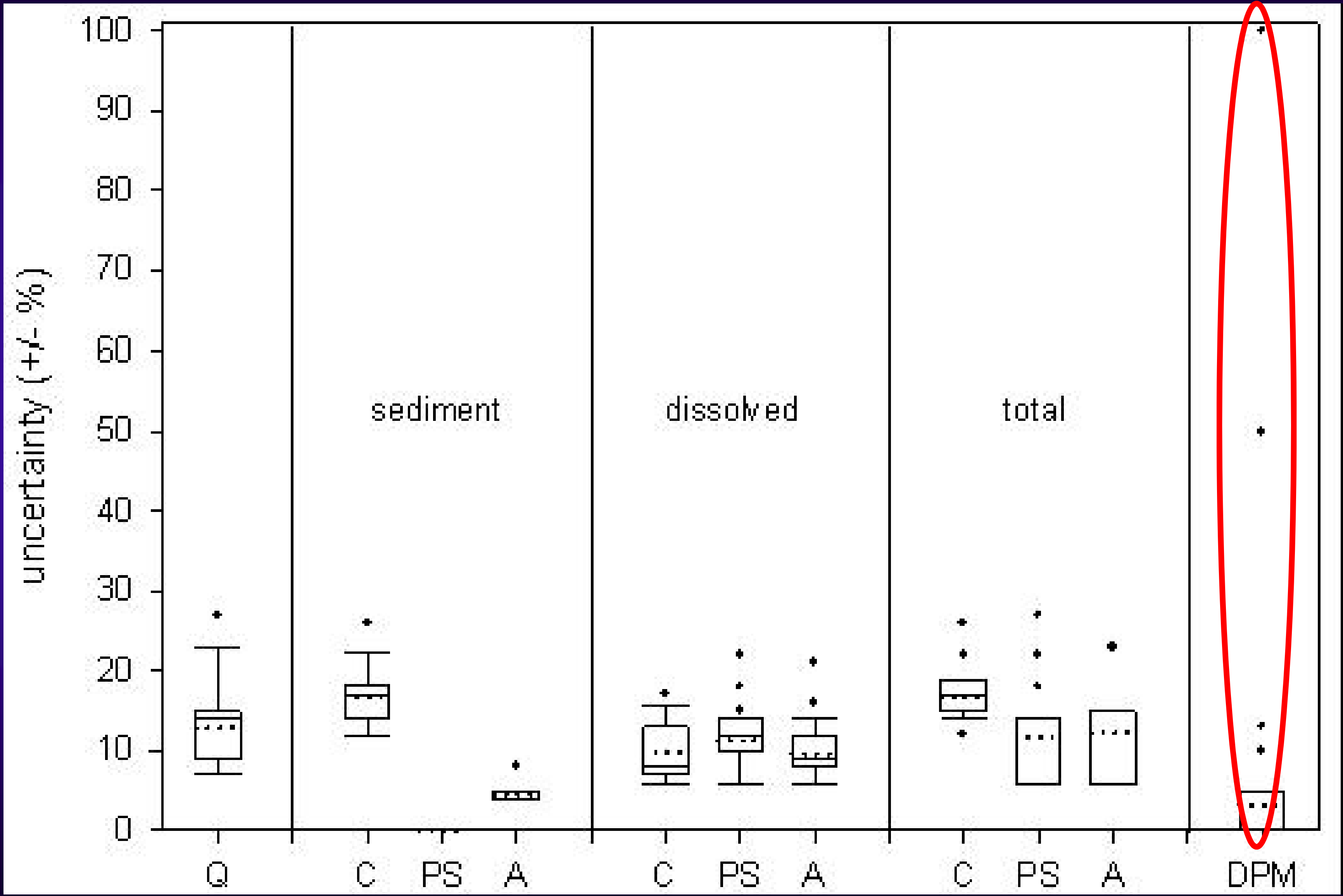

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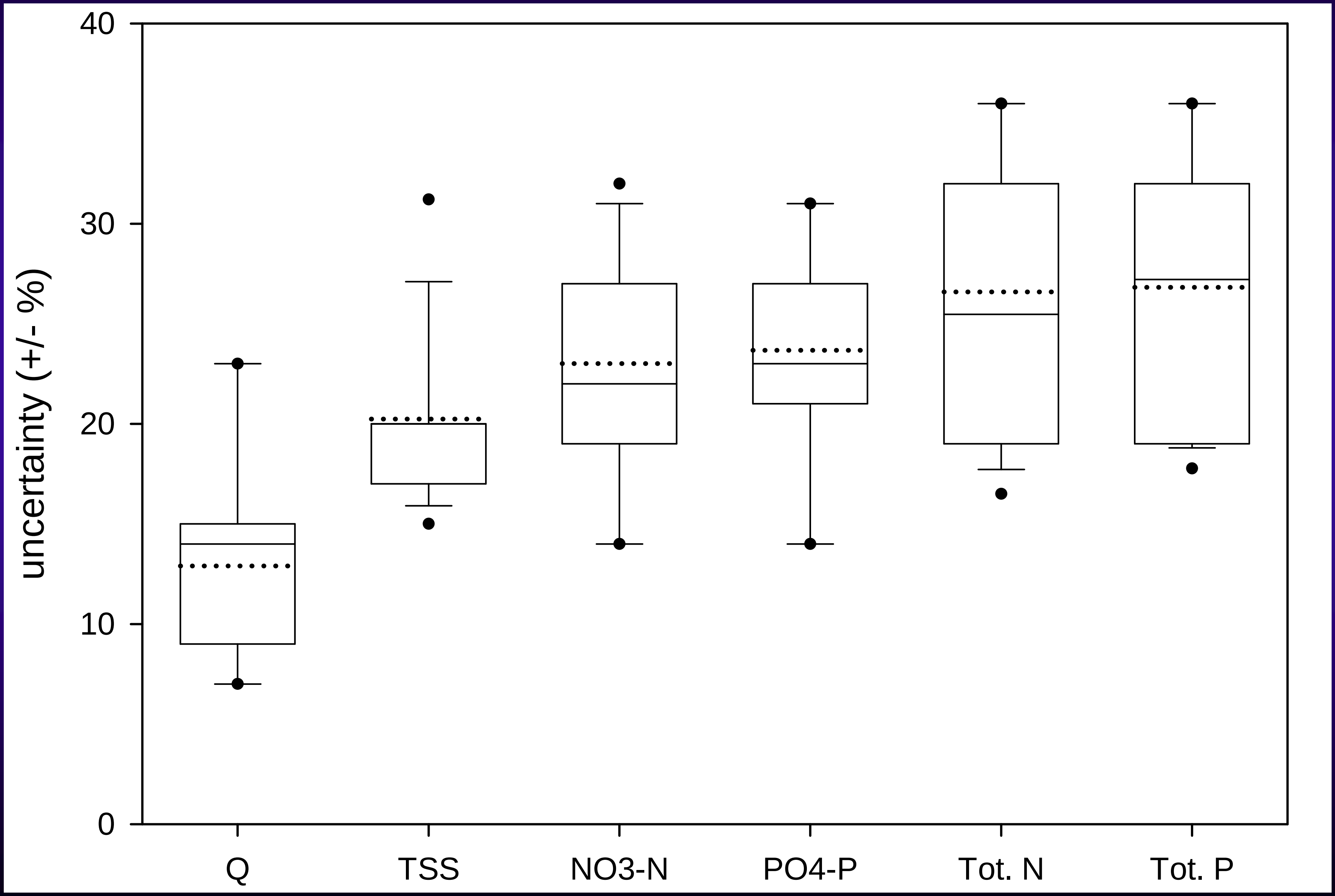


Closing Thoughts on Data Uncertainty

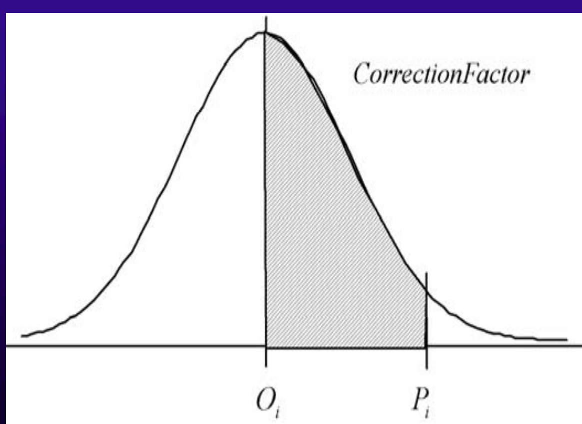
- Important for all H/WQ professionals to understand that…
  - measured streamflow and water quality data are uncertain
  - uncertainty increases dramatically without dedicated QA/QC
  - collection of high quality data requires considerable time, expense, personnel commitment

- Estimating uncertainty associated with measured data enhances both H/WQ monitoring and modeling
  - monitoring design
  - decision-making
  - scientific integrity
  - model calibration and validation

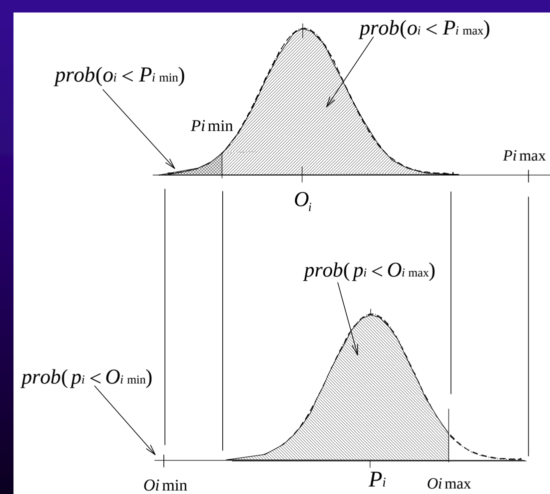
Relevance to Model Application

- Measurement (data) uncertainty <u>does</u> impact H/WQ modeling
  - Typically, modelers imply that calibration and validation data are not uncertain (±0%) by trying to reproduce measured values
  - A more appropriate approach attempts to simulate values within the uncertainty range of measured data

$$e_i = \frac{CF_i}{0.5} \times (O_i - P_i)$$



$$e(meas + pred)_i = CF(meas + pred)_i \times (O_i - P_i)$$



Any Questions??

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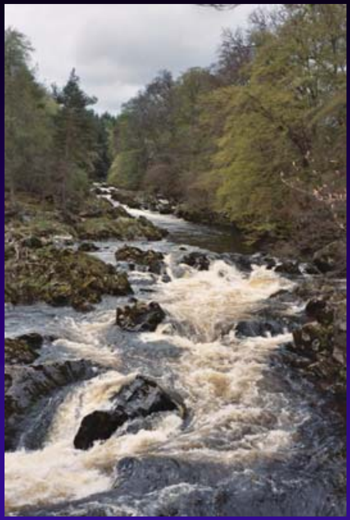

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