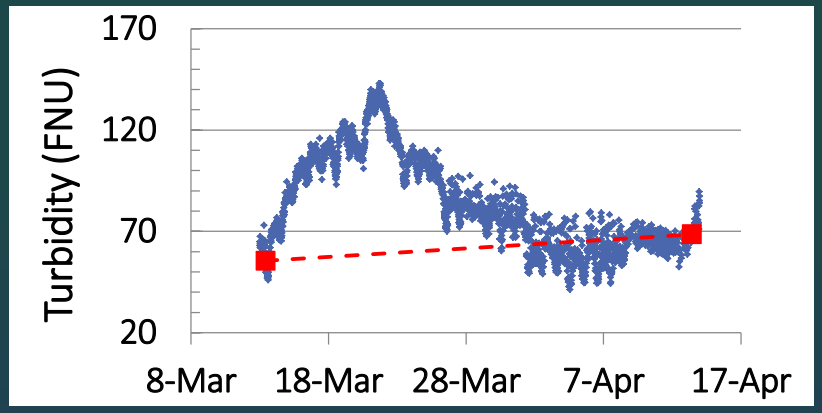
Continuous Water-Quality Monitoring: Implementation to application

Presented to the National Water-Quality Monitoring Council

February 12, 2015

U.S. Department of the Interior
U.S. Geological Survey

Why Continuous WQ Monitoring?



- Temporally dense
- How WQ processes drive WQ on site
- Target sampling efforts
- Compliance, recreation

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Common WQ Parameters

- Basic 5:
  - Temperature
  - Specific Conductance
  - pH
  - DO
  - Turbidity
- Others
  - Nitrate
  - Chlorophyll
  - Phycocyanin
  - CDOM/FDOM
  - PAR
  - TDG
  - Surrogates for nutrients, bacteria, sediment, etc.

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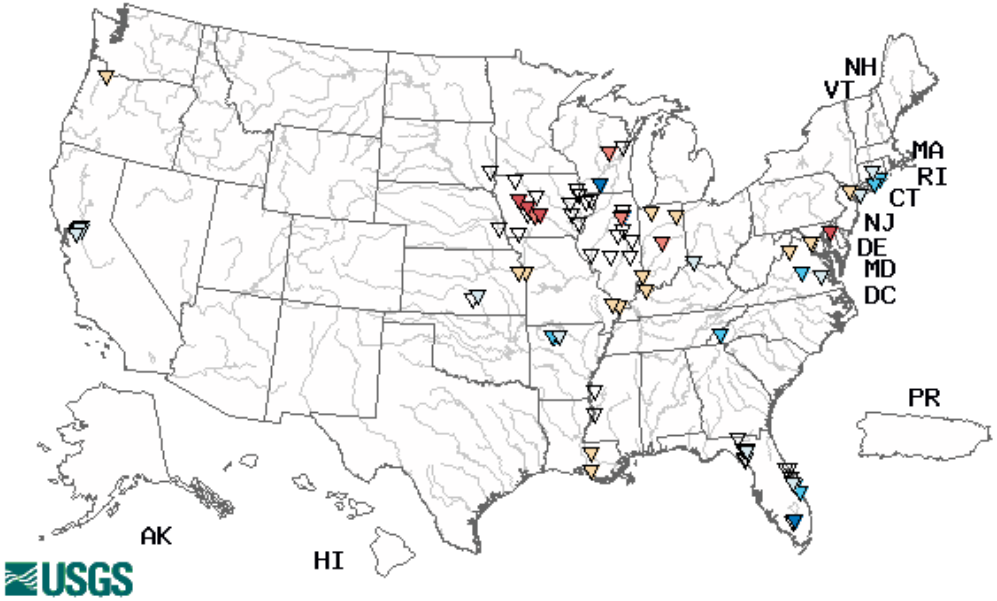
Water-Quality Watch

WaterQualityWatch -- Continuous Real-Time Water Quality of Surface Water in the United States

- Home
- About USGS WaterQualityWatch
- Current RTWQ Maps [Redisplay]
- State: United States
- Measurement: Nitrate
- [Animate Map]
- [Site List]
- Map of all USGS Water Data
- RTWQ FAQ
- State Links to Surrogates and Reports
- Technical Resources
- Other Links
- Search USGS Publications

Real-Time Nitrate, in mg/L

February 09, 2015 17:33ET



Explanation							
<.1	.1-.29	.3-.99	1-2.99	3-9.99	10-29.9	>30	No Data

Temp | Cond | pH | D.O. | Turb | Nitrate | Disch | Surrogates

Why Surrogates?

- Time-dense estimates of analytes
- Real-time info, defined uncertainty
- Identify sources and evaluate trends
- Rapid notification to public and managers
- Real-time comparison to water-quality criteria
- Probability of exceeding criteria

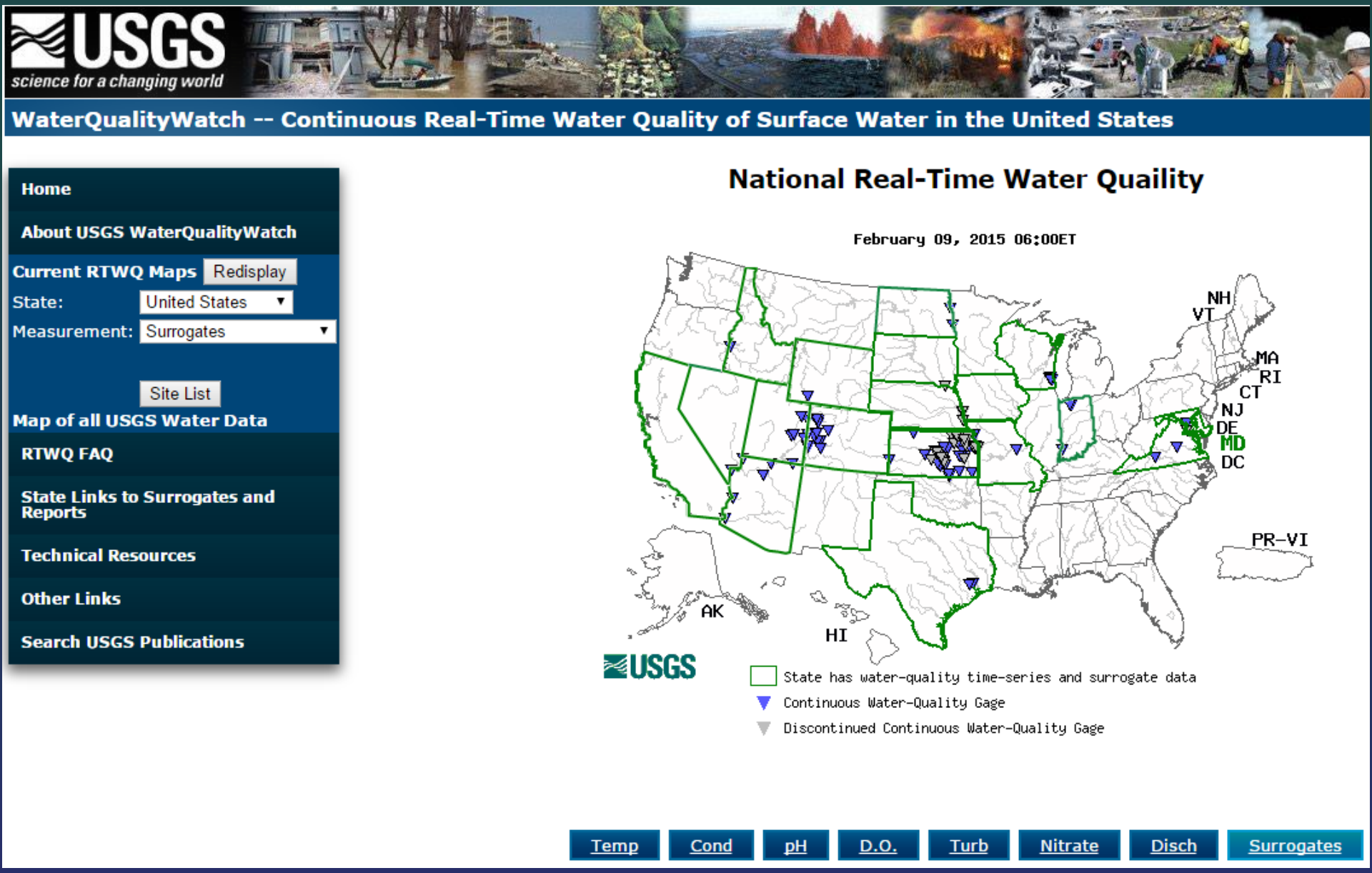
Requirements for Surrogate WQ Models

- Statistical significance of relation
- Discrete samples over range of conditions
- Regression model evaluation
  - Initially
  - Ongoing

Using Surrogates

Direct measurement	Computed from direct measurements
Gage Height/Stage	Streamflow (discharge)
Specific Conductance	Chloride, salinity, alkalinity, fluoride, dissolved solids, sodium, sulfate, nitrate, atrazine, trace metals
Turbidity	Total suspended solids, suspended sediment, fecal coliform, total nitrogen, total phosphorus
Dissolved oxygen	Percent saturation, BOD, methane in GW
FDOM	Methylmercury, DOC
Fluorescence	Algal concentration, algal toxins

USGS NRTWQ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WaterQualityWatch -- Continuous Real-Time Water Quality of Surface Water in the United States
Home
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State:
United States
Measurement:
Surrogates
Site List
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Other Links
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National Real-Time Water Quality
February 09, 2015 06:00ET
NH
VT
MA
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CT
NJ
DE
MD
DC
PR-VI
AK
HI
USGS
State has water-quality time-series and surrogate data
Continuous Water-Quality Gage
Discontinued Continuous Water-Quality Gage
Temp
Cond
pH
D.O.
Turb
Nitrate
Disch
Surrogates

Preparing for Data Collection

Considerations

- Project objectives & scope
- Site & equipment selection
- What data will be reported?
- How will data be used?
- Benefits or real-time reporting
- Training and QA protocols

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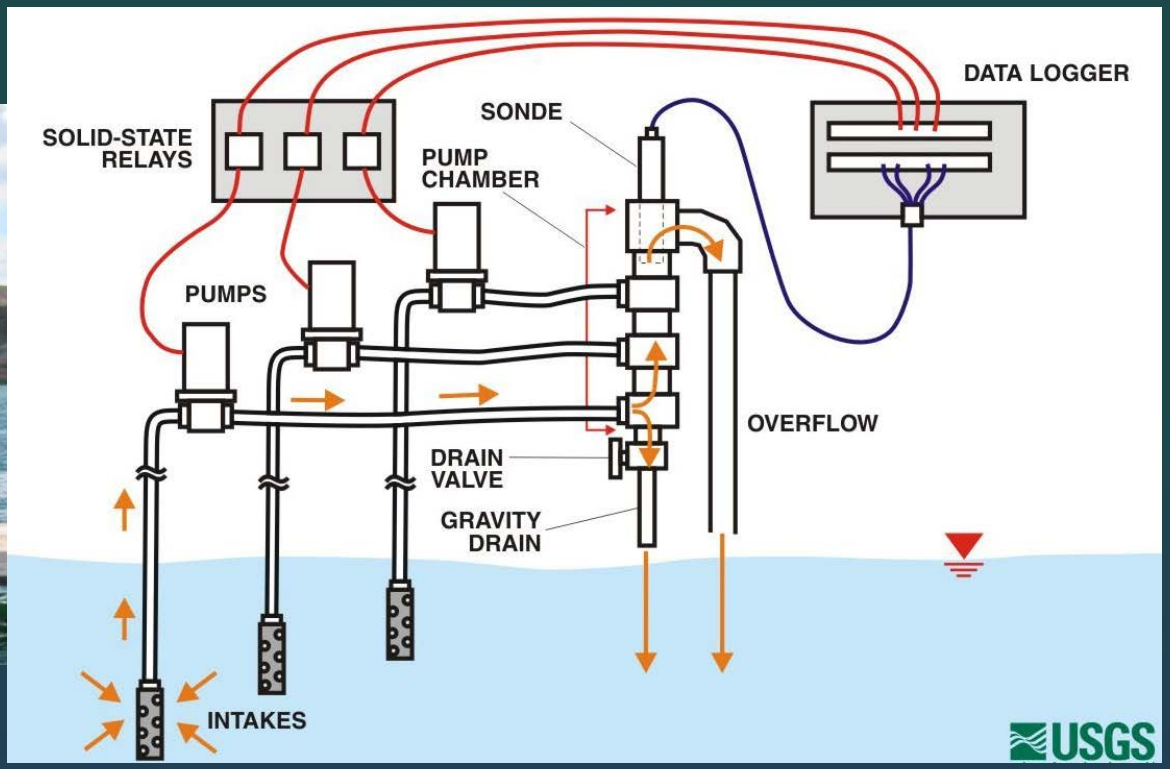
Common Data-Collection Objectives

- Hydrologic and water-quality processes
- Seasonal, diurnal, and event-driven changes
- Early warnings or compliance
- Estimates of concentration & load
- Optimize sample collection

Background Data Collection

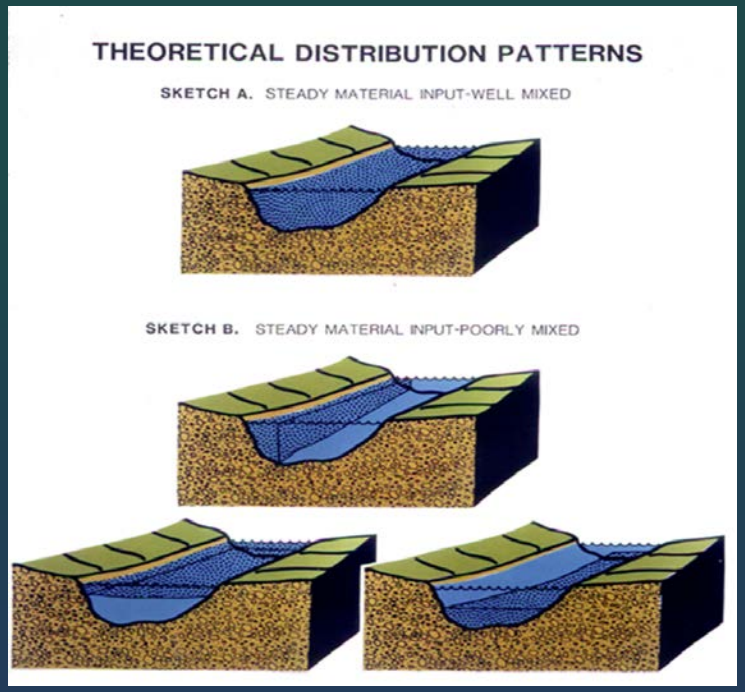
- Seasonal flow conditions
- Review relevant site data
  - ADCP profiles
  - Discrete WQ sample information
- Range of WQ conditions
- Complete cross-sectional profiles
- Complete depth profiles
- Fouling potential

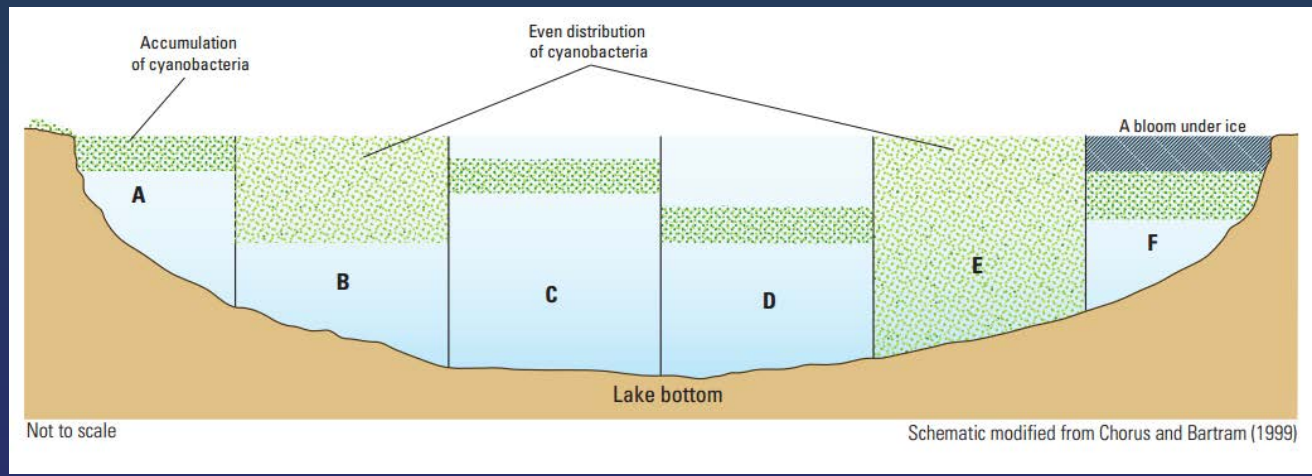


Site Selection and Installation

Site and Sensor Selection Considerations

- Project objectives
- Site characteristics
  - Flow, stage, debris
  - Channel & mixing
  - Safety & access
  - Range of WQ conditions
  - Fouling
- Cost





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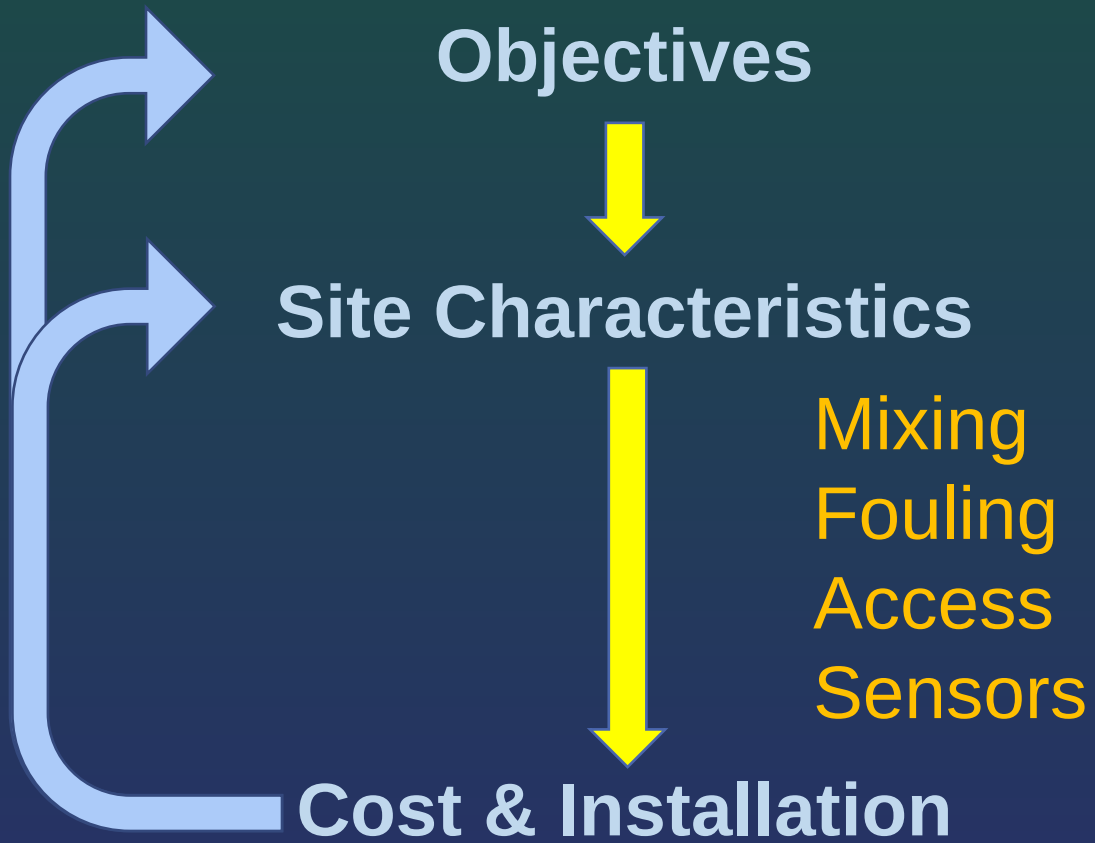
Preparation Feedback Loop



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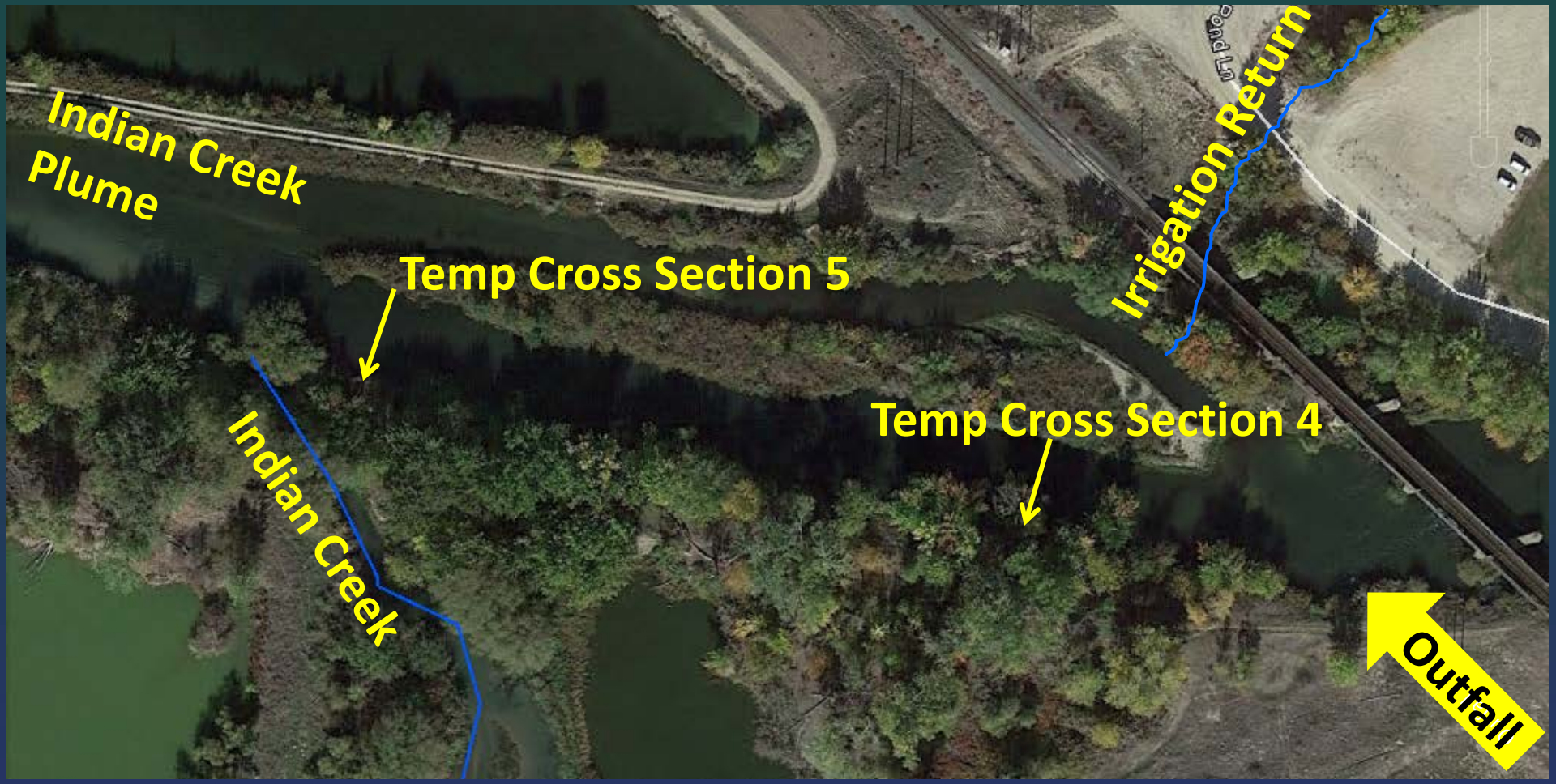
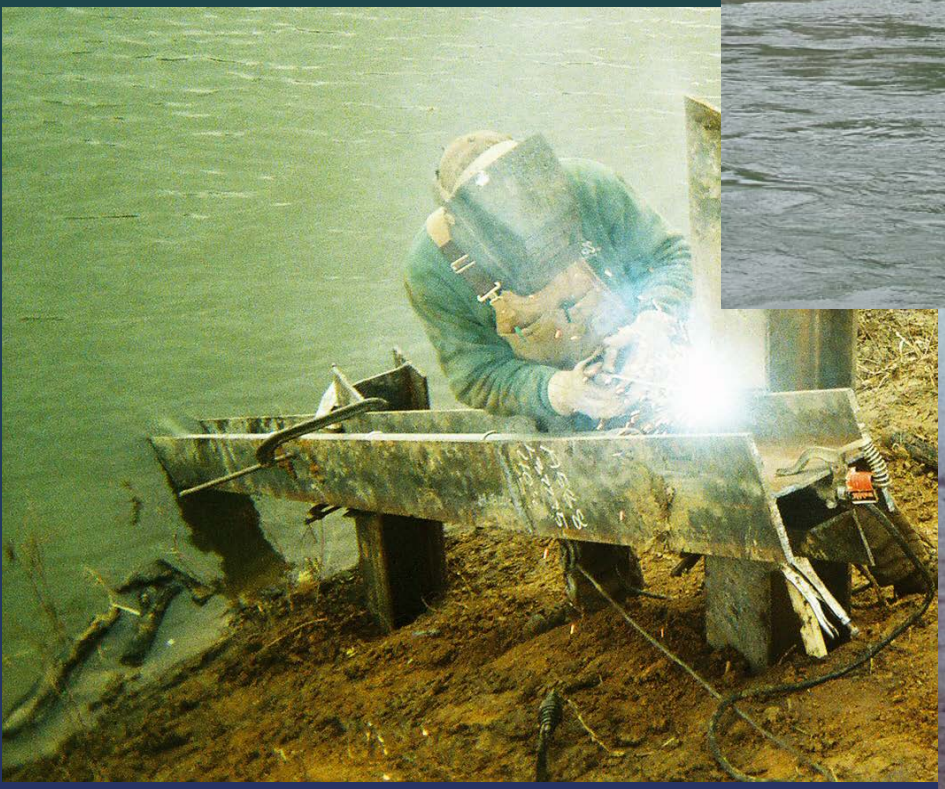
Example


Indian Creek Plume
Temp Cross Section 5
Irrigation Return
Temp Cross Section 4
Indian Creek
Outfall

Site Selection Matters



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Details

- Weather
- Crime
- Site access
- Sonde access
- Cross sectional access
- Range in stage and flow
- Event-driven WQ changes
- Fouling
- Telemetry and power
- Distance and per-diem
- Safety and human-power
- Sensor range
- Installation, supplies, design
- Permits
- Repairs

Photo Credits:
Austin Baldwin, USGS

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Installation

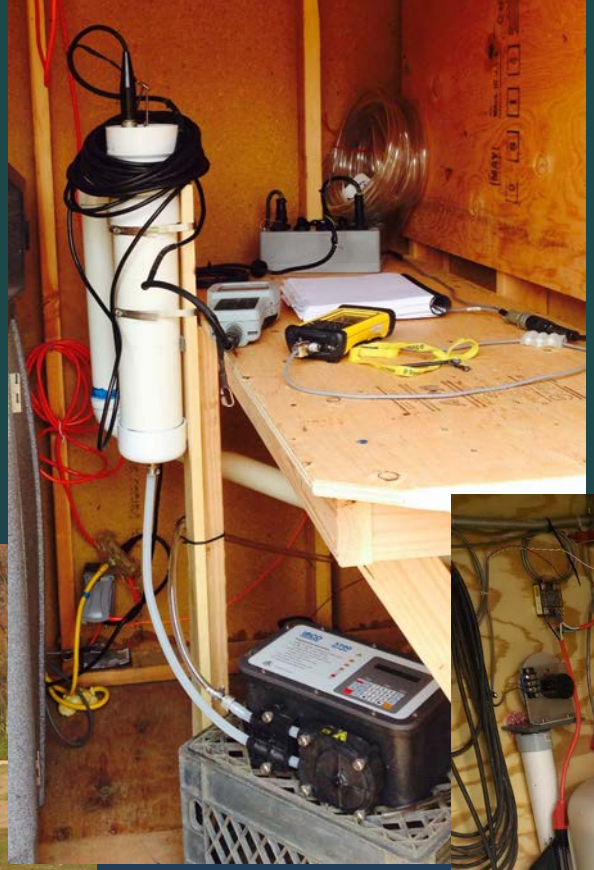
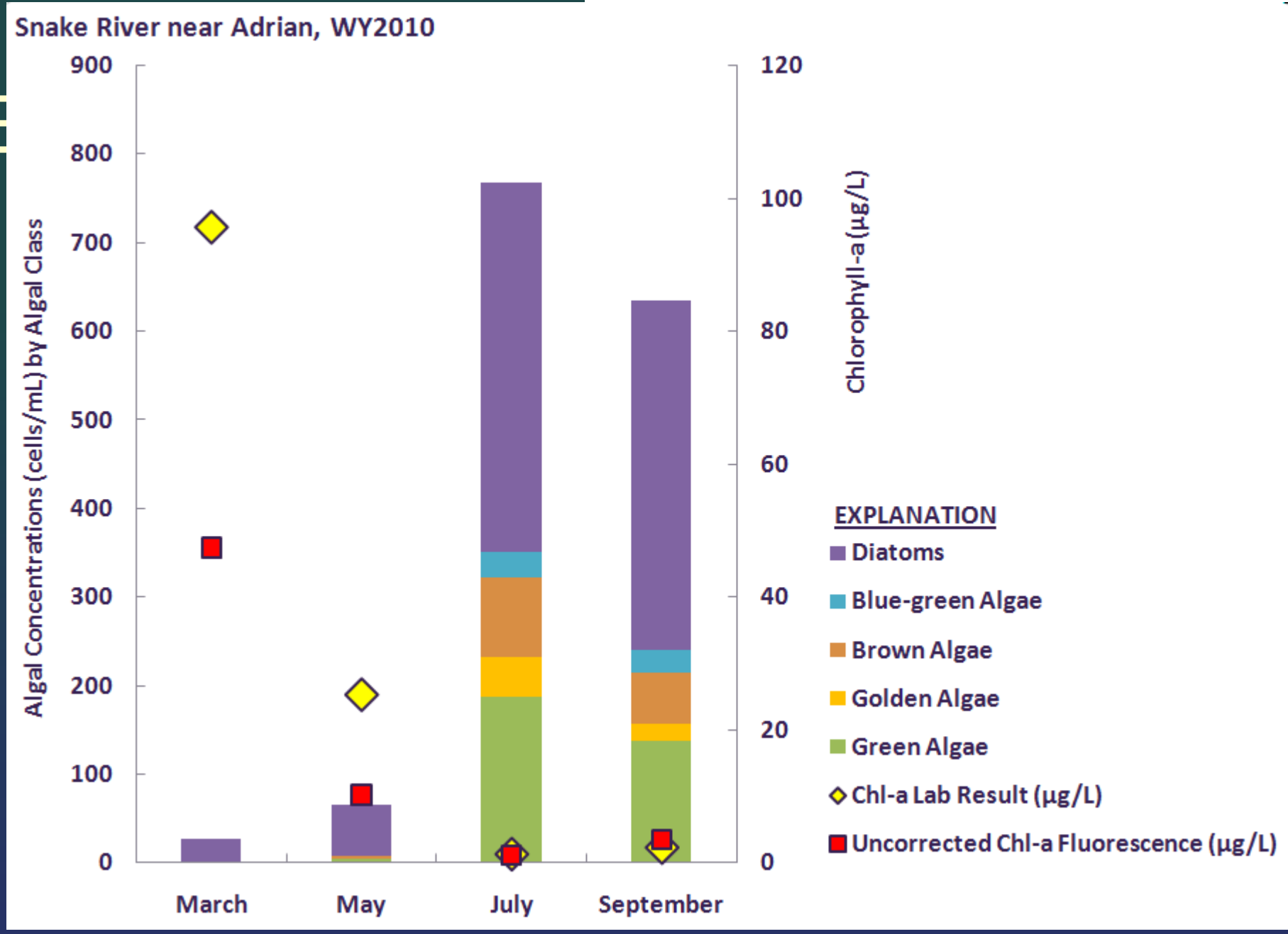


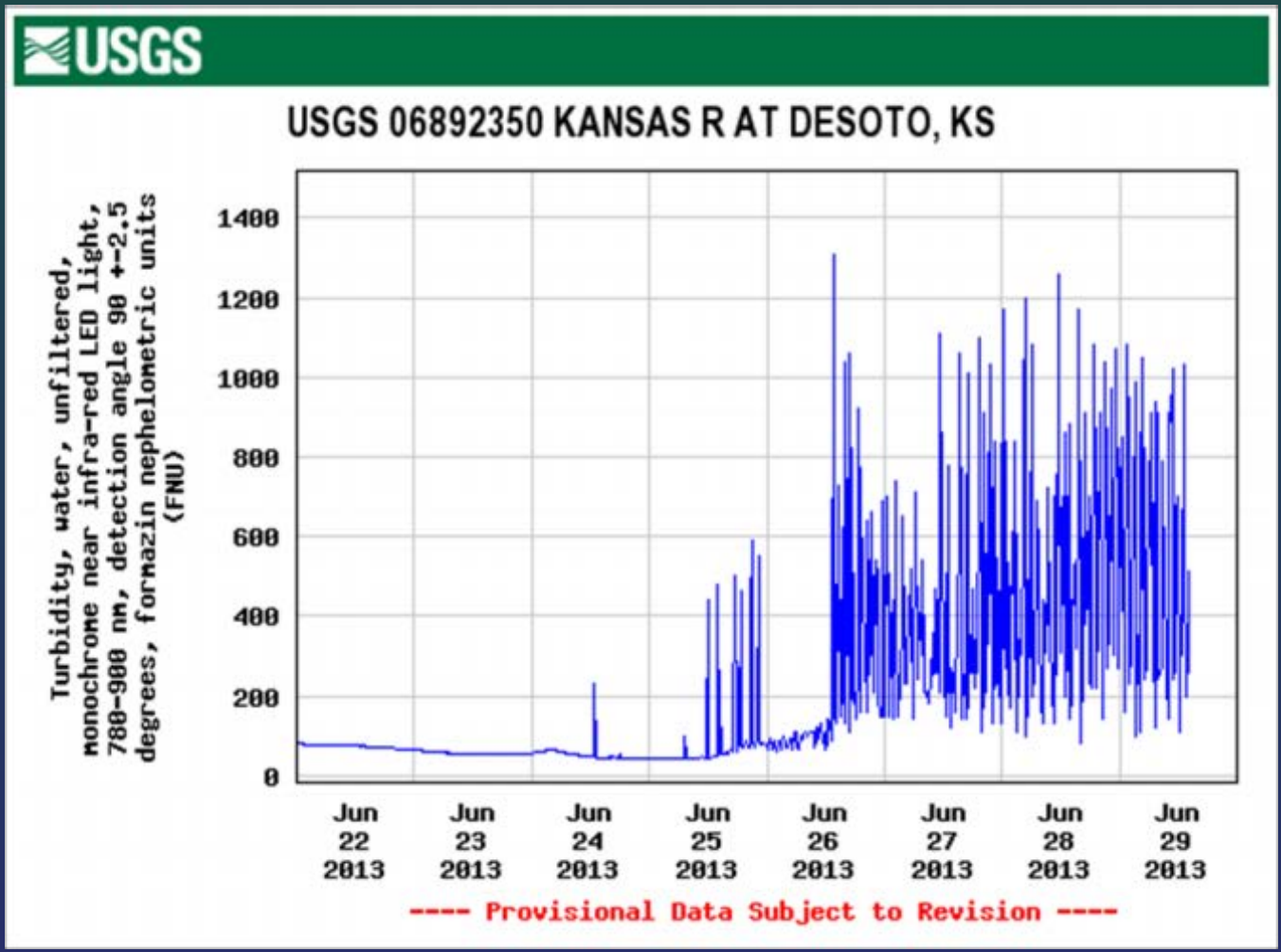
Photo Credits: Trudy Bennett, Austin Baldwin, USGS

Sensor Technology

- Range
- Fouling susceptibility
- Regulatory acceptance
- Data interpretation (ratios, variance, burst)
- Comparability among sites/projects
- Deployment logistics
- Sources of bias
- Maintenance and replacement costs
- Calibration standards
- Lab comparison needed?


Snake River near Adrian, WY2010
Algal Concentrations (cells/mL) by Algal Class
900
800
700
600
500
400
300
200
100
0
Chlorophyll-a (µg/L)
120
100
80
60
40
20
0
March
May
July
September
EXPLANATION
Diatoms
Blue-green Algae
Brown Algae
Golden Algae
Green Algae
Chl-a Lab Result (µg/L)
Uncorrected Chl-a Fluorescence (µg/L)

Quality Assurance and Quality Control

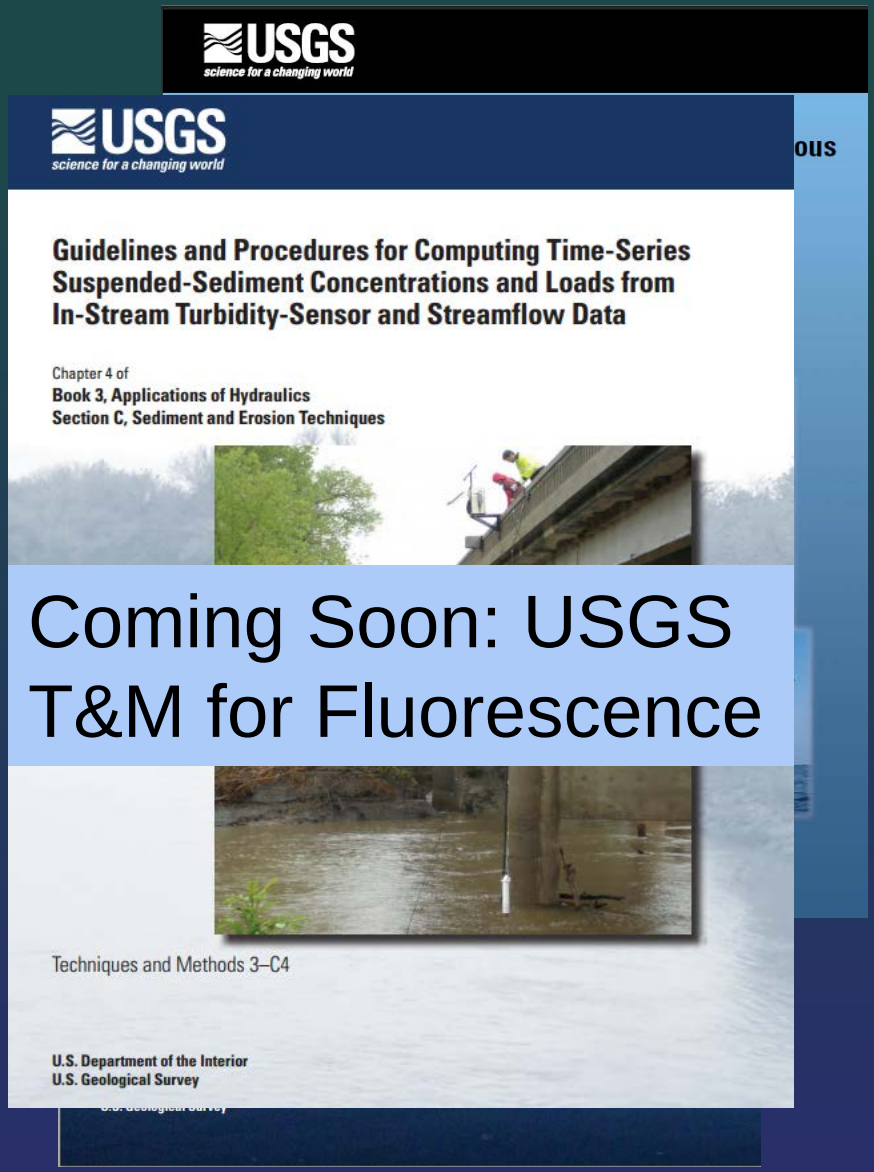


Daily Review of Real-time Data

- Transmission problems
- Excessive sensor fouling or drift
- Sensor or monitor malfunction
- User errors or maintenance problems
- Minimize bad data (displayed on the web)

USGS Quality Assurance

- National Field Manual
- Techniques and Methods Reports
- Center QA Plan
- Project QA Plan
- Electronic field forms
- Automated data processing
- X-section measures
- Annual written analyses
- HIF Testing programs



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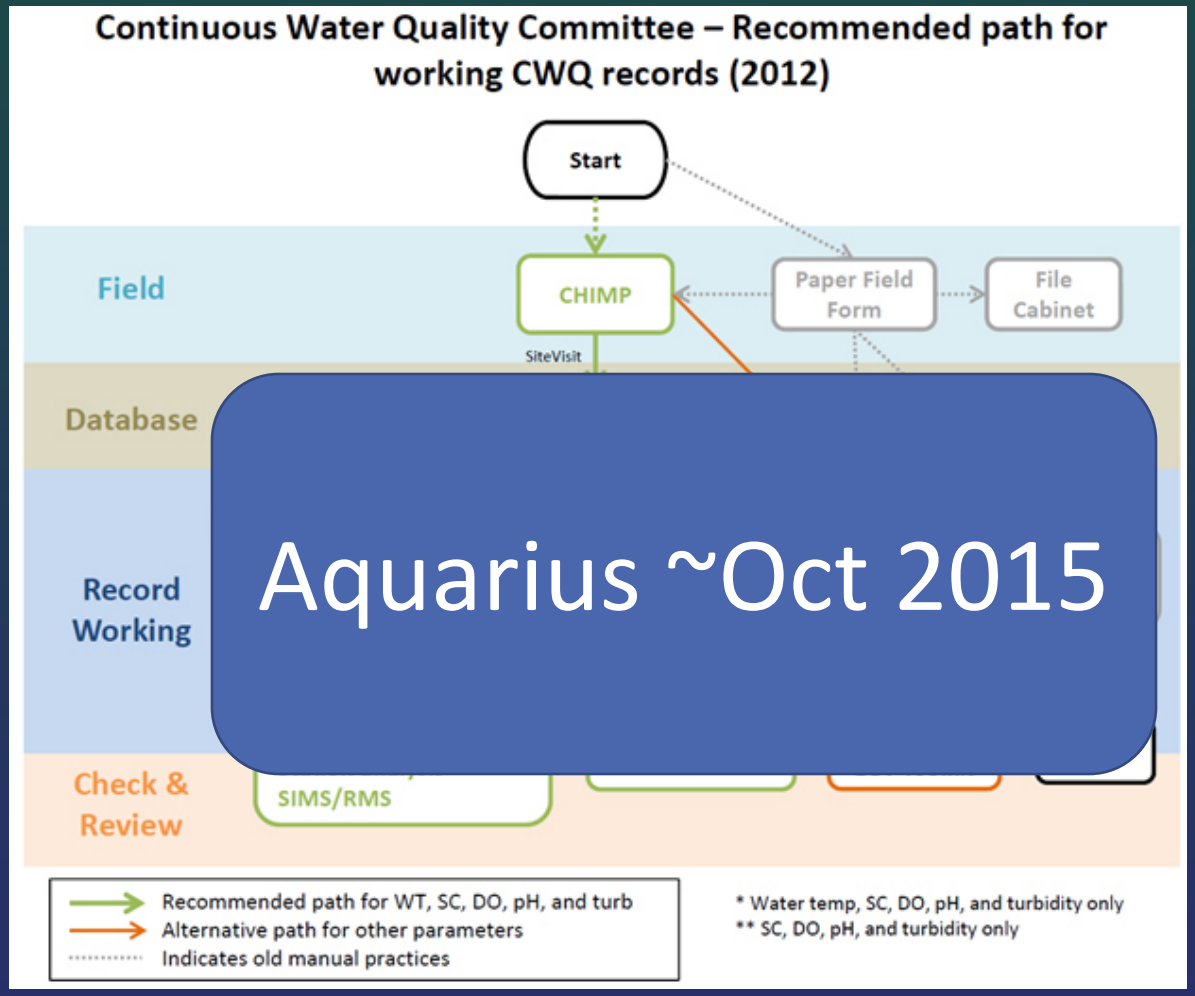
Quality Control

- Routine WQ monitor operation
  - Compare to calibration standards
  - Compare to independent sensors
  - Ambient monitoring during service visit
  - Cross-sections

Quality Assessment

- End-result of standardized workflow
- Timely, routine analysis of QA and QC data
- Quantified uncertainty

USGS Workflow Example



Aquarius ~Oct 2015

Standardized Field Protocol

- Calibrate independent sensor(s)
- Compare readings
- Clean deployed sensor(s)
- Compare readings
- Check deployed sensor(s) in standards
- Calibrate (tolerance criteria)
- Redeploy
- Final comparison

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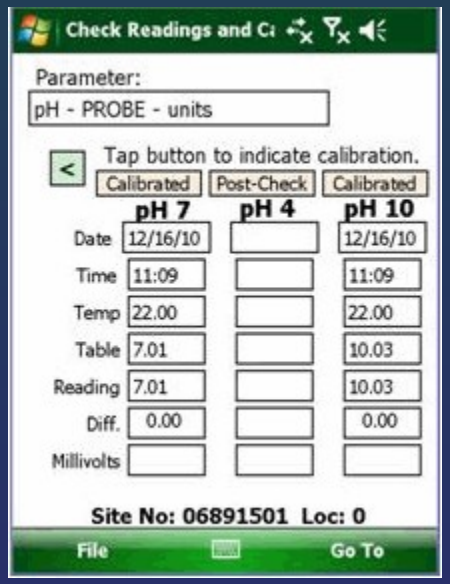
Field Considerations

- Air temp
- Equilibration in water
- Bracket WQ conditions with standards

Standardized Data Collection and Processing

- Electronic field form
- Field software/database integration
- Automated data corrections
  - Based on written guidance
  - User override
- Automated review output
- Three-tiered review
- Review tracking
- Data quality ratings



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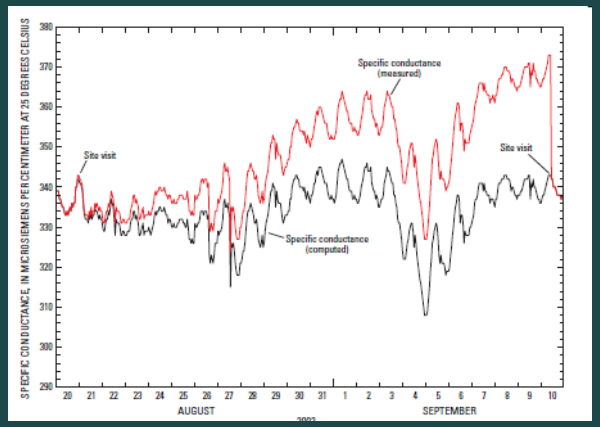
Data Corrections
(fouling, drift, other)



- Application thresholds (instrument noise)
- Default application methods
  - Average percent (SC, DO, Turbidity)
  - Arithmetic (pH, temp)
  - Proration
- Flexibility and user override
  - Unique situations (events, user error)
- Application thresholds (bad data)

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Fouling and Drift Examples

	Deployed Sensor	Independent Sensor
Before Cleaning Reading	10	5
After Cleaning Reading	8	5
Change	-2	0
Fouling Correction	(-2 - 0) / 10 = -20%	

	Deployed Sensor
Value of Calibration Standard	100
Reading in Calibration Standard	110
Calibration Drift Correction	(100 - 110) / 110 = -9%

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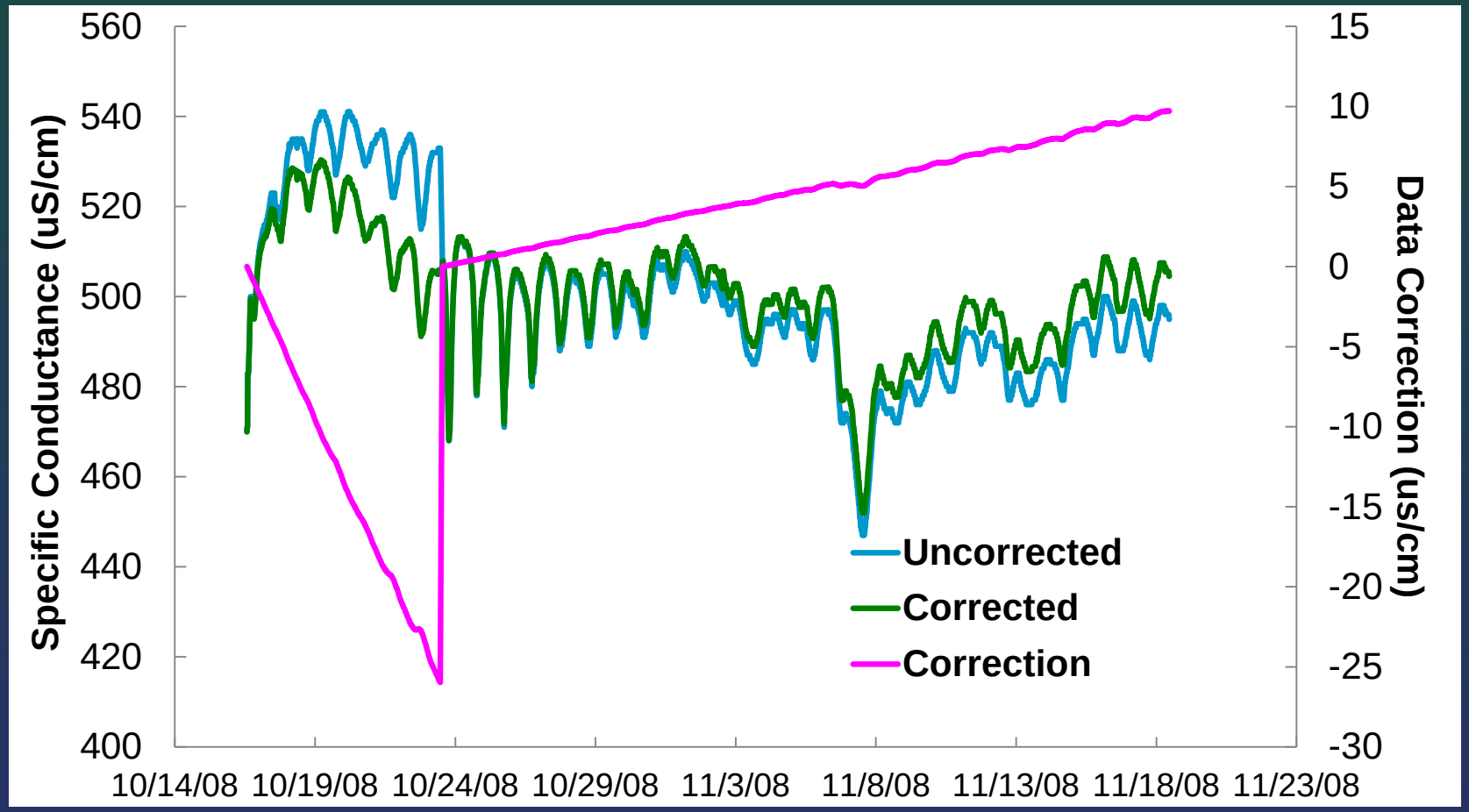
Example Correction



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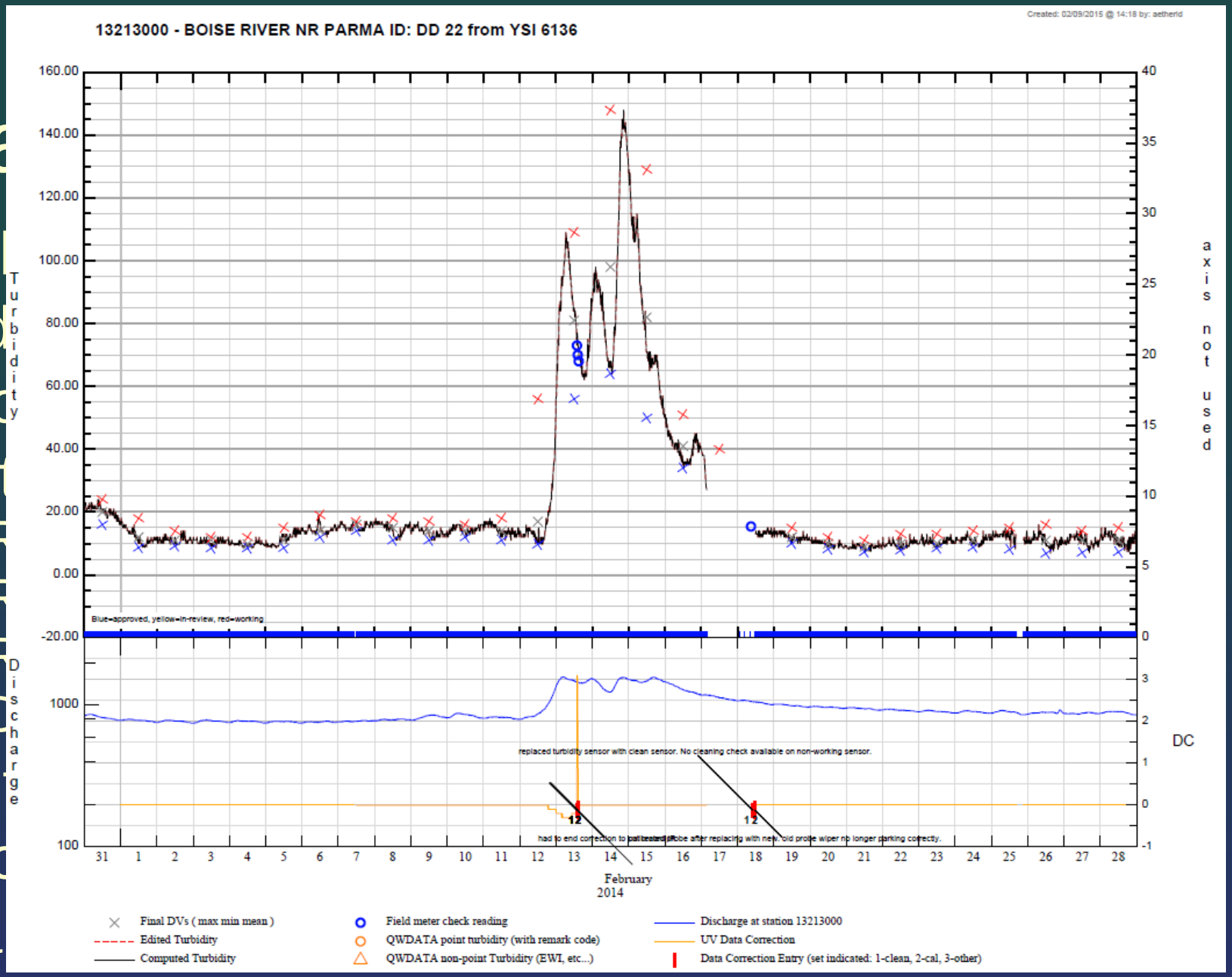
Correction Application Methods

- Pick a default
  - Option: Evaluate total error with tolerance criteria
  - Option: Apply all corrections
  - Option: Apply fouling, apply drift if outside tolerance criteria
  - Option: Evaluate both types of error with tolerance criteria
- Error tolerance integrated with field software
- Establish max corrections limit (delete data)
- Consider % corrections with low values (go arithmetic)

Sta

- Sc
- Ind
- Pro
- Est
  - R
  - R
  - R
  - D
- Au
- Arc
- Pa



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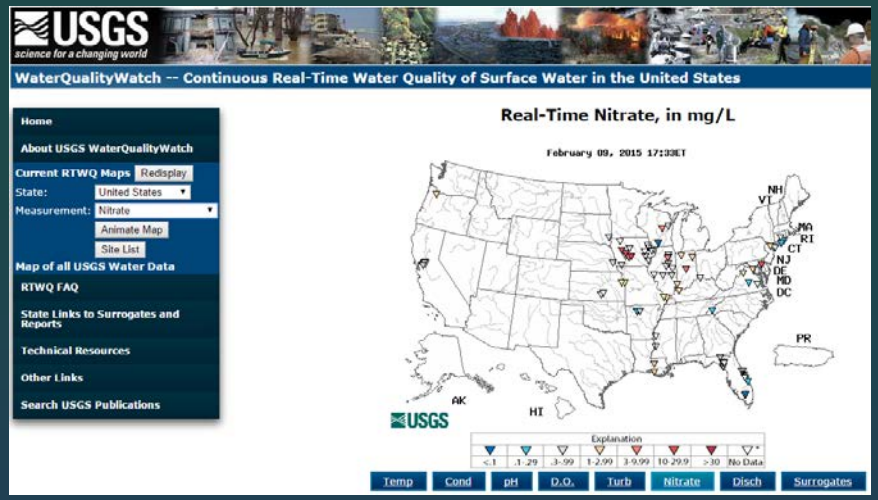
Standardized Data Service

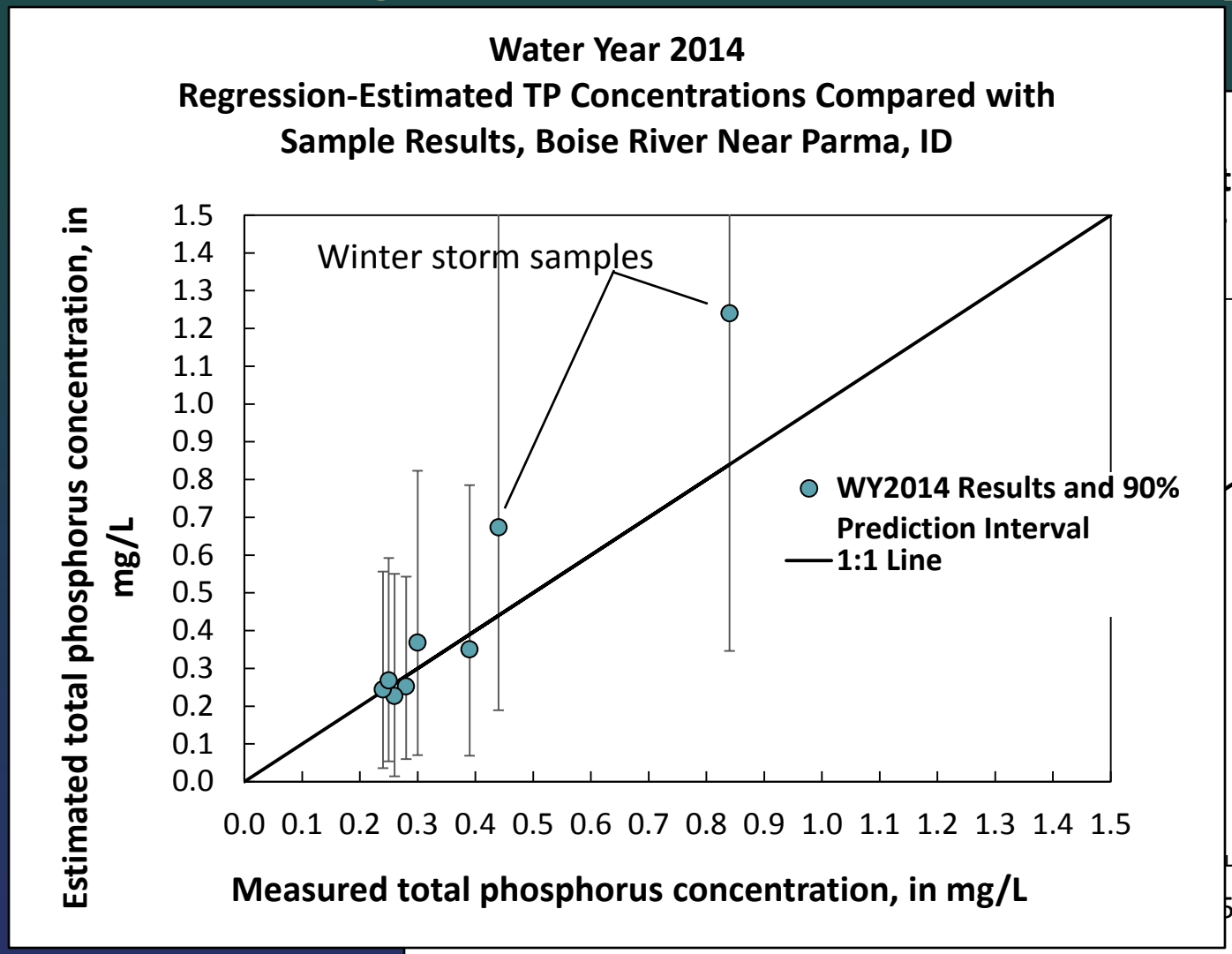


- Time (GMT)
- Hourly transmission
- Daily statistics
- Thresholds remove spikes
- Access control available
- Integration with field data collection
- Integration with data processing

Surrogate Model Workflow Considerations

- Timeliness of QA/QC
- Frequency of site visits
- Missing data interpolation? (not USGS policy)
  - Daily time-step required in WQ models
- Sample collection timing
- Model evaluation, record review

Surrogate Review Example



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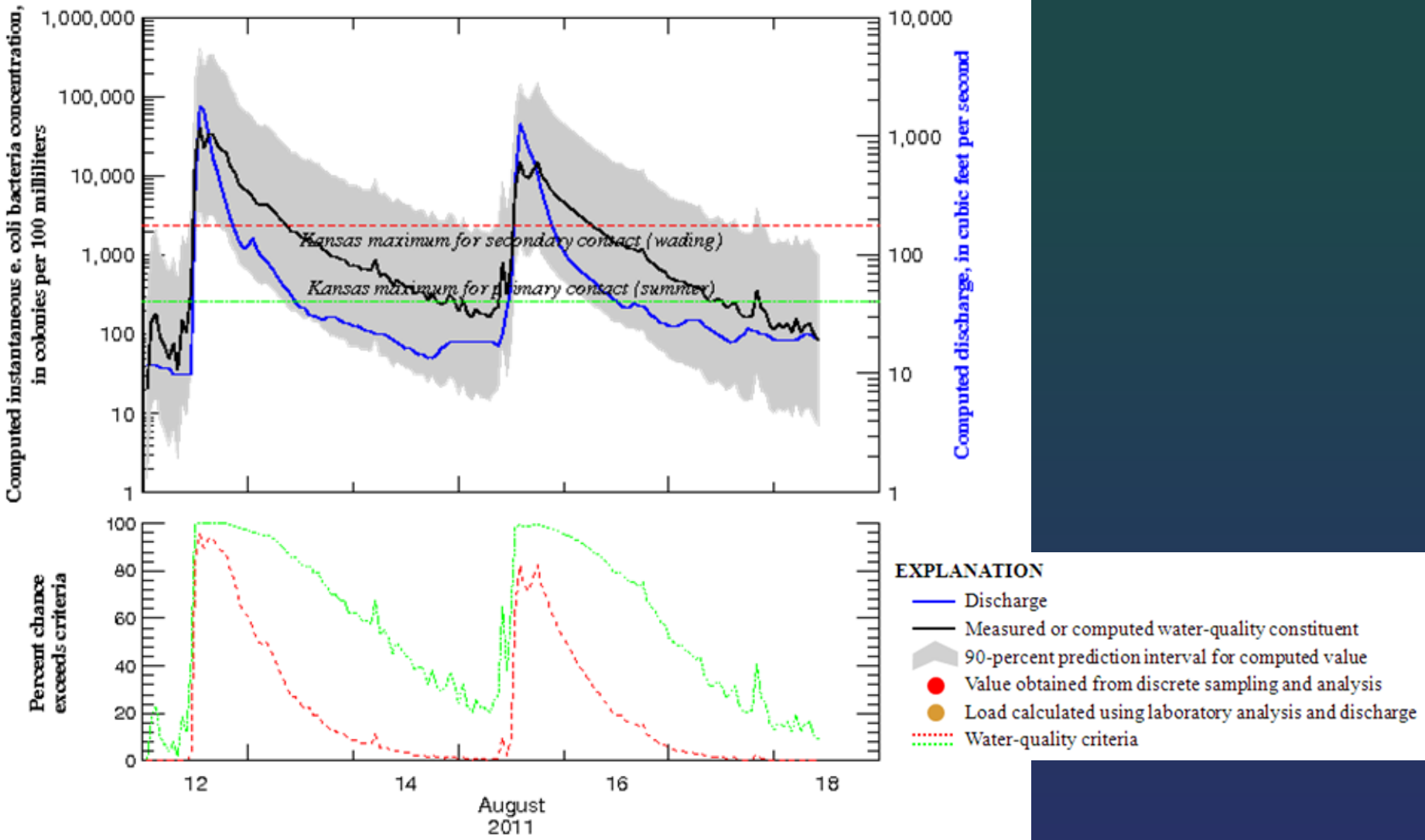
Data Applications

Management and Monitoring



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Computed instantaneous e. coli bacteria concentration in Indian Creek at State Line Road, Leawood, KS

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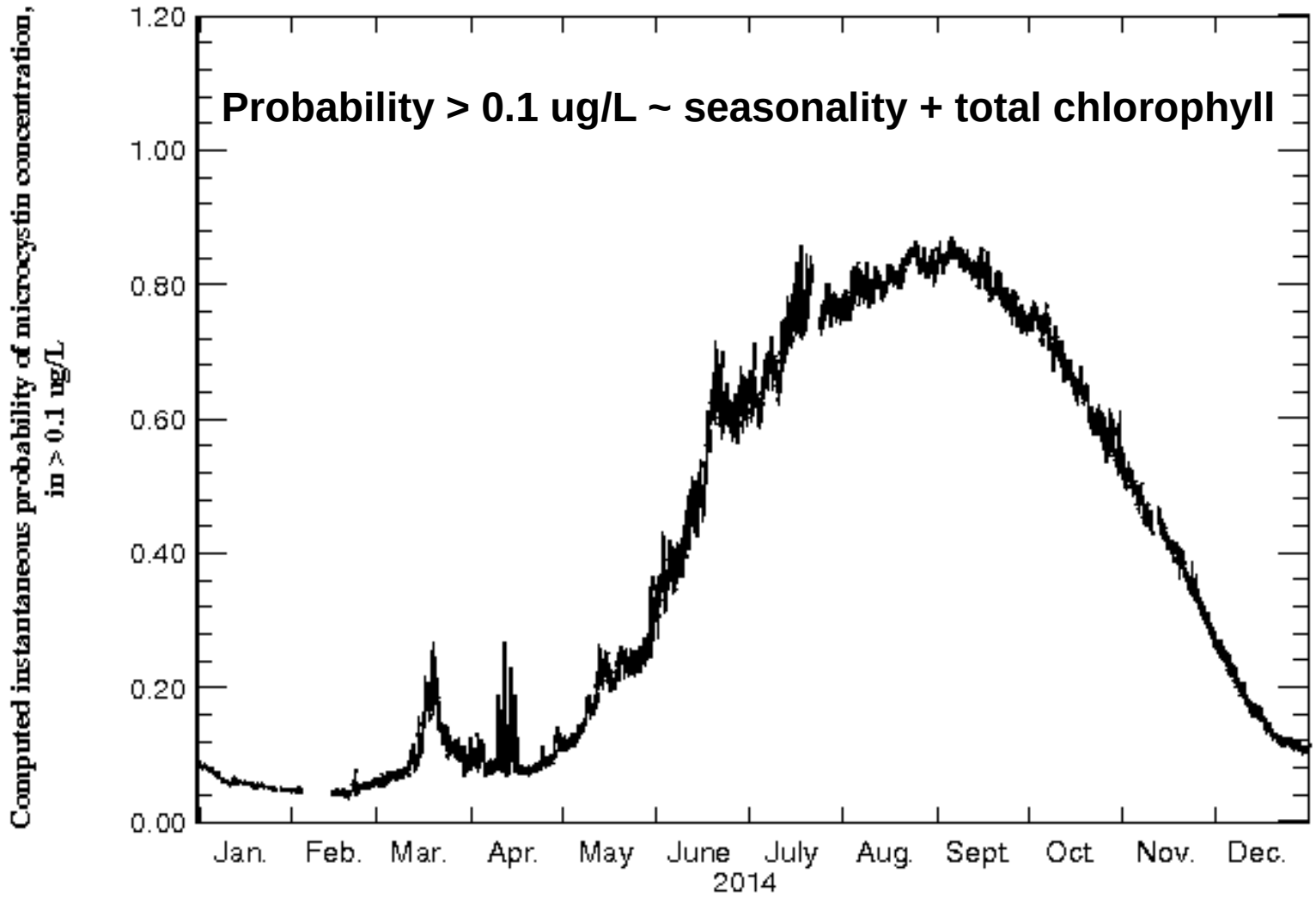
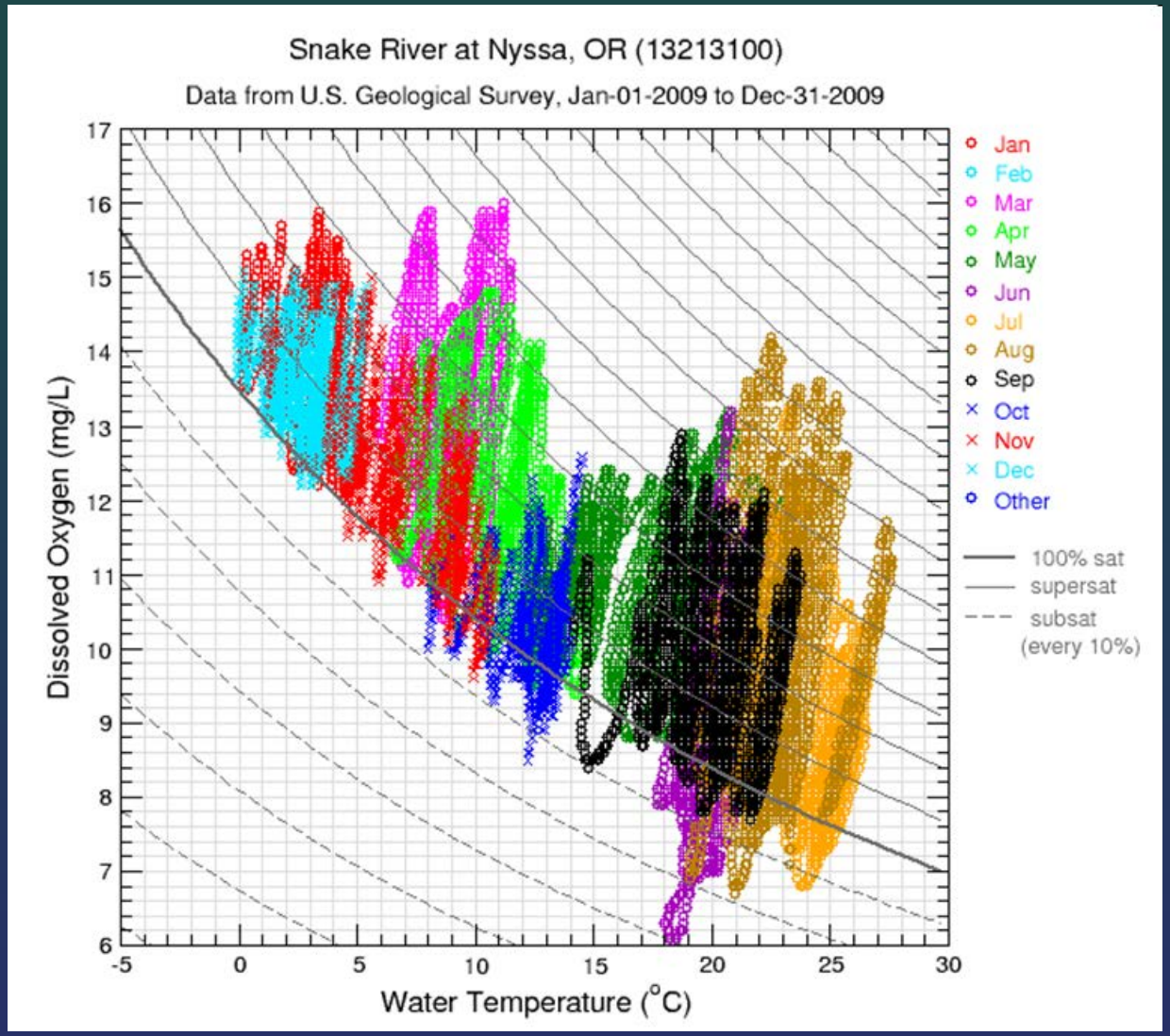
Microsystin Probability



Computed instantaneous probability of microcystin concentration in Cheney Reservoir near Cheney, KS

Continuous Dissolved Oxygen

- Diurnal range
- Indicator of productivity



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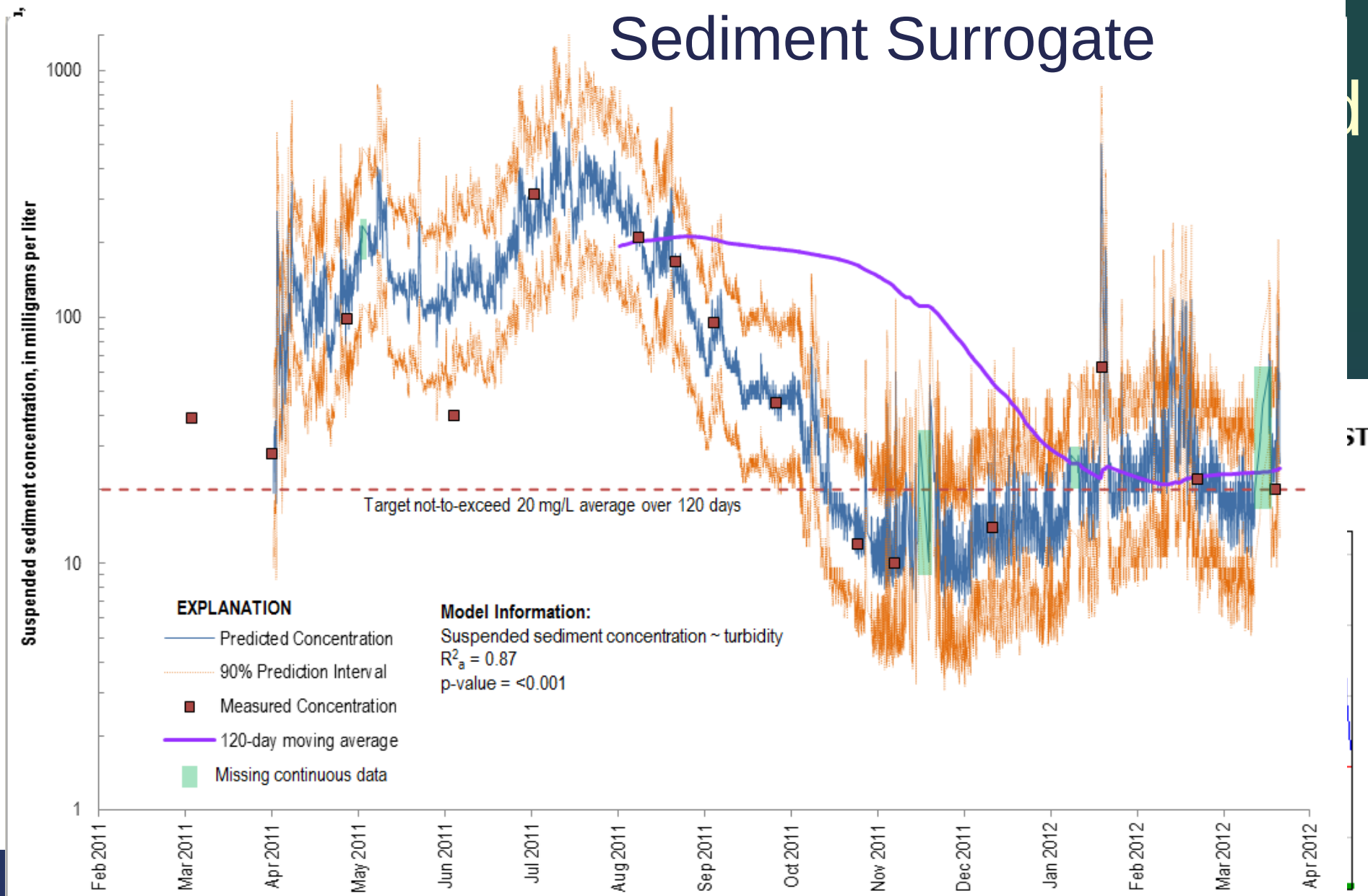
Sediment Surrogate



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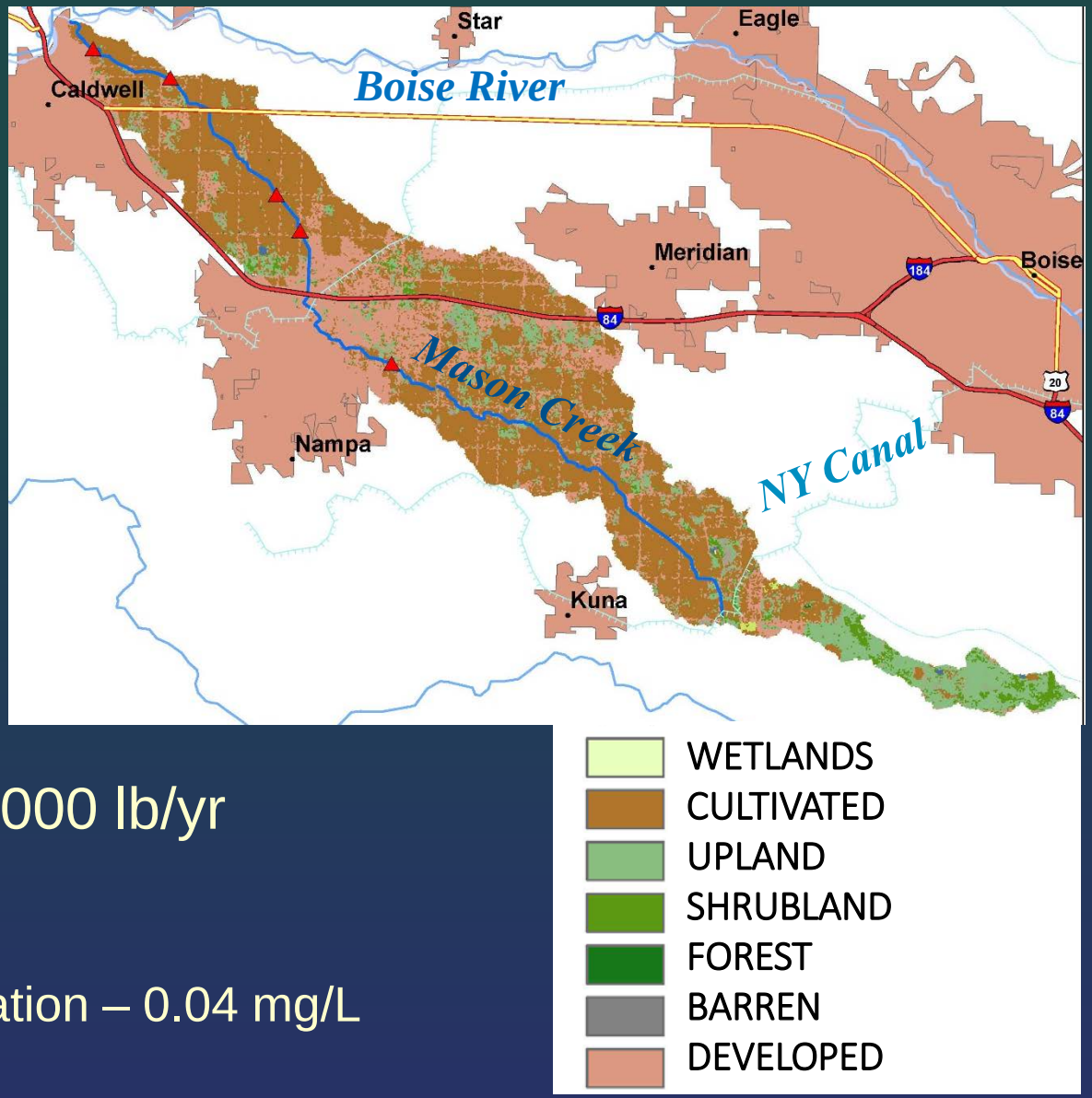
Ag BMP Analysis

- Minimal summer rain
- Winter BFI = .84
- ~50% Ag land use
- Estimate base load
- Estimate Ag load
- Ag Load/acre/season



- Example: XYZ BMP
- 5000 acres, -1 lb/ac, -5000 lb/yr
- Compute new
  - Daily load -25 lb/d
  - Flow-weighted concentration – 0.04 mg/L

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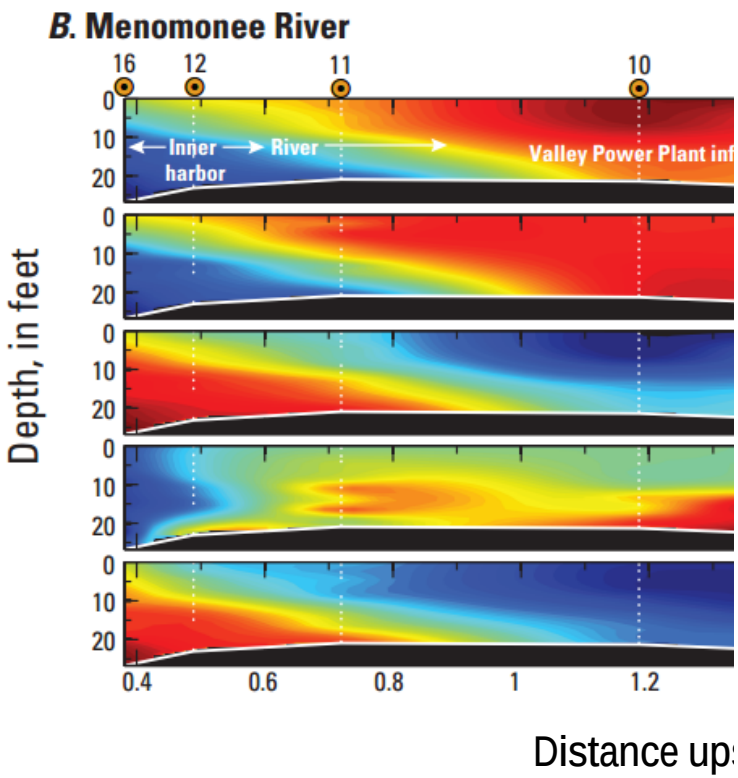
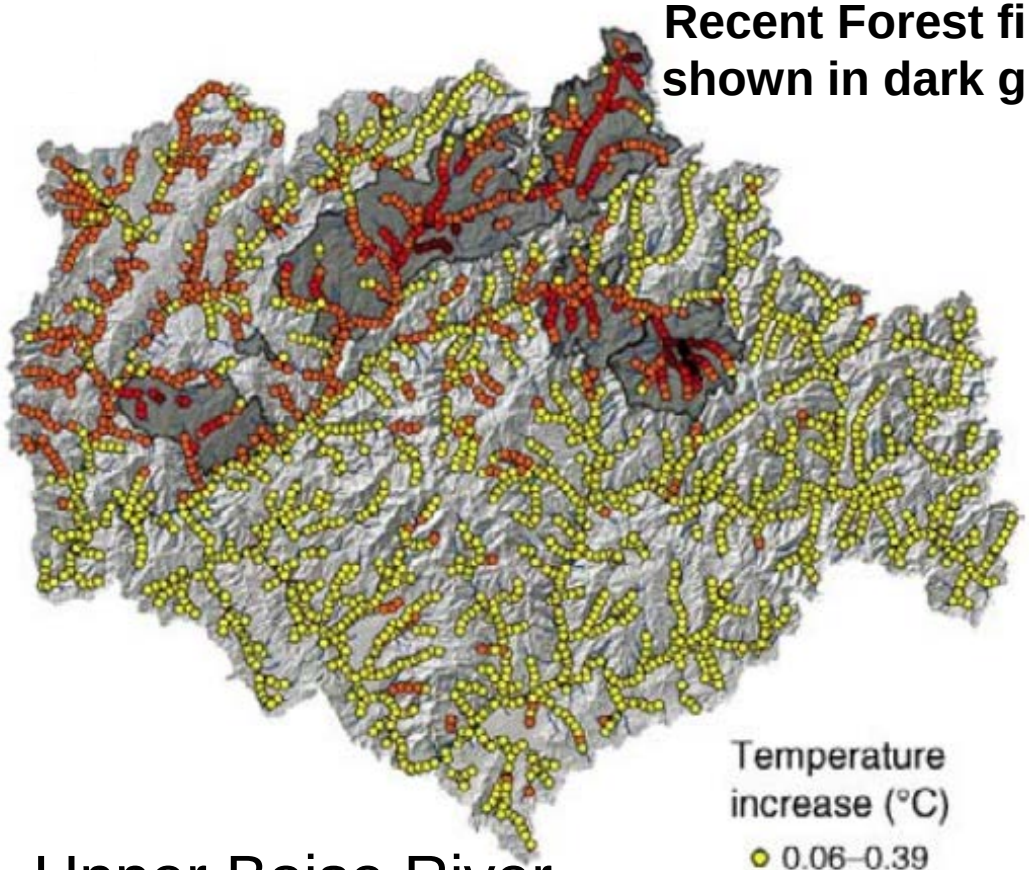
Longitudinal or Spatial Analysis

Source: Isaak and others, 2010



Source: Jackson, P.R., and Reneau, P.C., 201



Upper Boise River Basin Temperature Trend 1993-2006

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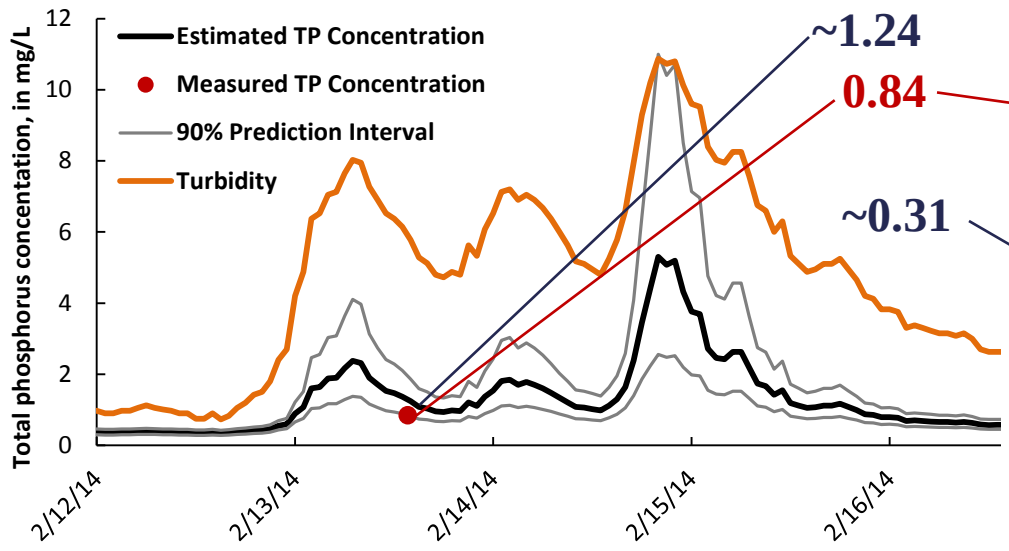
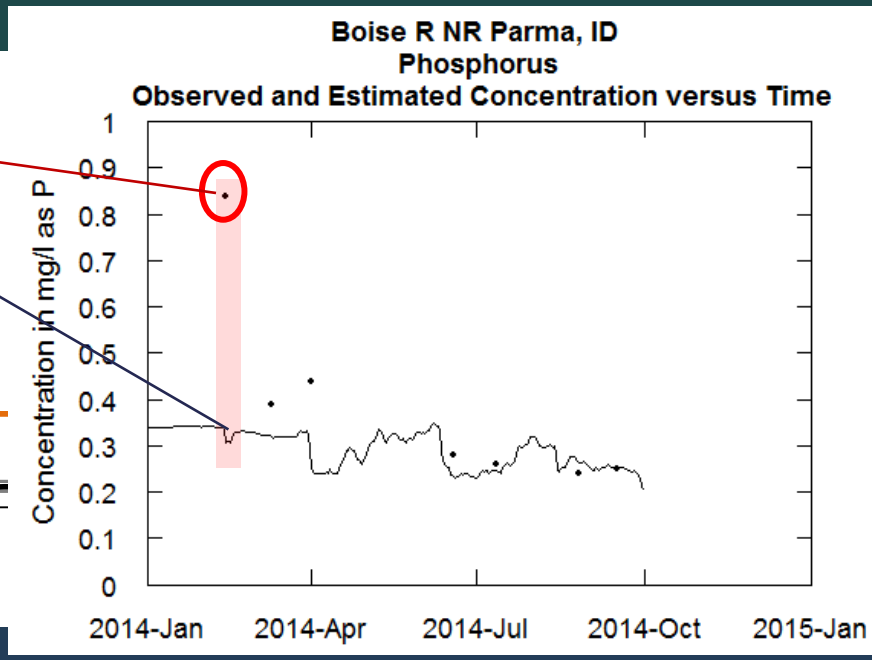
Improved Watershed Understanding





Estimated Total Phosphorus Concentrations and Loads from Two Models		
February 2014	**WRTDS**	**Surrogate Model**
Mean Daily Load	1,690 lb/d	3,260 lb/d
Mean Daily Concentration	0.33 mg/L	0.54 mg/L

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Many more

- Tidal flux of mercury using FDOM surrogate
- Sediment transport
  - Dam removal
  - Stormwater
  - Reservoir sedimentation
  - Wildfire effects
- Groundwater conditions
  - Methane and DO
  - Temperature and SW interaction
- Water temperature
  - Trends, climate change
  - Thermal discharges

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