

# Understanding and Reducing Uncertainty in Small Watershed Sampling

Daren Harmel



## Objectives

- Present background information on uncertainty in flow and water quality data
- Briefly describe the Data Uncertainty Estimation Tool for Hydrology and Water Quality (DUET- H/WQ)
- Discuss DUET results and personal experience related to uncertainty in small watershed sampling

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



## Uncertainty sources

- **discharge measurement** - individual Q's, stage-discharge relation, channel conditions
- **sample collection** - EWI vs. grab vs. automated, sampling frequency, location in x-section, discrete vs. composite
- **sample preservation/storage** - pre-processing, preservation, storage duration and conditions
- **laboratory analysis** - reagents, standards, method, instrument, best fit curve
- **data processing and management** - mistakes, missing data

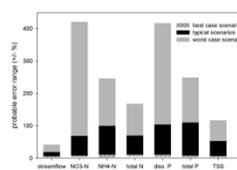
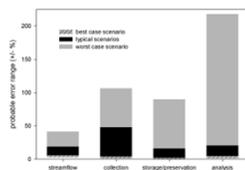


“The use of uncertainty estimation... (should be)... routine in hydrological and hydraulic science.”  
Pappenberger, Beven (2006)



## DUET- H/WQ

- **Developed uncertainty estimation framework (2006)**
  - focused on Q, TSS, N, and P data for small watersheds
  - listed published uncertainty estimates for four procedural categories
    - Q, sample collection, preservation/storage, lab analysis
  - estimated uncertainty for arbitrary “data quality” scenarios (best, typical, worst) with RMSE method



# DUET- H/WQ

- User-friendly enhancement of framework (2009).
  - “data processing and management” procedural category

DUET-HWQ - Lookup Table for calculation of uncertainty in discharge measurement

Select the published value for each step or source of uncertainty

Individual discharge measurement	Uncertainty	Reference
Direct - area-velocity method - poor conditions	±20%	Saun and Meyer (1992)
Direct - area-velocity method - ideal conditions	±5%	Saun and Meyer (1992)
Direct - area-velocity method - ideal conditions (2.0 ft velocity)	±5.1%	Palmer (1988)
Direct - area-velocity method - ideal conditions (0.5 ft velocity)	±15%	Stade (2004)
Manning's equation - Stable, uniform channel, surveyed reach and cross-section, accurate "T" estimate	±5%	Stade (2004)
Manning's equation - Unstable, irregular channel, surveyed reach and cross-section, poor "T" estimate	±15% to ±15% (average ±3.3%)	Tilly et al. (2006)
Direct - area-velocity method	±15%	Tilly et al. (2006)
Indirect - culvert equation	±15%	Tilly et al. (2006)

Continuous discharge measurement

Pre-calculated flow control structure (properly designed and installed) with periodic meter checks	Uncertainty	Reference
Pre-calculated flow control structure (properly designed and installed)	±5% to ±5%	Stade (2004)
Stable channel with stable control, 8-12 stage-discharge measurements per year	±10%	Stade (2004)
Shifting channel, 8-12 stage-discharge measurements per year	±20%	Stade (2004)
Non-stable channel conditions	±15%	Stade (2004)
Human velocity meter	—	N/A
OTHER	—	N/A

Continuous stage measurement

Float recorder	Uncertainty	Reference
Float recorder	±2%	Cooper (2005), uncalibrated data
Float recorder	±3 mm	Harley (1975)
GPS sensor 1/2 pressure transducer	±0.1%, ±0.02% stream error	USGS (2005)
USGS 730 bubble flow module	±0.025 ft ±0.0007 ft temp. change from 72 deg F	Telephone USGS (2005)
Camelot Scientific (2002) ultrasonic distance sensor	±0.01 ft or 0.4% of distance to water surface	Camelot Scientific (2002)
OTHER	—	N/A

Effect of streambed condition

Stable, firm bed	Uncertainty	Reference
Stable, firm bed	±5%	Saun and Meyer (1992)
Mobile, unstable bed	±10%	Saun and Meyer (1992)
OTHER	—	N/A

Cumulative uncertainty in discharge measurement ± 9.6%

Uncertainty Estimation Tool for Hydrology and Water Quality (DUET-HWQ)

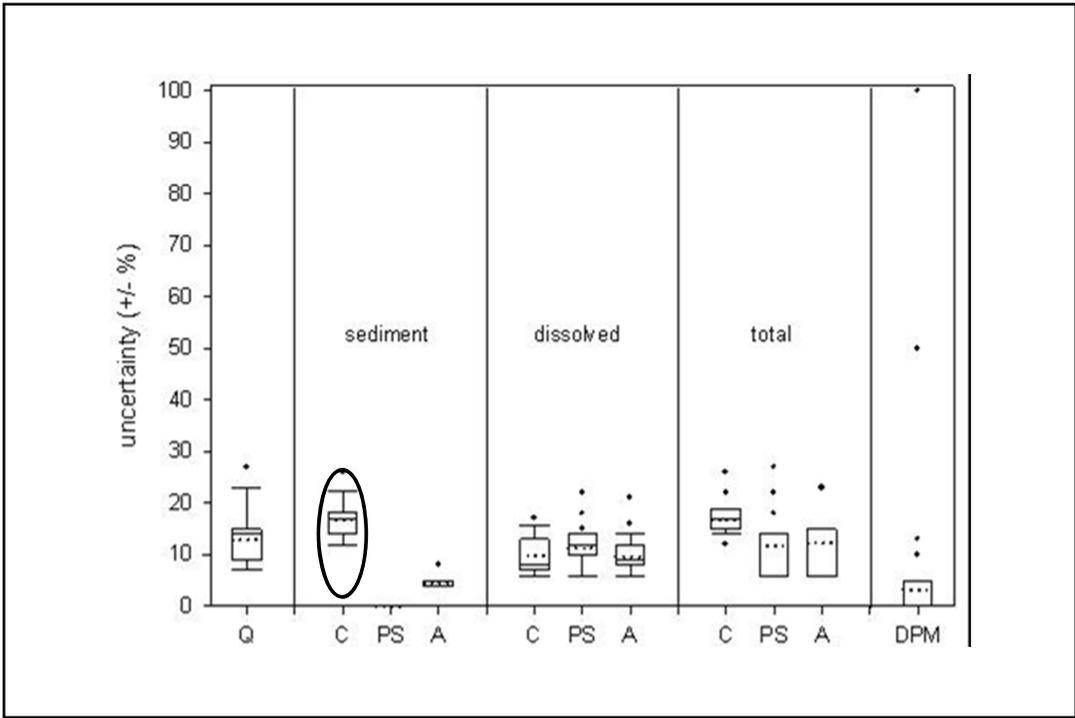
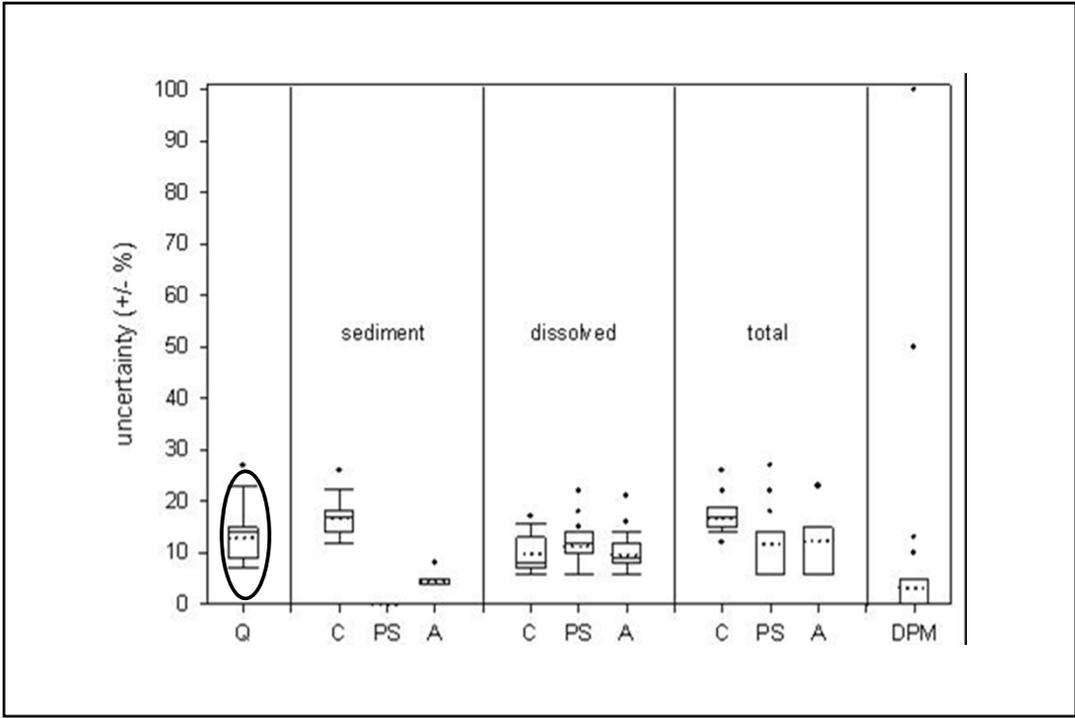
Site ID	Date_Time	discharge_(ft <sup>3</sup> /s)	Uncertainty(±%)	conc_NO3N_mg/l	Uncertainty(±%)
Wild Cr.	3/12/2007 11:30	0.0	50	1	42
Wild Cr.	3/12/2007 11:45	0.9	10	1	42
Wild Cr.	3/12/2007 12:00	14.9	23	1	42
Wild Cr.	3/12/2007 12:15	15.3	23	1	42
Wild Cr.	3/12/2007 12:30	15.8	23	1	42
Wild Cr.	3/12/2007 12:45	15.5	23	1	42
Wild Cr.	3/12/2007 13:00	15.3	23	1	42
Wild Cr.	3/12/2007 13:15	14.3	23	1	42
Wild Cr.	3/12/2007 13:30	13.9	23	1	42
Wild Cr.	3/12/2007 13:45	13.3	23	1	42
Wild Cr.	3/12/2007 14:00	12.6	23	1	42
Wild Cr.	3/12/2007 14:15	12.2	23	1	42
Wild Cr.	3/12/2007 14:30	11.6	23	1	42
Wild Cr.	3/12/2007 14:45	11.1	23	1	42
Wild Cr.	3/12/2007 15:00	10.4	23	1	42
Wild Cr.	3/12/2007 15:15	10.2	23	1	42
Wild Cr.	3/12/2007 15:30	9.7	10	1	42
Wild Cr.	3/12/2007 15:45	9.5	10	1	42
Wild Cr.	3/12/2007 16:00	9.0	10	1	42
Wild Cr.	3/12/2007 16:15	8.9	10	1	42
Wild Cr.	3/12/2007 16:30	8.5	10	1	42
Wild Cr.	3/12/2007 16:45	8.2	10	1	42

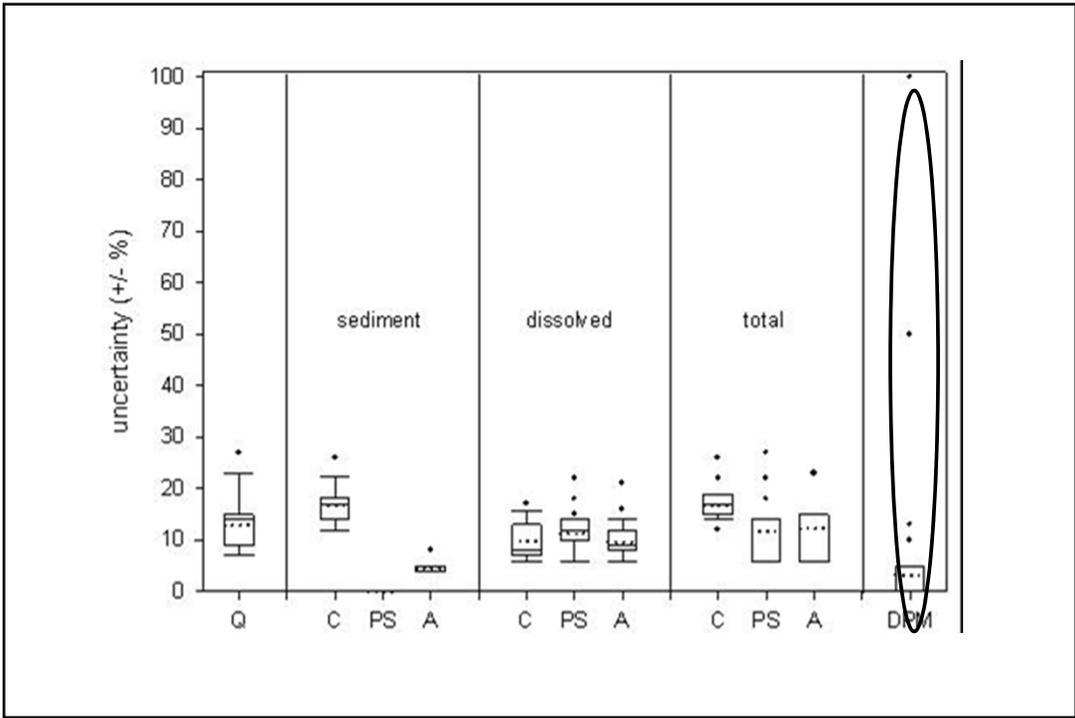
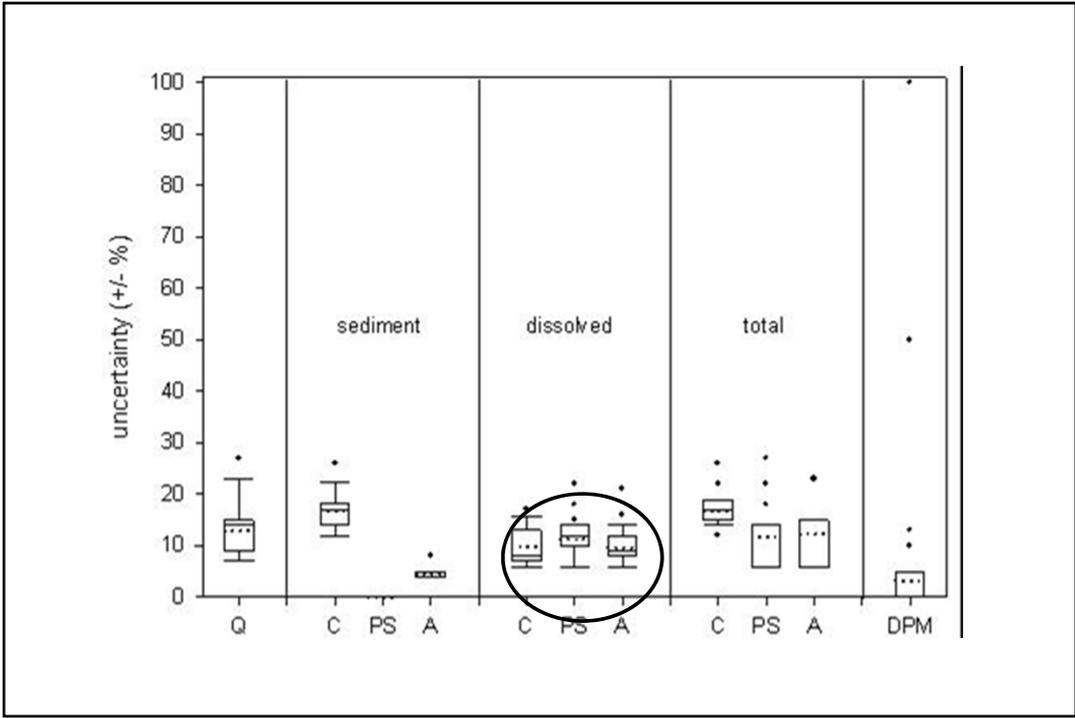
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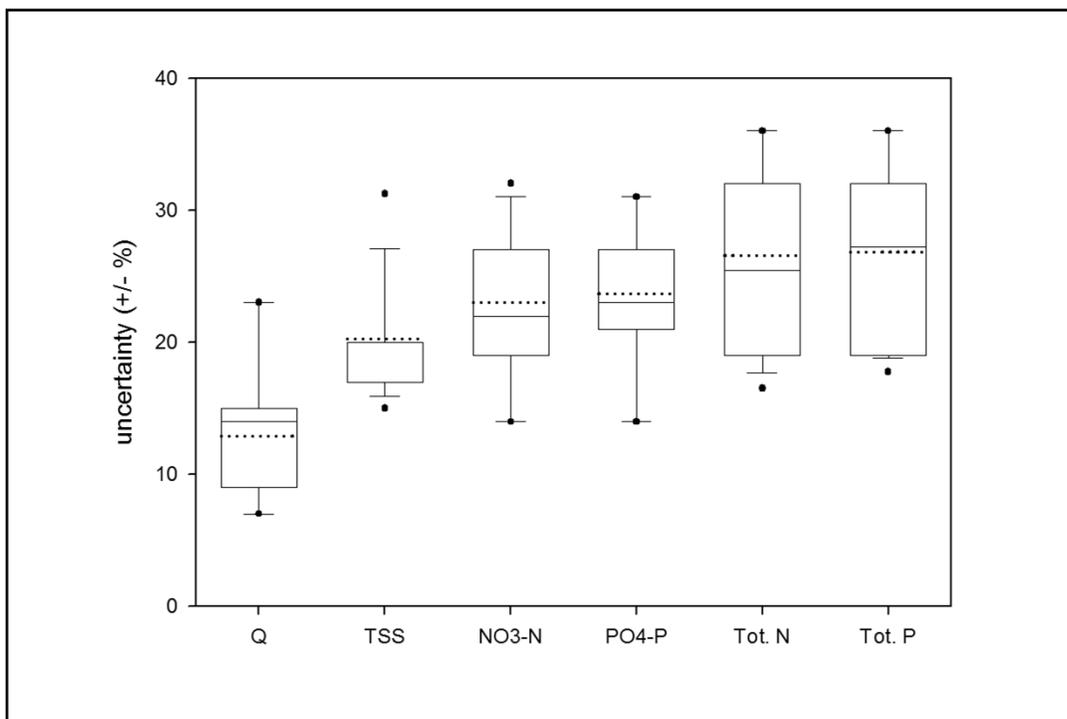
## DUET- H/WQ Application

- Applied to real-world data from five monitoring projects
  - various hydrologic settings, land uses, watershed sizes, and field and laboratory techniques
  - 131 storm events
- Estimated uncertainty:
  - contributed by each procedural category
  - in individual Q, TSS, NO<sub>3</sub>-N, PO<sub>4</sub>-P, total N, total P values









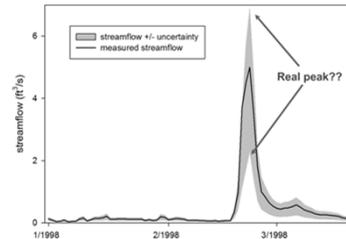
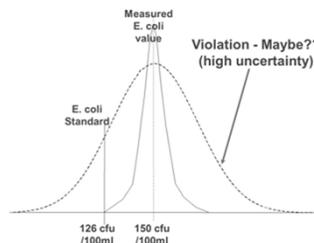
## Conclusions

- **Important for water resource professionals to understand that...**
  - **all measured flow and water quality data are uncertain**
  - **uncertainty increases dramatically without dedicated QA/QC; however, QA/QC should:**
    - **realistically address each procedural category**
    - **include uncertainty estimation and reporting to increase “value” of data.**



## Conclusions

- **Historically, uncertainty in flow and water quality data has rarely been estimated and included in:**
  - Research and monitoring
  - Data reporting
  - Regulation and policy
  - Model evaluation



## Conclusions

- **Uncertainty is almost always ignored in spite of:**
  - pleas for uncertainty analysis
  - fact that all measurements are inherently uncertain.

**However, the environmental and socio-economic ramifications of decisions based on these data are too great for the inherent uncertainty to continue to be ignored!!!**

**Any Questions??**

**Daren Harmel  
(254) 770-6521  
daren.harmel@ars.usda.gov**



**[www.ars.usda.gov/spa/hydro-collection](http://www.ars.usda.gov/spa/hydro-collection)**

**Includes uncertainty-related pubs (6) and  
sampling methods-related pubs (10)**