Uses of Field Measurements for Turbidity: Examination of the Spectrum of Available ~~Devices~~ Strategies

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Outline

- The nature of suspended sediment
- Turbidity as a surrogate to estimate suspended sediment levels
  - Turbidity vs. discharge as a correlating variable
  - Storm vs. annual correlations
- Strategies in using turbidity to answer key research and management questions

Nature of Suspended Sediment

- What is Suspended Sediment?
- Suspended sediment comes from varied sources
- Suspended sediment is variable in space and time
- Often most of suspended sediment annual load is confined to events over a short time period

Sediment

- **Sediment Defined**
  - "Inorganic Material or mass of it deposited as by water"
  - Can be of various sizes powder to car sized boulders.

- **Fine Sediment Definition:**
- ***"Sand Sized material and smaller (i.e. sand sized material and smaller, smaller than a lady bug 0.1" in diameter)"***
- ***Generally suspended sediment is made up of "fines"***

Types of Sediment Load

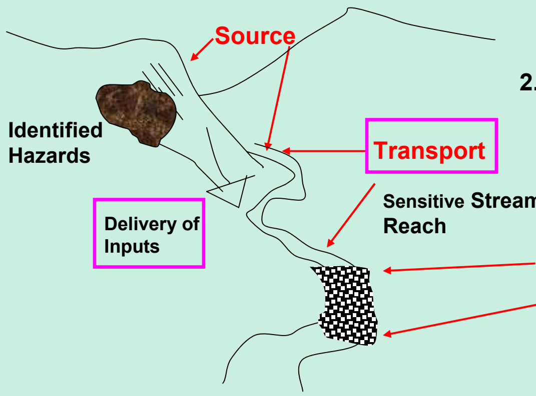
1. Total
2. Suspended vs. Bedload (concept based on position in water column)
3. Wash load vs. Bed material load (concept based on length of travel in suspension)
4. Suspension vs. Saltation vs. Contact load (simliar to 2 but more splitting

What influences particle lift and settling

- **Particle:**
  - Size
  - Shape
  - Specific Gravity
  - Roughness
  - Cohesion
- **Fluid**
  - Temperature
  - Specific gravity
  - Viscosity
- **Other**
  - Concentration
  - Wall effects

Where does sediment come from?

Delivery and Transport are Key



Examples:

1. There can be an upslope landslide that is disconnected from the stream that will not impact the stream
2. A road can have surface and ditch erosion but if ditch empties into field or forest no connection

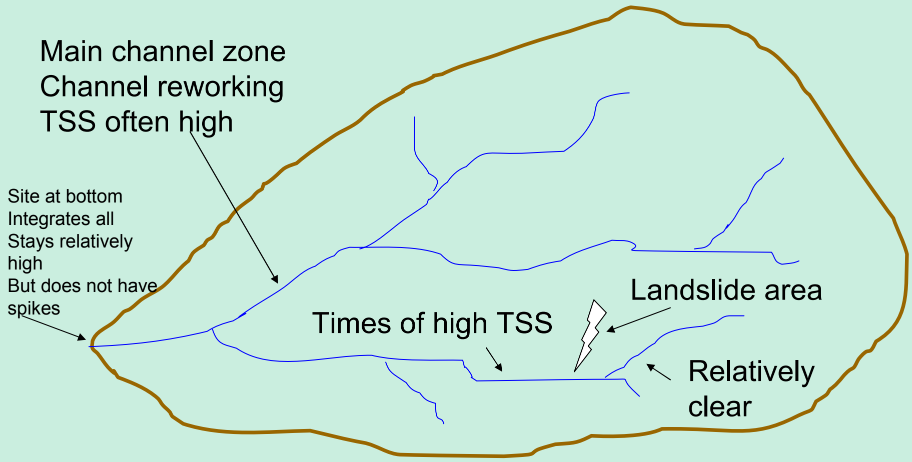
Adapted from Washington Watershed Analysis Manual; 1997

Sources and Delivery areas

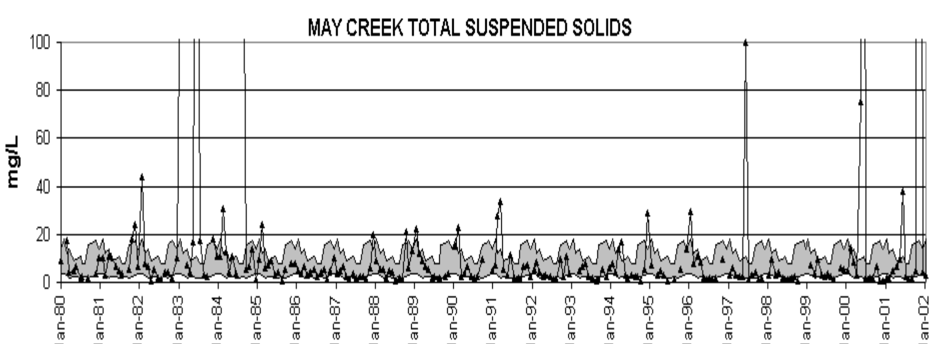
- In channel scour and deposition
- Channel adjacent bank failures
- Channel adjacent landslides
- Upslope landslides and deposits near stream
- Surface erosion from open fields and hill slopes upslope
- Surface erosion from roads and ditches

Because of the numerous source areas turbidity can vary in space

Makes locating equipment complicated

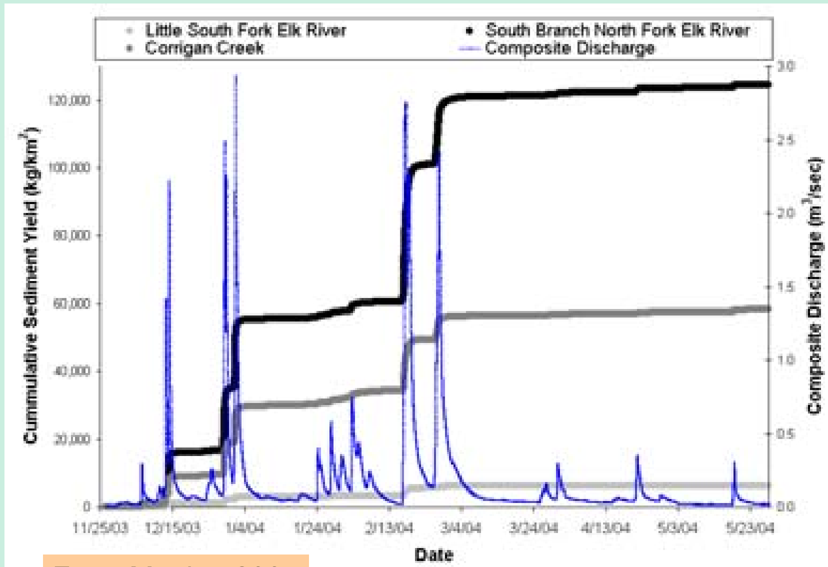


Suspended sediment is variable in time

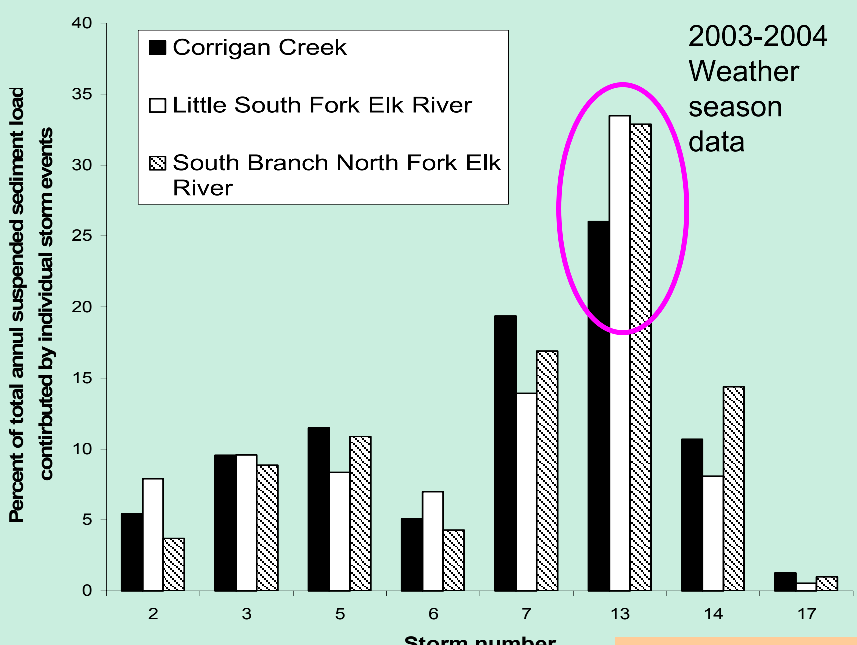


From King County – Washington State

Most sediment load is confined to a few events



From Manka, 2005

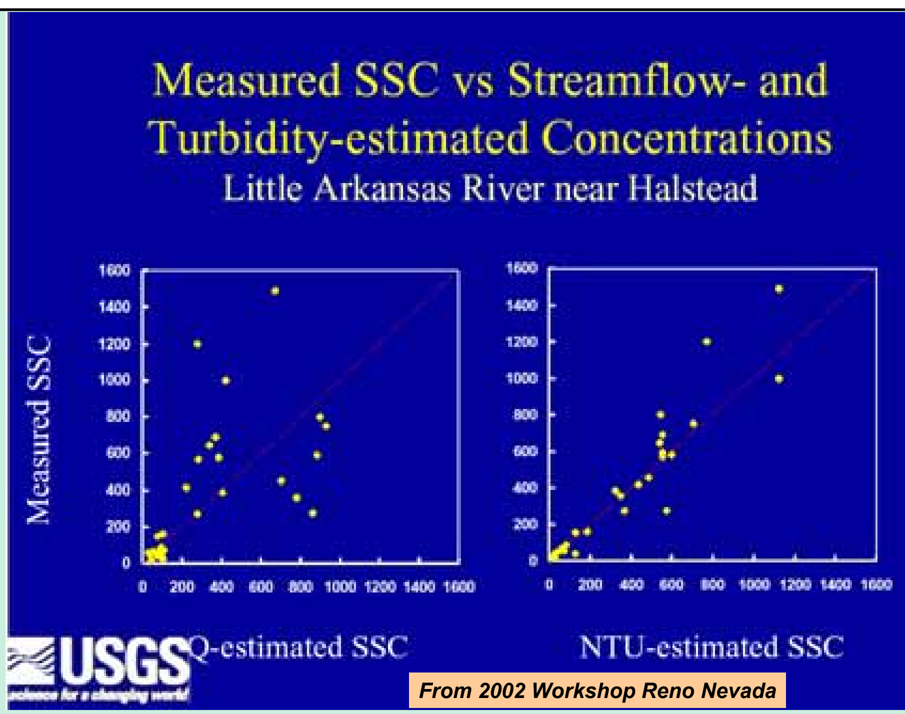


2003-2004 Weather season data

From Manka, 2005

Problems with temporal variability

- Different source areas may not be active for long periods of time so difficult to do a meaningful source area analysis
- Sometimes the time period between key events may be decades so making inferences from short term records is problematic
- **<u>We want to have something continuous</u>** to get at this issue but SSC sampling is time consuming and can not be done so must correlate SCC with something



From 2002 Workshop Reno Nevada

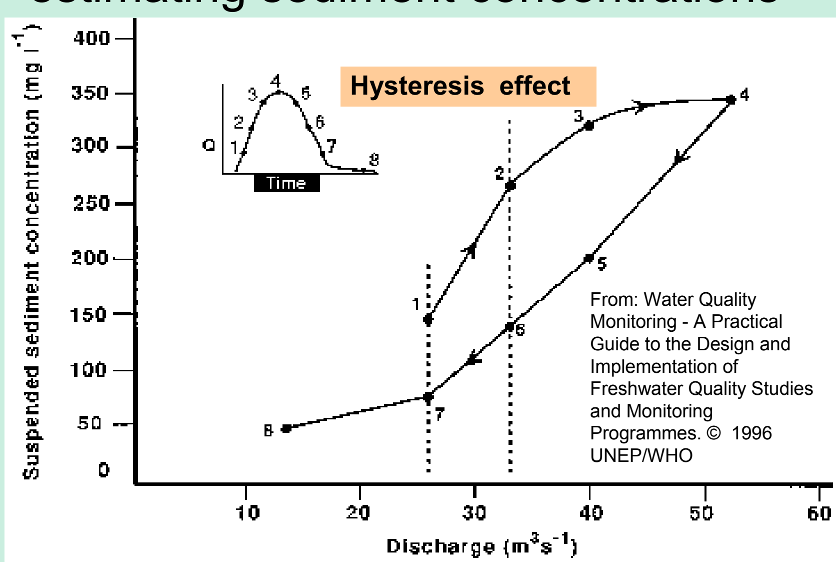
Comparison of Measured Instantaneous Suspended-Sediment Loads to Streamflow- and Turbidity-Estimated Suspended-Sediment Loads, 1998-2001

Suspended-sediment Load (tons per day)	Kansas R. at Desoto	L. Arkansas R. at Sedgwick
Mean measured load	49,500	3,010
Mean streamflow-estimated load	106,000	4,610
Percentage difference	-110	-53
Mean turbidity-estimated load	47,200	2,830
Percentage difference	4.6	6.0

USGS science for a changing world

From 2002 Workshop Reno Nevada

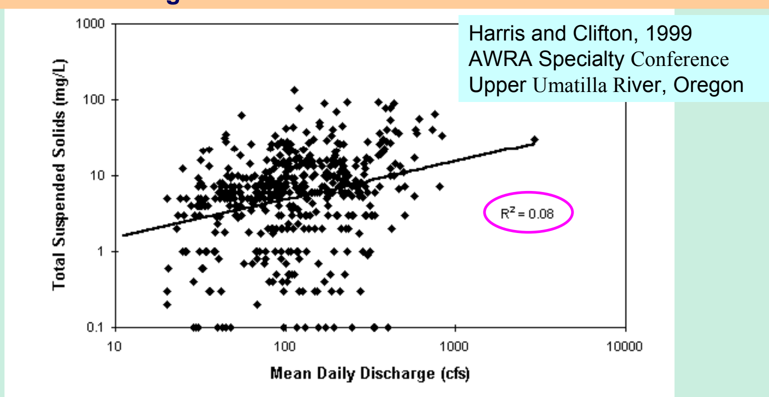
Why discharge is problematic for estimating sediment concentrations



More problems for Q vs. SSC

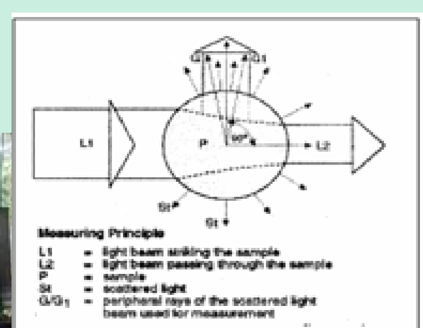
- **Because different sediment sources are activated for different events increasing discharge will be a relatively poor predictor of suspended sediment especially for mountain streams if combining storms**

- **Probably would be better for larger streams with much of turbidity caused by channel reworking or bank failures because more associated with high flows**



Turbidity: often used as index of suspended sediment

Turbidity is **defined** as an expression of the optical property that causes light to be scattered and absorbed, rather than transmitted, in straight lines.
This is often used as a surrogate for suspended sediment



Source: GLI, undated.

Turbidimeters -Nephelometric optics

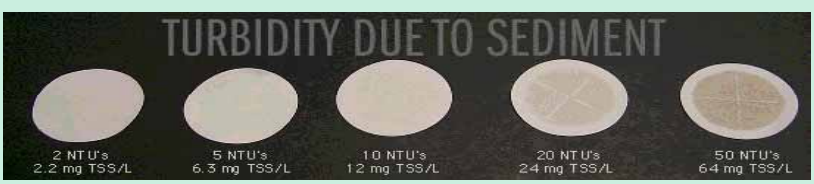
Theory:

- nephelometric turbidity estimated by the scattering effect suspended particles have on light
- detector is at 90° from the light source

Measures:

- (NTU) Nephelometric Turbidity Units
- standards used for calibration are formazin or other certified material
- JTU's are from an "older" technology in which a candle flame was viewed through a tube of water
- 1 NTU = 1 JTU (Jackson Turbidity Unit)
- Many types of meters under NTU standard with variations FNU etc…

Turbidity vs. SSC



$T = c\,G_c^n$ Emment, 1975

Where: G_C – Suspended Sediment Concentration

n – Exponent 0.6-0.7

c – Coefficient 0.7-1.3

n and c are based on ability of sediment particle to scatter light

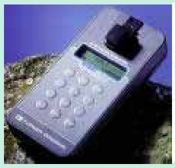
Quick and Dirty:

1 mgTSS/L ~ 1.0 - 1.5 NTU's of turbidity

Note: Turbidity scattering depends on particle size so this is only a rough approximation that is why we need correlation with SSC to get reliable estimates

Bench vs Submersible Turbidimeters

Water sample processing in office –grab samples



Continuous profile using submersible sensor

YSI wiping turbidity

YSI 6820 with unwiped turbidity

Hydrolab

Turbidity monitoring has the following advantages:

- Immediate measurement in the field can occur
- Continuous measurement is possible
- Instream sampling location is usually not a problem
- Single grab samples can often be shown to represent conditions over an entire cross-section.

Is Turbidity the answer?

Is turbidity the answer?

- Disadvantages of turbidity monitoring are as follows:
  - Setting up continuous recording stations can be expensive or alternatively
  - Grab sampling schemes require field staff to be available for work at night, on weekends, and in the rain.

  Also
  - A separate relationship between SSC and turbidity must be established for each watershed under investigation because relationship varies with load characteristics requiring bottle samples
  - Different types of turbidimeters may provide different readings

Modern Automated Turbidity station logistics

1. “Continuous” stage and turbidity measurements using a transducer for stage and probe for turbidity
2. Correlate stage to discharge using velocity area approach or weir equations
3. Correlate turbidity to SSC by taking bottle samples of turbidity using automated threshold sampling using electronic bottle sampler and processing bottle samples for suspended sediment concentrations*
4. Multiply SSC by Q to get loads

*May also take depth “integrated” grab samples to compare with automated bottle samples

*In developing correlations between SSC and turbidity you can do this annually or on a storm by storm basis.

Suspended Sediment vs. Turbidity

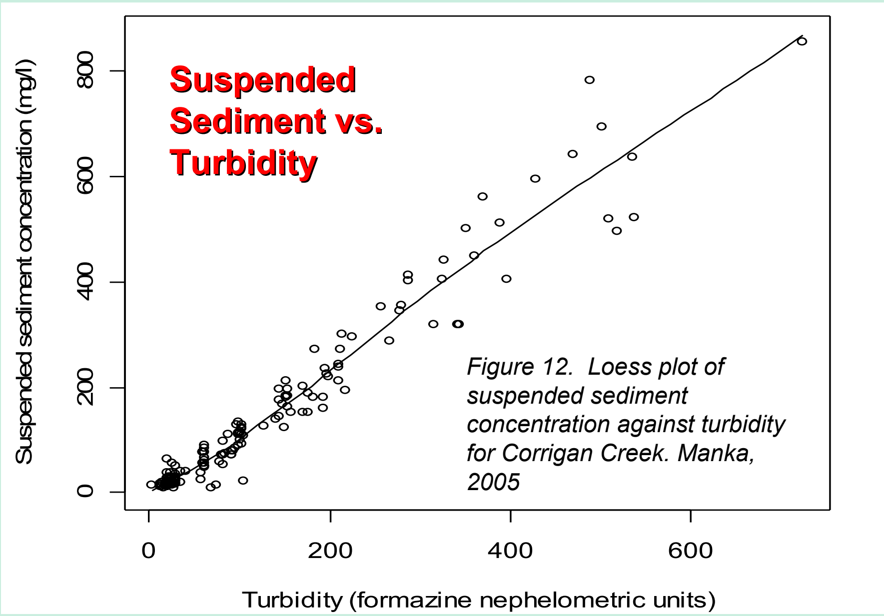


Figure 12. Loess plot of suspended sediment concentration against turbidity for Corrigan Creek. Manka, 2005

Does turbidity correlate to SSC on annual basis?

If storms have similar behavior in terms of sediment sources and types then ok.

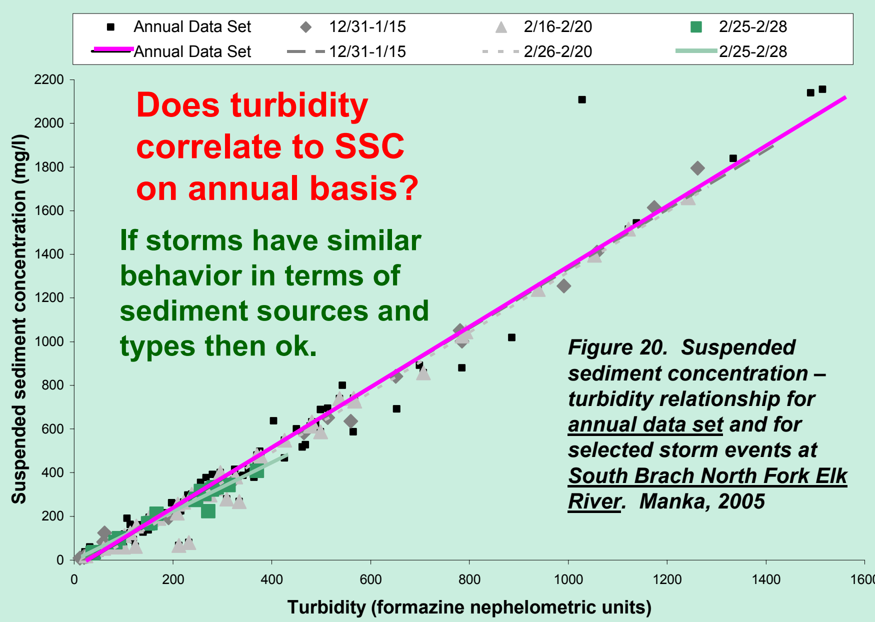


Figure 20. Suspended sediment concentration – turbidity relationship for annual data set and for selected storm events at South Brach North Fork Elk River. Manka, 2005

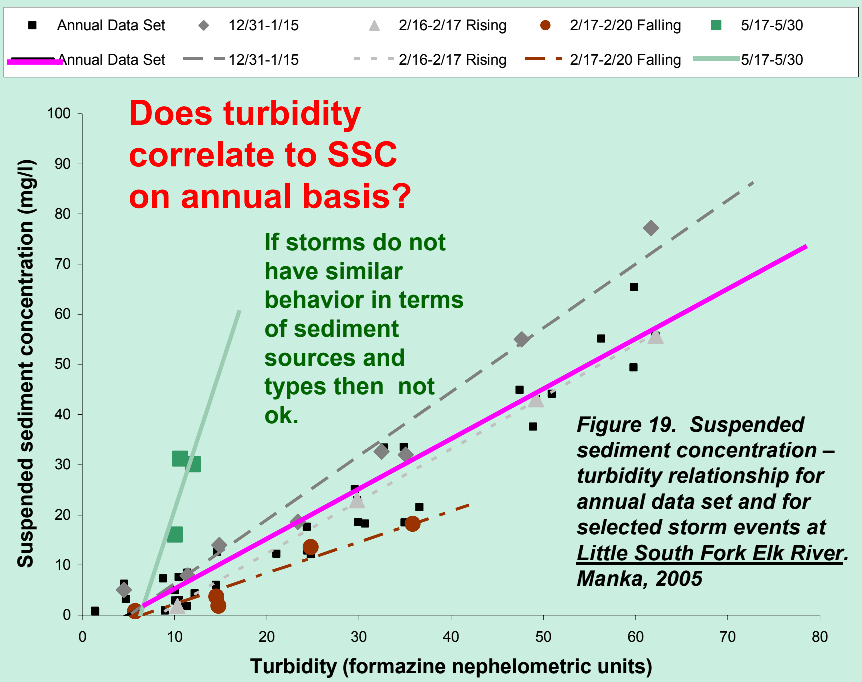


Figure 19. Suspended sediment concentration – turbidity relationship for annual data set and for selected storm events at Little South Fork Elk River. Manka, 2005

For Period of Record 11/26/03 07:20 - 06/16/04 14:50

From Manka, 2005

	Corrigan Creek	Little South Fork Elk River	South Branch North Fork Elk River
Total Discharge (m^3)	2,287,908	1,671,682	3,716,323
Watershed Area (km^2)	4.01	3.11	4.92
Unit Area Discharge (m^3/km^2)	569,914	537,867	755,200
Total Suspended Sediment Load (tons) From Annual Regression	221.1	20.4	601.5
Total Suspended Sediment Load (tons) From Individual Storm Regressions	237.1	18.0	594.7
Difference Between Estimates (tons)	16.0	-2.4	-6.8
Total Suspended Sediment Yield ($tons/km^2$) From Annual Regression	55.1	6.6	122.2
Total Suspended Sediment Yield ($tons/km^2$) From Individual Storm Regressions	59.1	5.8	120.8
Difference Between Estimates ($tons/km^2$)	4.0	-0.8	-1.4
Difference as a Percent of Individual Storm Regressions Estimate	6.7	-13.5	-1.1

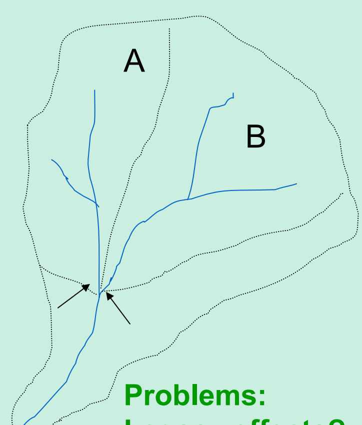
Traditional Reasons for Monitoring Turbidity or SSC or Loads

- Trend monitoring to track water quality improvement or degradation with overall management or changes
- Comparison of station turbidity against a water quality standard based on beneficial uses of water to see if in compliance
- Wanting to know how a treatment (i.e. management practice) effected suspended sediment loads downstream

Control/ Treatment

- Set up stations and take "several years" of data for calibration
- Treat upstream from one station
- Compare contrast in light of pre-treatment calibration period
- Often used for peak flow and water yield studies

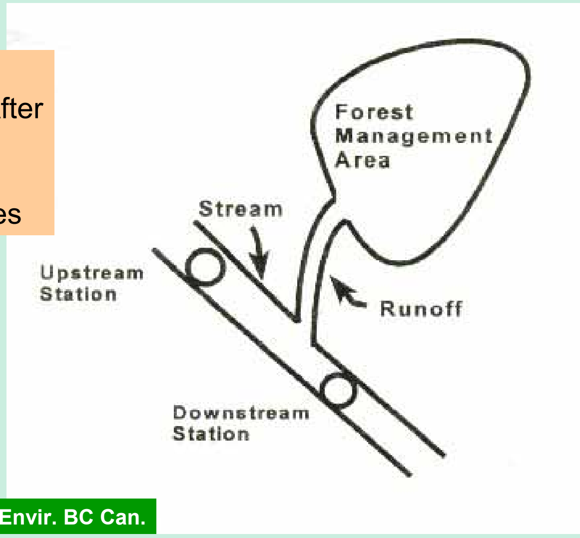
Note: you only get an effect you may not know why there is an effect



Problems:
Legacy effects?
Finding untreated?
Treating untreated?
Long-term funding?

Upstream / Downstream

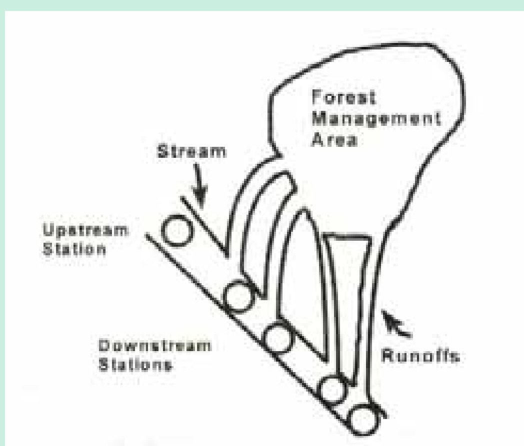
Need Before/After to make strong inferences



From Min Envir. BC Can.

Upstream / Downstream Reality Check

- The nature of non-point source is there are diffuse sources so the upstream downstream may not be “clean”



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Dealing with imperfect data

From Manka, 2005

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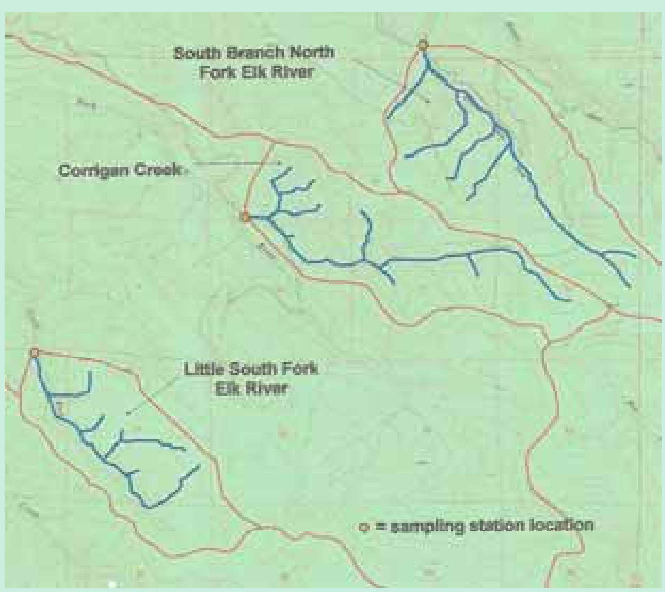
Unit Area Discharge (m^3/km^2)	569,914	537,867	755,200
Total Suspended Sediment Load (tons) From Annual Regression	221.1	20.4	601.5
	Logged 1950's Extensive Road	**"Pristine" Only one Short abandoned road section**	**Logged 1950's Extensive Road**

One year of data tempting
But what can you say?
What are you willing to say

Issues

- There is no before and after
- No calibration
- Mixture of legacy effects. How much is legacy vs. newer logging activity
- Natural conditions identical? unknown?
- What kind of inferences can we make?

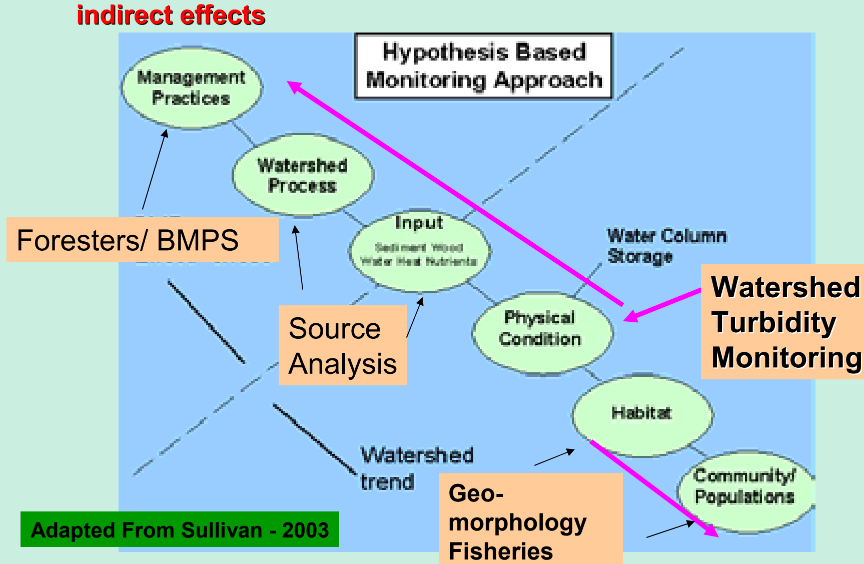


Bridging the Gaps in Understanding

- Source analysis look for potential source to see if similar
  - Legacy effect sources
  - Natural sources such as deep seated landslides encroaching on creek
  - Erosion due to channel instability and reworking
  - Erosion due to loss of roughness (loss of wood)
- As well as
  - Sources associated with recent logging activity

When the classic BACI is Lacking

- **Need to <u>tie sampling</u> at multiple scales for both immediate and indirect effects**



Other issues

- More than just loads
- "Dose analysis"
  - Thresholds frequency and magnitude of high sediment concentration and possible direct effects
- Sediment size composition "sands"
  - Wash load vs. deposition in low gradient reaches
- Organics in load as food source and other issues

Walnut Gulch During Peak Flow Event in Arizona

Conclusions

- The nature of suspended sediment (Variable most load from infrequent events)
- Turbidity as a surrogate to estimate suspended sediment levels (Most effective way because continuous)
  - Turbidity vs. discharge as a correlating variable **(Turbidity better)**
  - Storm vs. annual correlations **(Storm by Storm better)**
- Strategies in using turbidity to answer key research and management questions **(Many strategies available but must remember that turbidity is variable and that requires long-term records and or linking with other monitoring to answer questions)**