Issues related to the use of turbidity as a surrogate for suspended sediment

"The murkiness of turbidity measurements"

By

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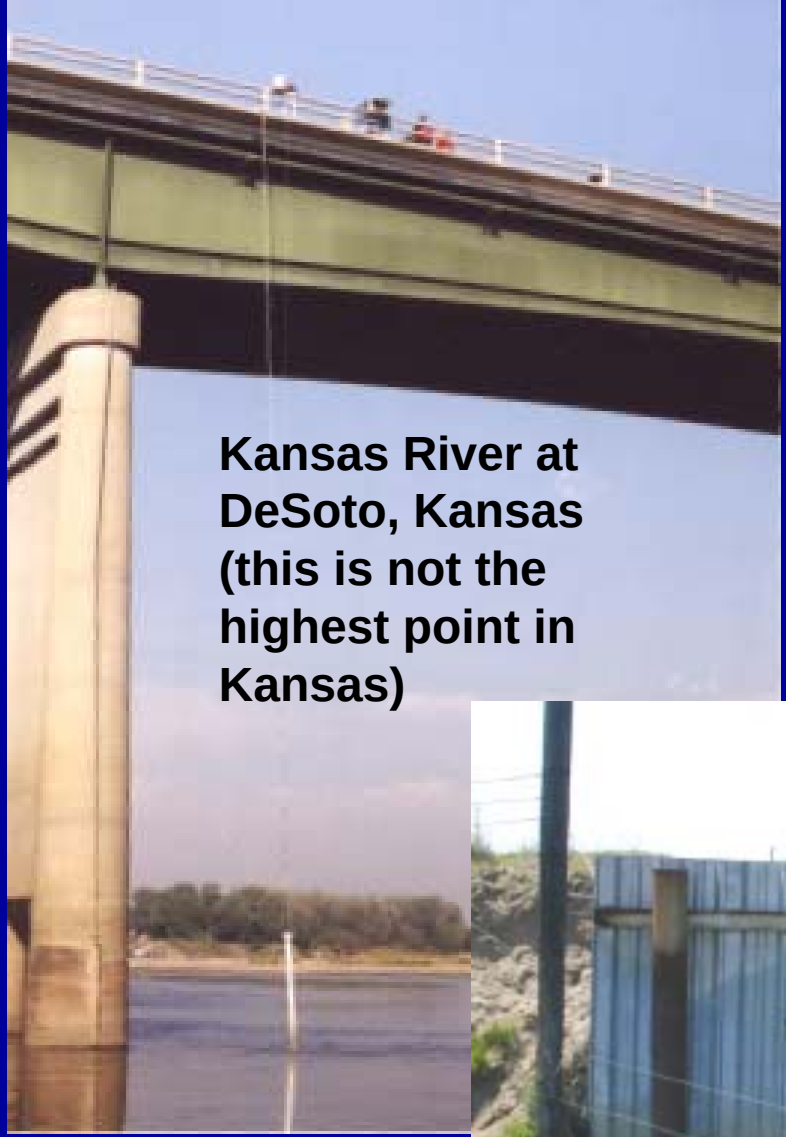
Lawrence, Kansas

USGS

Turbidity workshop, Reno Nevada, April 30, 2002



Kansas River at DeSoto, Kansas (this is not the highest point in Kansas)

Little Arkansas River near Sedgwick, KS

Rattlesnake Creek near Zenith, KS

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Problems with conventional monitoring:

- Sampling of seasonal, diurnal, and event driven fluctuations are frequently missed
- Annual load estimates are based on a small finite number of samples with undefined uncertainty
- Relations used for loads are based on the only data available continuously--streamflow
- Techniques used differ among monitoring groups EDI/EWI vs. grab samples
- Costs (and time) of manual sampling and analysis for equivalent data

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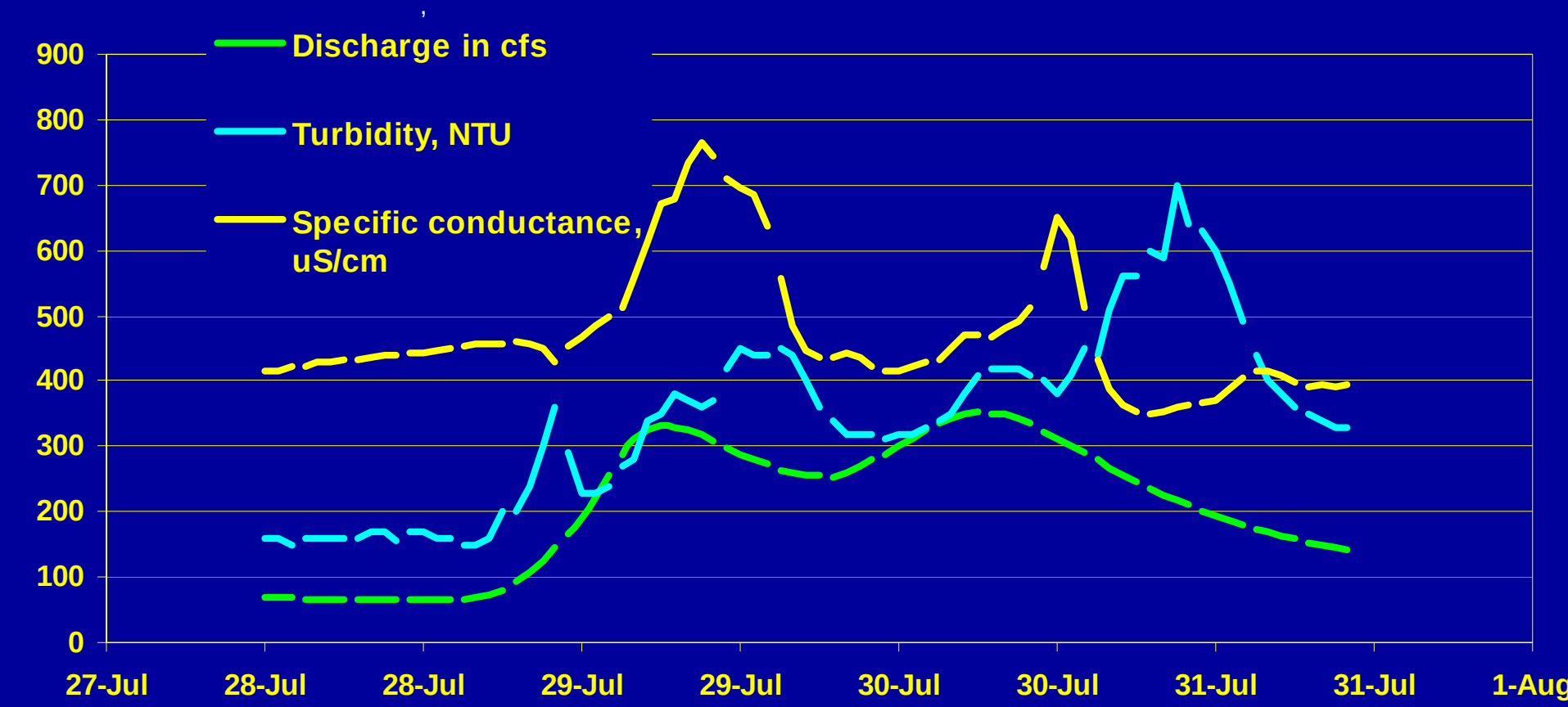
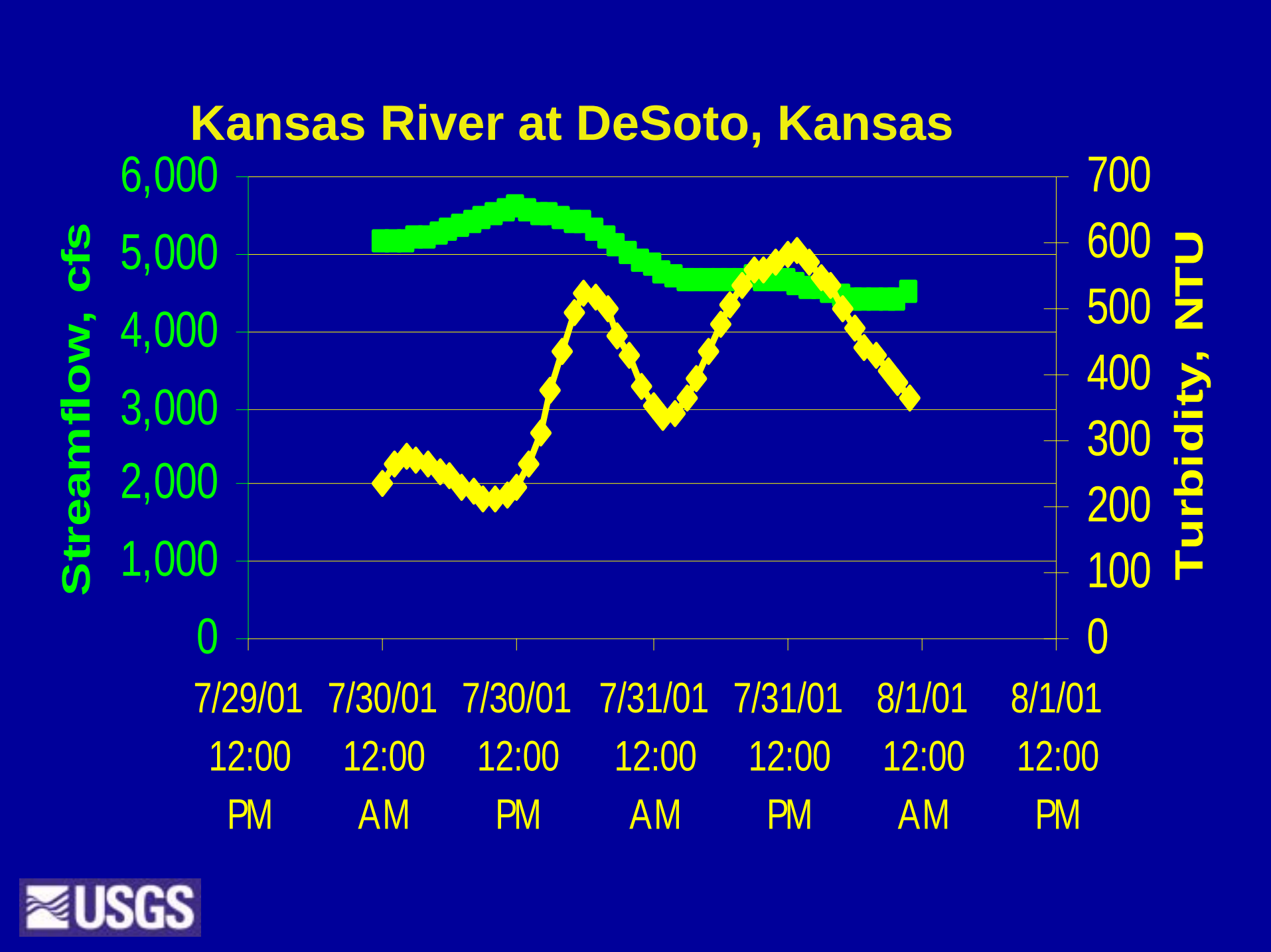
Do these data reflect your conceptual model of streamflow related to water quality?

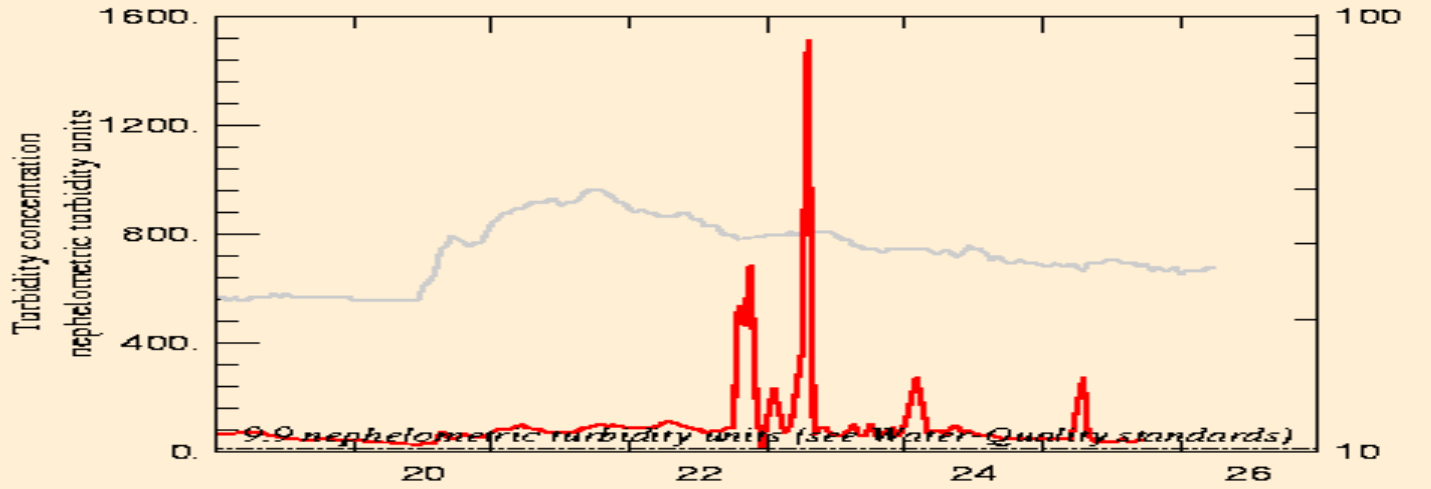


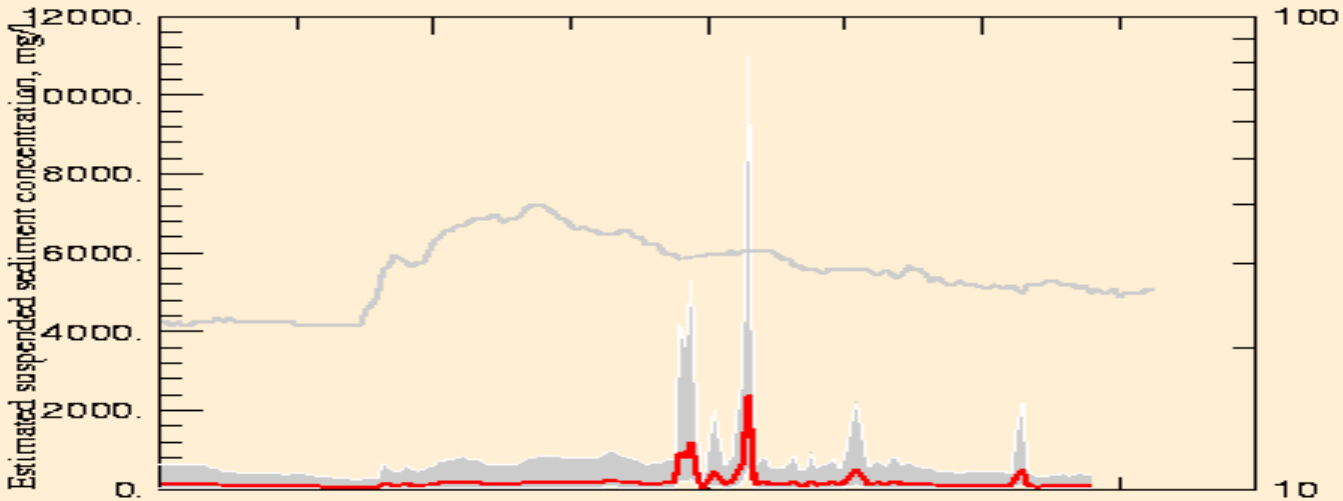
Little Arkansas River near Halstead, Kansas July 28-31, 2000

USGS


Kansas River at DeSoto, Kansas
Streamflow, cfs
6,000
5,000
4,000
3,000
2,000
1,000
0
Turbidity, NTU
700
600
500
400
300
200
100
0
7/29/01 12:00 PM
7/30/01 12:00 AM
7/30/01 12:00 PM
7/31/01 12:00 AM
7/31/01 12:00 PM
8/1/01 12:00 AM
8/1/01 12:00 PM
USGS

Rattlesnake Creek near Zenith, Kansas

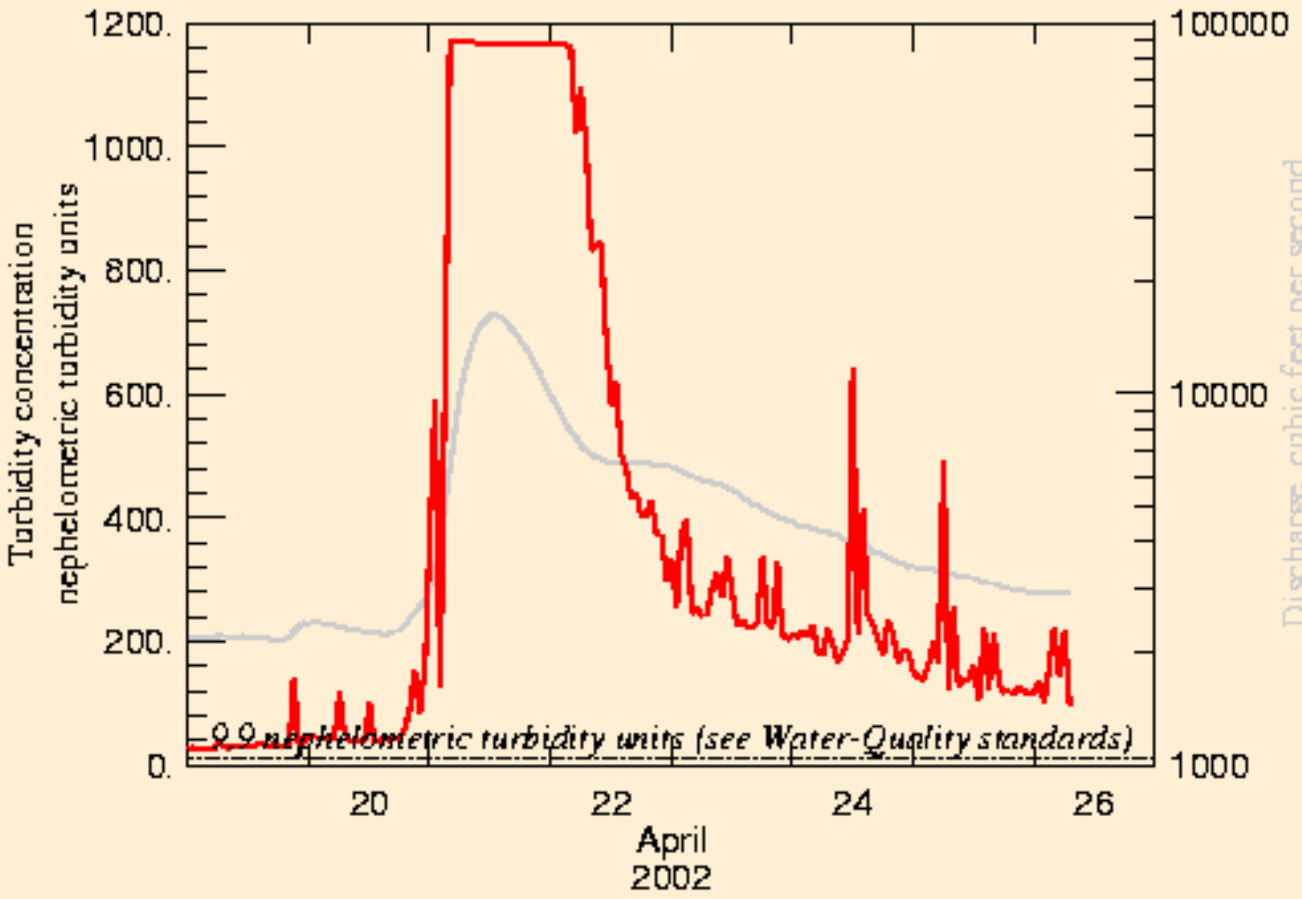




Estimated real-time suspended sediment concentration in Rattlesnake Creek near Zenith, KS

USGS http:// ks.water.usgs.gov/Kansas/rtqw/

Kansas River at DeSoto, Kansas

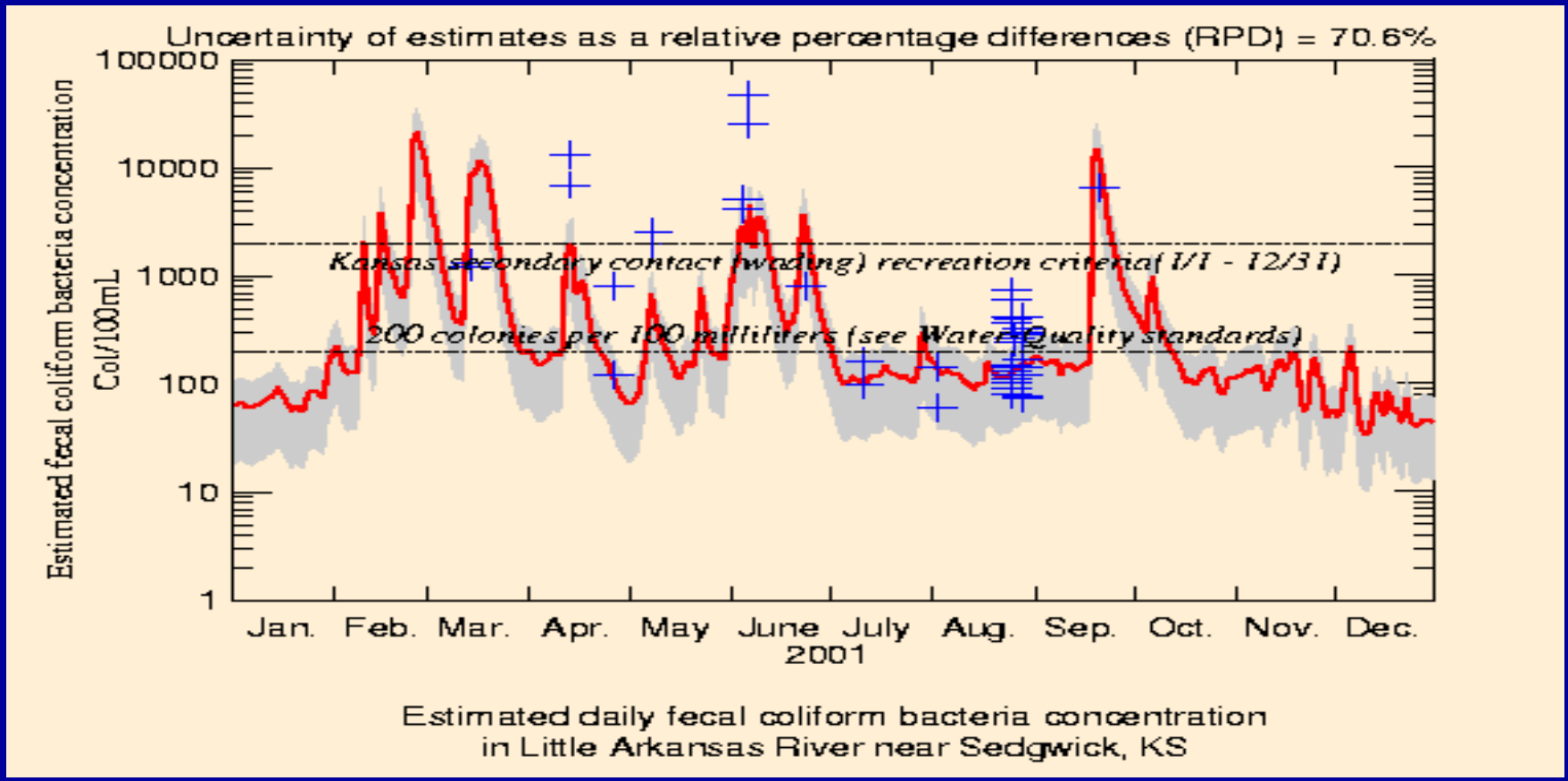


Measured real-time turbidity concentration
in Kansas River at DeSoto, KS
(Maximum censor value varies from 1200 to 1600 NTU)

USGS

http:// ks.water.usgs.gov/Kansas/rtqw/

Little Arkansas River near Sedgwick, Kansas
Fecal Coliform Densities, 2001



USGS

http:// ks.water.usgs.gov/Kansas/rtqw/

Issues with turbidity measurements as a surrogate

- **Methods used for measurement**
- **Wavelengths of light used for measurement**
- **Detector orientation**
- **Standards used for calibration**
- **Grain size and color effects**
- **Reporting of data**
- **Future needs**

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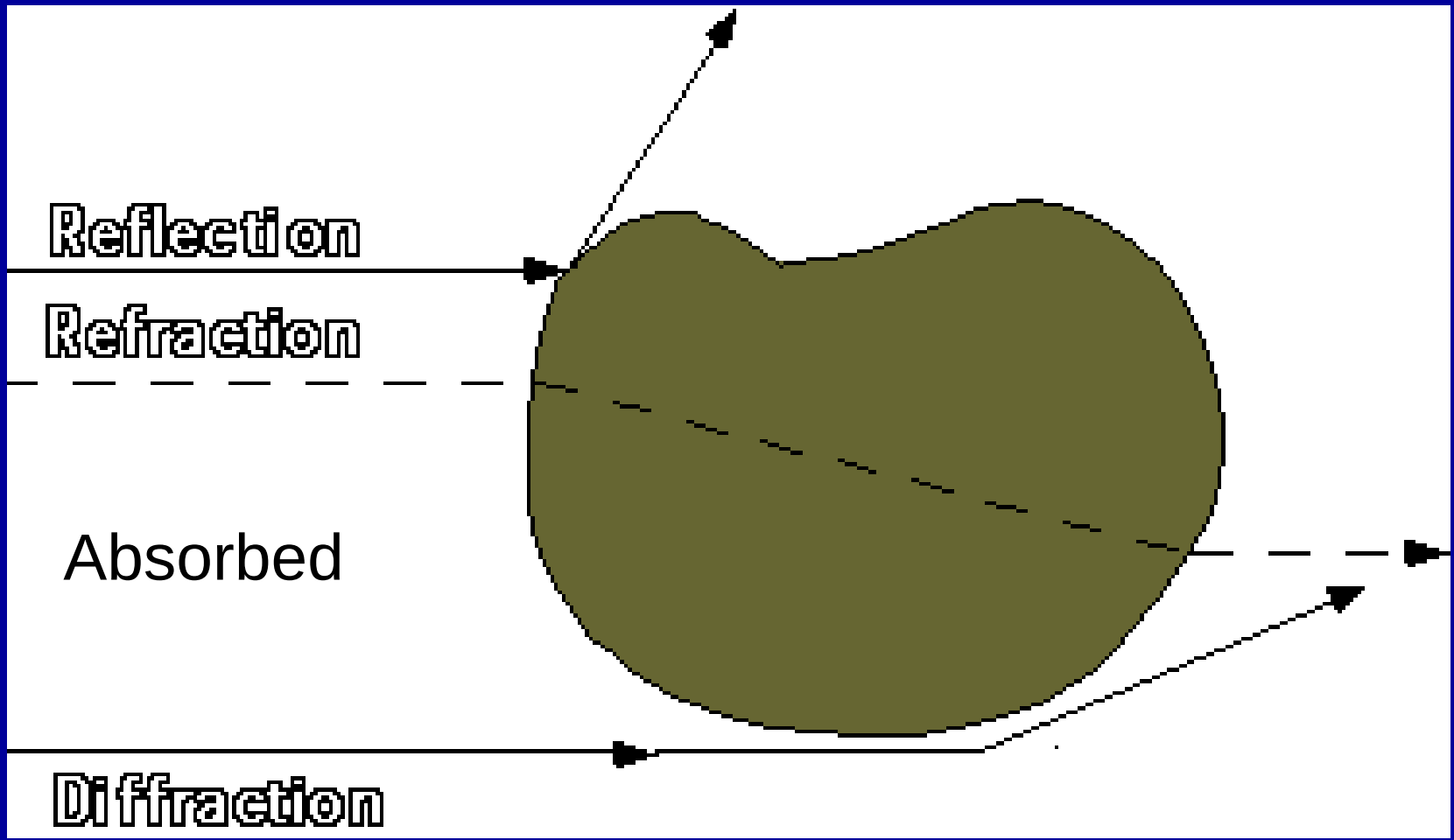
Turbidity definition

- **Decrease in the transparency of water due to the presence of suspended and some dissolved substances**
- **Operationally defined by method used and instrument configuration using nephelometry**

USGS

Light through a solution with solids



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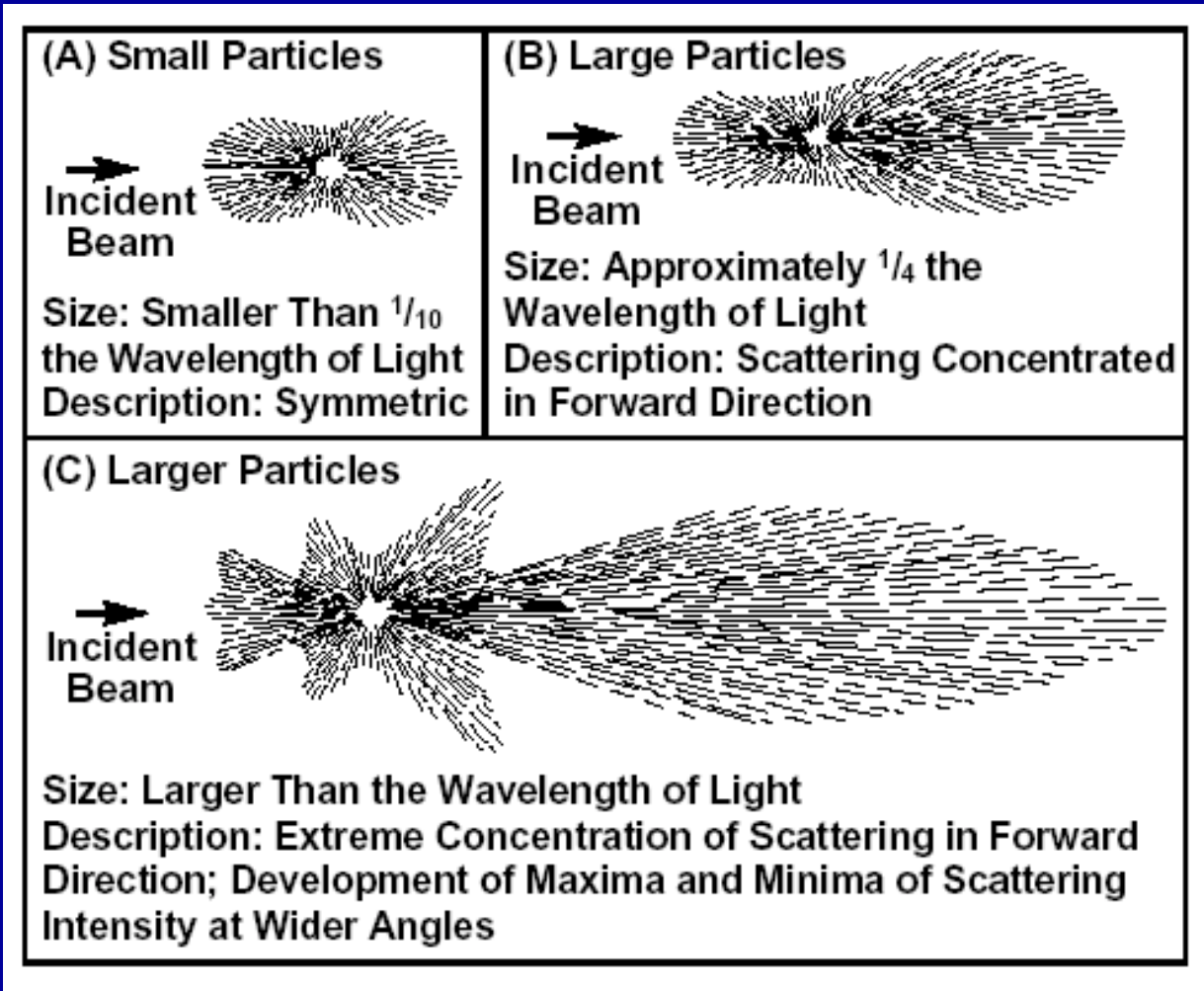
Scattering of light by substances in water



From Brumberger and other "Light Scattering" Science and Technology, 1968
Reproduced from Sadar, 1998

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Nephelometric Turbidity

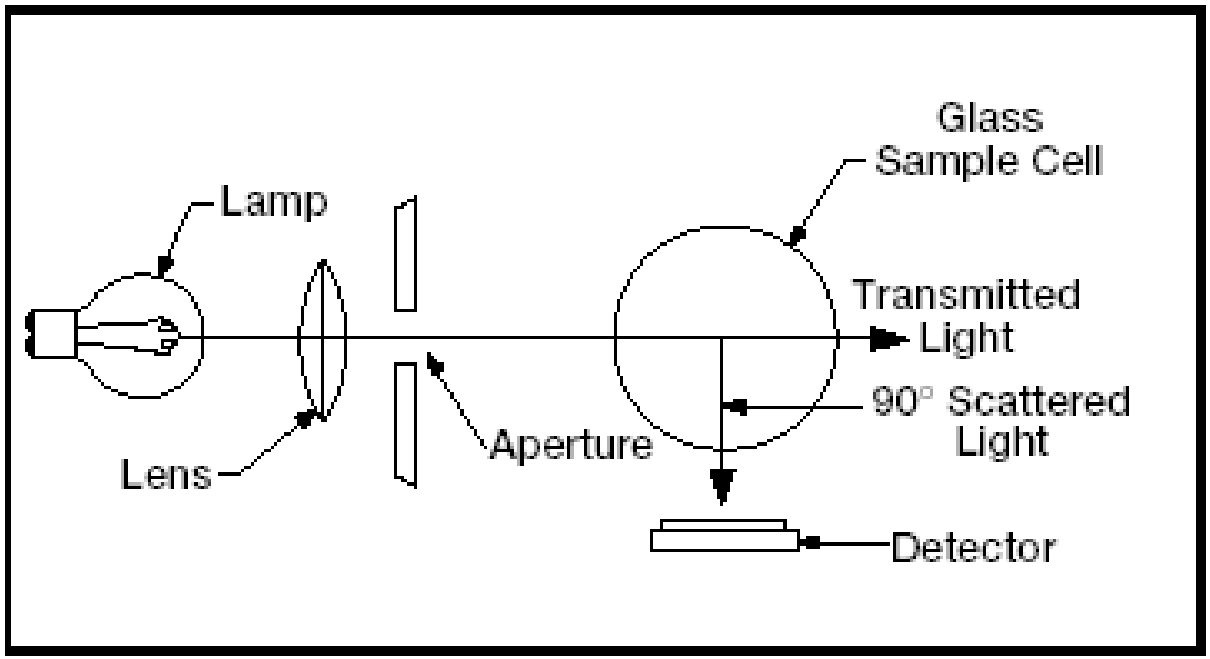

Figure 4. In nephelometric measurement, turbidity is determined by the light scattered at an angle of 90° from the incident beam.

From Mike Sadar "Turbidity Science" 1998

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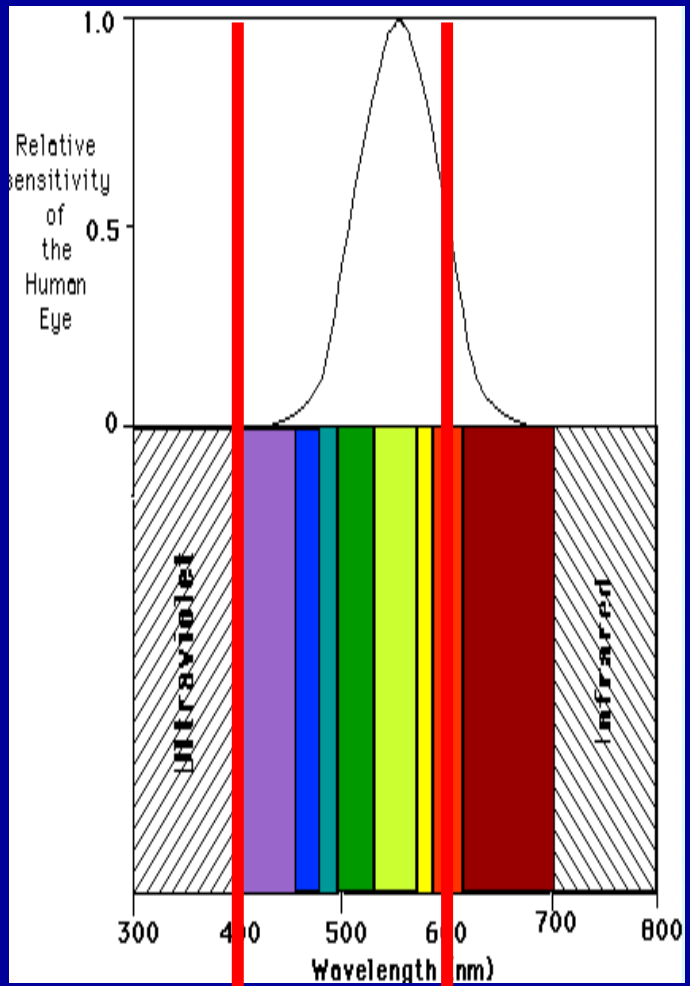
Incident Light Wavelengths



ISO 7027
GLI Method 2

EPA 180.1

860

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Comparison of Turbidity methods

- EPA 180.1- Drinking water <40 NTU
  - Tungsten lamp, 400-600 nm
  - Detector 90 +/- 30 degrees
- ISO 7027
  - Diffuse-Drinking water <40 FTU
    - Diode, 860 +/- 30 nm
    - Detector 90 +/- 2.5 degrees
  - Attenuated- streams and wastewater 40-4,000 FAU
    - Diode, 860 +/- 30 nm
    - Detector 90 +/- 2.5 degrees
- GLI Method 2- Drinking water <40 NTU
  - Two diodes, 860 +/- 30 nm
  - Two detectors each at 90 +/- 2.5 degrees

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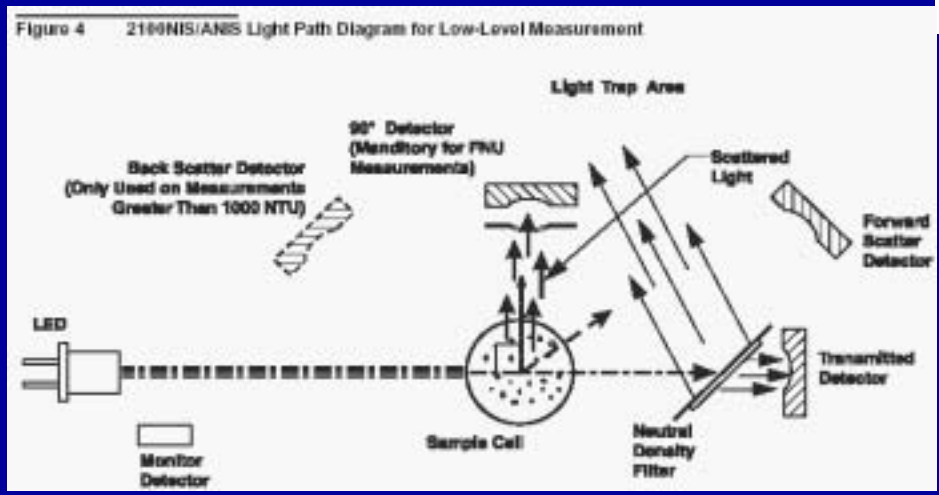
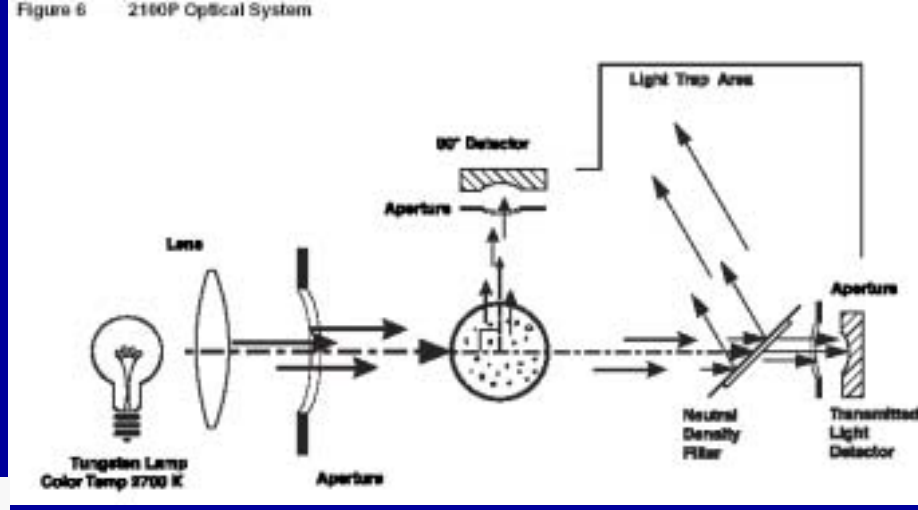
Detector orientations

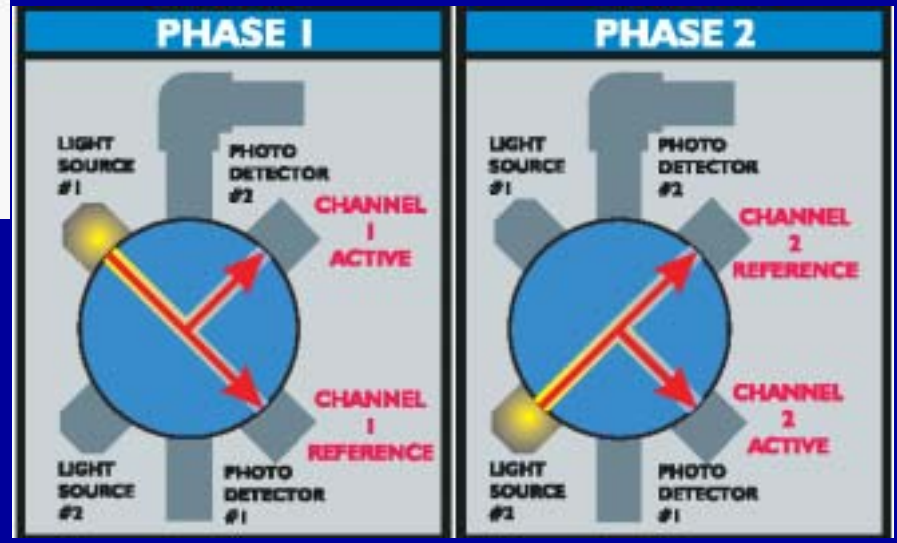
From Mike Sadar, Turbidity Instrument Comparison HACH, 1999
Technical Information Series, 7063



ISO 7027



EPA 180.1



GLI Method 2
http:// www.gliint.com/

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Calibration standards

- **Primary Standards**
  - **Formazin polymers**
  - **Other synthetic polymer standards**
- **Secondary Standards**
  - **Synthetic polymers**
  - **Blocks, cubes, filaments**

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Standards issues

- Stability of standards
- Safety of formazin– compounds used to make formazin are known carcinogens
- Inconsistent particle size ranges from 0.1 to 10 microns Papacosta (2002)
- Differing instrument responses for other polymers relative to formazin
- Instrument manufacturer guidelines need to be followed to have reproducible measurements

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Grain size and color effects of grains

- **Substantial negative bias possible with grain color and water color for EPA 180.1**
- **Negative bias for “black” colored sediments (Sutherland and others, 2001)**
- **Grain size and orientation all can affect the readings**

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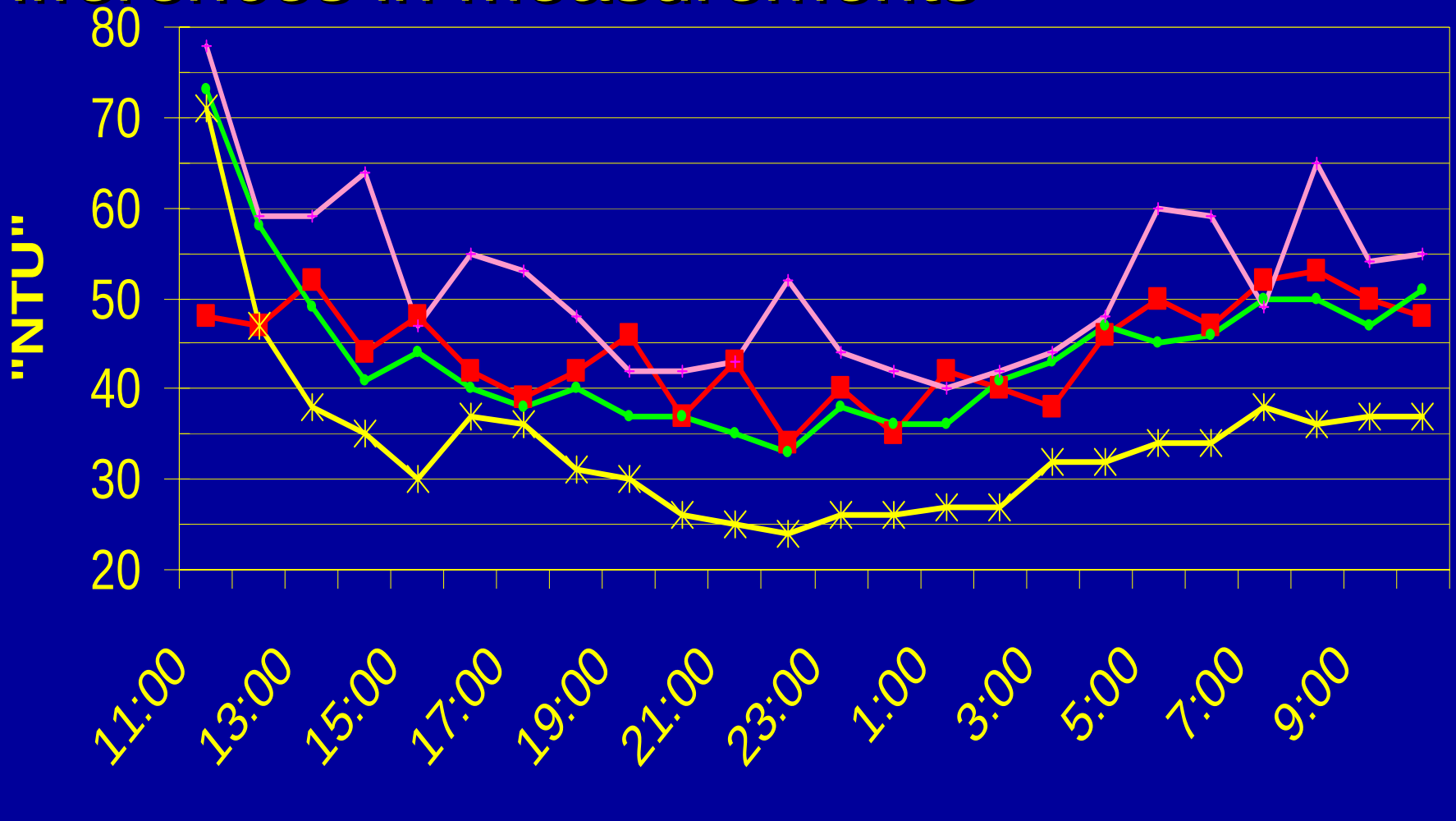
Differences in measurements



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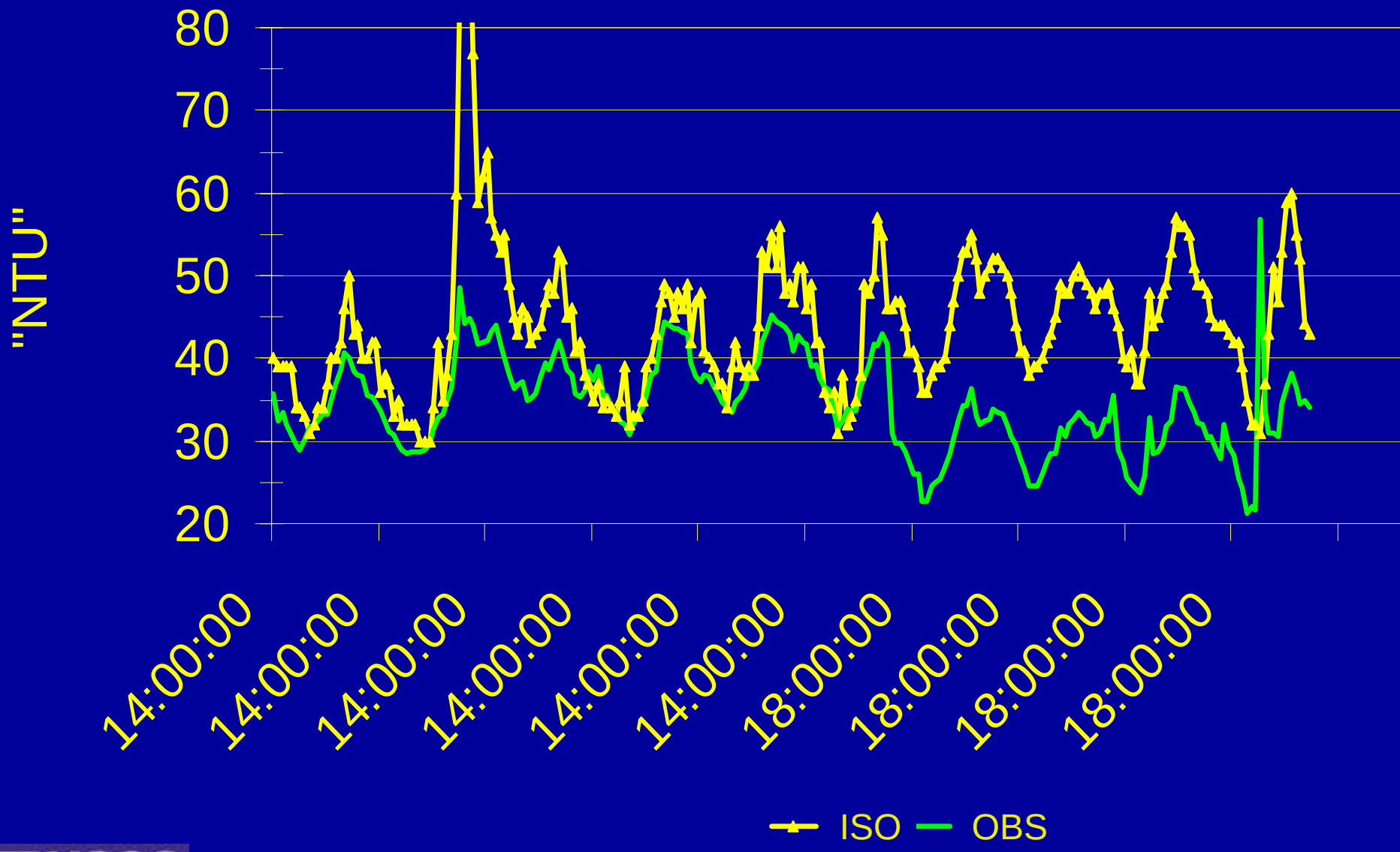
Comparison of OBS to In-stream ISO



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Summary of comparison of instrument methods

- **All methods measure a response to suspended material in the water that are qualitatively in agreement**
- **Readings from the different methods or meters generally differ by more than 10 percent**
- **All of the measurements are reported as NTU**

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Storage of data

- **Not all “NTU” are equal.**
- **Storage of EPA 180.1, ISO 7027-diffuse, ISO 7027-attenuated, GLI Method 2, ratio mode measurements, and OBS measurements must be differentiated**
- **Method, instrument manufacturer and model, and calibration standards need to be stored with data for valid comparisons to be made**

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UK Monitoring Certification Scheme (MCERTS)

- **Objectives**
  - **Clearly state for regulated industries its requirements**
  - **Improve the reliability of monitoring results**
- **Drafted for review January 7, 2002**
- **Includes proposals for turbidity, COD, DO, flow, NO_3, pH, samplers, TOC, TP, and NH_3**
- **Available at**
- http:// www.environment-agency.gov.uk/business/mcerts/water/

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Summary of proposed MCERTS requirements for turbidity

- Reported as FTU, 0-2,000 FTU
- Performance requirements including span, response time, flow rate, pressure, temperature, humidity, incident light, entrained gases limits
- Maintain at least 94 % up time in performance tests
- Environmental conformity and performance tests
- Upper range limits
- Maximum permissible error +/- 2 % in lab and +/- 4 % in field not exceeded in more than 10 % of pairs
- Maintainable with only monthly visits
- Uncertainty documented
- Effects of loss of power supply and reset defaults

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Summary site test performance requirements

- Representative- range of expected values and pattern of variation documented
- Continuously operated for at least 12 weeks
- Safe access to the site
- Reference checks to formazin performed with 12 paired readings every 4 weeks at least 1 day apart and no more than 5 pairs in one week
- Maintain a log book of labor and equipment requirements

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Immediate needs for turbidity as a surrogate

- **Differentiate data storage from different methods and when instrument design is changed**
- **Document color effects of differing grain mineral compositions**
- **Develop a method/standard specifically designed and approved as an in-stream sediment surrogate**
- **Different meters and readings should be compared to each other and to SSC or other constituents of interest**

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Future needs for in-situ measurement of sediment and associated constituents

- **Consider reporting data in units of beam attenuation coefficient (beam transmissometer) as suggested by Davies-Collies and Smith (2001)**
- **Measure concentrations from 1 to at least 5,000mg/L**
- **Sensitive to grain sizes from a couple microns to at least 2 millimeters**
- **Be deployable in stream under all conditions**
- **Have mechanical or other devices that minimize servicing**
- **Read all colored material equally**
- **Eliminate maximum problem or equip with autoranging**
- **Communicate the uncertainty of the measurements and estimated concentrations**

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Real-time water quality - Microsoft Internet Explorer

File Edit View Favorites Tools Help

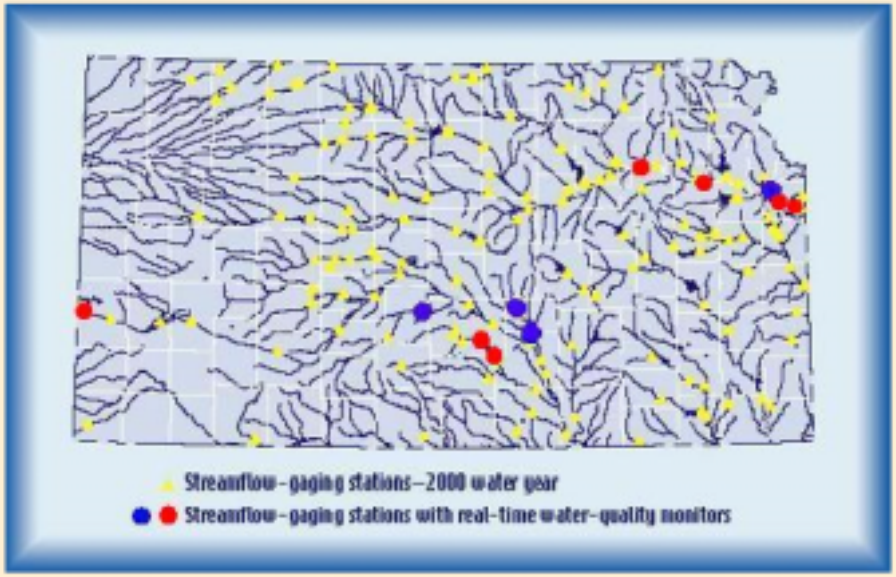
Back Search Favorites History

Address http://ks.water.usgs.gov/Kansas/rtqw/ Go Links

USGS science for a changing world

Real-Time Water-Quality Concentrations and Loads Estimated Using Regression Analysis

- Background Information
  - Water-quality standards
  - Regression analysis
  - Equation tables
  - Uncertainty
- Water Quality Studies in Kansas
  - Real-time WQ home
  - Water quality
  - Equus Beds GW recharge
  - Quivira
  - Lake Olathe
  - Cheney



This map shows USGS streamgages (yellow triangles) in Kansas. Estimated concentrations and loads are available for stations shown as blue and red dots. Click a red dot to view real-time water-quality data for a site and a blue dot where estimates are being developed.

The U.S. Geological Survey's streamgaging network provides information to resource

Internet

USGS

http:// ks.water.usgs.gov/Kansas/rtqw/