Use of Real-Time Monitoring to Predict Concentrations of Select Constituents in the Menomonee River Watershed, Milwaukee, Wisconsin

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In cooperation with MMSD

Outline

- Project goals
- Data collection
- Development of regression models
- Validation and revision of models

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Project Goals

1. **Develop regression models to estimate**

- Chloride,
- Total suspended solids,
- Total phosphorus,
- *E. coli* bacteria,
- Fecal coliform bacteria

using more easily measured variables

- Water temperature,
- Specific conductance,
- Turbidity,
- Dissolved oxygen,
- Discharge

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Project Goals

WHY?

- **Provide instantaneous estimates of important water-quality indicators**

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Project Goals

WHY?

- Provide **instantaneous** estimates of important water-quality indicators

- **Capture temporal variability**

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Project Goals

WHY?

- Provide **instantaneous** estimates of important water-quality indicators
- Capture temporal variability
- **Better load estimates (vs. estimates based on discharge)**

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Project Goals

WHY?

- Provide **instantaneous** estimates of important water-quality indicators
- Capture temporal variability
- Better load estimates (vs. estimates based on discharge)
- **Long term: trends, land use changes, effects of improvement projects and BMPs**

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Project Goals

2. **Assess validity of models using subsequent data**

Will models created in 2009 be valid in 2010, 2011?

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Outline

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Data Collection

Real-time water-quality sondes

- Water temperature
- Specific conductance
- Turbidity
- Dissolved oxygen

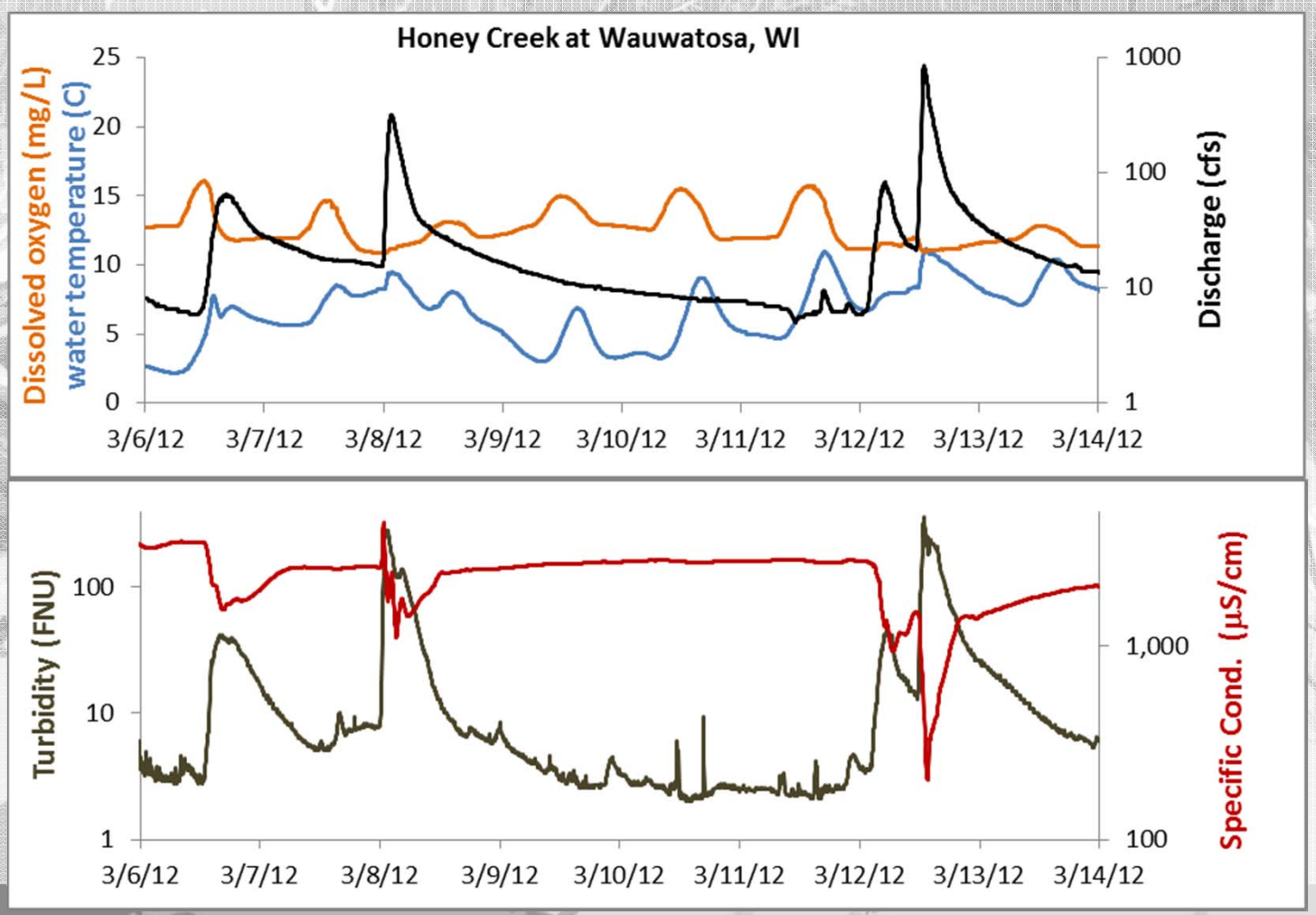
Measured every 5 minutes

Stage (discharge)

Data Collection

Real-time water-quality data

daily cycles *rapid* changes



Data Collection

Automated samplers

Stormflow: 2-4 samples/storm

Baseflow: 1/month

32 - 101 samples/site

Analyzed for

- Chloride
- Total suspended solids
- Total phosphorus
- *E. coli* bacteria
- Fecal coliform bacteria

Outline

- Project goals
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- **Development of regression models**
- Validation and revision of models

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Development of Regression Models

- 1 year of data (WY2009), 32–101 samples/model
- Site specific
- Simple and multiple linear regression using SAS software
- Followed process described by Rasmussen and others, 2009*

Explanatory variables

- Discharge
- Water temperature
- Turbidity
- Dissolved oxygen
- Specific conductance
- Sine Julian day
- Cosine Julian day

Response variables

- Chloride
- Total suspended solids
- Total phosphorus
- *E. coli* bacteria
- Fecal coliform bacteria

* Rasmussen, P.P., Gray, J.R., Glysson, G.D., and Ziegler, A.C., 2009, U.S. Geological Survey Techniques and Methods book 3, chap. C4, 53 p.

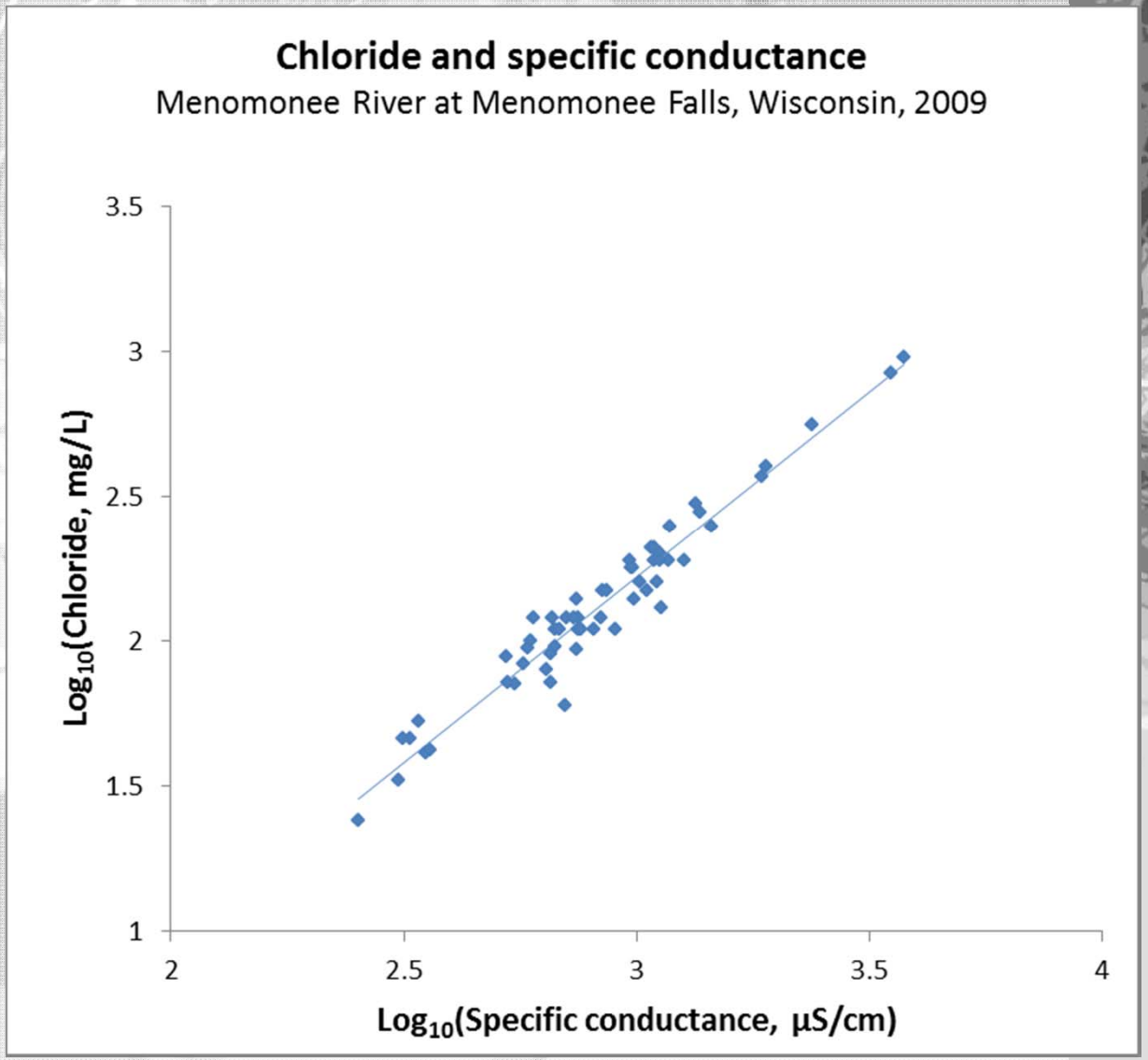
Development of Regression Models

Chloride:

Log_{10}**Cl**=
-1.63 + 1.28log_{10}(**SC**)

Adj. R^2 = 0.94

n = 59



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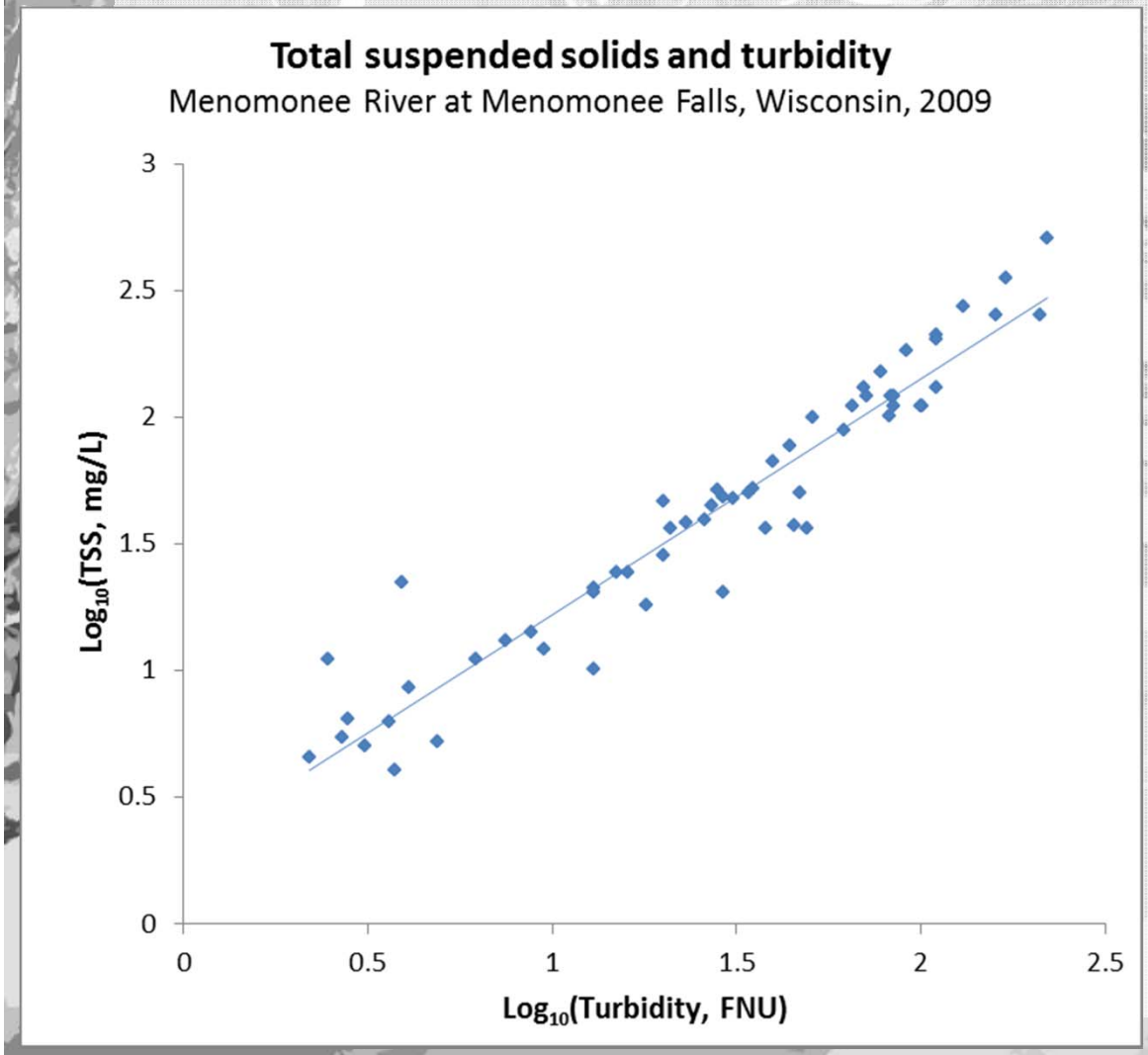
Development of Regression Models



Total suspended solids:

$Log_{10}SS = 0.256 + 0.953 log_{10}(Turb)$

Adj. $R^2 = 0.92$

n = 59

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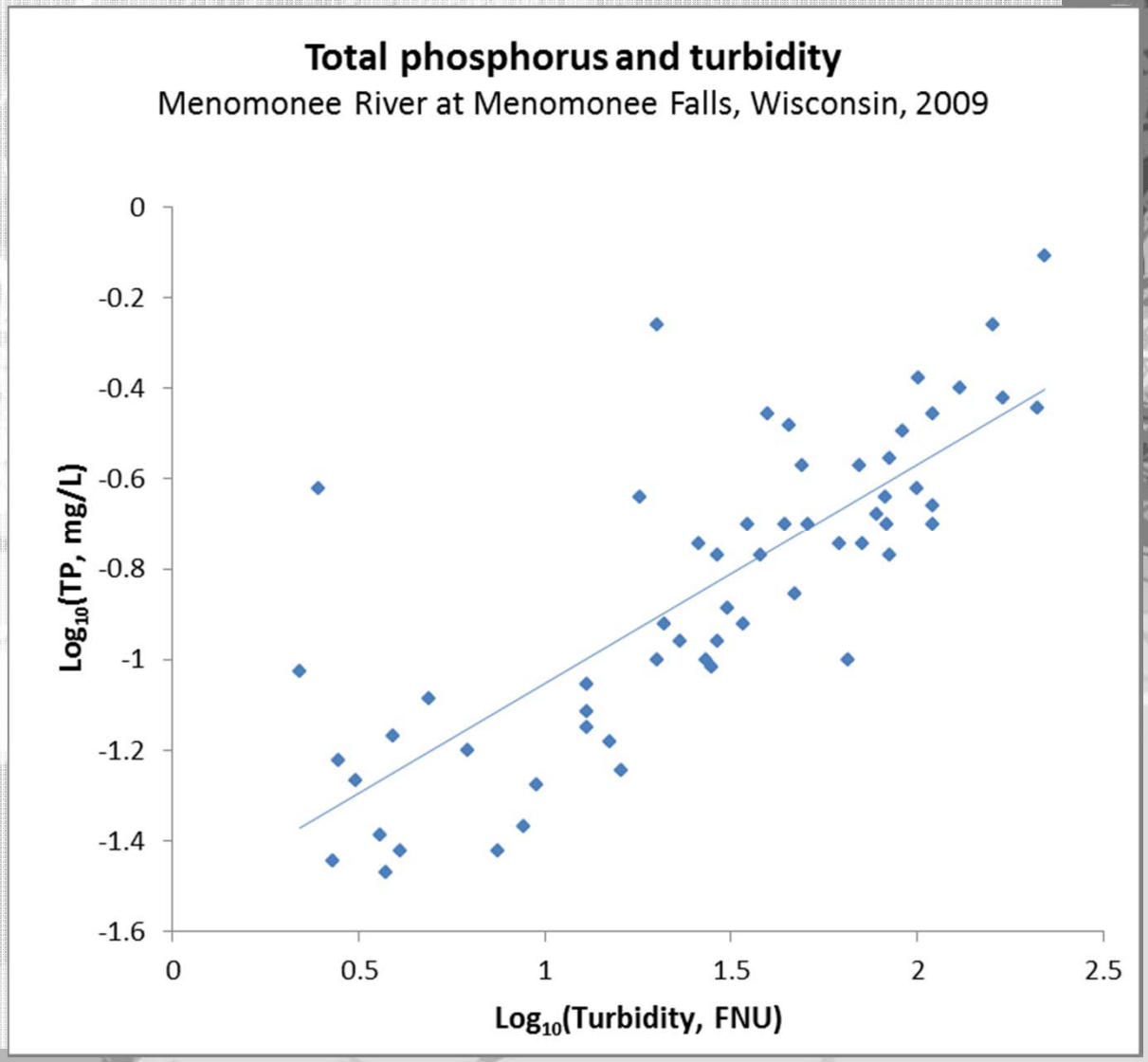
Development of Regression Models

Total phosphorus:

Log_{10}**TP**=
-1.55+ 0.492log_{10} (**Turb**)

Adj. R^2 = 0.62

n = 59



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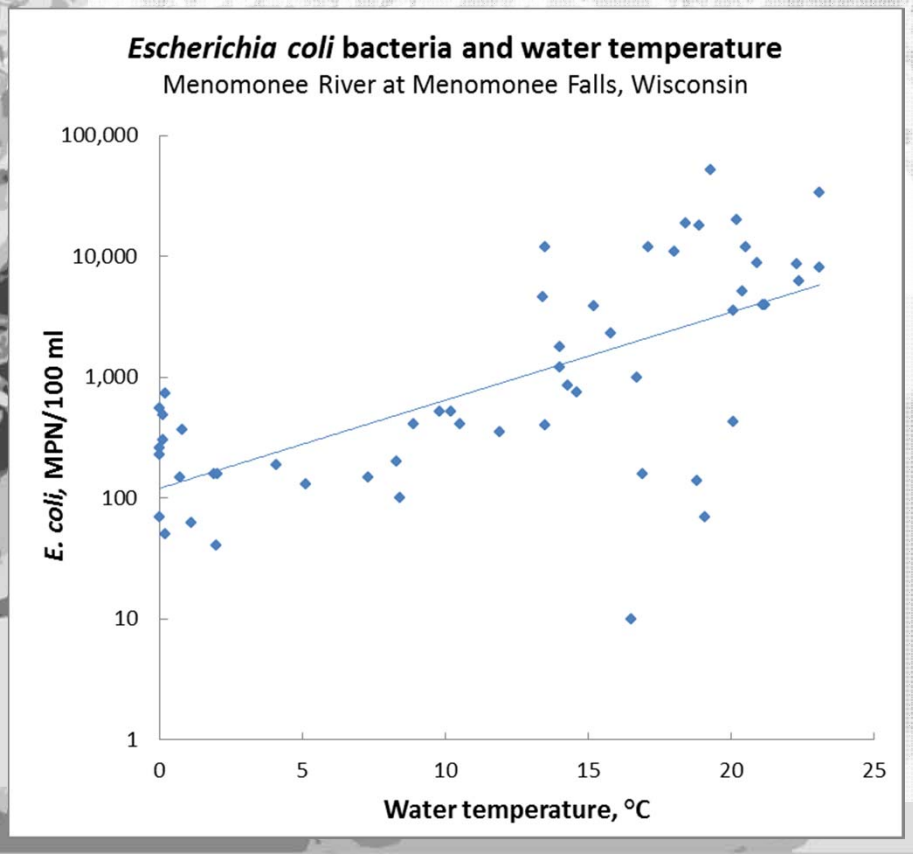
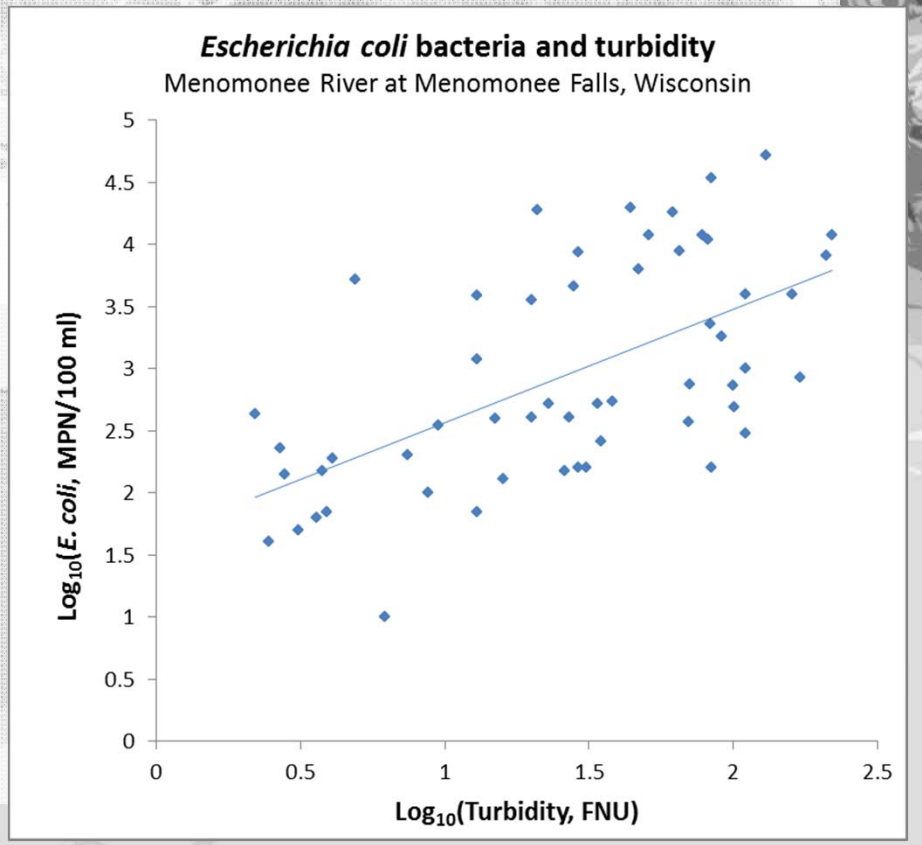
Development of Regression Models

***E. coli* bacteria**:

Log_{10}**EC**= 1.30+ 0.057(**WT**) + 0.674log_{10} (**Turb**)

Adj. R^2 = 0.60 n = 55



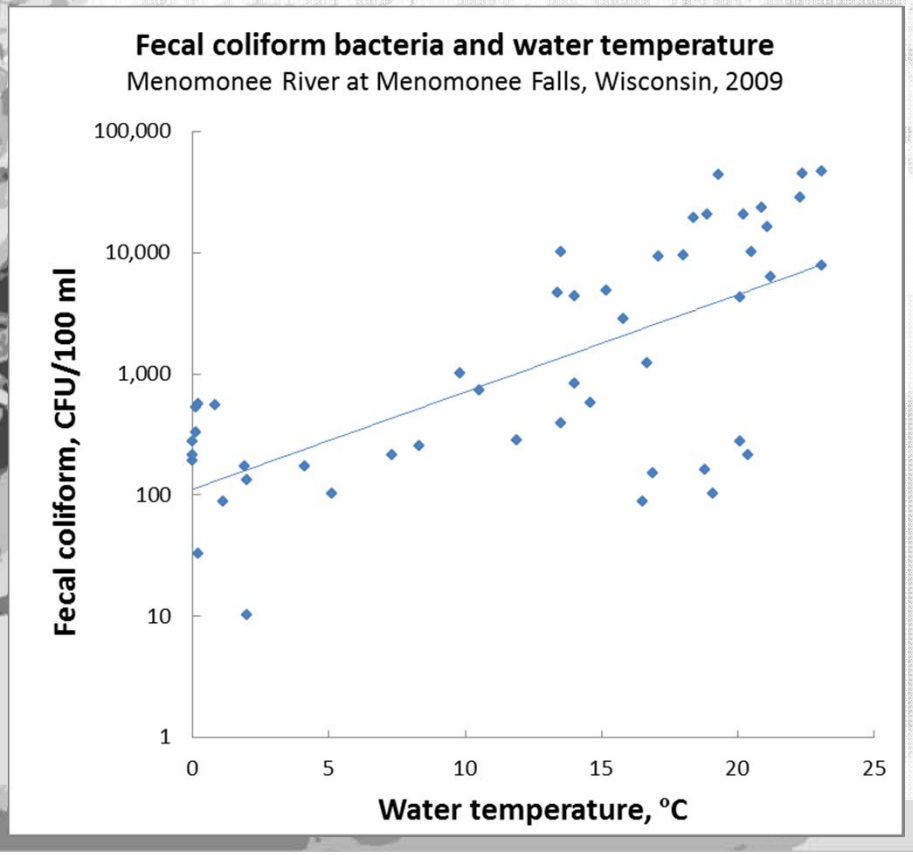


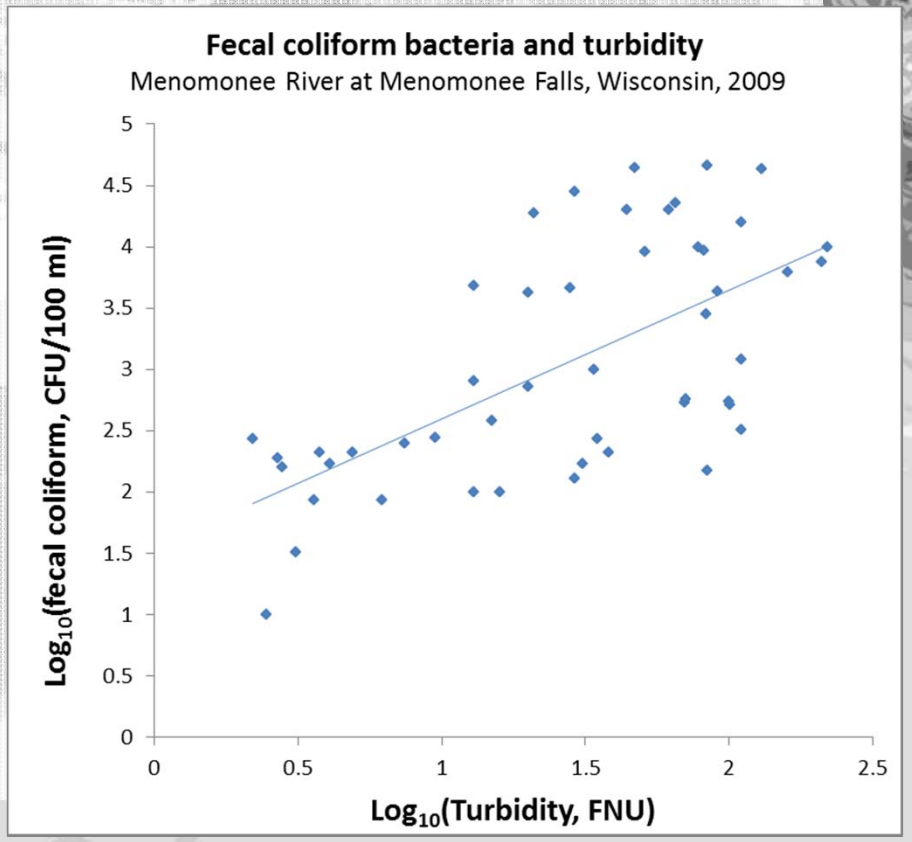
Development of Regression Models

Fecal coliform bacteria:

Log_{10}**FC**= 1.07+ 0.063(**WT**) + 0.834log_{10} (**Turb**)

Adj. R^2 = 0.68 n = 49





Wisconsin Real-Time Water Quality

Home | View Data | Methods | Constituents | Models | Bibliography | Links

NRTWQ Home >> Wisconsin >> View Data >> 04087119

Plot | Data Table | Statistics | Duration Curve | Site Info | Model Info

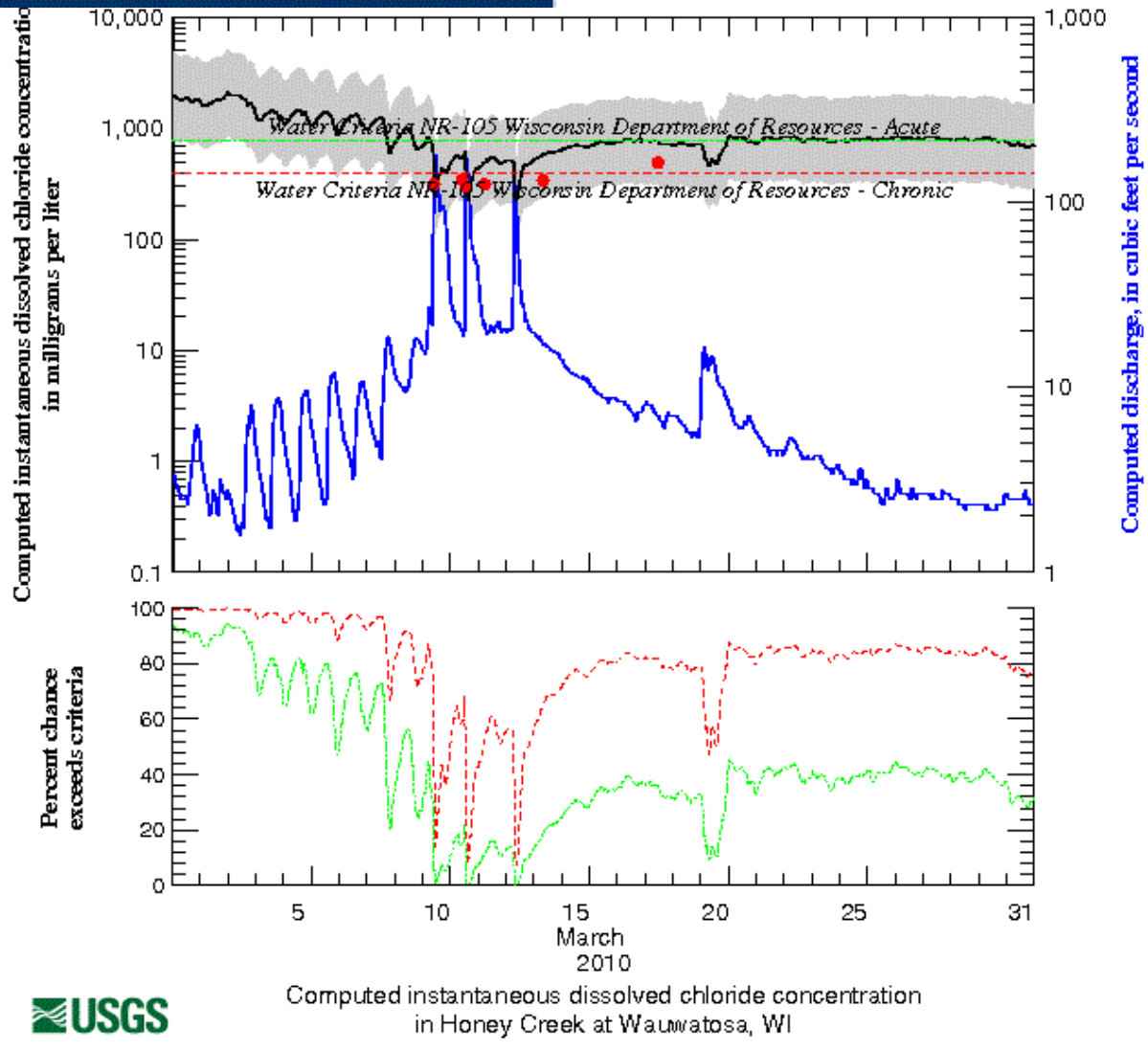
USGS station: 04087119 Honey Creek at Wauwatosa, WI — Go to NWISWeb

Constituent: Computed chloride | concentration | hourly | < | Go | >

Time period: Year 2010 | Month | March

USGS
National Real-Time
Water Quality
website
nrtwq.usgs.gov

Real-time measurements
+
regression models
=
Real-time estimates



Computed instantaneous dissolved chloride concentration in Honey Creek at Wauwatosa, WI

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Outline

- Project goals
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- **Validation and revision of models**

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Model Validation & Revision

Initial models developed using 1 year of data (2009)

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Model Validation & Revision

Initial models developed using 1 year of data (2009)

…2 years and 557 samples later…

Are models created in 2009 valid in 2010, 2011?

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Model Validation & Revision

…OR, is there too much variability from one year to the next?

Climatic variations

Land use changes? **Channel morphology changes**


Honey Creek
before July 2010


Honey Creek
after July 2010
flood

Model Validation & Revision

Analysis of covariance (ANCOVA)

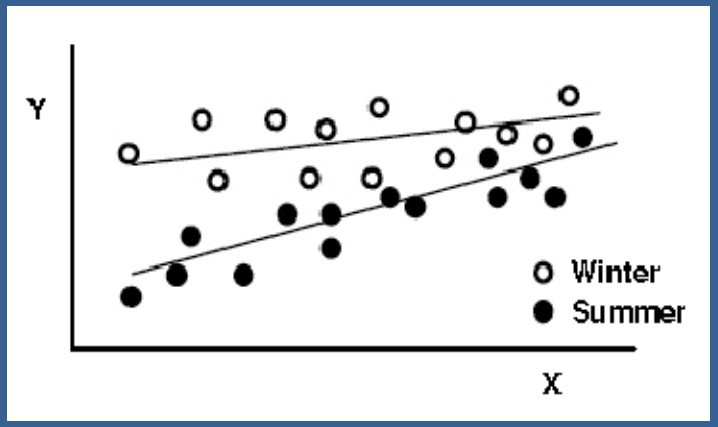
1. Create new regression models* using only new data (2010/2011)
2. Compare new models to existing models using ANCOVA

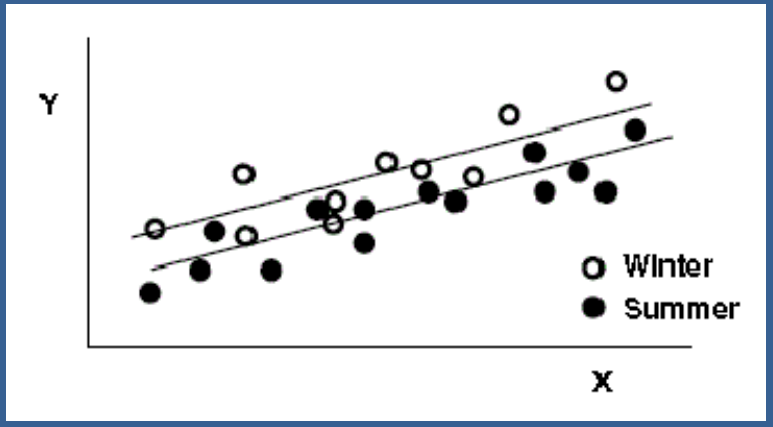
** using the same explanatory variables as used in the 2009 models*

Null hypothesis ($\mathbf{H_0}$):

No difference in slope or y-int. of the two models ($p > .05$).

If $p < .05$, **reject** null hypothesis! Models are different.





Helsel and Hirsch, 2002, USGS Techniques of Water-Resources Investigations, book 4, chap. A3, 510 p.

Model Validation & Revision

Chloride

2009 model:

Log_{10} (Chl) = -1.62 + 1.28 log_{10} (SC)

n: 59, Adj. R^2: 0.95

2010/2011 model:

Log_{10} (Chl) = -1.93 + 1.38 log_{10} (SC)

n: 91, Adj. R^2: 0.94

ANCOVA p-values:

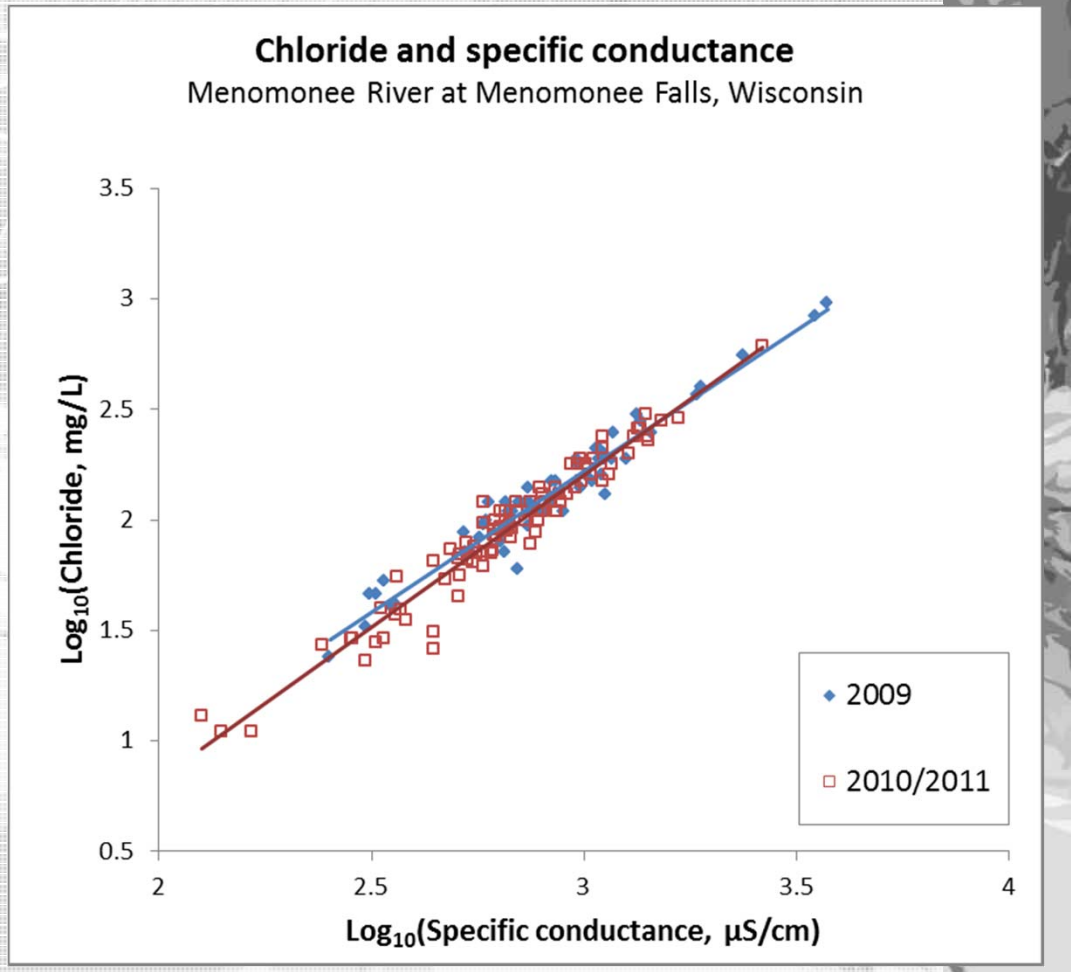
Intercept: 0.052

log_{10}Turb: 0.077

P-values > 0.05,

Cannot reject null hypothesis.

(H_0: the two models are the same)



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Model Validation & Revision

Total suspended solids

2009 model:

Log_{10} (TSS) = 0.292 + 0.929 log_{10} (Turb)

n: 59, Adj. R^2: 0.92

2010/2011 model:

Log_{10} (TSS) = 0.029 + 1.102 log_{10} (Turb)

n: 91, Adj. R^2: 0.92

ANCOVA p-values:

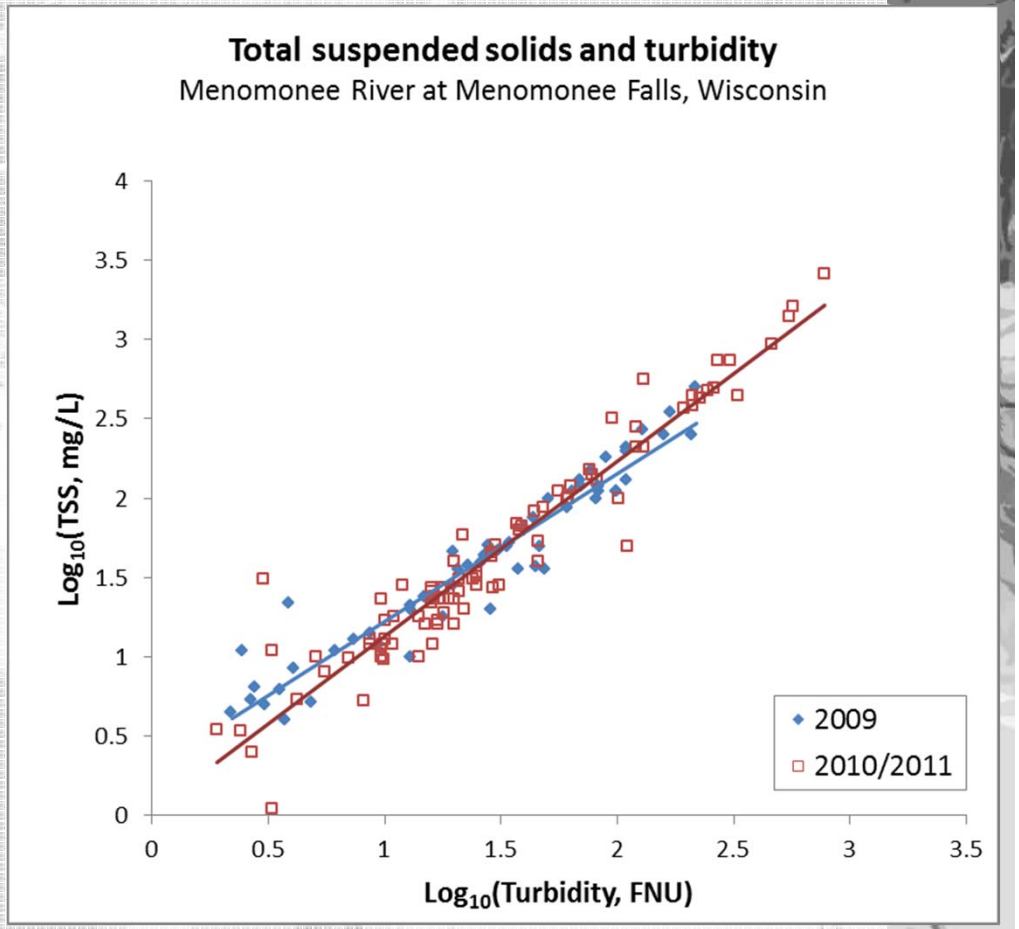
Intercept: 0.002

log_{10}Turb: 0.001

P-values < 0.05,

Reject null hypothesis!

Models are significantly different.



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Model Validation & Revision

Total phosphorus

2009 model:

Log_{10} (TP) = -1.538 + 0.486 log_{10} (Turb)

n: 59, Adj. R^2: 0.63

2010/2011 model:

Log_{10} (TP) = -1.728 + 0.608 log_{10} (Turb)

n: 91, Adj. R^2: 0.86

ANCOVA p-values:

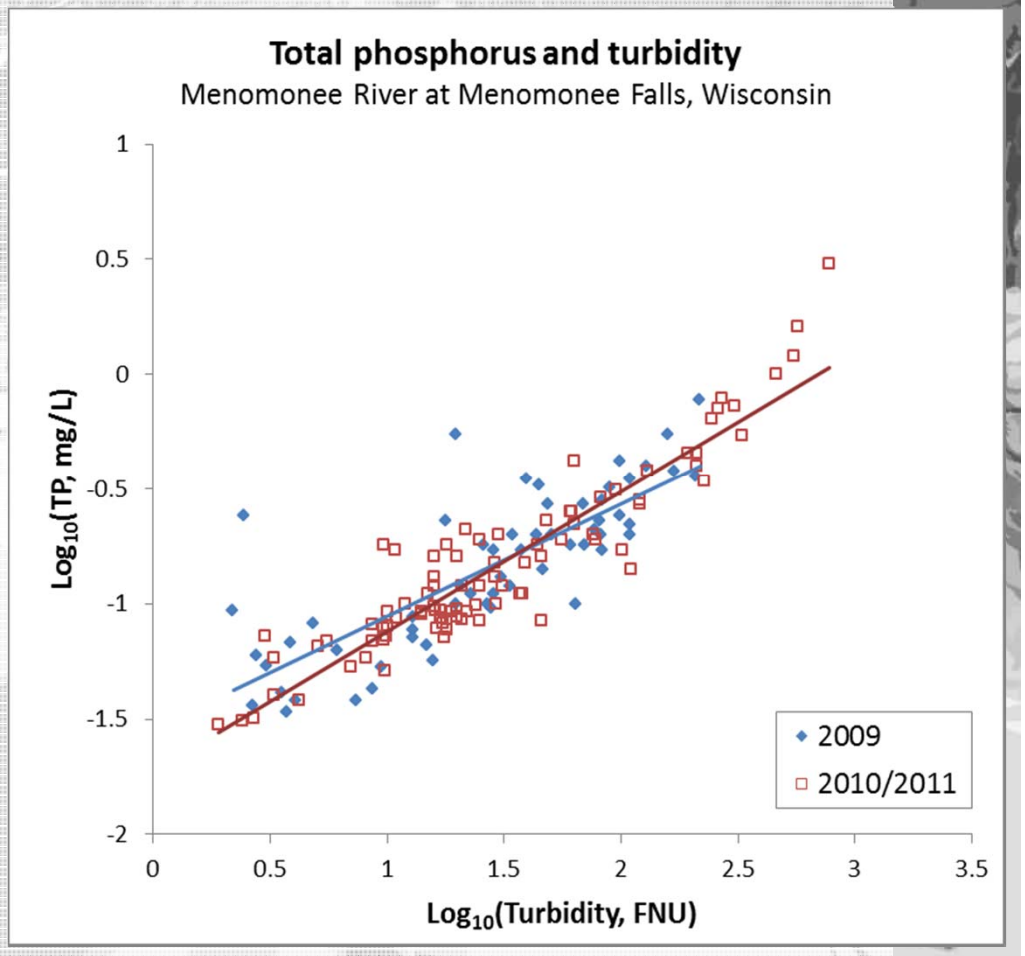
Intercept: 0.018

log_{10}Turb: 0.018

P-values < 0.05,

Reject null hypothesis!

Models are significantly different.



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Model Validation & Revision

E. coli bacteria

2009 model:

Log_{10} (EC) = 1.301 + 0.059 (WT) + 0.667 log_{10} (Turb)

n: 55, Adj. R^2: 0.60

2010/2011 model:

Log_{10} (EC) = 1.429 + 0.041 (WT) + 0.787 log_{10} (Turb)

n: 78, Adj. R^2: 0.62

ANCOVA p-values:

Intercept: 0.64

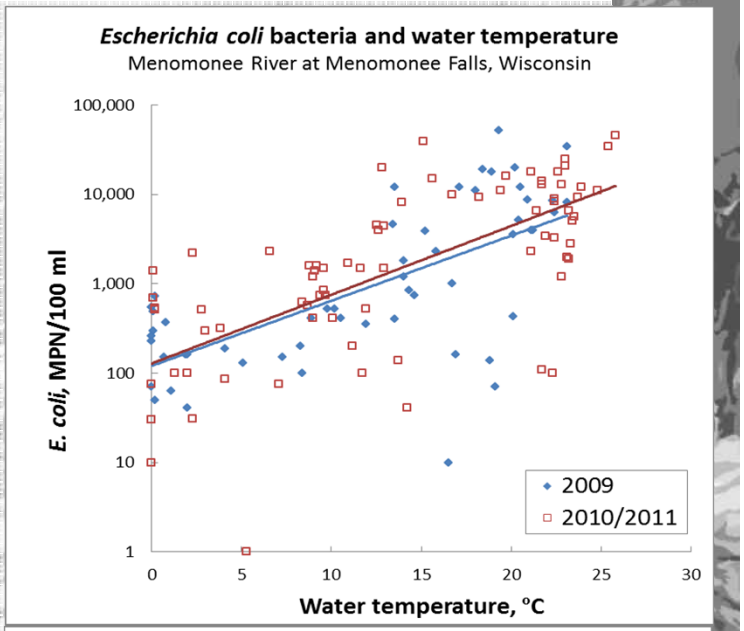
Wtemp coefficient: 0.21

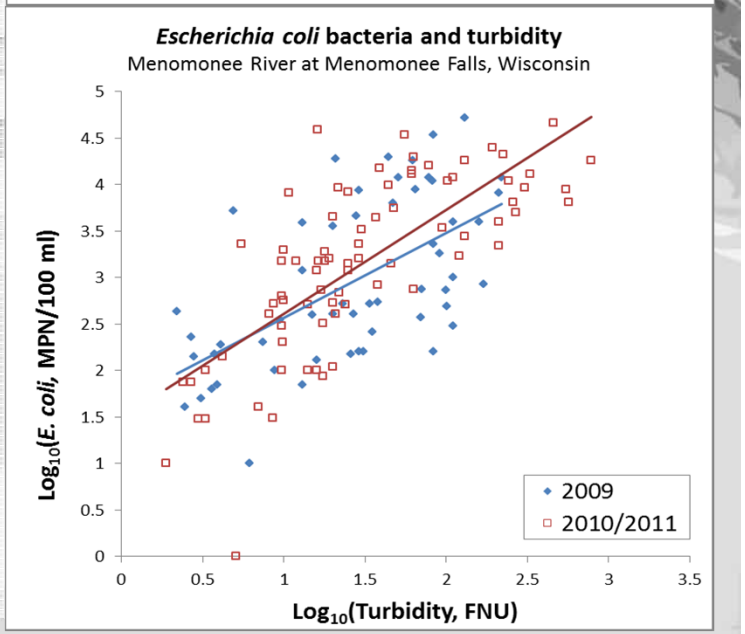
log_{10}Turb coefficient: 0.54

P-values > 0.05,

Cannot reject null hypothesis.

(H_0: the two models are the same)





Model Validation & Revision

Fecal coliform bacteria

2009 model:

Log_{10} (FC) = 1.080 + 0.065 (WT) + 0.810 log_{10} (Turb)

n: 49, Adj. R^2: 0.68

2010/2011 model:

Log_{10} (FC) = 1.449 + 0.057 (WT) + 0.736 log_{10} (Turb)

n: 70, Adj. R^2: 0.72

ANCOVA p-values:

Intercept: 0.18

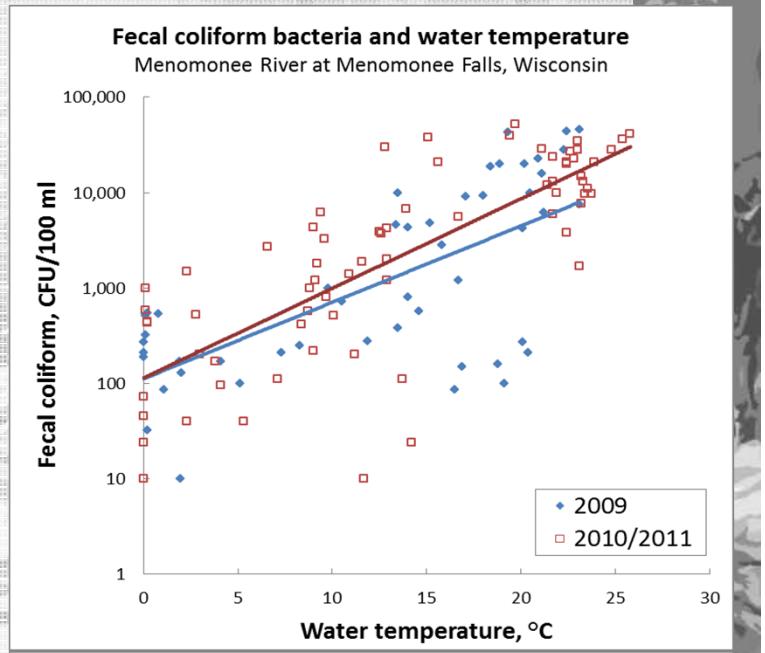
Wtemp coefficient: 0.59

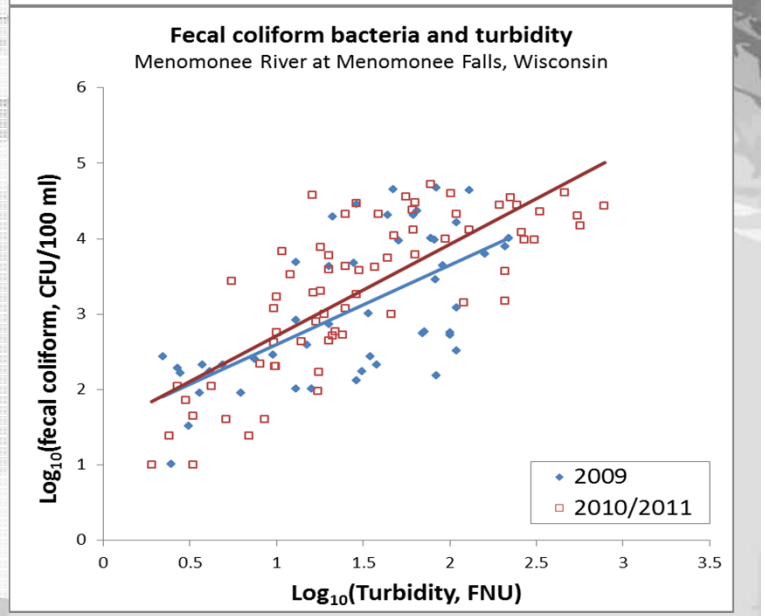
log_{10}Turb coefficient: 0.70

P-values > 0.05,

Cannot reject null hypothesis.

(H_0: the two models are the same)





Model Validation & Revision

Are models created in 2009 valid in 2010, 2011?

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Model Validation & Revision

Are models created in 2009 valid in 2010, 2011?

Yes and No

11 models showed significant change from 2009 to 2010/2011

14 models showed no change

	Sites				
	Donges	MF	Honey	70th	16th
Chloride			Δ		
Total suspended solids		Δ	Δ	Δ	
Total phosphorus	Δ	Δ	Δ	Δ	
E. coli				Δ	Δ
Fecal coliform			Δ		

Model Validation & Revision

Do the 2009 models improve with addition of 2010/2011 data?

Model Validation & Revision

Do the 2009 models improve with addition of 2010/2011 data?

- ↑ 13 improved
- – 6 stayed same
- ↓ 6 got worse

Changes in adj. R^2 resulting from addition of 2010/2011 data:

	Sites				
	Donges	MF	Honey	70th	16th
Chloride	↑	–	↑	–	–
Total suspended solids	↓	–	–	–	↓
Total phosphorus	↑	↑	↑	↑	↑
E. coli	↑	↑	↓	↓	↑
Fecal coliform	↑	↑	↓	↓	↑

Where do we go from here?

Publish revised models (using all data, '09-'11)

Update models on NRTWQ website to make publicly available

Continue sampling at reduced frequency

~13 samples/site/year

Repeat validation process after a couple of years

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Thanks!

Staff at USGS Wisconsin Water Science Center

&

Milwaukee Metropolitan Sewerage District

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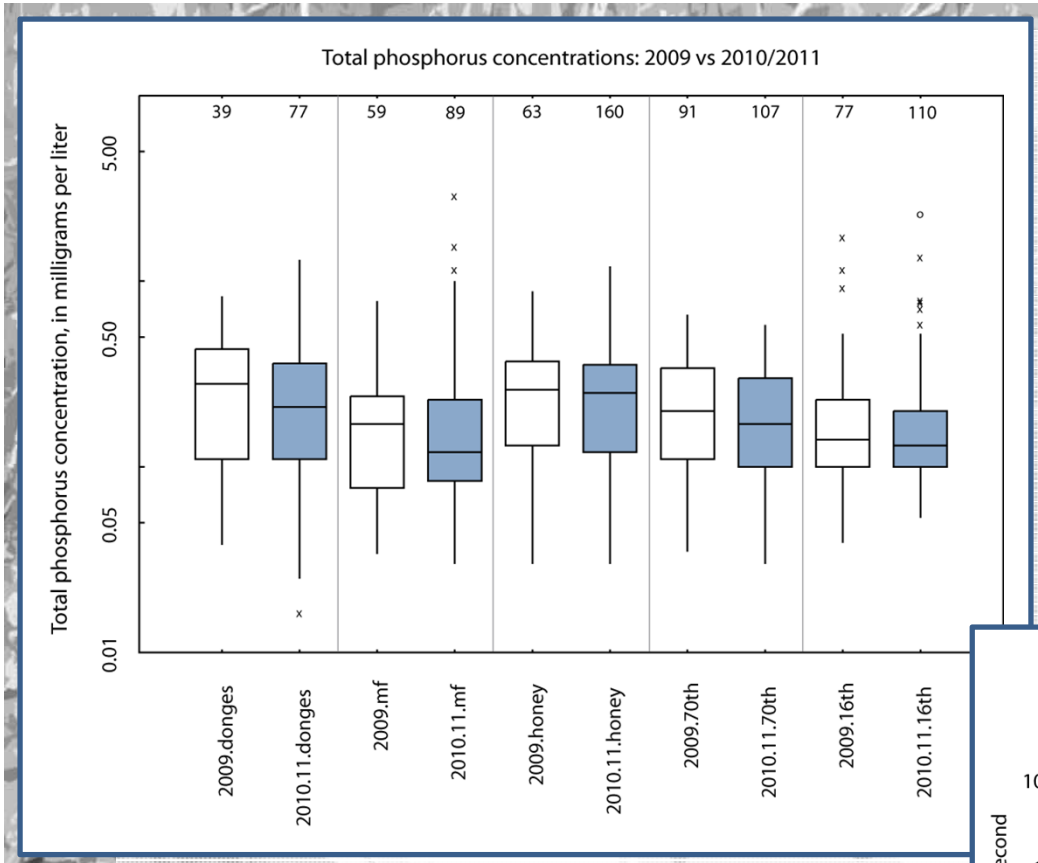
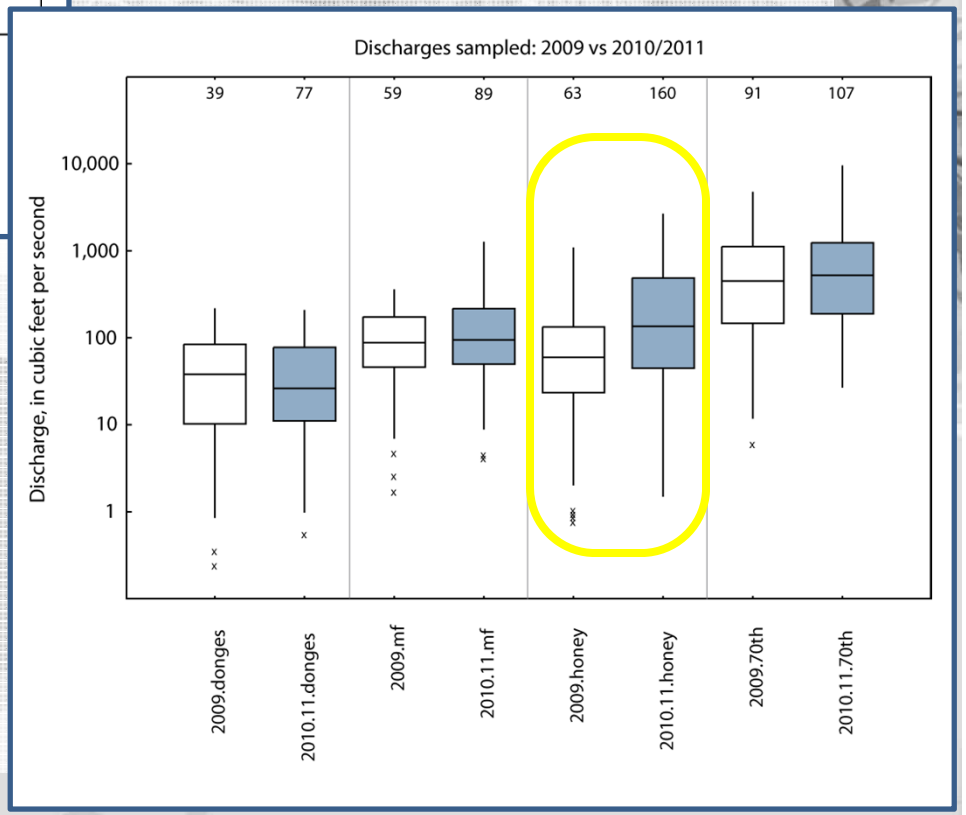
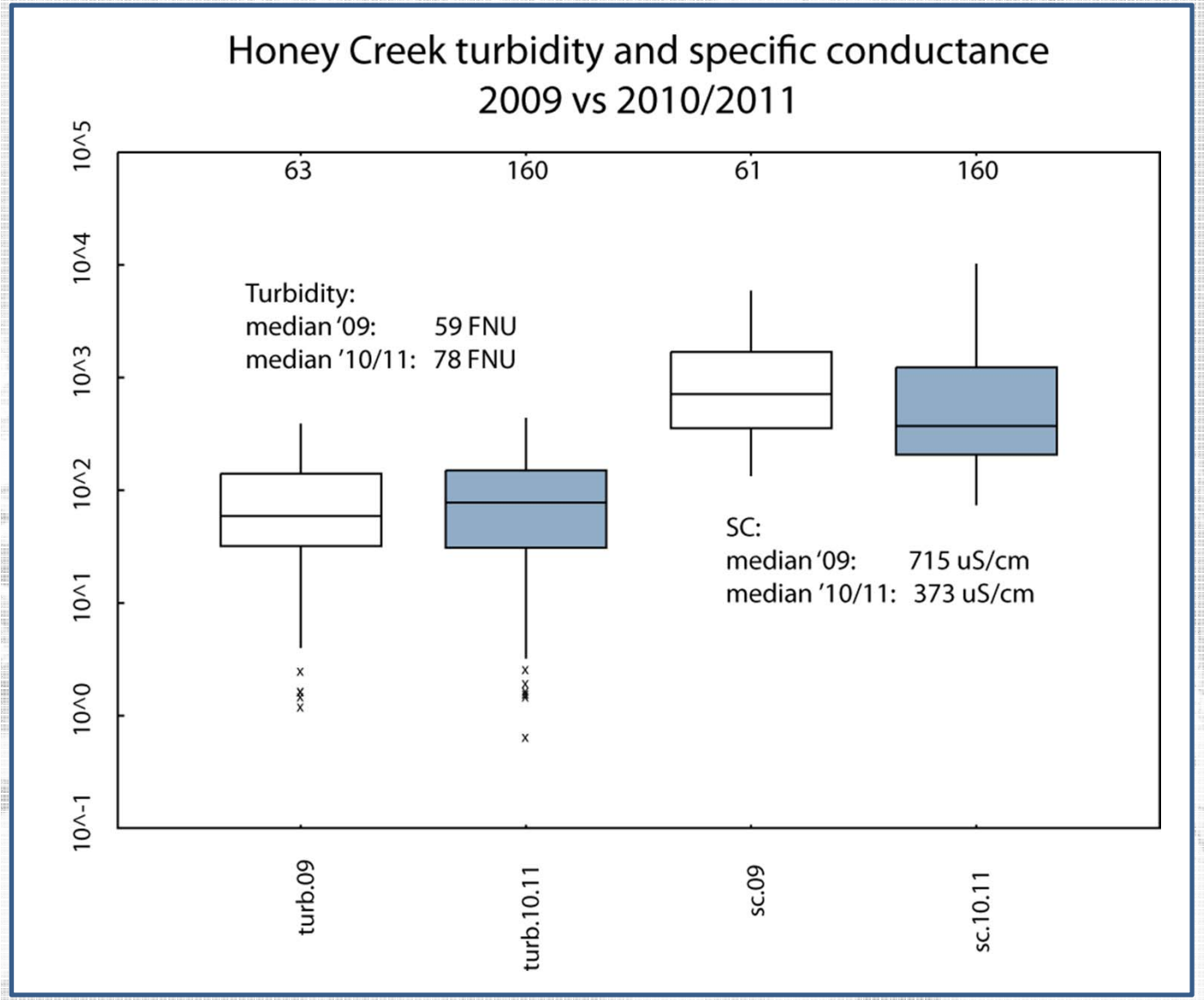
Total phosphorus, 2009 vs 2010/2011



Sampled discharges, 2009 vs 2010/2011




Honey Creek turbidity and specific conductance
2009 vs 2010/2011
10^5
10^4
10^3
10^2
10^1
10^0
10^-1
63
160
61
160
Turbidity:
median '09: 59 FNU
median '10/11: 78 FNU
SC:
median '09: 715 uS/cm
median '10/11: 373 uS/cm
turb.09
turb.10.11
sc.09
sc.10.11

Model Validation & Revision

	Donges	MF	Honey	70th	16th
Chloride	↑		↑		
Total suspended solids	↓				↓
Total phosphorus	↑	↑	↑	↑	↑
E. coli	↑	↑	↓	↓	↑
Fecal coliform	↑	↑	↓	↓	↑

Data Collection

Automated samplers

Sample all flow levels