Continuous & Real-Time Monitoring: Direct Measures and Surrogates

Andy Ziegler (USGS)–Director/WQ Specialist, Kansas Water Science Center

Overview of Continuous Real-time Session track, Continuous and real-time water-quality monitoring; where are we and where are we going? (and why aren't we there yet!)

Stewart Rounds (USGS)—WQ Specialist, Oregon Water Science Center

Continuous Water-Quality Monitoring in Oregon with a historical perspective (and What can you do with all these data?)

Keli Goodman (NEON)— Aquatic Biogeochemist, (Aquatics/STREON), Boulder

Water quality monitoring in the U.S. National Ecological Observatory Network (NEON)

Mario Tamburri (ACT)— Executive Director, Alliance for Coastal Technologies, University of Maryland Center for Environmental Science

Alliance for Coastal Technologies– Where are we and where are we going?

Brian Bergamaschi (USGS)– Research Chemist, Sacramento, CA

USGS/CUASHI workshop on in-situ optical sensor networks

Ryan Pugh, Environmental Scientist, Water Resources Management Division, DEC, Newfoundland and Labrador, CA,

Regulatory Applications of Real-time Water Quality Data in Newfoundland and Labrador

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

Eighth National Monitoring Conference
Water: One Resource-Shared Effort-Common Future
Portland, Oregon May 1, 2012

Opening Panel goals:

- Whet your appetite for the fantastic collection of presentations for the next 4 days in the Continuous Real-Time Monitoring sessions
- Present an overview of continuous monitoring, some history, tools, and networks
- Spur discussions and move this science tool forward
- Encourage MORE SITES and networks implemented to answer the needs of society and the environment- strive for Regulatory acceptance!
- Offer some thoughts on where we are and where to go….
- TRY IT!

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Some Local and National examples!

RM B117-119 B3– Assessing Water Quality Conditions in Estuaries

Moderator: Hugh Sullivan EPA

Scott Ator, Eva DiDonato, Hilary Neckles, and Lyndal Johnson

How do we operate monitors in streams?

RM B117-119 C3 Tuesday 3:30-5:00 pm

Emerging Technologies & Techniques in Real-time Monitoring

Moderator: Chuck Dvorsky

George Aiken, Brian Pellerin, Michelle Maier, and Mike Sadar

What about using UV Sensors?

Some examples!

RM B117-119 D3 Wednesday 8:00 – 9:30 am

UV Sensors: Nitrate

Moderator: Brian Pellerin

Teri Snazelle, Brian Bergamaschi, John Franco Saraceno, Jessica Garrett

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What about real-time water quality and "surrogates"?

Do we have the session for you!

RM B117-119 E3 Wednesday- 10:30-12:00 pm

Real-time surrogates

Moderator: Pat Rasmussen

Austin Baldwin, Benjamin Hammond, Jami Goldman, Gary Welker

How do we use these monitors in networks?

You can't miss any of these presentations!

RM B117-119 F3 Wednesday 1:30-3:00 pm

Incorporating innovations into network design

Moderator: Andy Ziegler

Ken Hyer, Chuck Dvorsky, Ryan Pugh, Charlie Peters

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What about data quality assurance?

These folks tell you how to do it right!

RM B117-119 G3 Tuesday- 3:30-5:00 pm

- **Continuous real-time monitoring: QA from start to finish**
- **Moderator: Dan Sullivan**
- **Chuck Dvorsky, Revital Katznelson, Peter Stoks, Richard Wagner**

And even more Quality assurance– and data display…

Cool stuff! (no, really,--it is!)

RM B 117-119 I3 Thursday 10:00-11:30 am

- **Data Quality Management Tools and techniques**
- **Moderator: Terry Schertz**

Wesley Brooks, Mohammad Islam, Pat Rasmussen, Stewart Rounds

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How about some more cool applications?

It doesn't get any better than this!

RM B117-119 J3 Thursday 1:00- 2:30 pm

Innovative Techniques for Monitoring, Session 1

Moderator: Jane Caffrey

Estelle Baures, Edward Patino, Ryan Pugh, Glenn Warren

There is more!

Applications you can do too!

RM B117-119 K3 Thursday 3:30-5:00 pm

Innovative Techniques for Monitoring, Session 2

Moderator: Mike Eberle

Melissa Baker, Bill Selbig, Katherine Skalak, Steve Sobieszczk

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And last but not least…..

What about understanding new gizmos?

Rm A106- M3 Friday- 10:00 -11:30 am

Evaluation of new in-situ sensors

Moderator: Brian Bergamaschi

Kenna Butler, Tamara Kraus, Justin Ndukaife, George Aiken

AND---- There are additional presentations in other sessions that use continuous monitoring as a tool in understanding the environment

But wait-- There's MORE!

Check out the more than 100 poster and vendor booths that have continuous data applications and gizmos !

And don't forget to periodically check the NWQMC web page– lots of recent advances http://acwi.gov/monitoring/

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science for a changing world

Continuous and real-time water-quality monitoring; where are we and where are we going? (and why aren't we there yet!)

Andy Ziegler
USGS Kansas Water Science Center

With contributions, collaboration, and occasional disruption from

Vicki Christensen, Teresa Rasmussen, Tim Cohn, Brad Garner, John Gray, Jerry Blain, Dave Wolock, Callie Oblinger, Dennis Helsel, Heather Bragg, Chauncey Anderson, George Aiken, Rich Hawlkinson, Rob Ellinson, Rick Wagner, Ryan Pugh, Xiaodong Jian, Casey Lee, Janice Ward, Jerry Feese, Tim Miller, Harry Lins, Dave Schoellhamer, Jerad Bales, Stewart Rounds, Dave Holtschlag, Mark Landers, Hal Matraw, Jim Blakey, Renee Paterson, Callie Oblinger, Dan Sullivan, Pat Rasmussen, Walt Aucott, Steve Sorensen, Dave Lorenz, Cherie Miller, Art Horowitz, Dale Blevins, Charlie Demas, Steve Brady, Rob Runkle, Brian Bergamaschi, Cal Albert, Dave Topping, Donna Francy, Chauncey Anderson, Mario Tamburri, Trudy Bennett, Bob Hirsch, Dave Mueller, Doug Glysson, Tom Stiles, Ken Hyer, Dave Rus, Terry Schertz, Mark Uhrich, Charlie Crawford, Brian Pellerin, John Ficke, Kevin Richards, Donna Myers, Renee Paterson and many others

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

Eighth National Monitoring Conference Water: One Resource-Shared Effort-Common Future
Portland, Oregon May 1, 2012

Why monitor water quality continuously?

- **Time-dense continuous water quantity and quality data (in real-time) improves our understanding of hydrology and water quality that are used by management agencies to improve the quality of human life and that of the environment.**

- **Provides warning for water supply and recreation**
- **Captures seasonal, diel, and event-driven fluctuations**
- **Improves concentration and load estimates with defined uncertainty (8,760 hourly values per year)**
- **Optimizes the collection of samples**

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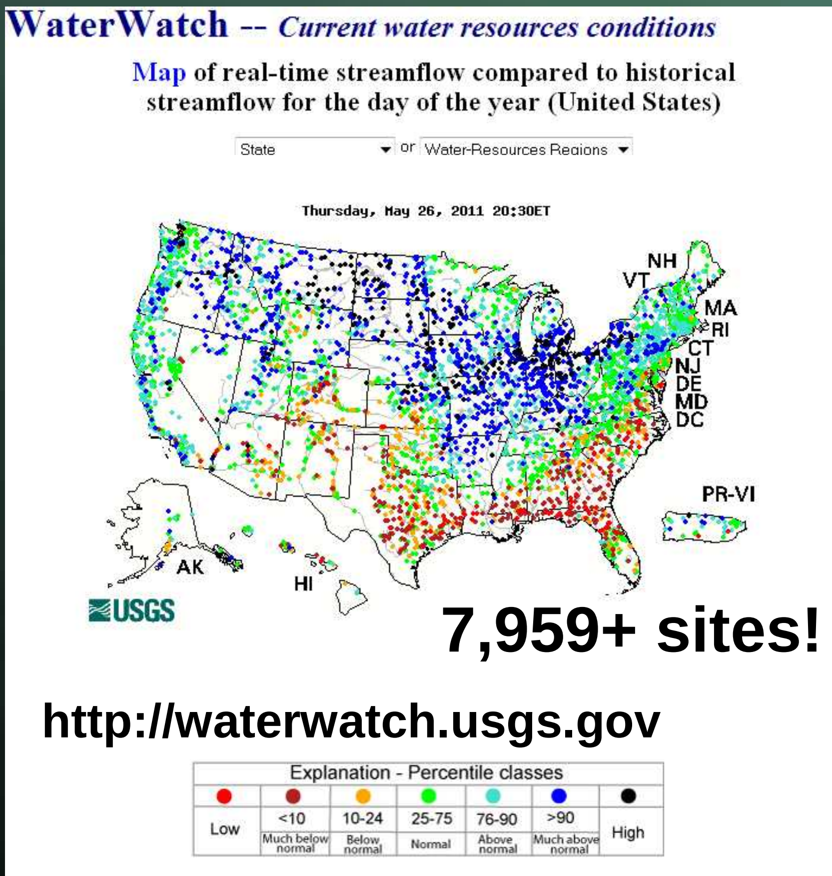
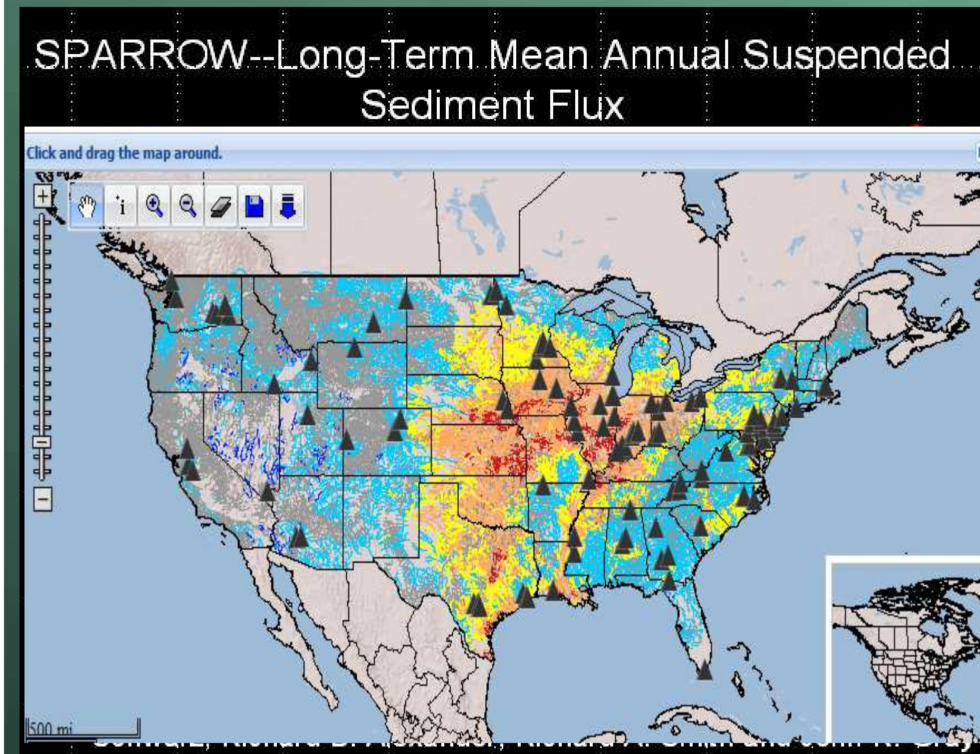
Vision: Water-quality information, anywhere (and) at anytime (Thank you, Bob Hirsch!)



7,959+ sites!

http://waterwatch.usgs.gov



WARP http://infotrek.er.usgs.gov/warp/

Our goal *is* to provide nationally consistent water-quality concentrations and loads with associated uncertainty on all time and spatial scales with a historical perspective … (and maybe even forecasting!)

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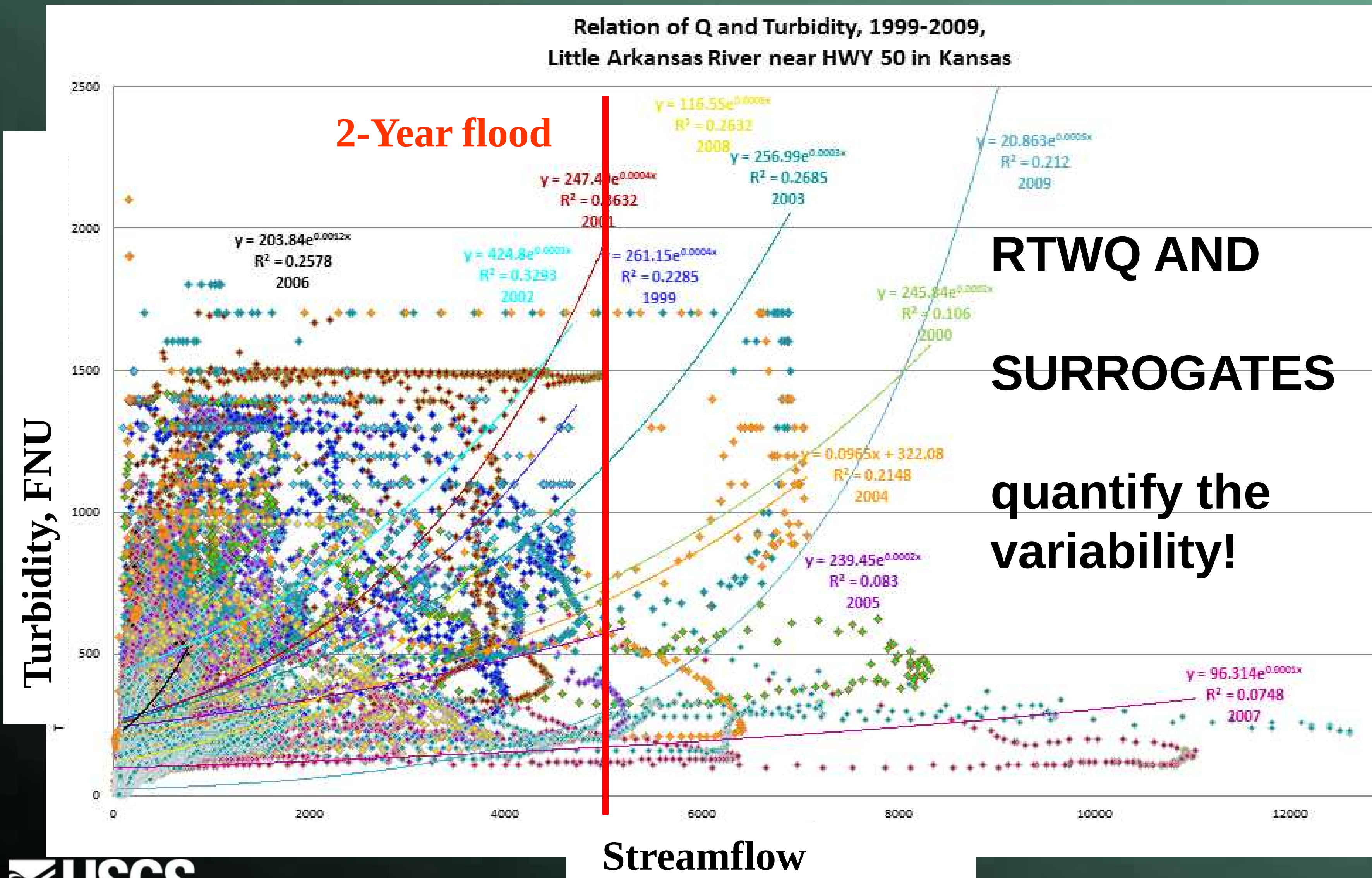
Streamflow relation to water quality is complex and variable

Can we capture, quantify, understand, and regulate this water-quality variability with 6 or 10 or 20 or 50 or more samples per year?



Spatially continuous data and information--Satellite information to interpolate between measurement points– all on a near real-time basis

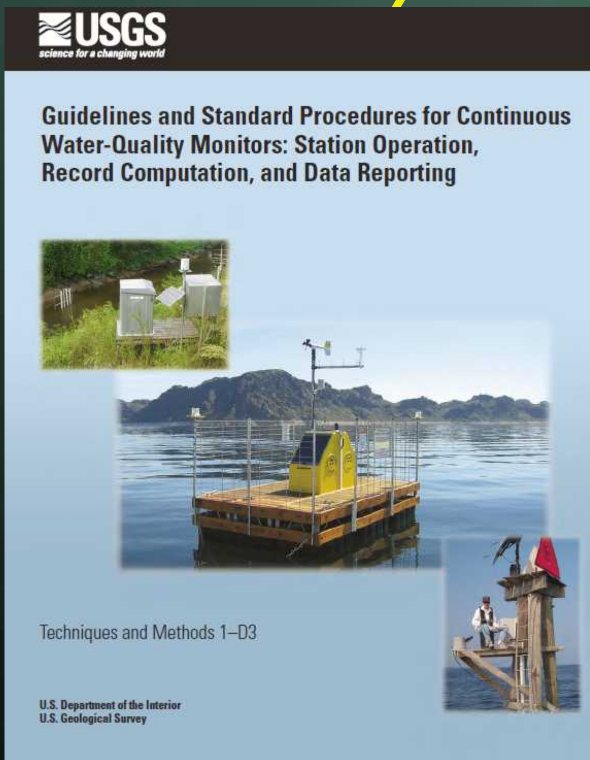
Worldwide & U.S.– lots of sites on-line

- European Union Environment Agency http://eyeonearth.cloudapp.net/
- Canada/Newfoundland –Labrador http://www.env.gov.nl.ca/env/waterres/rti/stations.html
  - Workshops proceedings since 2007 http://www.env.gov.nl.ca/env/waterres/rti/rtwq/workshops.html
- Our Lake—Central NY http://www.ourlake.org/index.html
- San Joaquin River Real-Time Water Quality Program
  http://www.water.ca.gov/waterquality/sjr_realtime/
- Lake Access http://www.lakeaccess.org/
- Sanibel-Captiva Conservation Foundation River, Estuary and Coastal Observing Network
  - http://recon.sccf.org/
- Susquehanna River Basin Commission
  - http://www.srbc.net/programs/remotenetwork.htm
- Eyes on Bay- Chesapeake
  - http://mddnr.chesapeakebay.net/eyesonthebay/index.cfm
- IOOS (Integrated Ocean Observing System)
  - http://www.obsregistry.org/map.php
- Central & Northern CA
  - http://www.cencoos.org/sections/conditions/waterquality.shtml
- CICEET Great Bay Real-Time Environmental Monitoring Network
  - http://www.greatbaydata.org/
- NANOOS- Real-time Water Quality Data for shellfish growers in the Pacific NW
  - http://www.nanoos-shellfish.org/Oregon/21.aspx
- Texas Commission on Environmental Quality
  - http://tceq.net/cgi-bin/compliance/monops/water_monitors.pl

Neat sites and different approaches to presenting information

Today– Data and gizmos and protocols– Wagner.. "New" tools are available-In-stream continuous monitors…Improved 4 visits per year, but still fouling

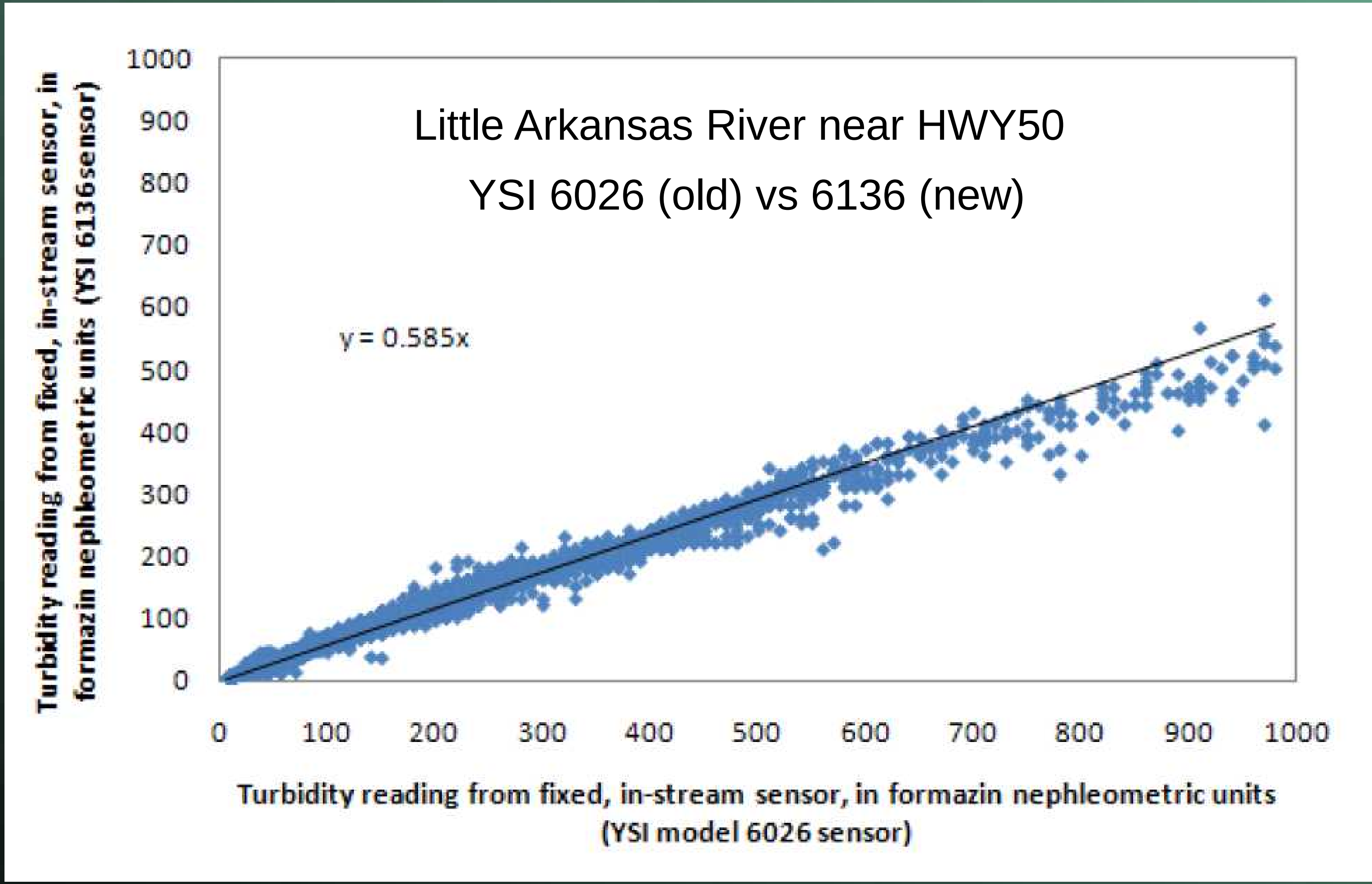
Turbidity sensor



- pH
- Water Temperature
- Dissolved Oxygen
- Specific Conductance
- Turbidity
- ORP
- Fluorescence
- Acoustics..
- UV nitrate/CDOM/ FDOM

Turbidity used as early as 1940s (JTU for sediment). Walling used in 1974 similar to today's instruments. Dave Schoellhamer in USGS among first to develop sediment concentrations using OBS– late 1980s in SF Bay

BEWARE– not all gizmos yield equivalent values! Turbidity example



Must understand how and what a gizmo measures and reports!

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Examples of Monitor Installations

Little Arkansas River near Halstead, KS

Lake Olathe

Kansas River at DeSoto, Kansas

Rattlesnake Creek near Zenith, KS

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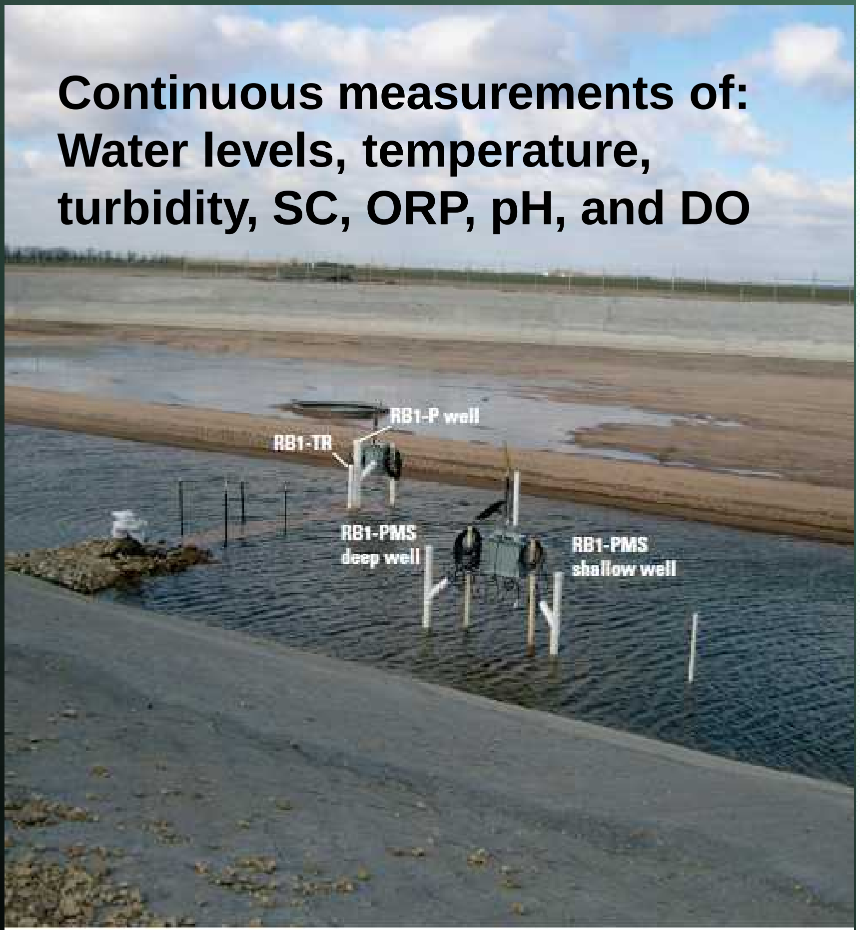
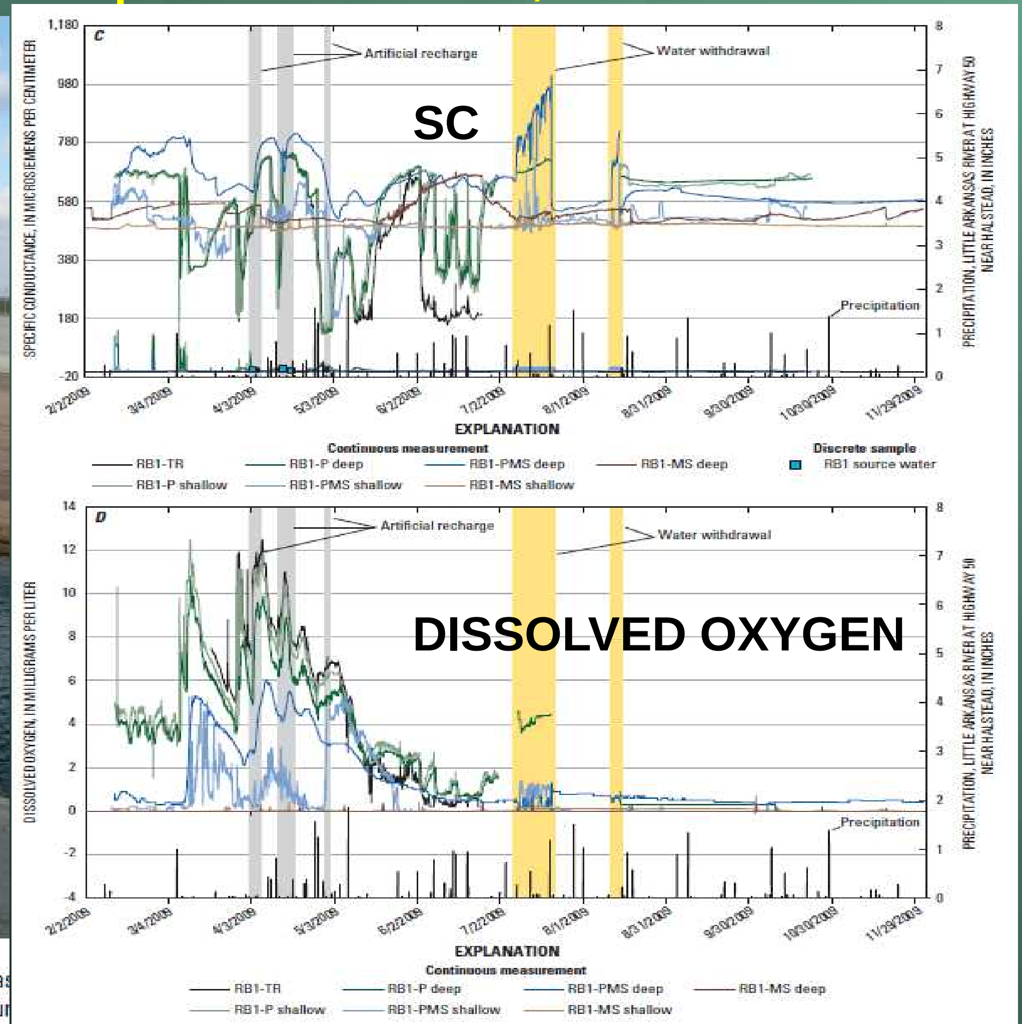
What About Groundwater?– Of Course!

Effects of experimental passive artificial recharge of treated surface water on water quality of the Equus Beds Aquifer near Wichita, KS 2009-2010

Continuous measurements of: Water levels, temperature, turbidity, SC, ORP, pH, and DO



1-TR, RB1-P well, and RB1-PMS wells installed along the eastern edge of the original RB1 bas
te. Photographed from a location northeast of the trench, RB1-P well and RB1-PMS wells dur



USGS SIR 2011-5070; Garinger, King, and Ziegler

“Automated” records- QA/QC and benefits

- Rule-based approach provides consistent data-correction computation

- Automating data-correction computation and application
  - eliminates transcription errors
  - saves time
  - replaces existing spreadsheets

- Integration of graphical and tabular data display allows for efficient, intuitive record working, review, and approval

- Repetitive tasks in workflow are mostly eliminated, saving hydrographer’s time **and decrease costs (estimate -25%)**

- Enhances our ability to successfully QA and finalize data in real time–

Value Engineering 2009– USGS, YSI, and InSitu

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Today—USGS "Watches" and real-time information products on the web

- NWQMC– National Data Portal– all USGS and EPA discrete water-quality data combined http://www.waterqualitydata.us/

- NWISWeb http://waterdata.usgs.gov/nwis/qw/

  WATER ALERT– sign up and have info directly emailed to you with specific user-defined criteria http://water.usgs.gov/wateralert/

- WaterQualityWatch -- Continuous Real-Time Water Quality of Surface Water in the United States http://waterwatch.usgs.gov/wqwatch/
  - Linkage to NWISweb data with some value added- Current and historic unit values are available since October 2007

- Data Grapher http://or.water.usgs.gov/grapher/
  - Plots all data available for measured unit values with multiple sites and graph types

- NATIONAL REAL-TIME WATER QUALITY http://nrtwq.usgs.gov/
  - Page to present all past and current computed "surrogate" and measured water quality for concentrations, loads, and model information

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WQWATCH/ NRTWQ– EXPANDING RAPIDLY! (700 in 1999)

8,000+ streamflow; 1,981 temperature, 912 specific conductance, 372 pH, 454 dissolved oxygen, 396 turbidity sites (90 in 2000), nitrate 7

396 turbidity sites nationally (40 States plus PR); OR (26), GA(21), PA (20), KS (19),TX (16)

http://waterwatch.usgs.gov/wqwatch

http://nrtwq.usgs.gov/

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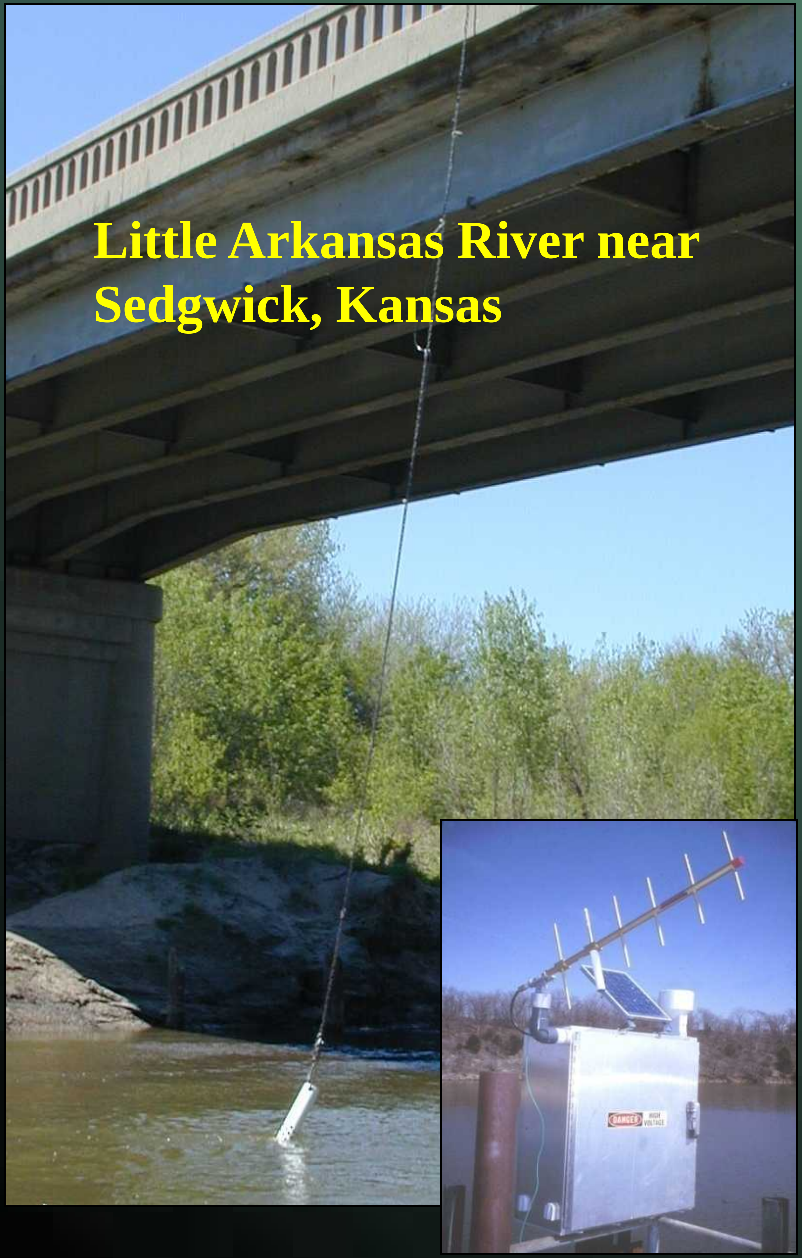
USGS Real-Time Water Quality "Computed" Approach:



- Add water-quality monitors at streamgages and transmit data "real" time
- Collect water samples over the range of hydrologic and chemical conditions
- Develop site-specific regression models using samples and sensor values
- Compute concentrations and loads
- Publish regression models
- Display computations, uncertainty, and probability on the Web
- Continued sampling to verify models

Christensen, Jian, Ziegler, 2000…………

Rasmussen, Gray, Glysson, and Ziegler, 2009, http://pubs.usgs.gov/tm/tm3c4/

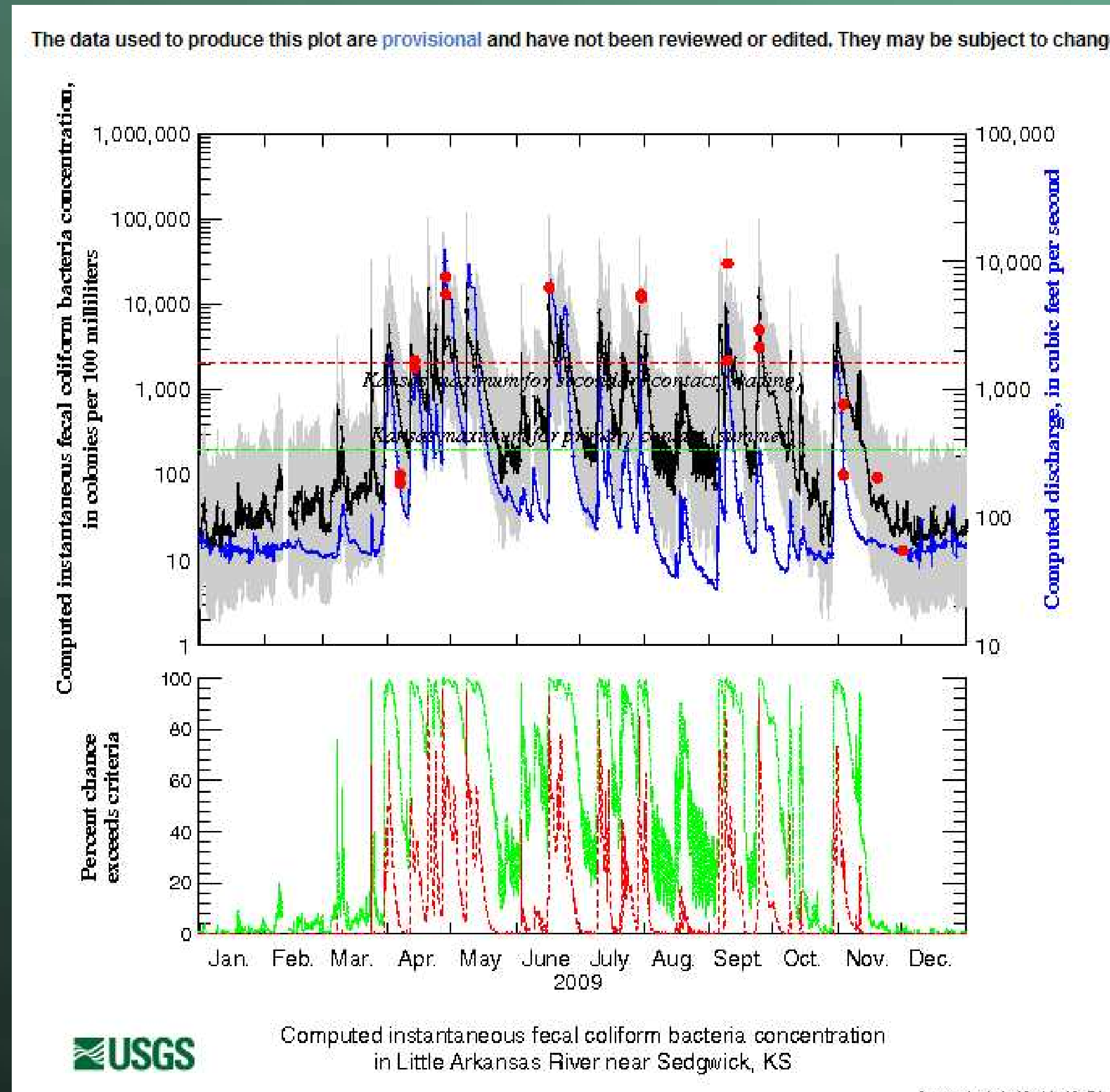
Bacteria frequently exceed water-quality standards

Real-time computed concentrations of bacteria, uncertainty, and probability of exceeding WQ criteria

(look at the sample data….)

Aren't continuous surrogates better?

	Comp.	Meas.
n =	8,647 vs.	15
Mean =	780 vs.	5,700
Median =	200 vs.	1,800



Concentration more important than load for health

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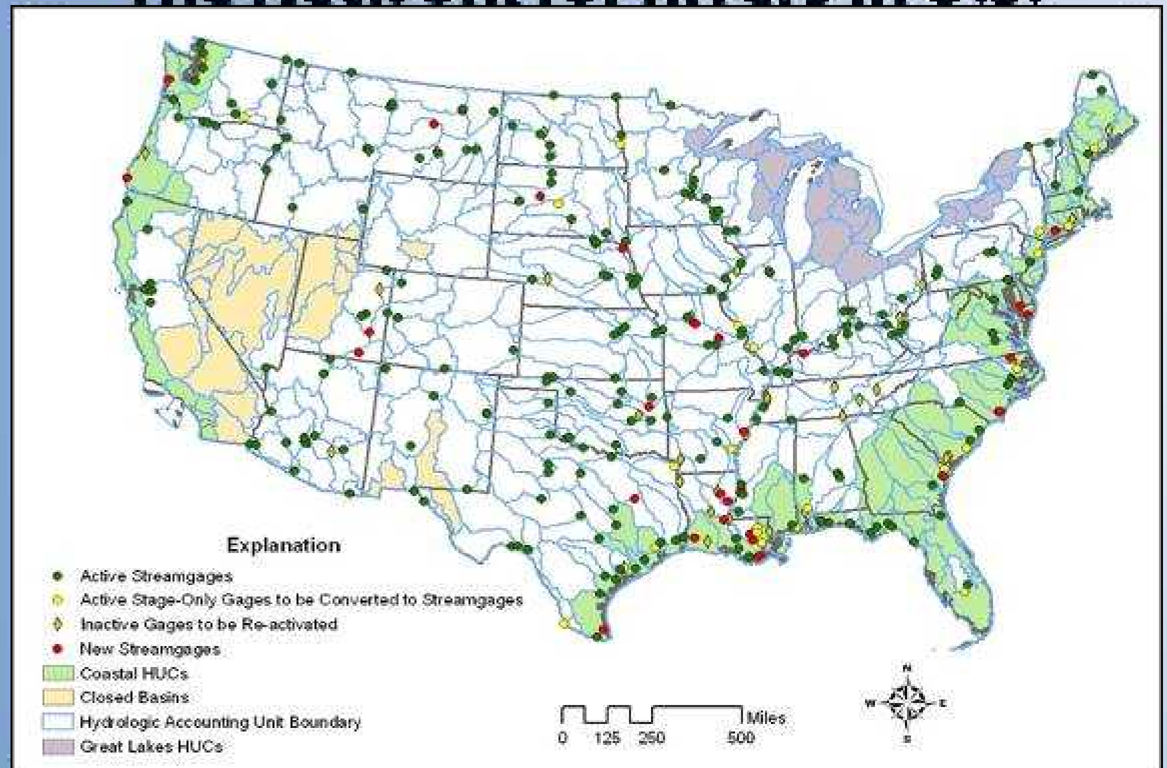
http://nrtwq.usgs.gov/explore/plot?site_no=07144100&pcode=31625&period=2009_all&timestep=uv

Is it time for a National Collaborative Continuous WQ network?

YES!

The Network for Rivers in U.S.



The Network for rivers is designed to assess:

- streamflow, contaminant loads, biological conditions at the outlet of each Hydrologic Accounting Unit at HUC6
- streamflow and constituent loads from coastal rivers.

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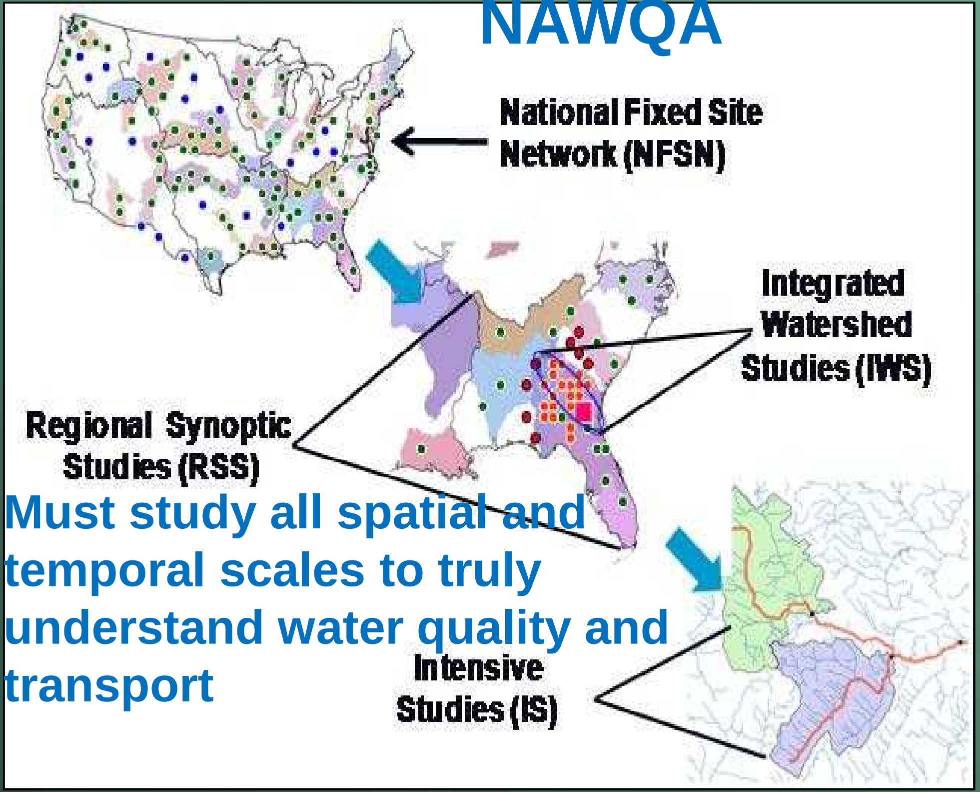
http://acwi.gov/monitoring/network/

What do we gain from a National Continuous Water-Quality Network?

- **Information to assess, describe, and understand water quality for all uses—drinking water, recreation, environment**
- **Infrastructure that measures water quality in very small to large river and estuaries-MS**
- **Use of today's technology rather than approaches developed 50 (or more) years ago that are only sufficient for annual loads—at best**



Must study all spatial and temporal scales to truly understand water quality and transport

- **Evaluation of the effectiveness in many and large and expensive programs (AG crop programs, EPA 319, …) designed or thought to improve water quality (but are these measurements made on the time scale that answers these questions?)**

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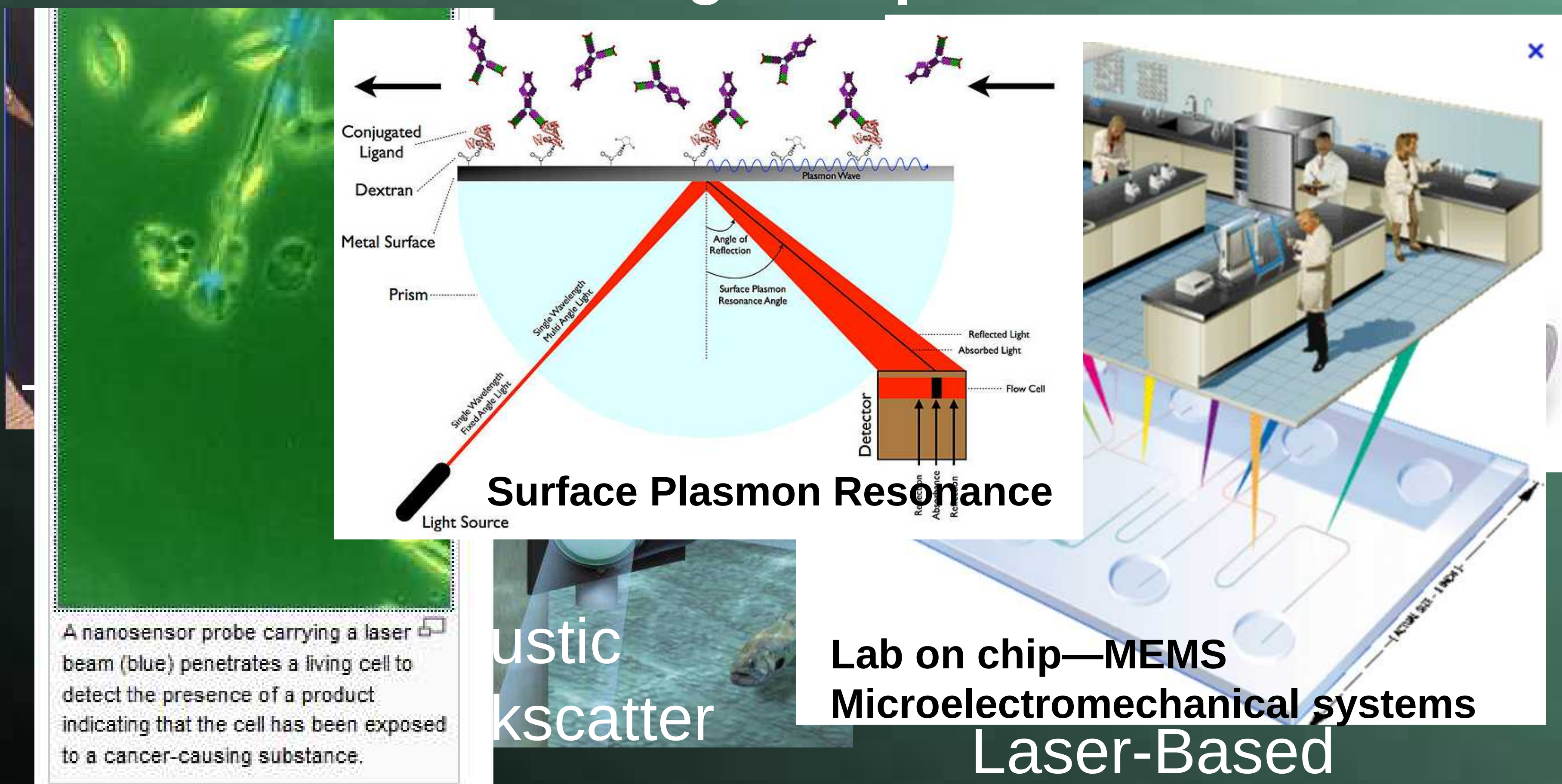
Future--DATA--Improved Sensors!

- ***Streamflow, turbidity***, ***acoustic backscatter***, ***ultraviolet nitrate, laser-based*** **sensors–measurements using EM spectrum…**



We need even better sensors

Future—Data and databases

- Use new technology-More sensors/direct measurement
- Tell manufacturers what we want and need!
- Low maintenance or self-cleaning sensors
- Sensors that work in groundwater/reducing conditions
- MCERTs—NWQMC– ASTM– some standardization
- National *Collaborative* Network- sediment/nutrients NAWQA Cycle 3
- Continued Nationally consistent protocols for;
  - O&M of sensors
  - O&M of sensors in wells
  - Generic testing protocols for new gizmos
  - Data storage and method delineation
- Automated data entry–wireless!
- Automated record processing/working tools
- Storage of estimates/computations
  - National "surrogate" web page for estimates/computations and retaining the historical statistical models: NRTWQ…….NWIS
- Acceptance of these Qaed data in regulatory enforcement– we need to lead and demonstrate!

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Future: Statistics, models, web

- National Consistency
  - T&Ms for instantaneous constituent concentrations and loads
    - Ohio bacteria
    - KTR line
    - LOADEST– (annual)
    - Instantaneous Turbidity/sediment protocol- Pat Rasmussen and others, 2009
  - Generic T&M protocol for computation of any constituent
  - On-line documentation of all models– like we do now for streamflow

- Automated statistical calibration model development done consistently with specific numeric criteria-

- Scenario testing/ future water-quality prediction– Recreational forecasts, Water-treatment forecasts, etc.

- Marriage of instantaneous point estimates with satellite imagery and/or spatial models-Water Quality anywhere, anytime

If we can think of it, we can do it !

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Vision= There= Water Quality anywhere and at anytime so, Why aren't we "there" yet?

Many exciting applications, but slow regulatory acceptance. Regulatory acceptance is needed before we can expand and have a true National Monitoring Network.

Impediments?

- **We are confident that we explain water quality with a few samples, because we always have– the problem is that we really can't on the time density we need to answer the science questions.**
- **Instruments are not standardized—**
- **Protocols needed to document QA/QC– and limitations—**
- **Surrogates and protocols are needed**
- **Some thoughts from 7th NWQMC conference in Denver** http://acwi.gov/monitoring/conference/2010/ES02_CRT_Ziegler/PanelDiscussionNotes.pdf

Each of us individually can work on removing these impediments.

Let's just TRY It and *Really* just do it!

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Continuous Water Quality Pledge!

- **I (state name), pledge to install, improve, and promote continuous water quality monitors at more sites to develop national and international networks, applications meeting regulatory needs, and explore these data to improve our understanding of the environment to answer the questions of society today and tomorrow.**

- **Short version:**

RTWQ— *REALLY Just do it!*

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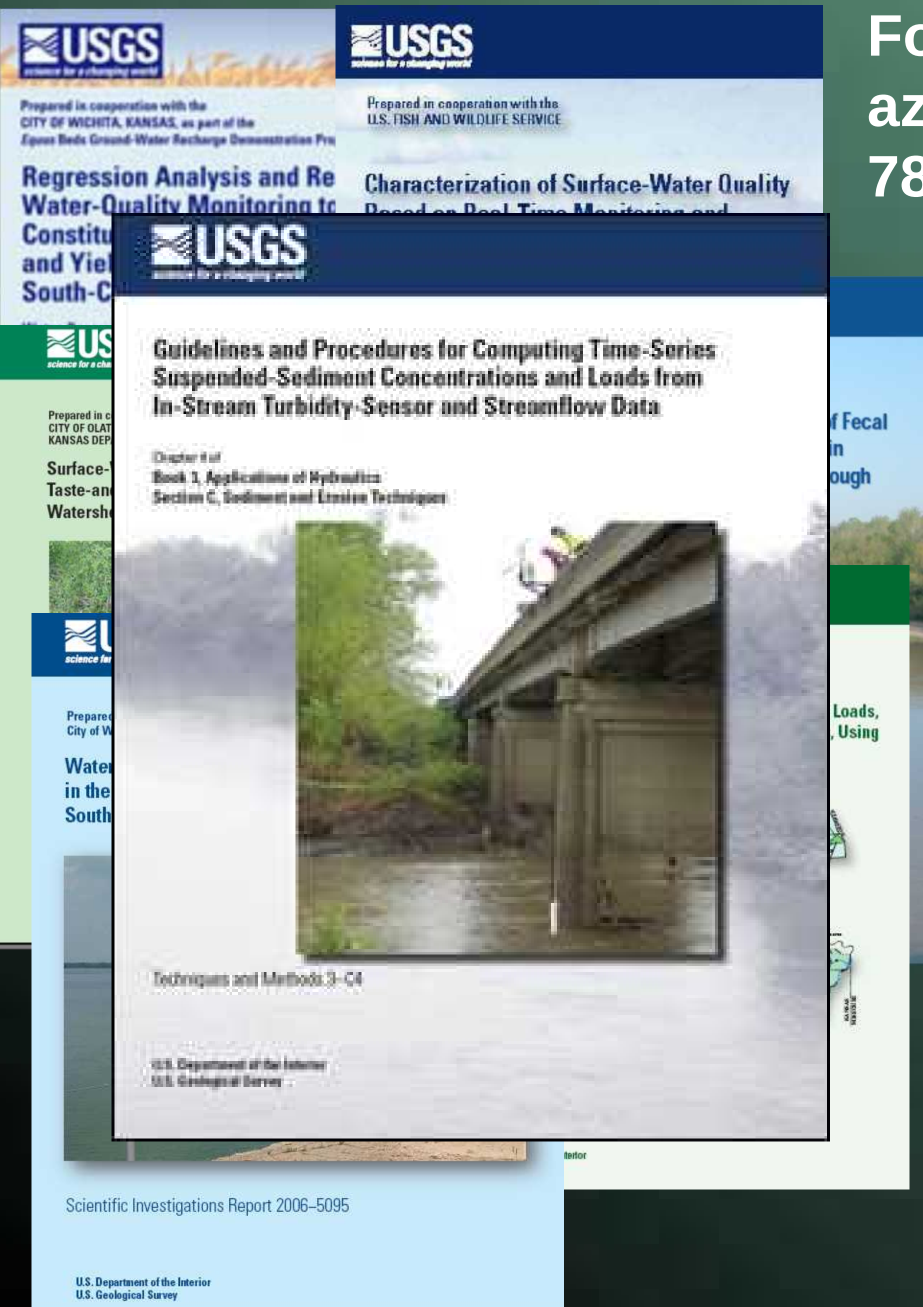
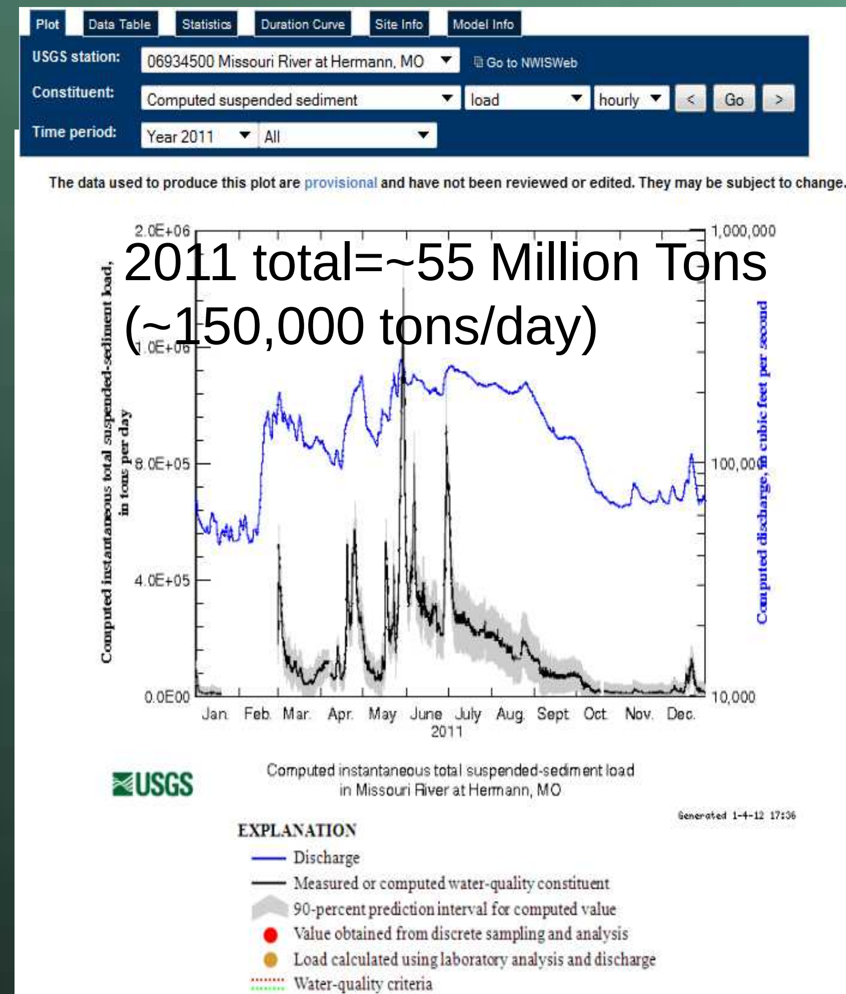
USGS Real-Time Web Page and Reports



For more information: Andy Ziegler
aziegler@usgs.gov
785-832-3539



http:// nrtwq.usgs.gov/

USGS TODAY– Some examples of providing instantaneous continuous data and “surrogate” computations on the web

- **NWIS Web– discharge computed at 8,000+ sites**
  http://waterdata.usgs.gov
- **CA- SF Bay- Sediment, etc. Since 1989**
  http://sfbay.wr.usgs.gov/sediment/cont_monitoring/index.html
- **KS (1999)-MD, IA, MO, NE, SD, TX, VA, and WI– ~2000-bacteria, sediment, chloride, atrazine, geosmin, etc., http://nrtwq.usgs.gov/ks/**
- **CO- Total dissolved solids transport ~1989**
  http://co.water.usgs.gov/projects/ArkQW/index.cfm
- **OH-beachwatch-bacteria-http://www.ohionowcast.info/index.asp**
- **MT/WY- Sodium absorption ratios- DISCONTINUED**
  http://tonguerivermonitoring.cr.usgs.gov/
  http://mt.water.usgs.gov/projects/tongueriver/

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Selected Real-Time Water Quality Publications

- **Helsel and Hirsch, 1992, (2002), Statistical Methods in water resources — Hydrologic Analysis and interpretation: Techniques of Water Resources Investigations of the U.S. Geological Survey, chap. A3, book 4, 510p.**

- **Buchanan, P.A., and Schoellhamer, D.H., 1995,** Summary of suspended-solids concentration data, Central and South San Francisco Bays, California, water years 1992 and 1993: U.S. Geological Survey Open-File Report 94-543, 15 p.

- **Christensen, V.G., Jian, Xiaodong, and Ziegler, A.C., 2000, Regression analysis and real-time water-quality monitoring to estimate constituent concentrations, loads, and yields in the Little Arkansas River, south-central Kansas, 1995–99: U.S. Geological Survey Water-Resources Investigations Report 00–4126, 36 p.**

- **Wagner, R.J., Boulger, R.W., Jr., Oblinger, C.J., and Smith, B.A., 2006, Guidelines and standard procedures for continuous water-quality monitors—Station operation, record computation, and data reporting: U.S. Geological Survey Techniques and Methods 1–D3, 51 p. + 8 attachments; accessed April 10, 2006, at *http://pubs.water.usgs.gov/tm1d3***

- **Rasmussen, P.P and Ziegler, A.C., 2003, Comparison and continuous estimates of fecal coliform bacteria and *Escherichia Coli* bacteria in selected Kansas streams, May 1999 through April 2002, Water Resources Investigations Report, 03-4056, 97p.**

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More Real-Time Water Quality Publications

- Runkel, Robert L.; Crawford, Charles G.; Cohn, Timothy A., 2004, Load estimator (LOADEST): a FORTRAN program for estimating constituent loads in streams and rivers: U.S. Geological Survey Techniques and Methods Book 4, Chapter A5, 69 p.
- Francy, D.S., and Darner, R.A., 2006, Procedures for Developing Models To Predict Exceedances of Recreational Water-Quality Standards at Coastal Beaches: U.S. Geological Survey Techniques and Methods 6–B5, 34 p.
- Granato, G.E., 2006, Kendall-Theil Robust Line (KTRLine -version 1.0)__A visual basic program for calculating and graphing robust nonparametric estimates of linear-regression coefficients between two continuous variables: Techniques and Methods of the U.S. Geological Survey, book 3 chap. A7, 31p.
- Rasmussen, Patrick P.; Gray, John R.; Glysson, G. Douglas; Ziegler, Andrew C., 2009, Guidelines and Procedures for Computing Time-Series Suspended-Sediment Concentrations and Loads from In-Stream Turbidity-Sensor and Streamflow Data: Techniques and Methods of the U.S. Geological Survey, book 3 chap. C4, 54p.

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