LISST-SL, SSC, and ADCP Data Analysis and Surrogate Testing

Washington WSC, Illinois WSC, and OSW Collaboration

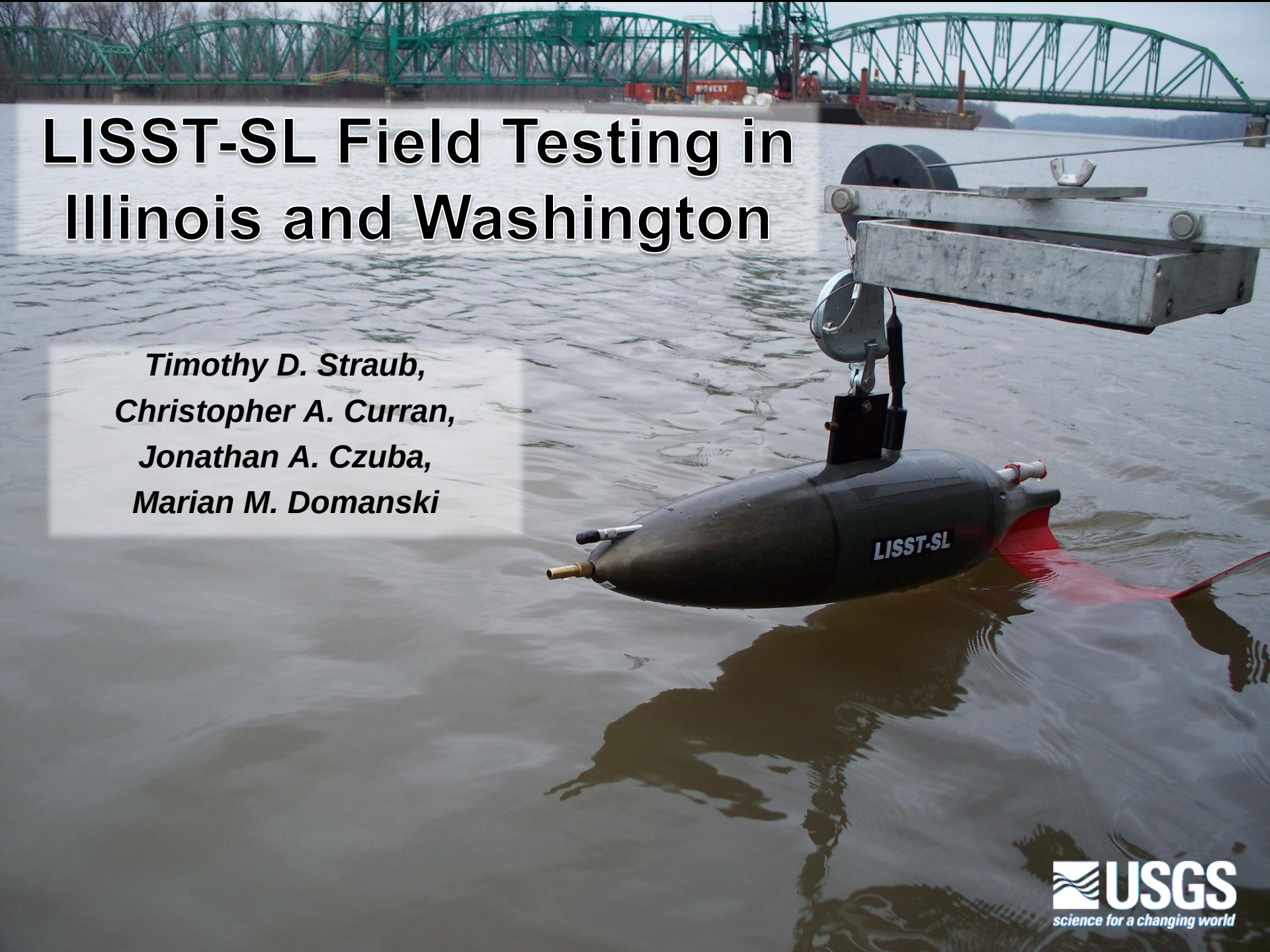
FISP Technical Committee Meeting
October 24, 2012

LISST-SL, SSC, and ADCP Data Analysis and Surrogate Testing

- Field Testing in Washington and Illinois
  - LISST-SL and SSC comparisons
  - SSC estimation from down-looking acoustic Doppler current profilers using an acoustic backscatter calibration procedure and MATLAB-based tool

LISST-SL Field Testing in Illinois and Washington

Timothy D. Straub,
Christopher A. Curran,
Jonathan A. Czuba,
Marian M. Domanski

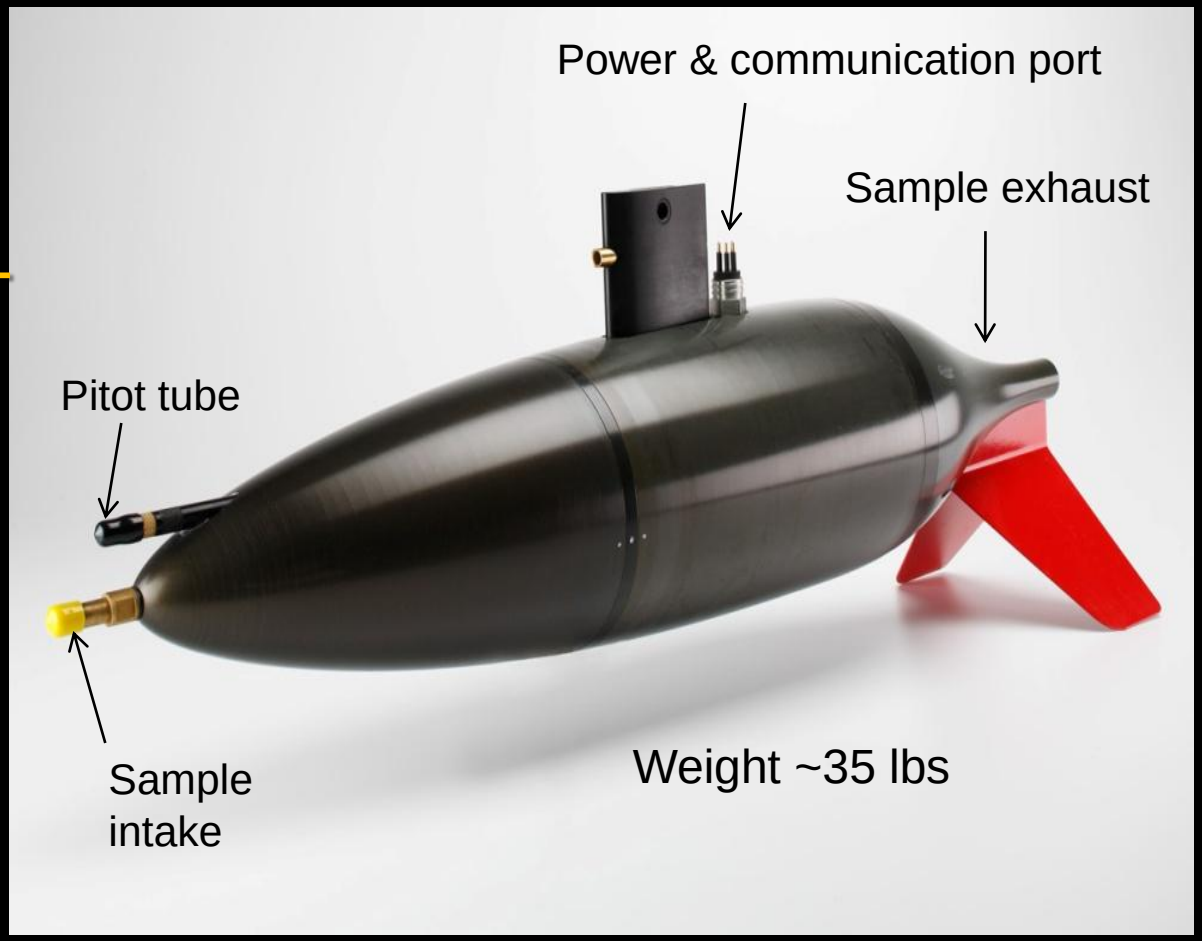


USGS
science for a changing world

LISST-SL Isokinetic Sampler

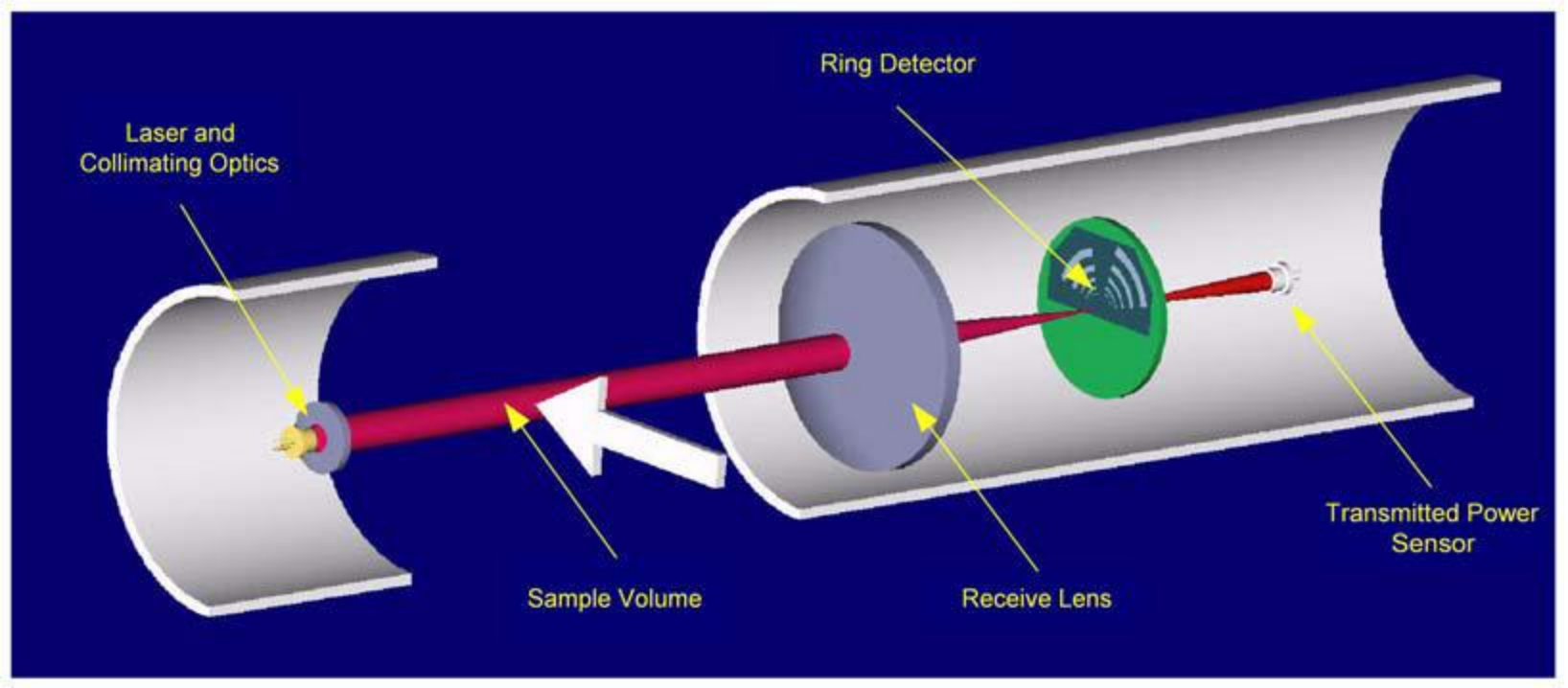
StreamLined (SL) version of the Laser In-Situ Scattering and Transmissometry (LISST)

- Suspended-sediment concentration
  - 10-3,000 mg/L
- Particle-size distribution
  - 2-381 μm
  - 32 classes
- Velocity
  - 0-8 m/s
- Depth
  - 0.15-30 m
- Temperature



Source: Sequoia Scientific, Inc.

Principles of Operation



Source: LISST-SL User's Guide, Sequoia Scientific, Inc.

Topside Control Box

Weather-proof container

Lithium-ion batteries (24 V)

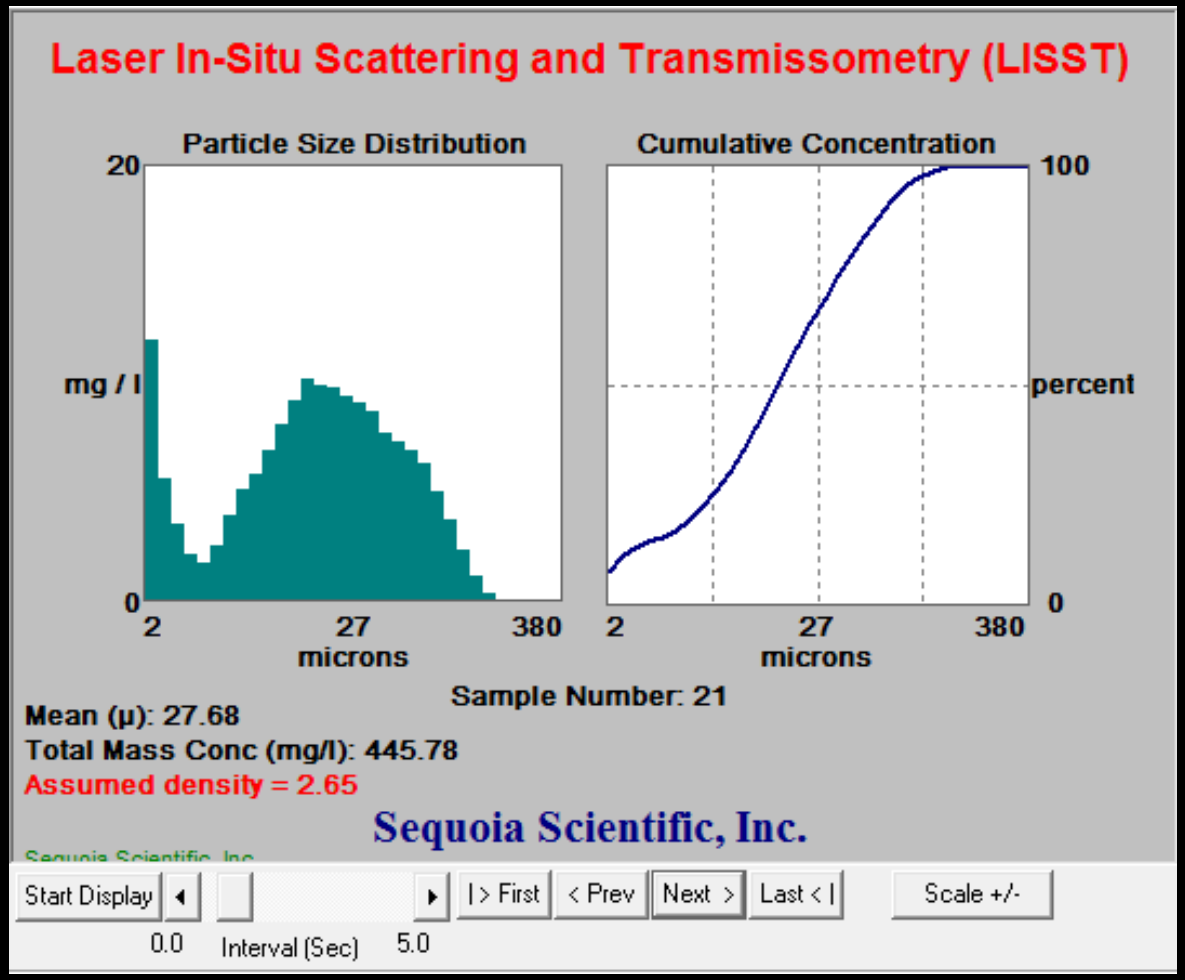
Communication & battery recharge

Power on/off

Touch-screen display menu

Connector port to B-reel/ LISST-SL

Data Example



Provisional data subject to revision

Typical Boat Setup

Typical Bridge Setup

Washington – Added Weight Mount

Sample Parameter Ranges

- 20 IL and WA datasets
  - Over 250 samples at 16 sites
- Concentration
  - 12 – 2,170 mg/L (from physical samples analyzed at lab)
- Velocity
  - 1.1 – 7.6 ft/s
- Depth
  - 2 – 30 ft

Provisional data subject to revision

Physical Sample and Laboratory Analysis Inventory

LISST-SL Testing:

>250 samples

>130 Sand/Fine Split

>60 Full Particle Size

23 Pycnometer

5 Loss of Ignition

Labs Used:

Kentucky Lab

- Pipette

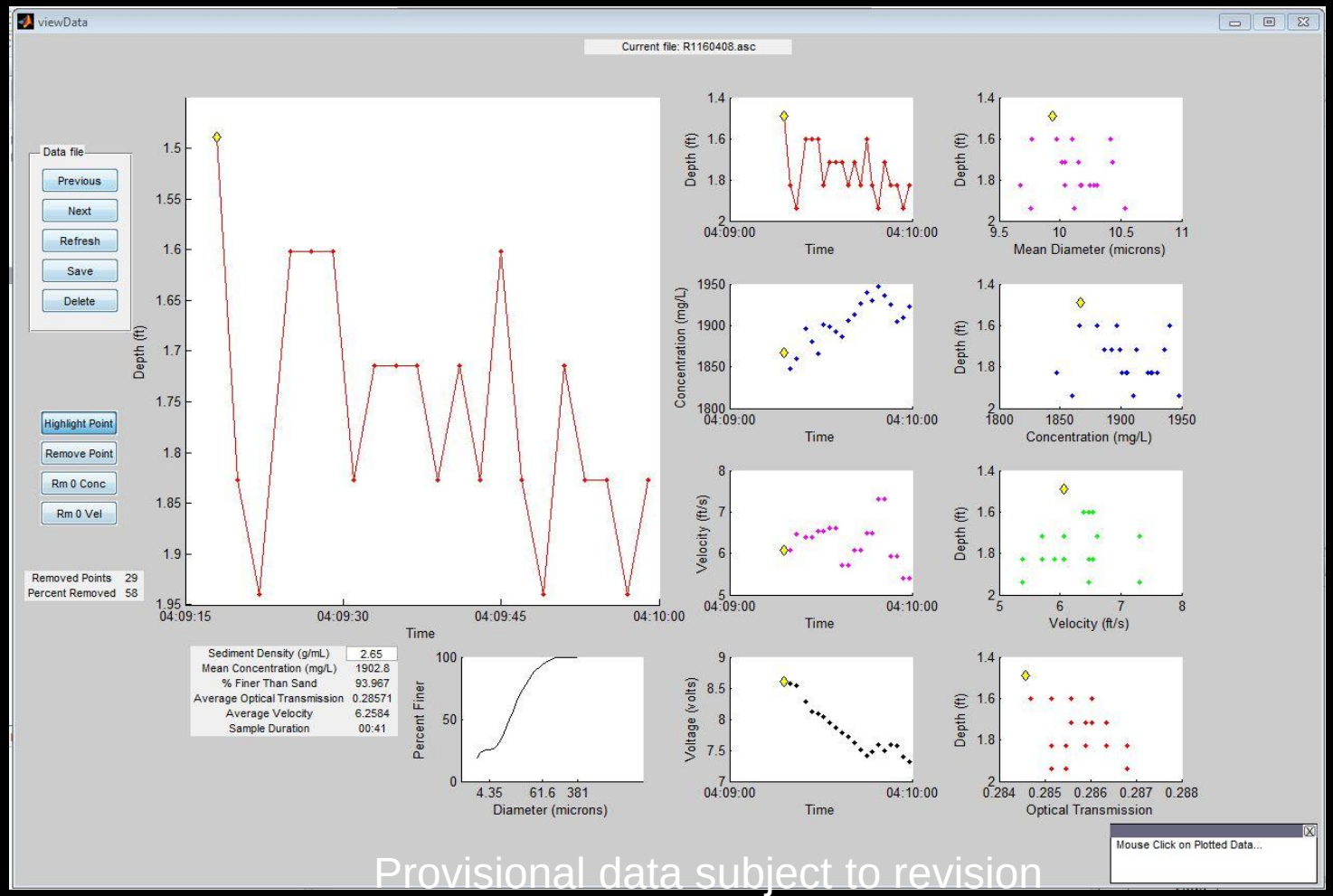
CVO Lab

- SediGraph/Sieve
- Pycnometer
- Digital Imaging

LISST-SL Data Processing

- Over 1,000 Files on LISST-SL Topside Controller Box
  - -Solution: MATLAB programs to view and process

Point Sample Example



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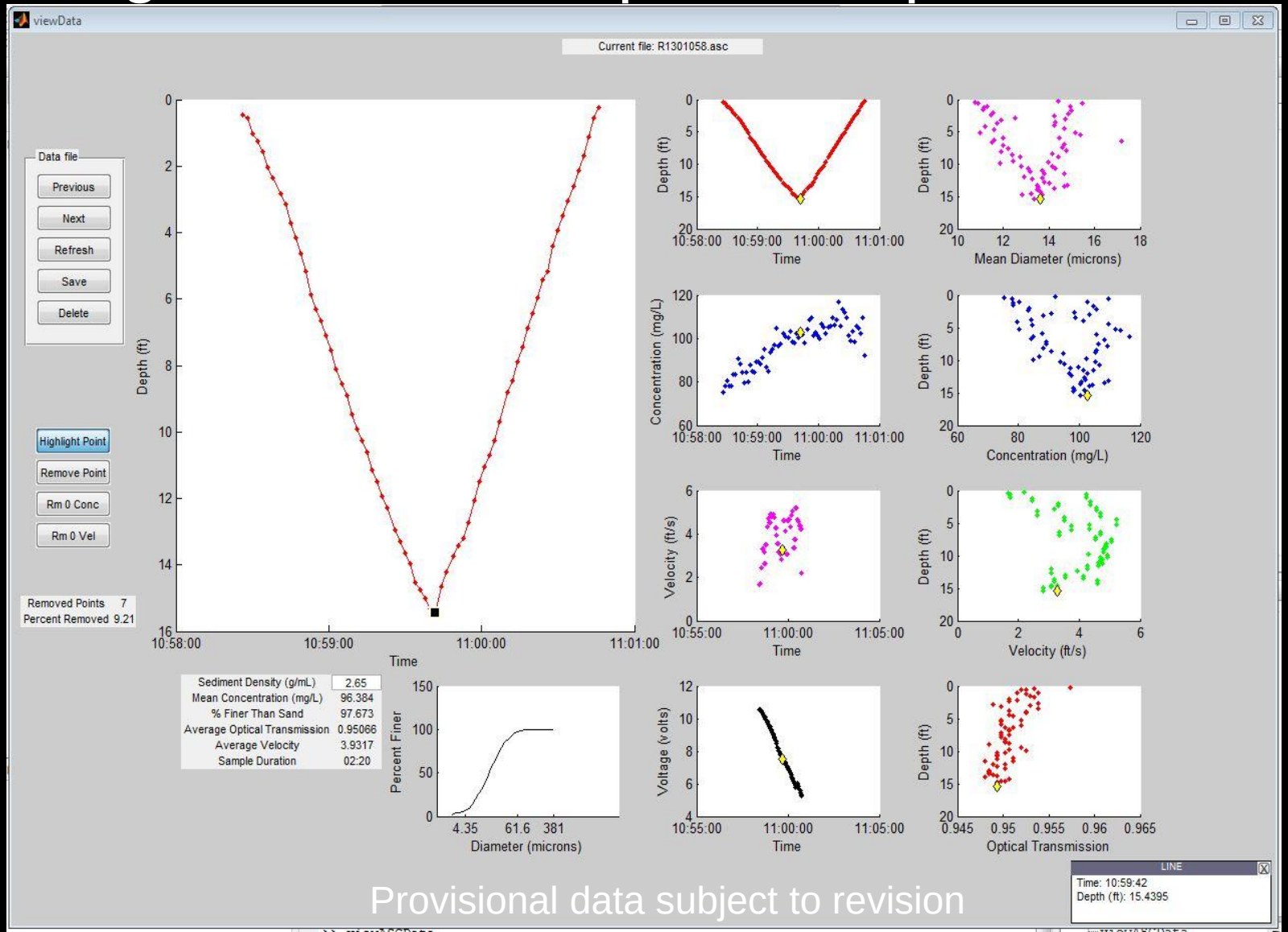
LISST-SL Data Processing

Single Vertical Sample Example



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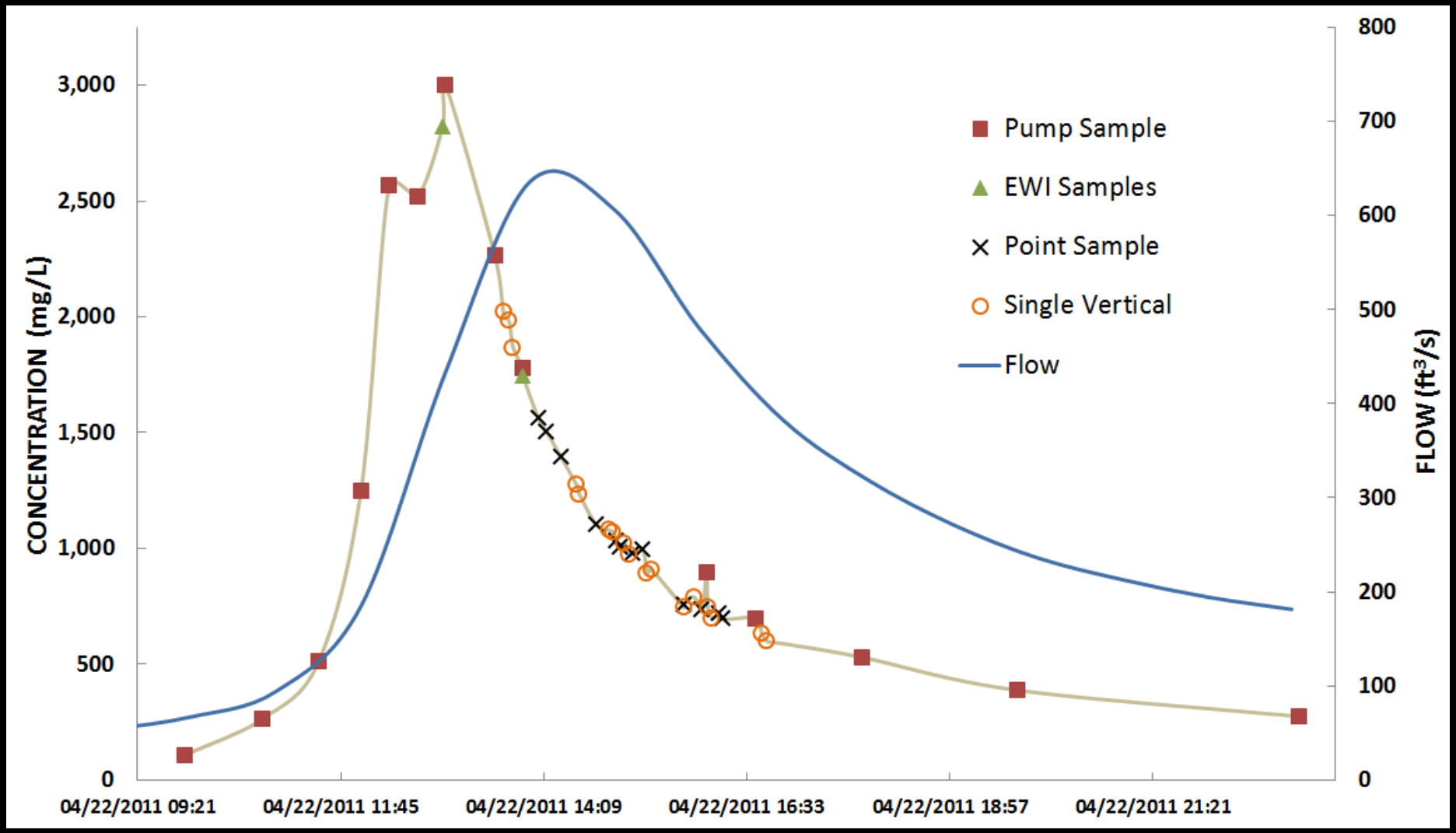
Example Data at Kickapoo Bloomington



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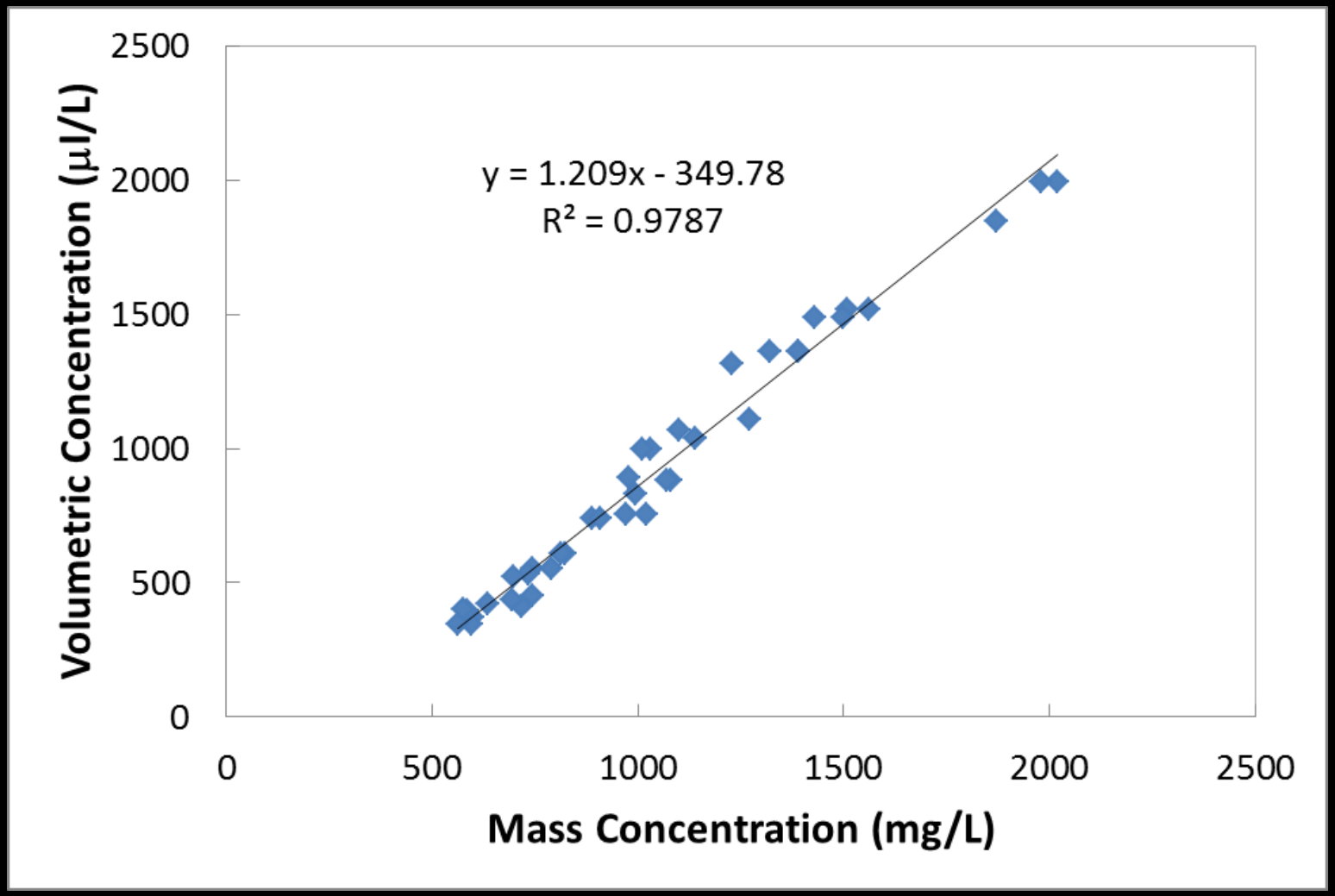
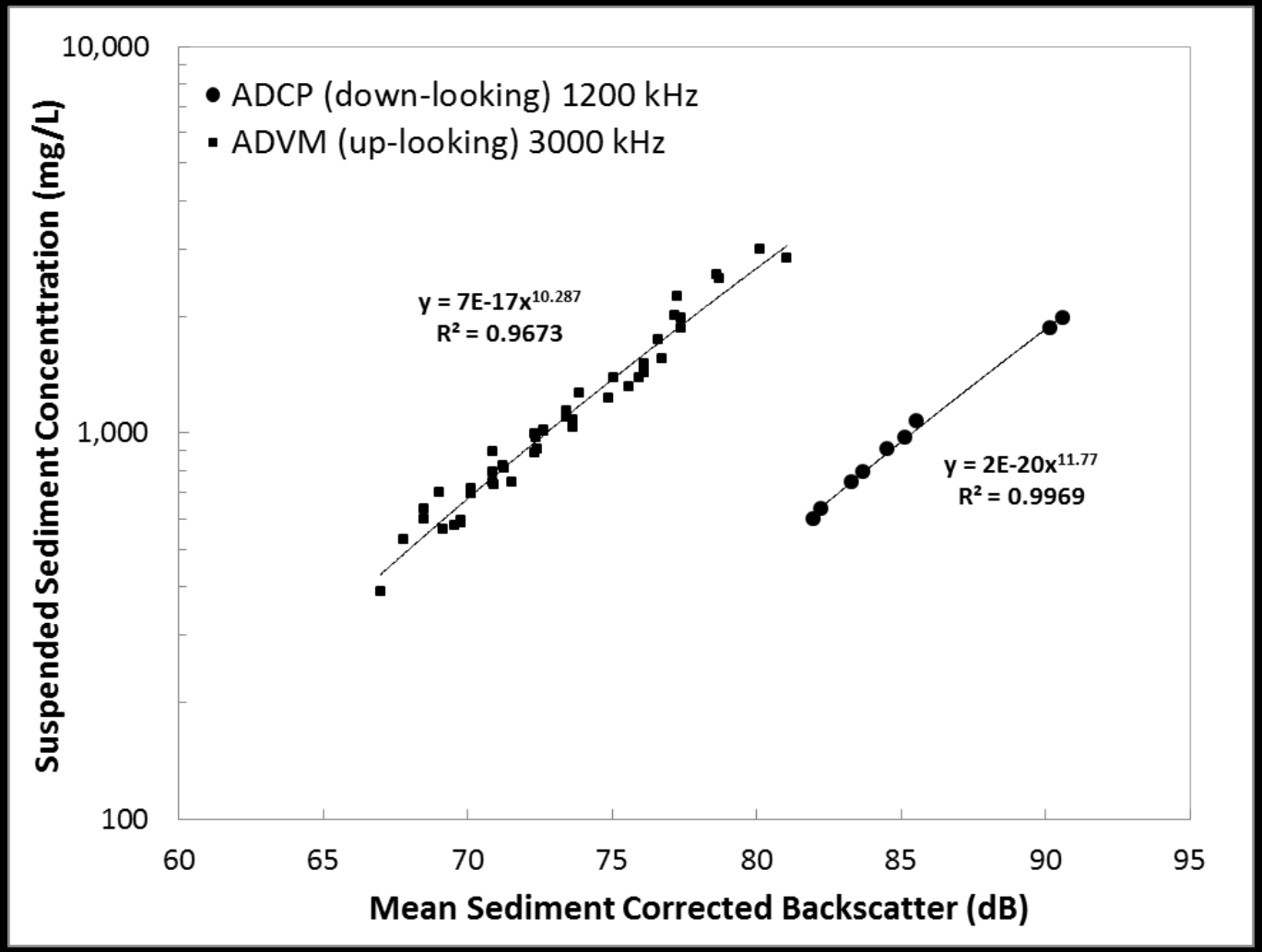
Example Data at Kickapoo Bloomington



Provisional data subject to revision

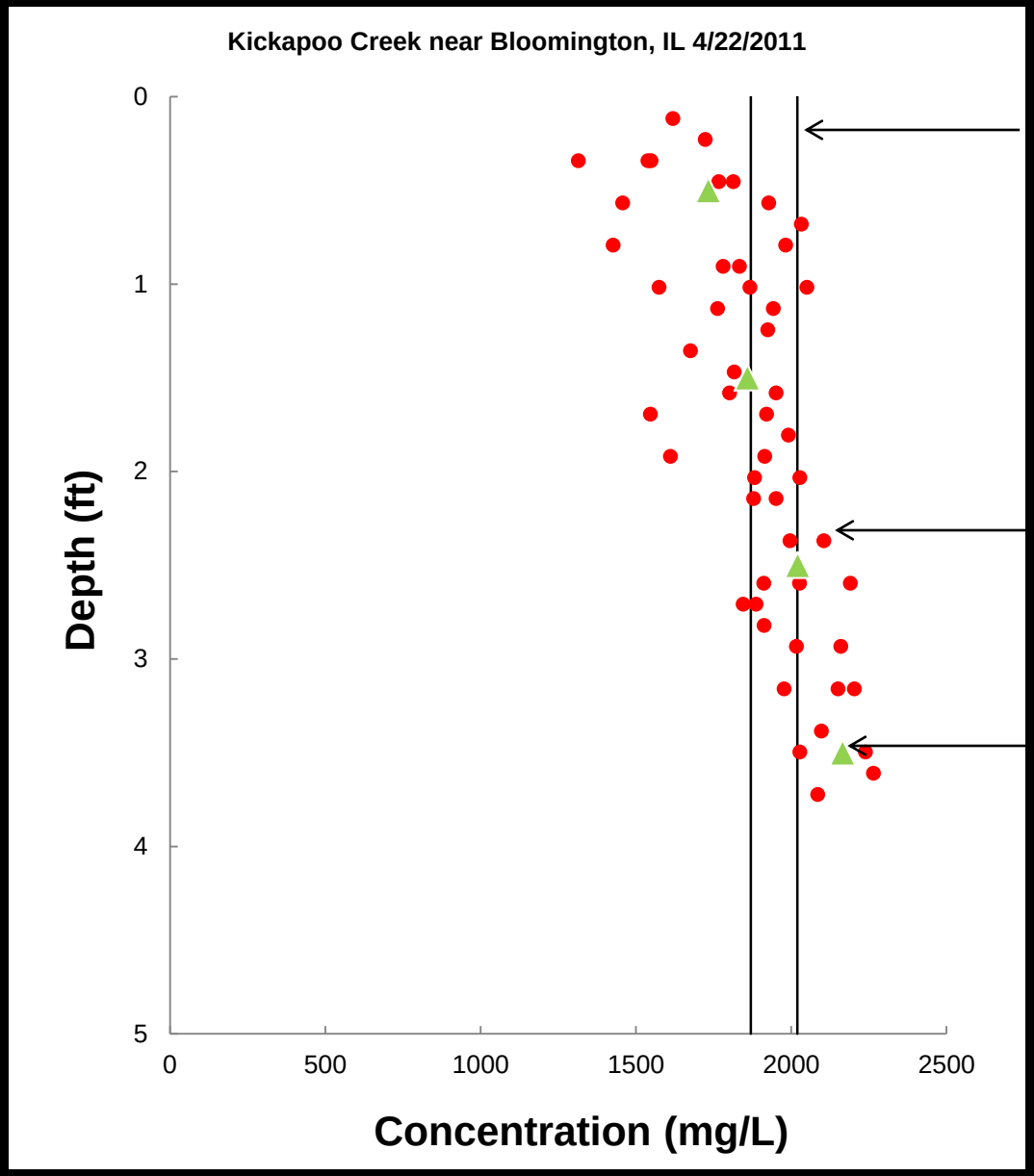
Example Data at Kickapoo Bloomington

ADVM and ADCP
Sediment Corrected Backscatter



Provisional data subject to revision

Example Data at Kickapoo Bloomington



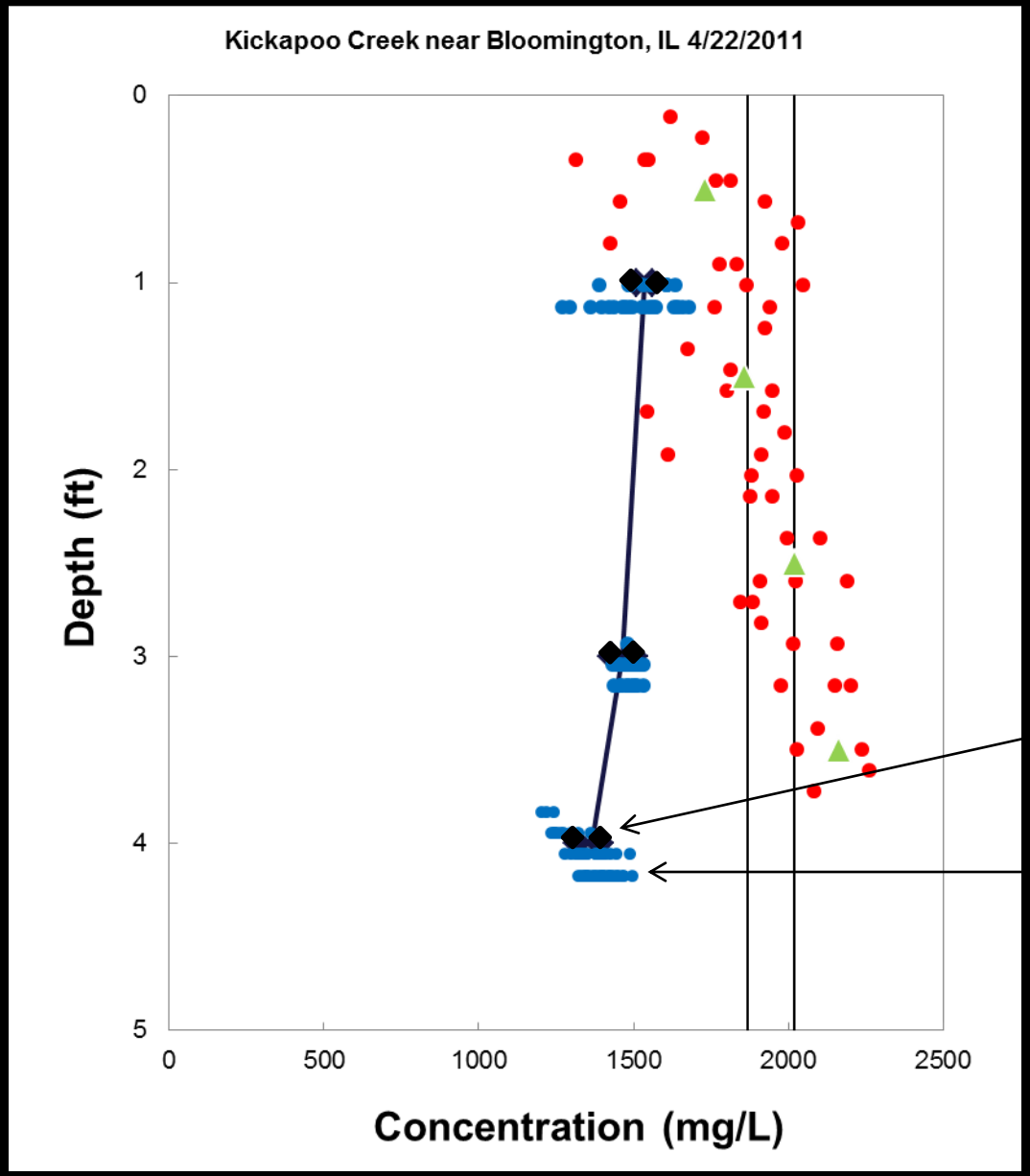
Black vertical lines indicate single vertical mass concentration from a physical sample

Red dots indicate LISST-SL volumetric concentrations

Green triangles indicate average LISST-SL conc at a given depth

Provisional data subject to revision

Example Data at Kickapoo Bloomington

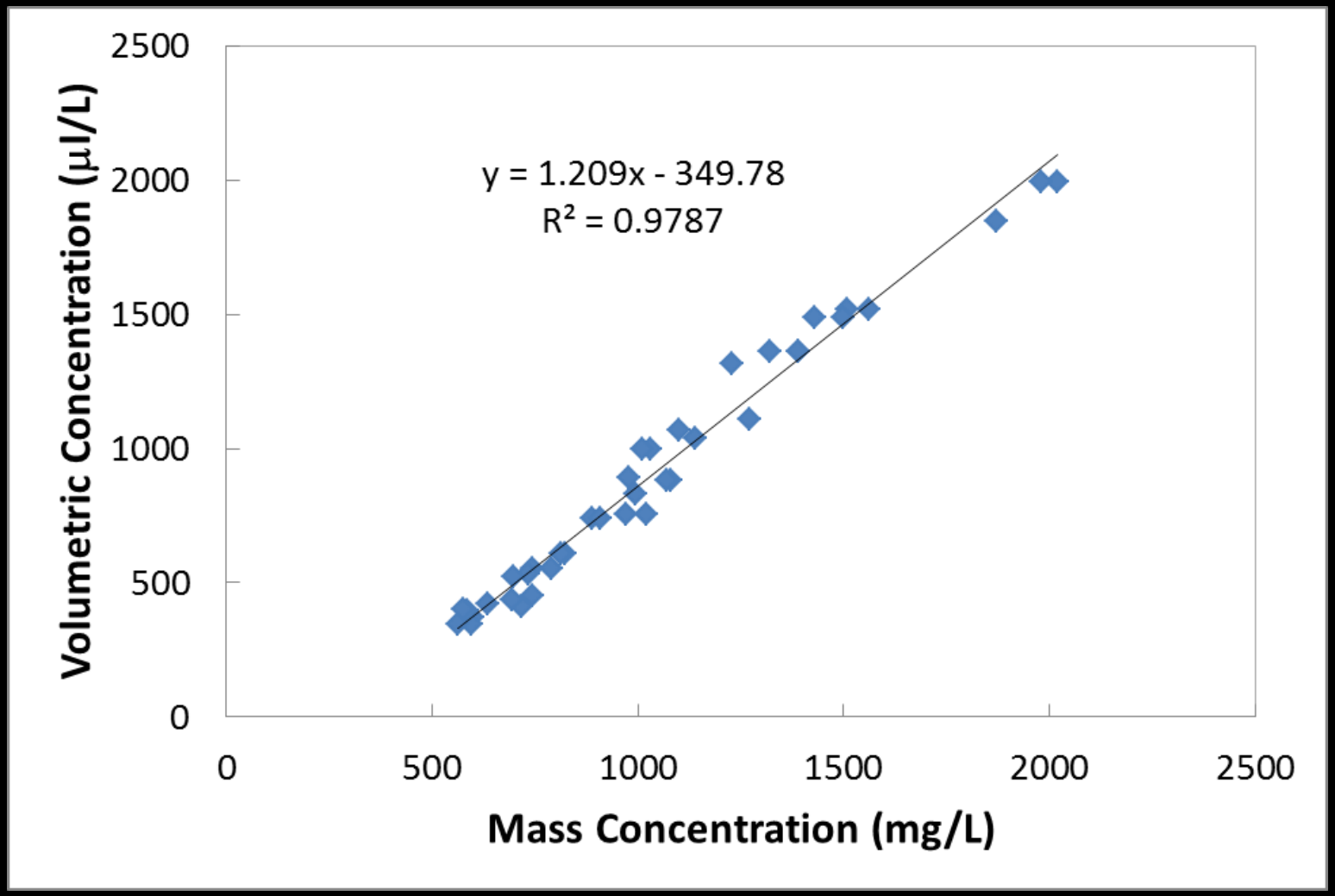


Navy diamonds indicate point mass concentration from a physical sample

Blue circles indicate LISST-SL volumetric concentrations

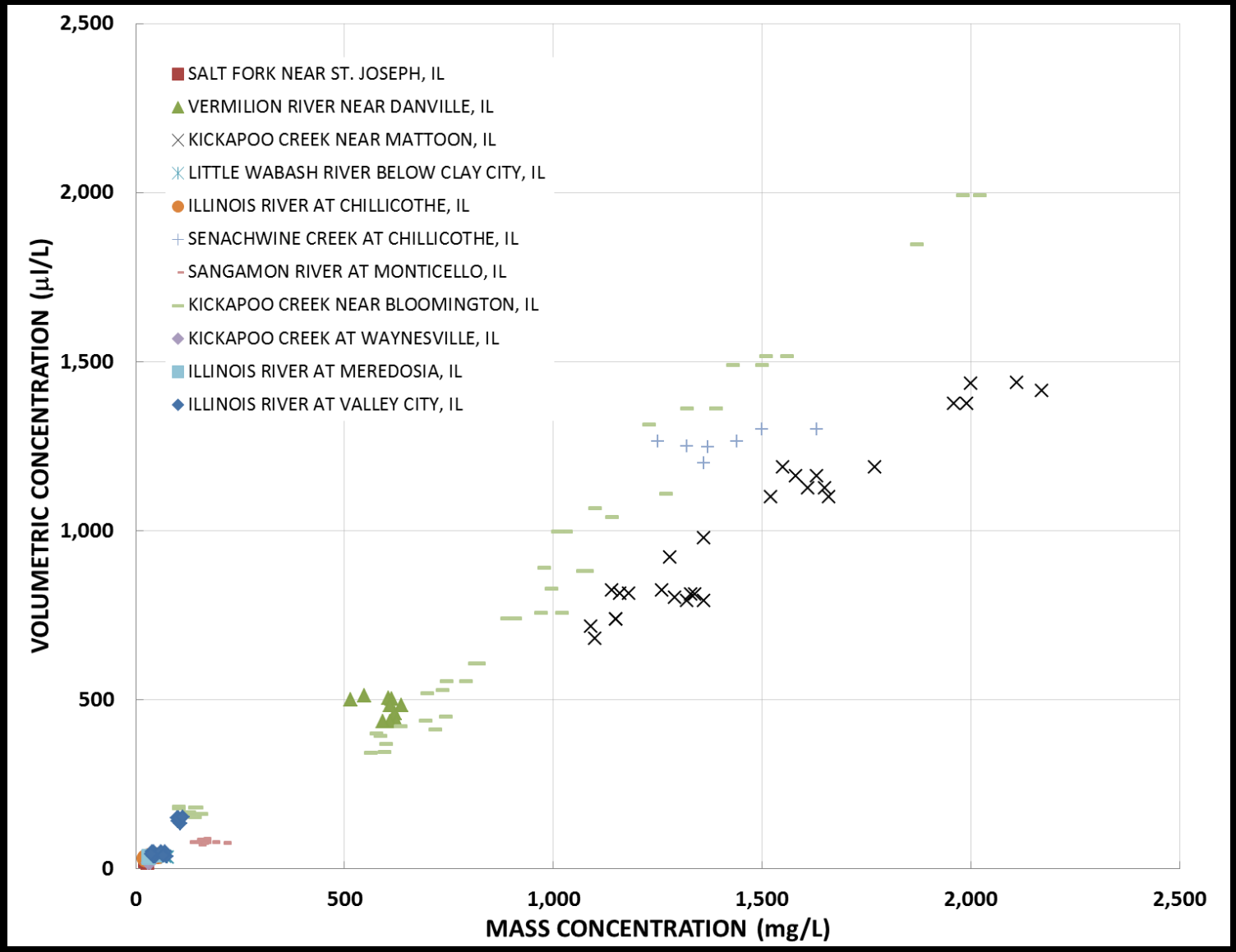
Provisional data subject to revision

Example Data at Kickapoo Bloomington



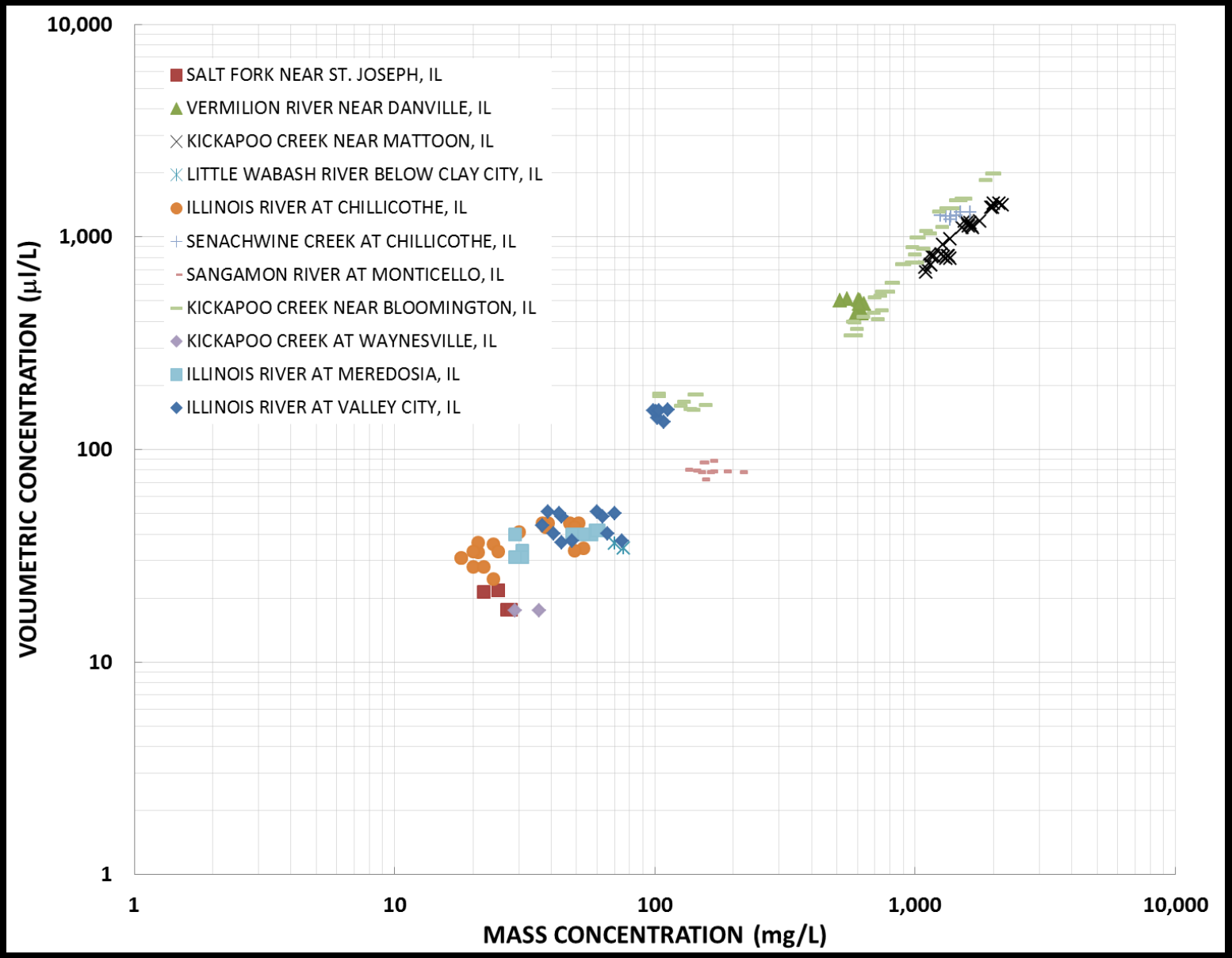
Provisional data subject to revision

IL Concentration Results



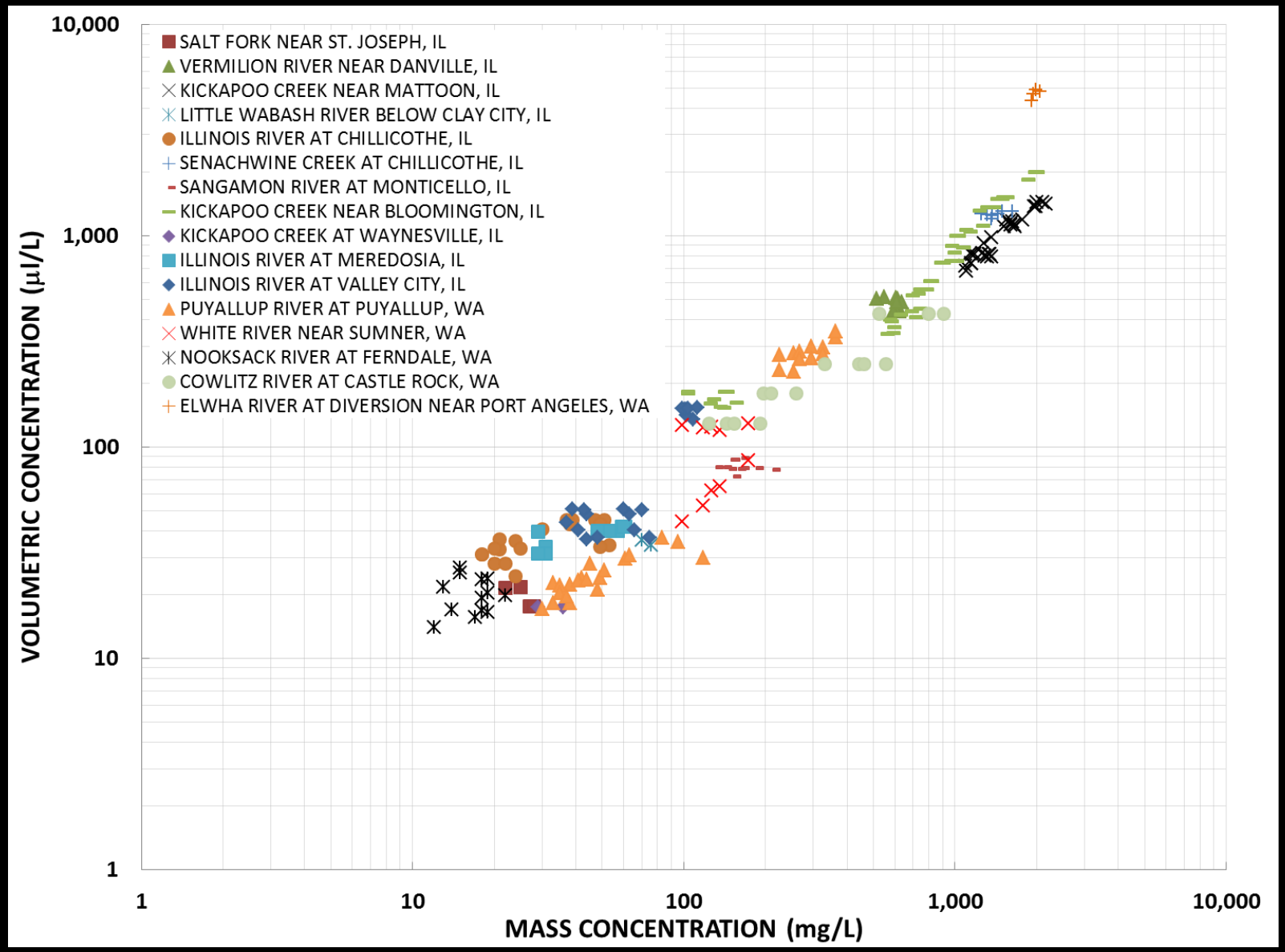
Provisional data subject to revision

IL Concentration Results



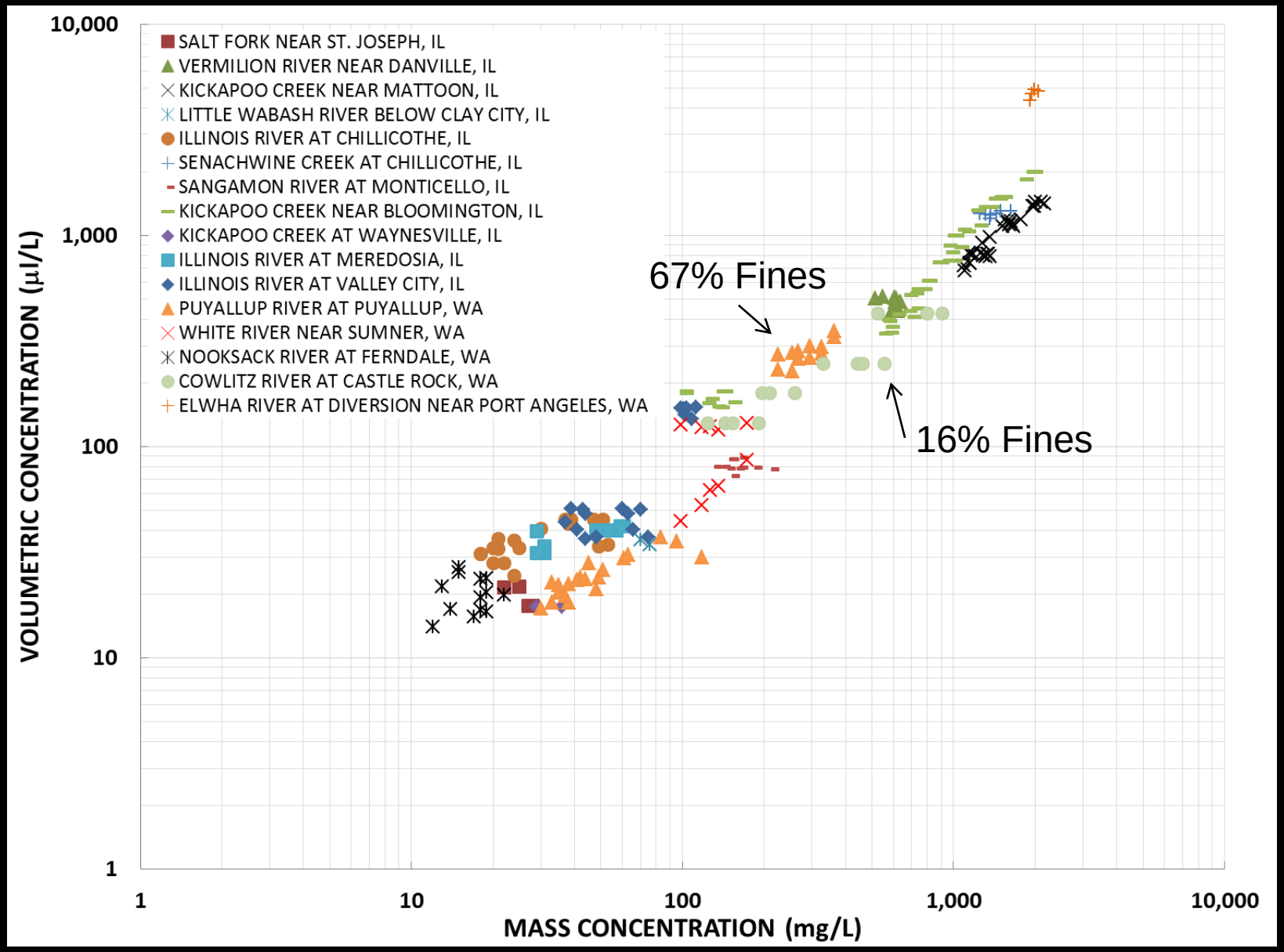
Provisional data subject to revision

IL and WA Concentration Results



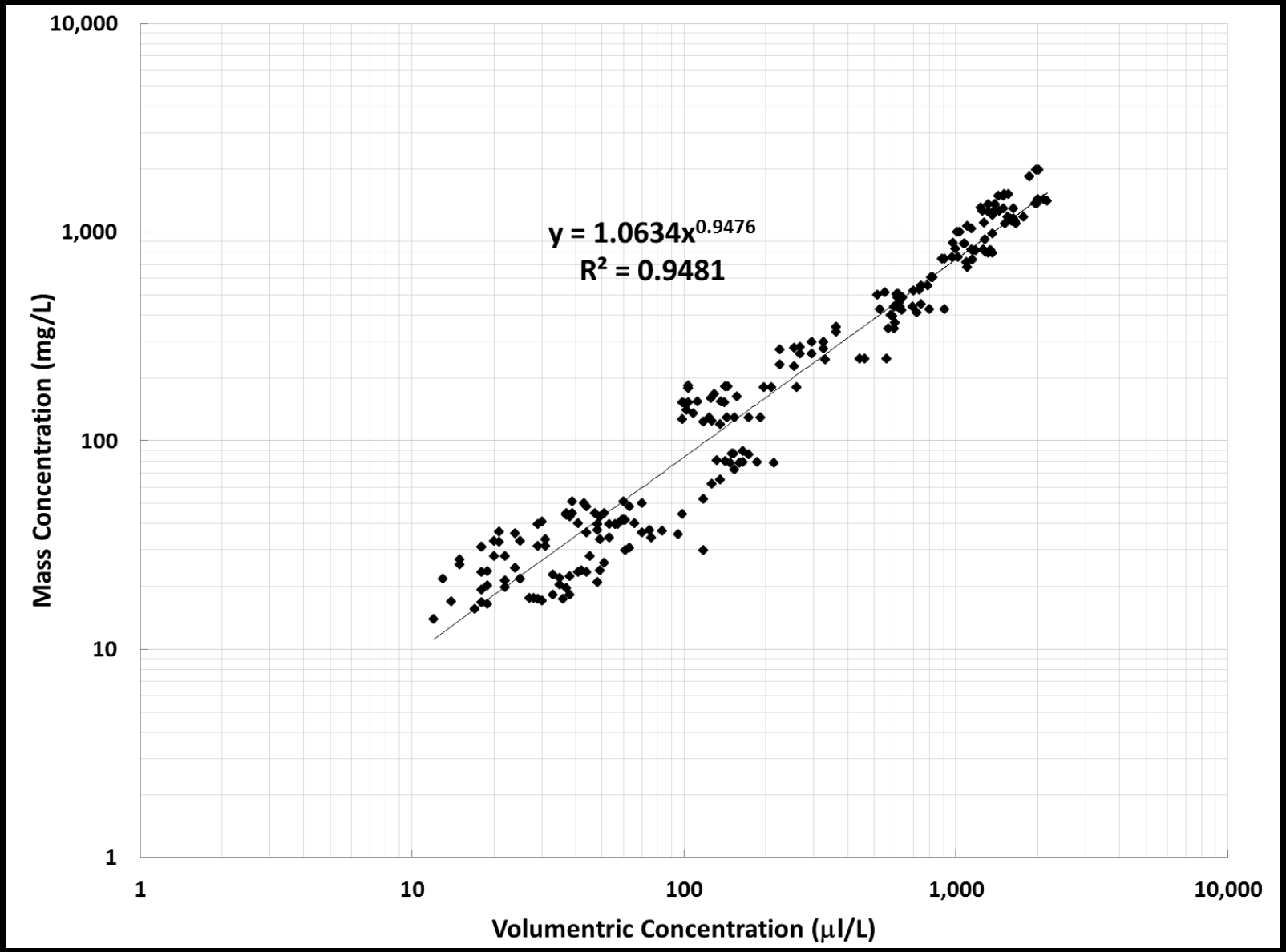
Provisional data subject to revision

IL and WA Concentration Results



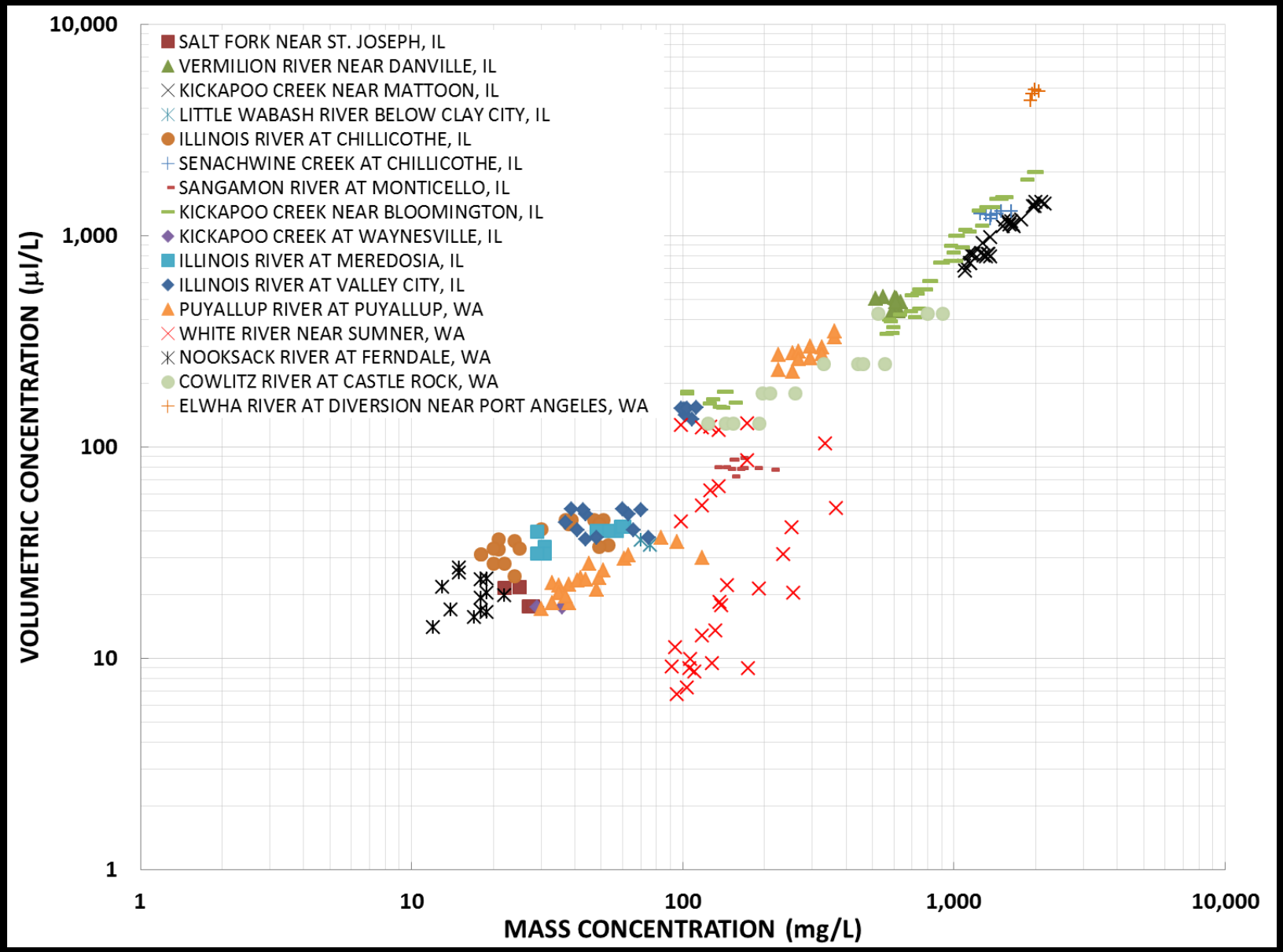
Provisional data subject to revision

IL and WA Concentration Results



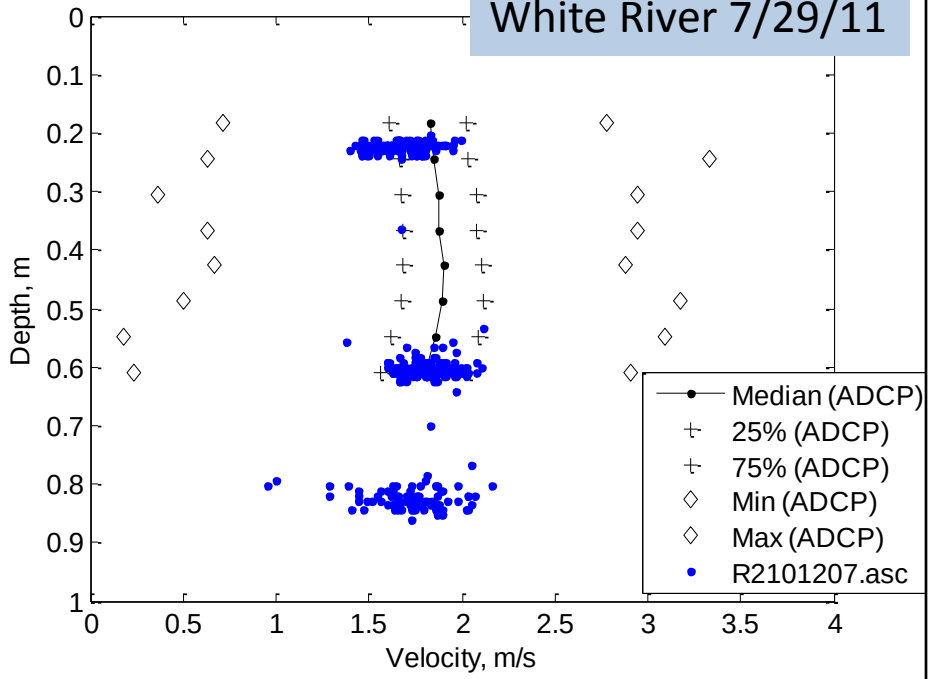
Provisional data subject to revision

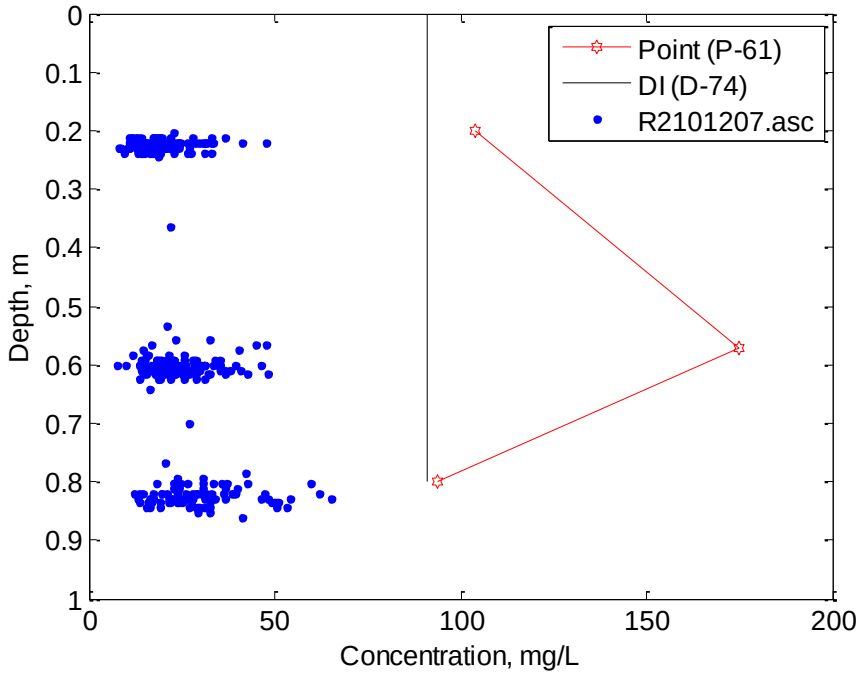
IL and WA Concentration Results

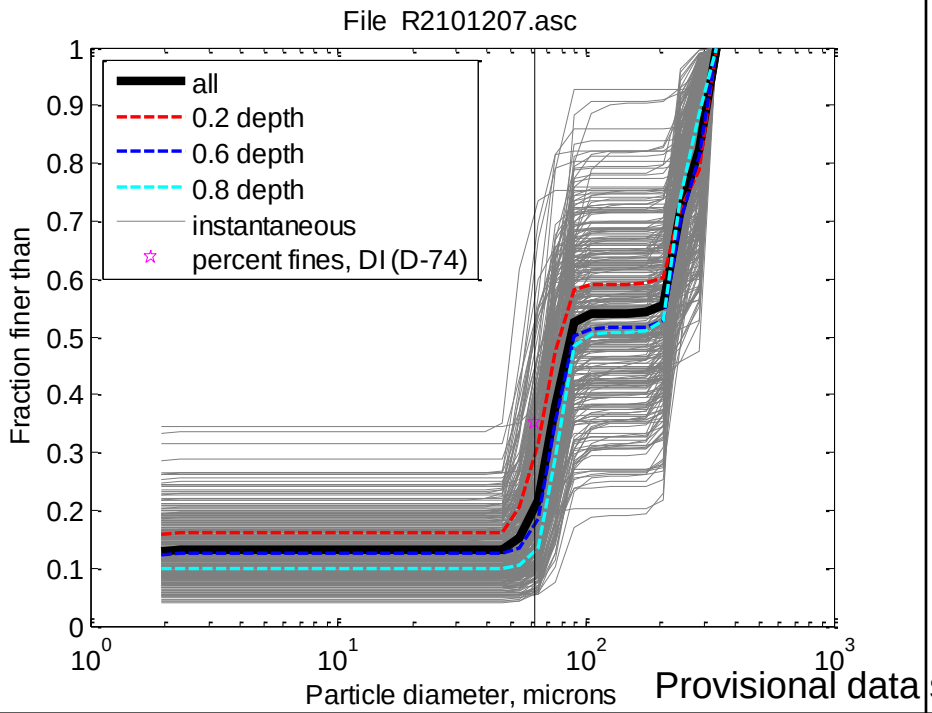


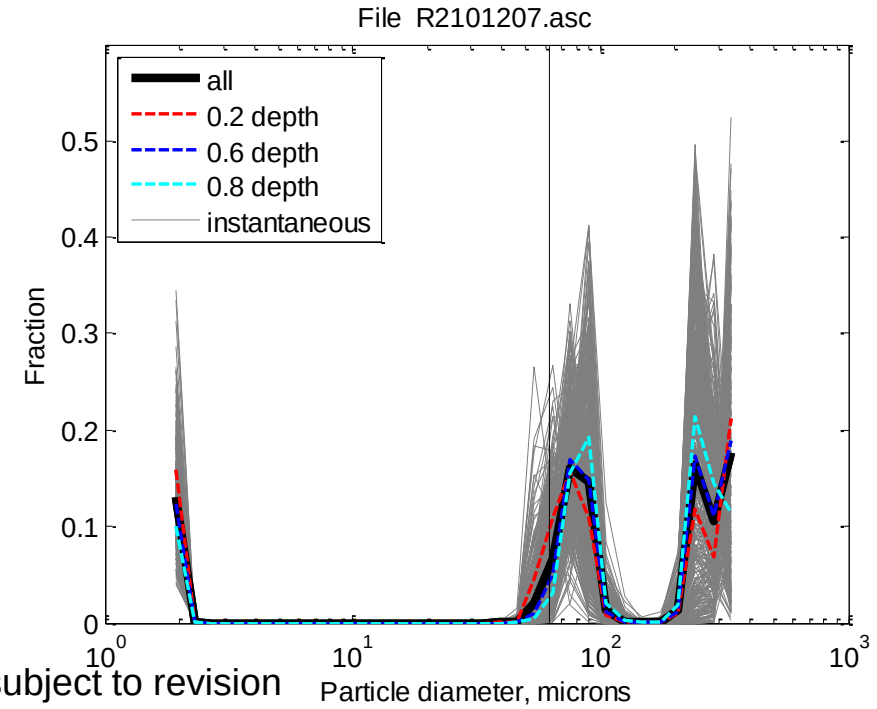
Provisional data subject to revision

White River 7/29/11









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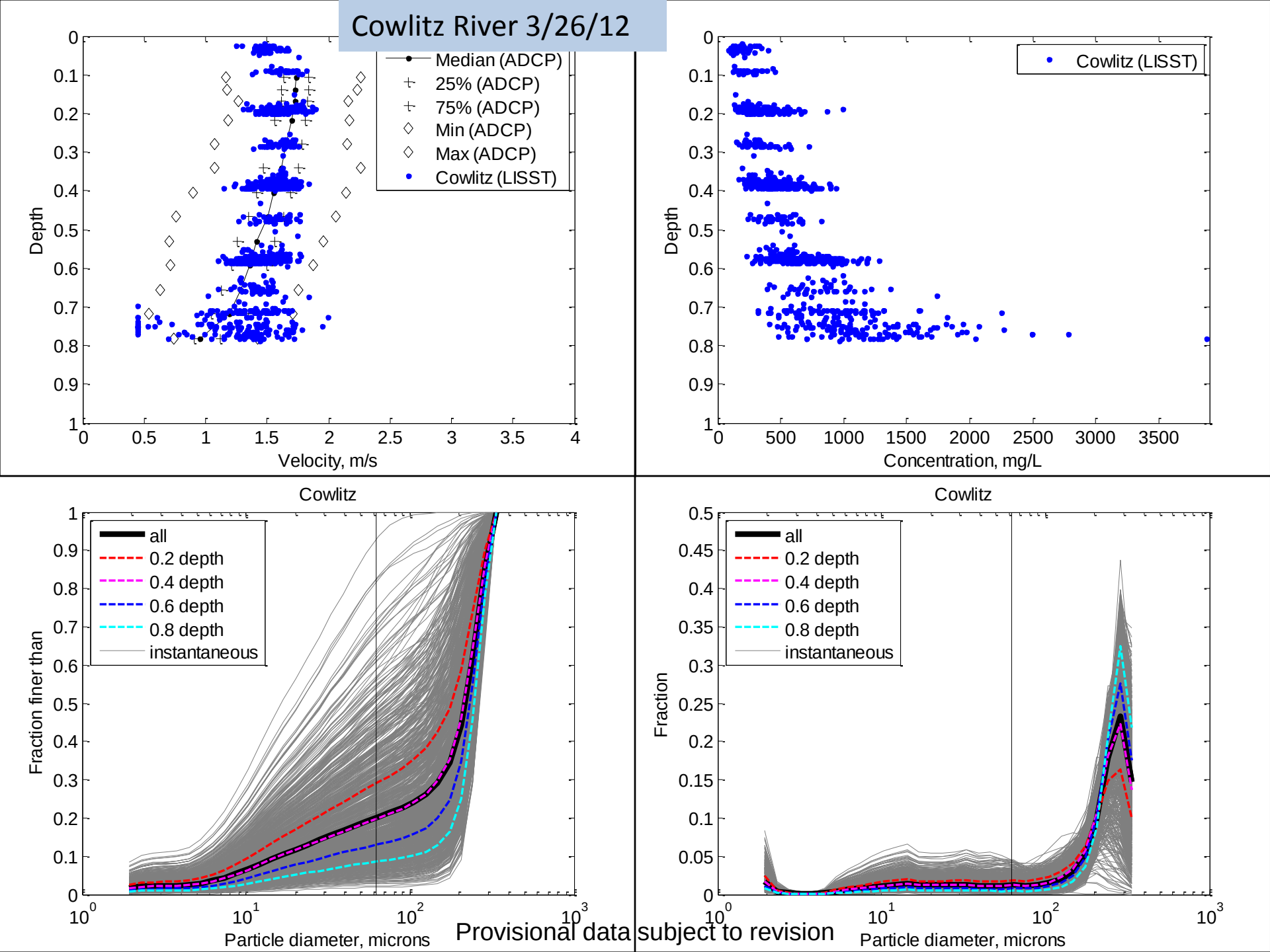
Cowlitz River 3/26/12



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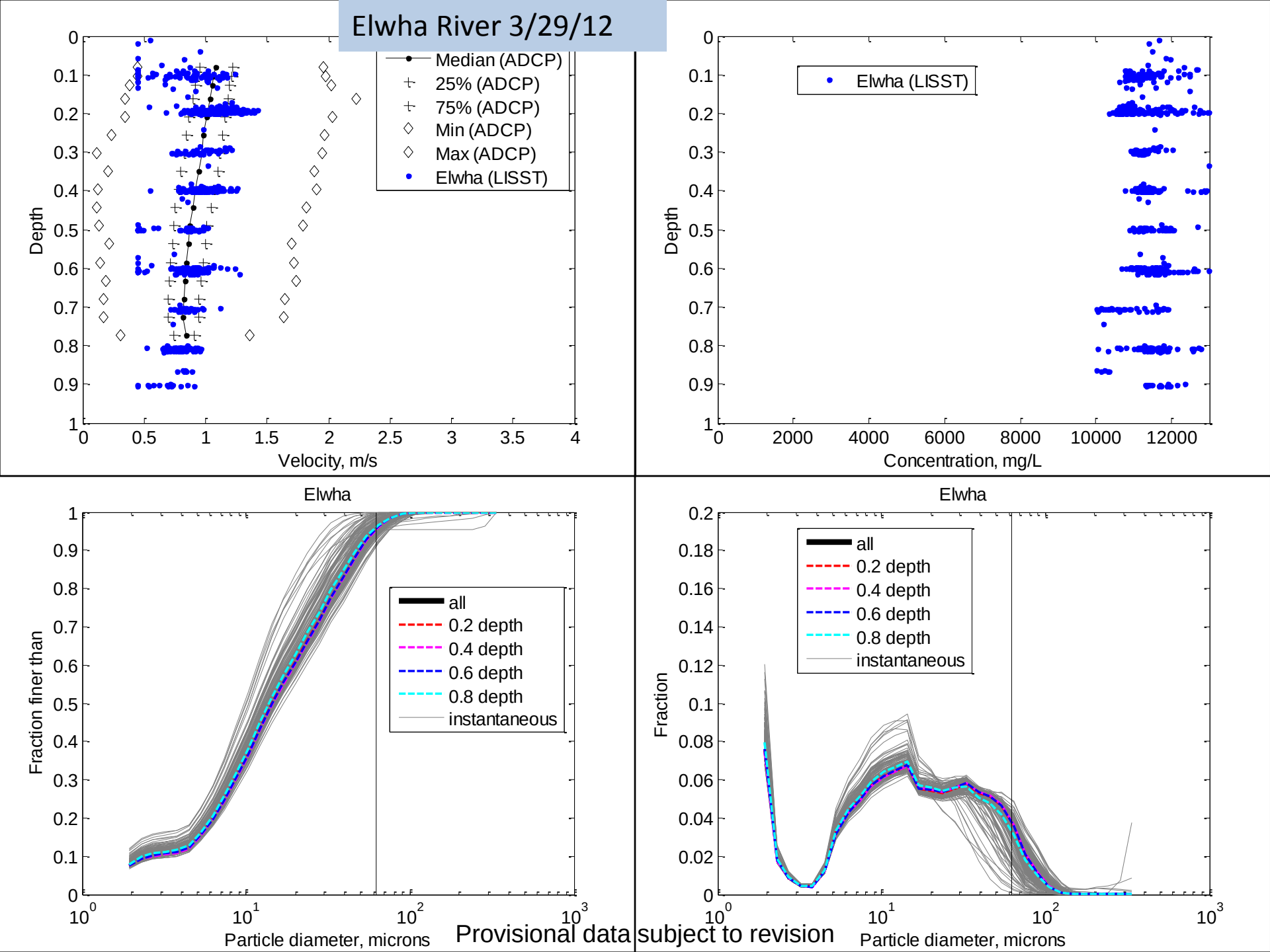
Elwha River 3/29/12



Provisional data subject to revision

IL Concentration Results

Statistic	Laboratory Concentration (Mass Conc) (mg/L)	LISST-SL Concentration (Vol Conc)[1] (μl/L)
Minimum	18	17
Maximum	2170	1994
Average	557	448
Samples Used	163	163

[1] Volumetric concentration in this table is not adjusted for unmeasured fraction (percent of physical sample mass less than 2 microns and greater than 381 microns). The unmeasured fraction ranged from 32 to 65 percent for 25 samples analyzed.

Provisional data subject to revision

WA Concentration Results

Statistic	Laboratory Concentration (Mass Conc) (mg/L)	LISST-SL Concentration (Vol Conc)[1] (μl/L)
Minimum	12	7
Maximum	2054	4892
Average	242	296
Samples Used	93	93

[1] Volumetric concentration in this table is not adjusted for unmeasured fraction (percent of physical sample mass less than 2 microns and greater than 381 microns).

Provisional data subject to revision

Percent Finer than Sand

IL

Statistic	Percent finer than 0.0625 mm
Minimum	68
Maximum	100
Average	92
Samples Used	102

WA

Statistic	Percent finer than 0.0625 mm
Minimum	3
Maximum	91
Average	43
Samples Used	54

Provisional data subject to revision

Pycnometer (Density) Testing

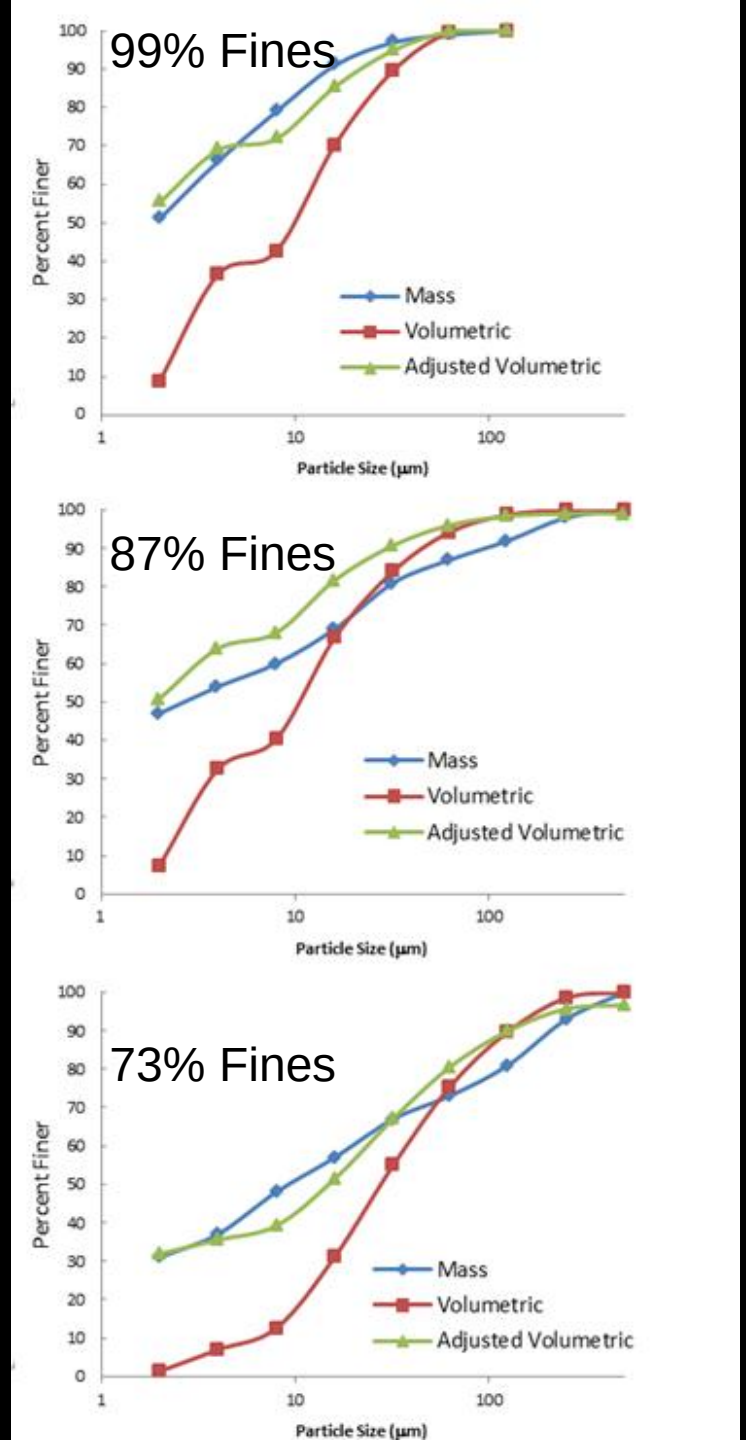
IL

Statistic	Density (g/ml)
Minimum	2.56
Maximum	2.72
Average	2.64
Samples Used	17

WA

Statistic	Density (g/ml)
Minimum	2.68
Maximum	2.85
Average	2.75
Samples Used	6

Provisional data subject to revision



IL Data

Comparison of particle-size distributions for three sites with a broad range of percent finer than 0.0625 mm and unmeasured LISST-SL fraction.

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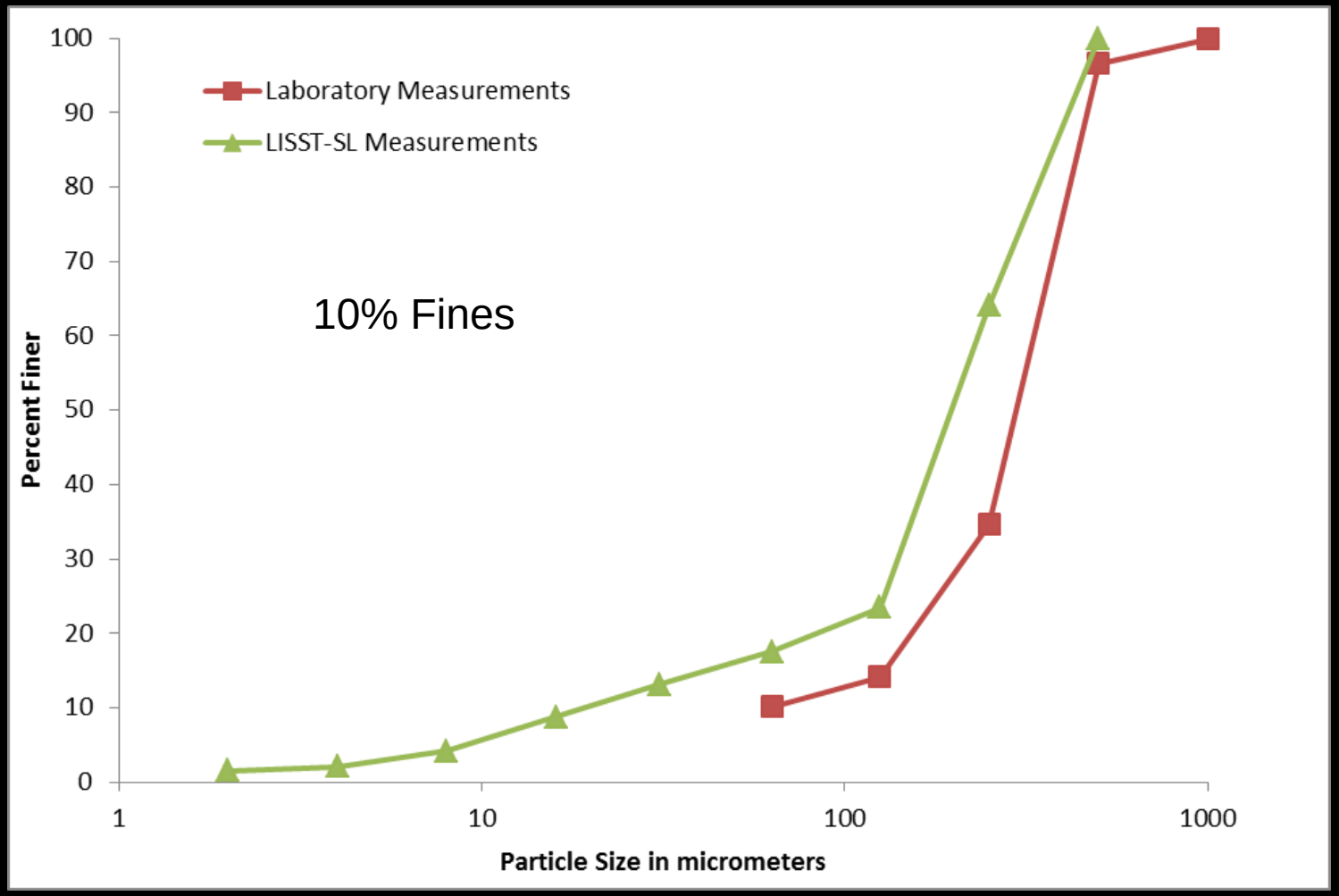
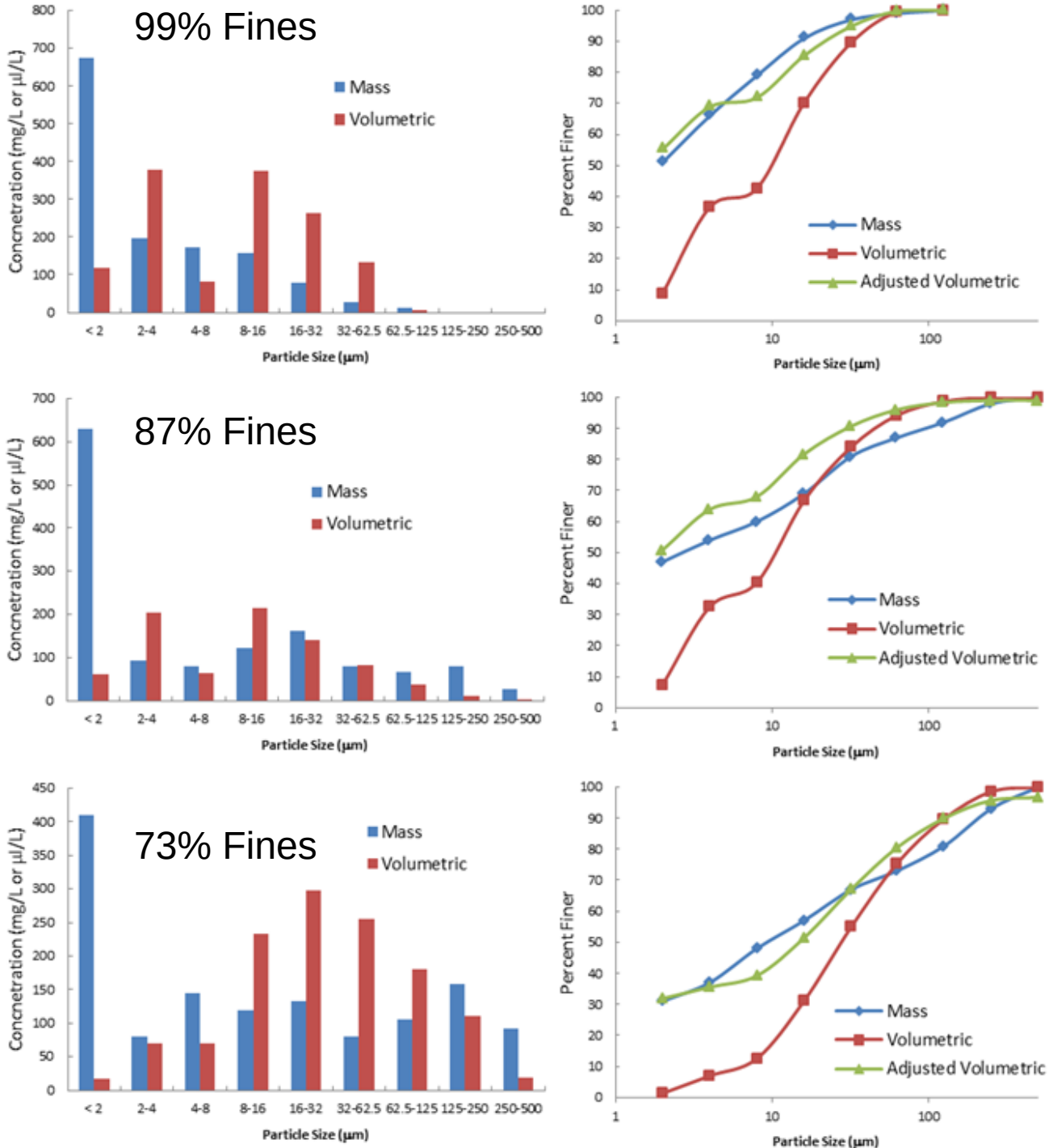
WA Particle Size Data



Provisional data subject to revision

IL Data



Comparison of particle-size distributions for three sites with a broad range of percent finer than 0.0625 mm and unmeasured LISST-SL fraction.

Provisional data subject to revision

Deployment Experiences

- Pitot Tube

- Tail Fin Configuration

Summary

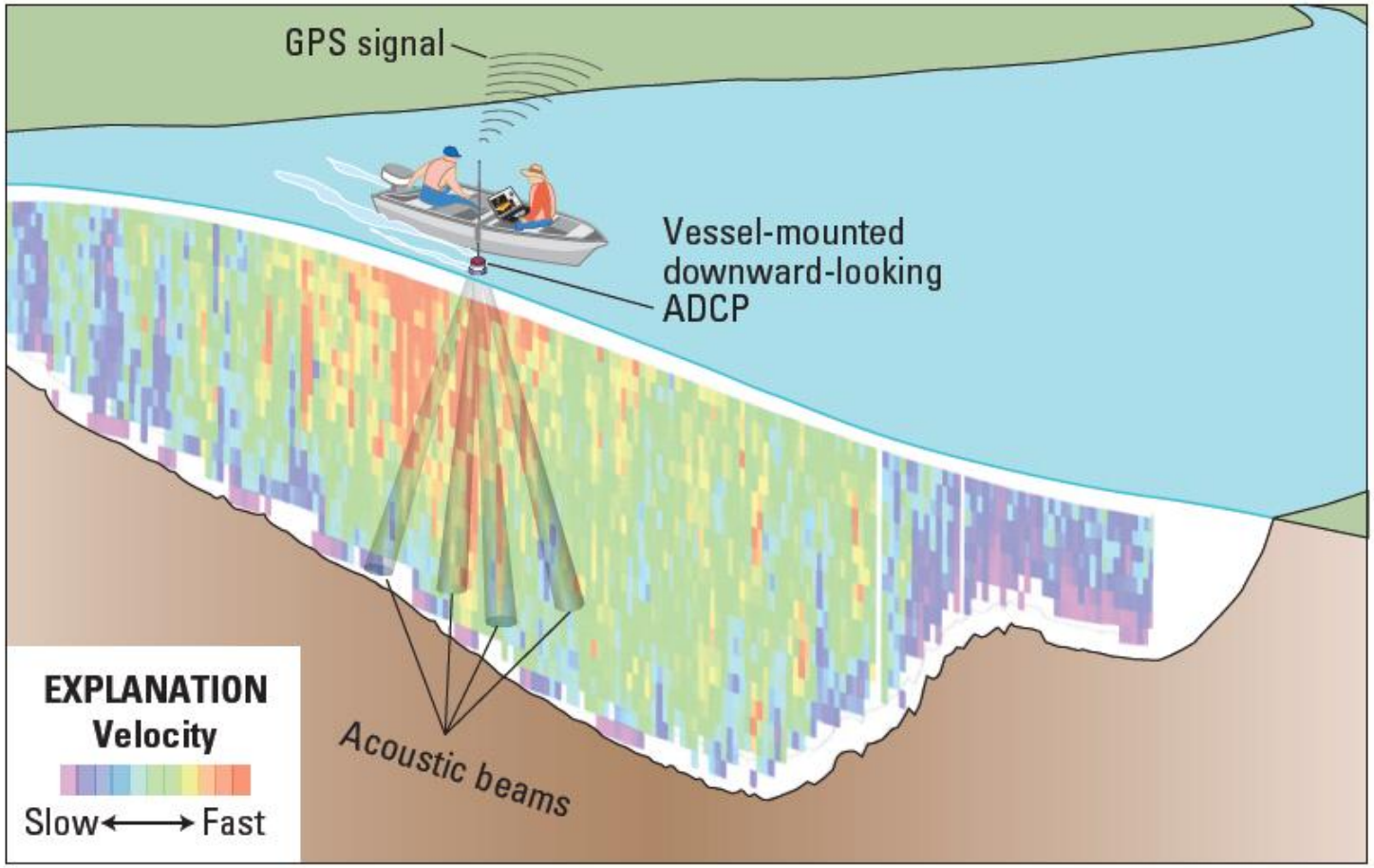
- Volumetric concentration is a good surrogate for mass concentration
- In-situ density measurement would be beneficial
- Additional analysis of the existing particle size data is needed

Estimation of suspended-sediment concentration from down-looking acoustic Doppler current profilers using an acoustic backscatter calibration procedure and MATLAB-based tool

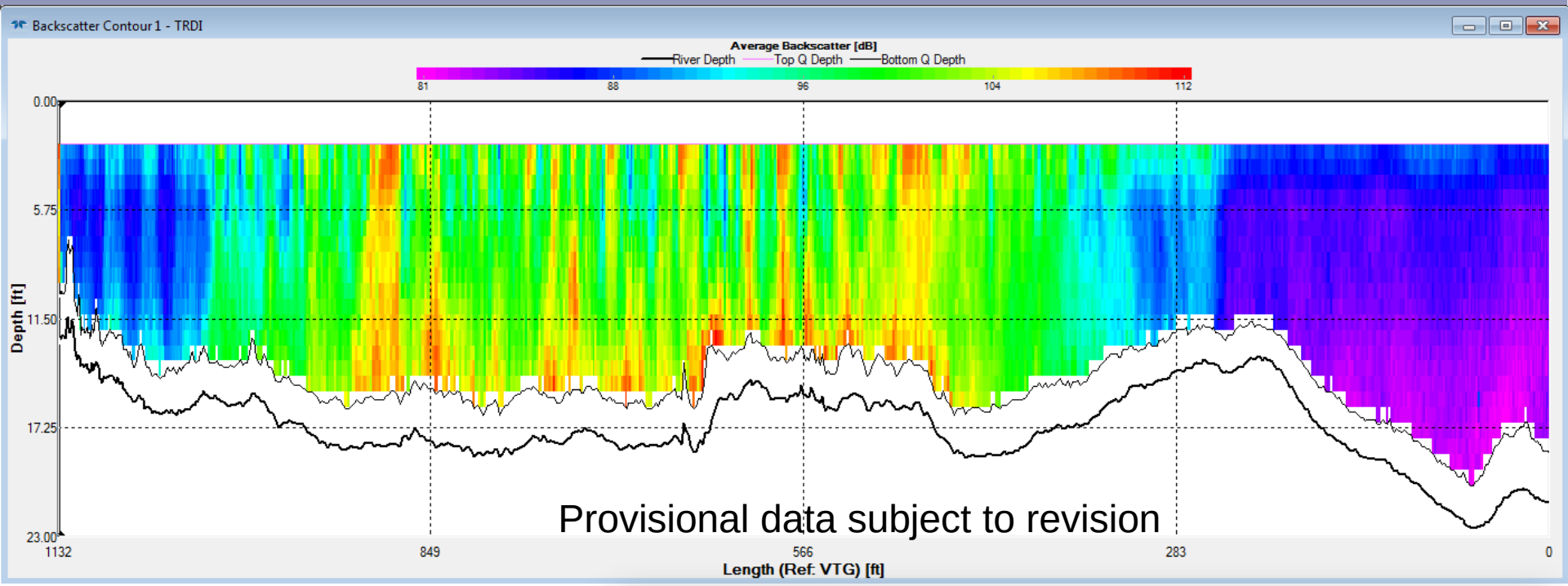
Justin A. Boldt, Jonathan A. Czuba, Timothy D. Straub, Christopher A. Curran, Ricardo N. Szupiany, and Kevin A. Oberg

Hydro Acoustics USGS

ADCP Cross Section



Missouri River, St. Charles, MO



Nezu, I. and Nakagawa, H. (1993). *Turbulence in Open-Channel Flows*, IAHR Monograph. A.A. Balkema, Rotterdam, The Netherlands, 281 pp.

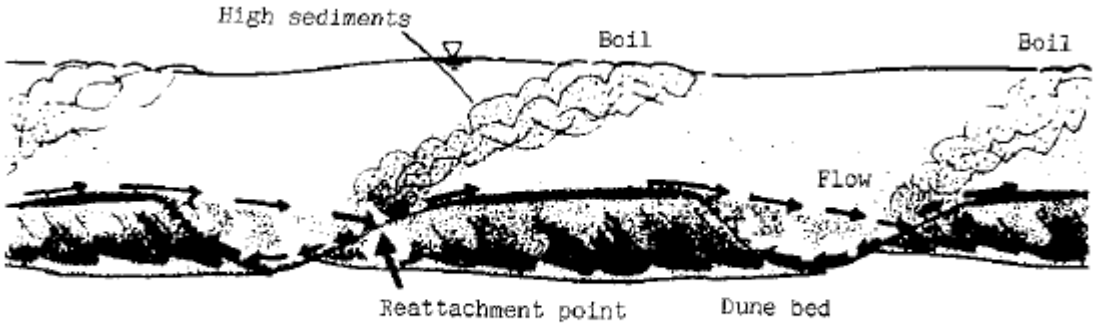
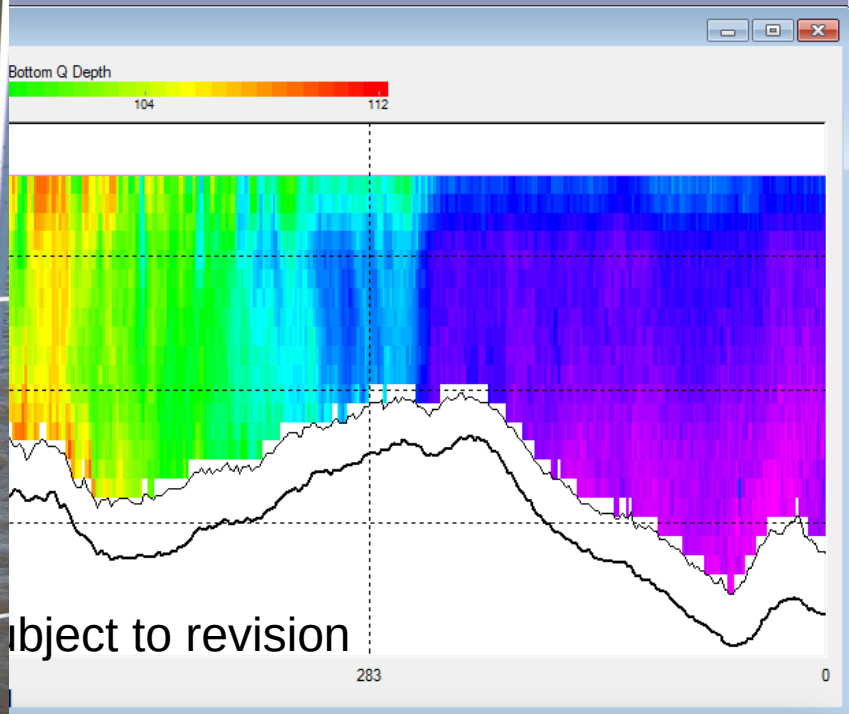
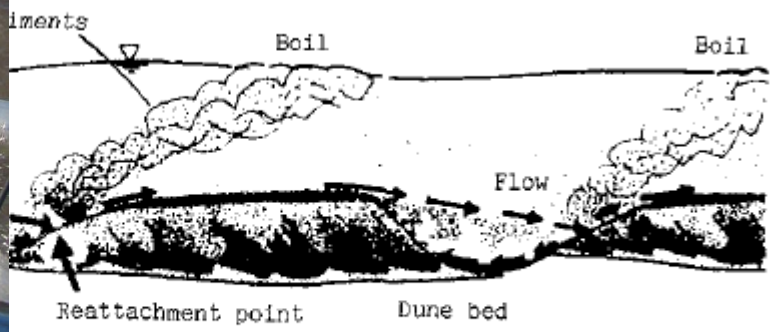


Figure 9.6 Large and energetic kolk-boils generated from the reattachment point of developing dunes, (Iseya & Ikeda 1986).

Hydro Acoustics USGS

. Charles, MO





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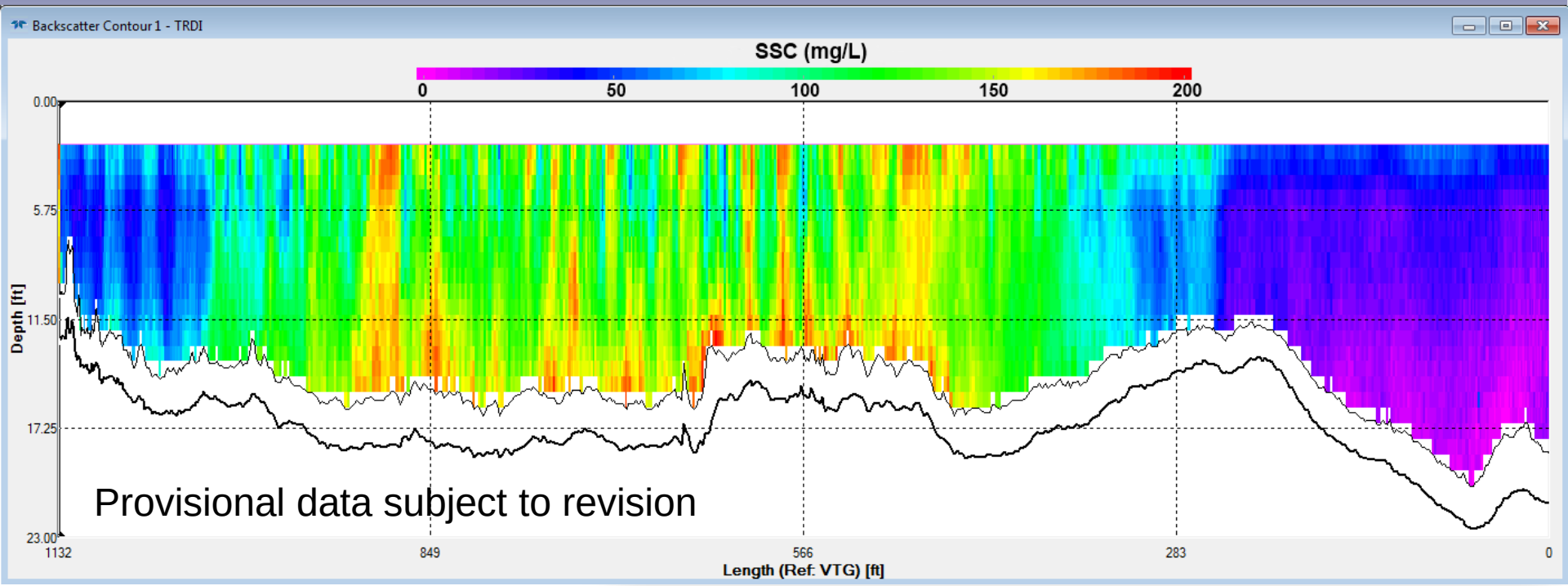
86).

Missouri River, St. Charles, MO



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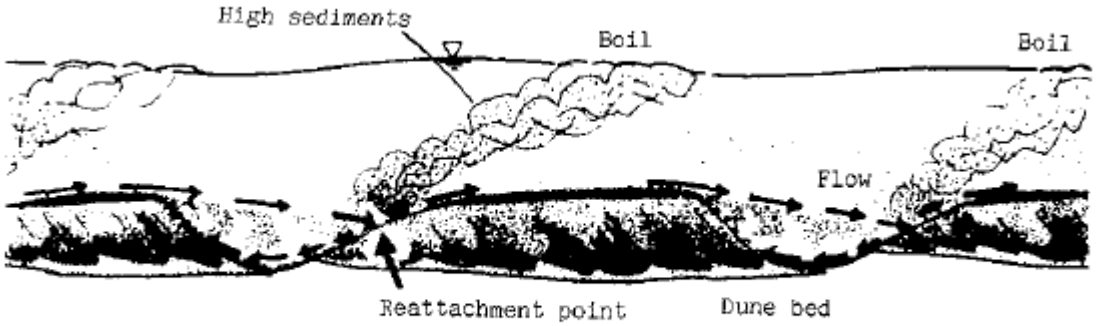


Figure 9.6 Large and energetic kolk-boils generated from the reattachment point of developing dunes, (Iseya & Ikeda 1986).

Hydro Acoustics USGS

Overview

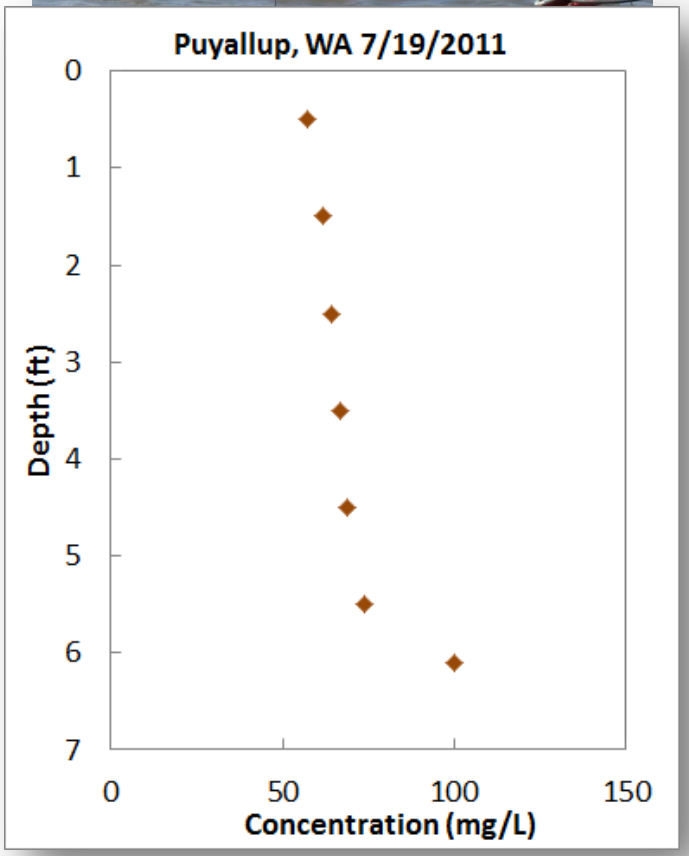
- MATLAB-based Tool
- Calibration Method
- Results and Data Display

MATLAB-based Tool

INPUTS

ASCII output file → **MATLAB-based tool**

Sediment data → **MATLAB-based tool**



Provisional data subject to revision

VMT Stationary Add-in

Velocity Mapping Toolbox (VMT)

Stationary Add-in

v. 1.0 beta

ADCP frequency

- 600 kHz
- 1200 kHz

Load Stationary Data

File loaded:

Dashboard

- No. of ens:
- No. of bins:
- Duration (sec):
- Bin size (cm):
- Froude No.:
- Reynolds No.:
- Equivalent bed roughness (m):
- Friction coefficient 1:
- Friction coefficient 2:

Select method - Shear velocity (cm/s)

- Log law - bottom 50%
- Log law - middle 50%
- Log law - top 50%
- Log law - entire profile
- Reynolds shear stress (u'w')

Ensemble start

Ensemble end

Force Fill

Bed shear stress (N/m^2)

- tau0L:
- tau0S:
- tau0ka:
- tau0ka2:
- tau0kb:
- tau0kb2:
- tau0q:

Select plots

Select All | Clear All

Output KML file (Google Earth)

- Ship track
- Velocity and backscatter time series

Velocity

- Depth-averaged streamwise velocity
- Time-averaged velocity
- Time-averaged velocity with RMS
- Normalized velocity
- Cumulative U
- Cumulative U at depths

Backscatter

- Time-averaged backscatter
- Depth-averaged backscatter
- Contour plot with Q2 and Q4

Turbulence

- Normalized turbulence intensity
  - with semi-theoretical curves
- Turbulence intensity ratios
  - with semi-theoretical curves
- Normalized turbulent kinetic energy
  - with semi-theoretical curves

Reynolds Shear Stress

- Time-averaged Reynolds shear stress
- Shear velocity from u'w'

Quadrant Analysis

- Quadrant plot
- No. events over depth

Power Spectra

- u (ensemble averaged)
- w (ensemble averaged)
- u (contour)
- w (contour)

- Cross-correlation
- Time-averaged anisotropy
- Anisotropy vs streamwise velocity

Plot

Sediment Analysis

Sediment Analysis

Select an option

- Obtain a calibration
- Apply a calibration

SSC = 10^(a * SCB + b)

a =

b =

Inputs

Select beam(s)

Echo intensity scale factor:

- Beam 1
- Beam 2
- Beam 3
- Beam 4

Sediment attenuation method

- Topping & Wright
  - from to
  - (0 = top, 100 = bottom)
- Urick Sheng Hay
  - Sediment density: g/cm^3
  - Mean sediment dia: microns
- Manual Input
  - alphaS: dB/m

Load SSC Data

Dashboard

- alphaW: dB/m
- alphaS: dB/m

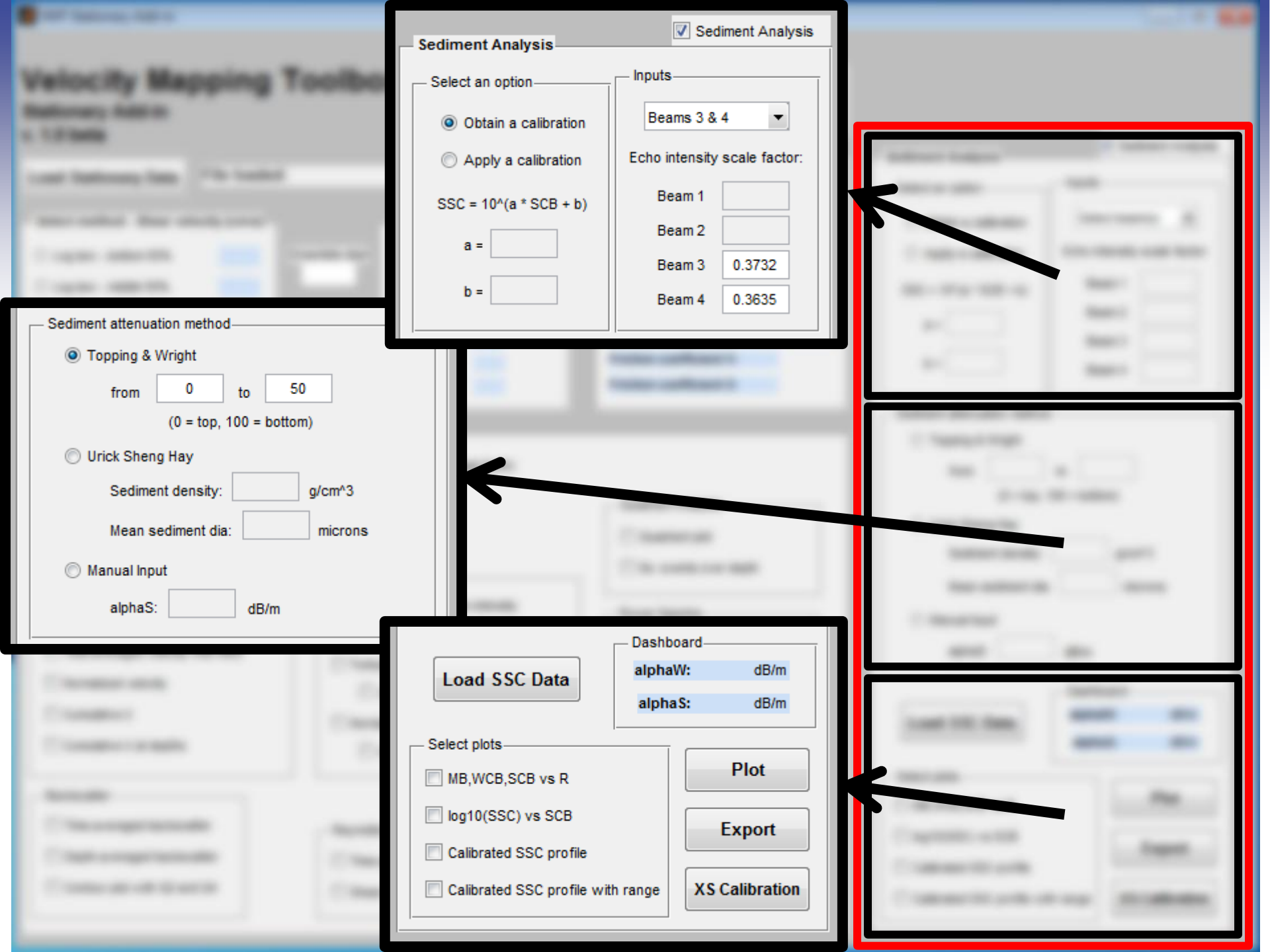
Select plots

- MB,WCB,SCB vs R
- log10(SSC) vs SCB
- Calibrated SSC profile
- Calibrated SSC profile with range

Plot

Export

XS Calibration


Sediment Analysis
Sediment Analysis
Select an option
Obtain a calibration
Apply a calibration
SSC = 10^(a * SCB + b)
a =
b =
Inputs
Beams 3 & 4
Echo intensity scale factor:
Beam 1
Beam 2
Beam 3
0.3732
Beam 4
0.3635
Sediment attenuation method
Topping & Wright
from
0
to
50
(0 = top, 100 = bottom)
Urick Sheng Hay
Sediment density:
g/cm^3
Mean sediment dia:
microns
Manual Input
alphaS:
dB/m
Load SSC Data
Dashboard
alphaW:
dB/m
alphaS:
dB/m
Select plots
MB,WCB,SCB vs R
log10(SSC) vs SCB
Calibrated SSC profile
Calibrated SSC profile with range
Plot
Export
XS Calibration

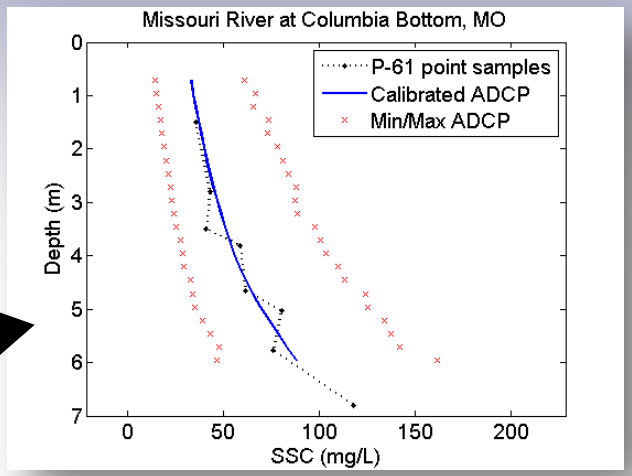
MATLAB-based Tool

INPUTS

ASCII output file

Sediment data

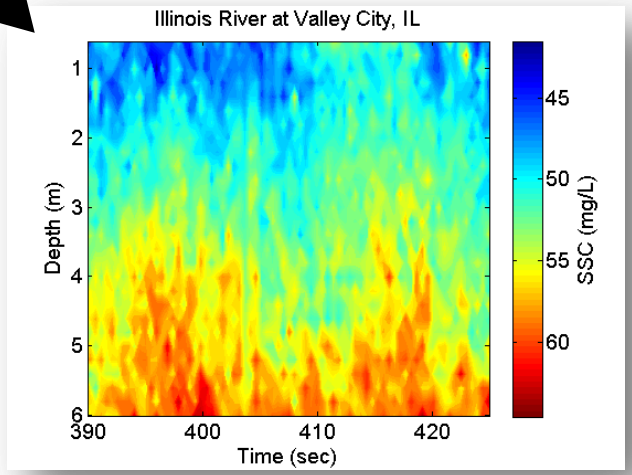
MATLAB-based tool



α_w & α_s

mean SCB

$$SSC = 10^{(a*SCB+b)}$$



Provisional data subject to revision

Calibration Method

$$SCB = K_c * RB + 20 * \log_{10}(\psi R) + 2\alpha_w R + 2\alpha_s R$$

K_c = instrument echo intensity scale factor

Ψ = near-field correction (Downing et al., 1995)

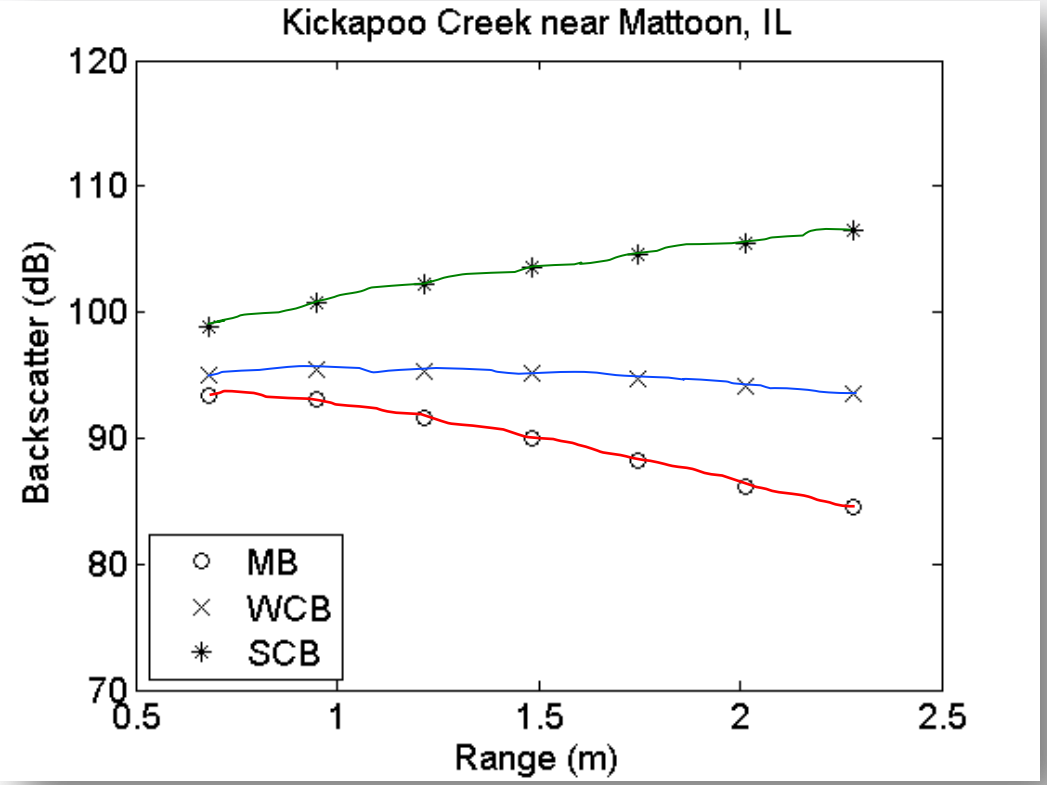
α_w = sound absorption coefficient (Schulkin and March, 1962)

R = range along beam

α_s = sediment attenuation coefficient (Wright et al., 2010 & Landers, 2010)

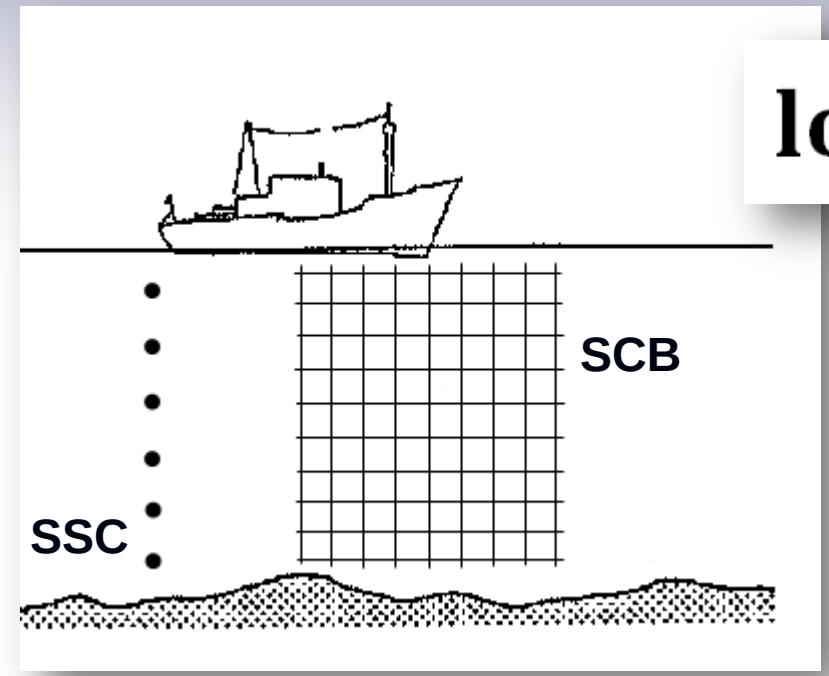
Calibration Method

$$SCB = K_c * RB + 20 * \log_{10}(\psi R) + 2\alpha_w R + 2\alpha_s R$$

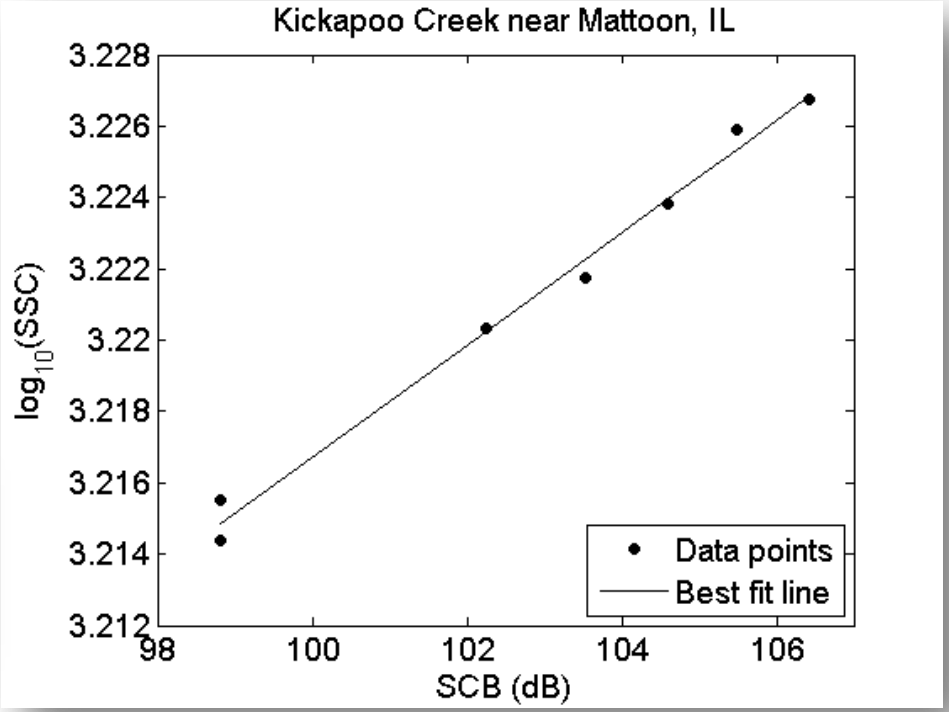


Provisional data subject to revision

Calibration Method



$$\log_{10} SSC = a * SCB + b$$



$$SSC = 10^{(a*SCB+b)}$$

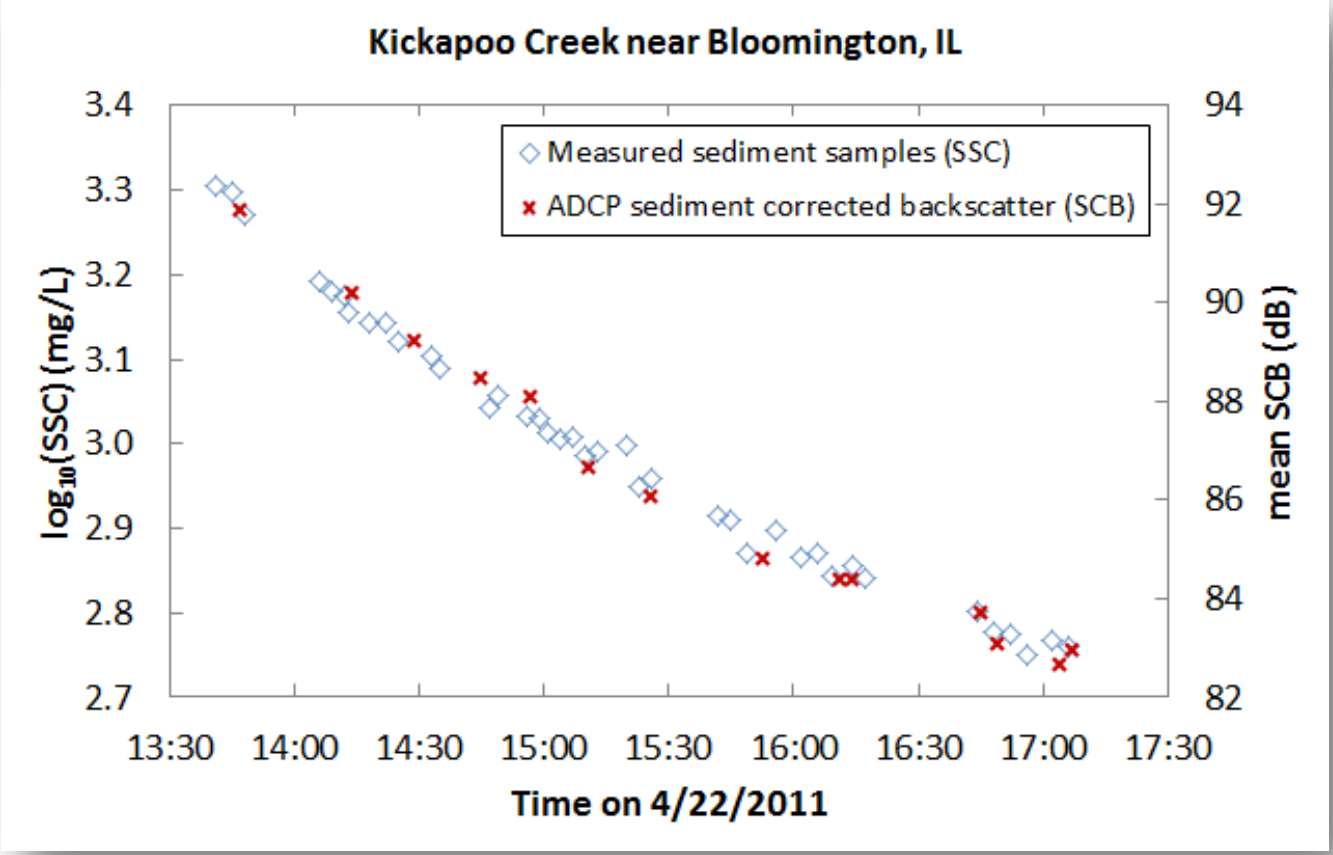
Provisional data subject to revision

Kickapoo Creek near Bloomington, IL

April 22, 2011

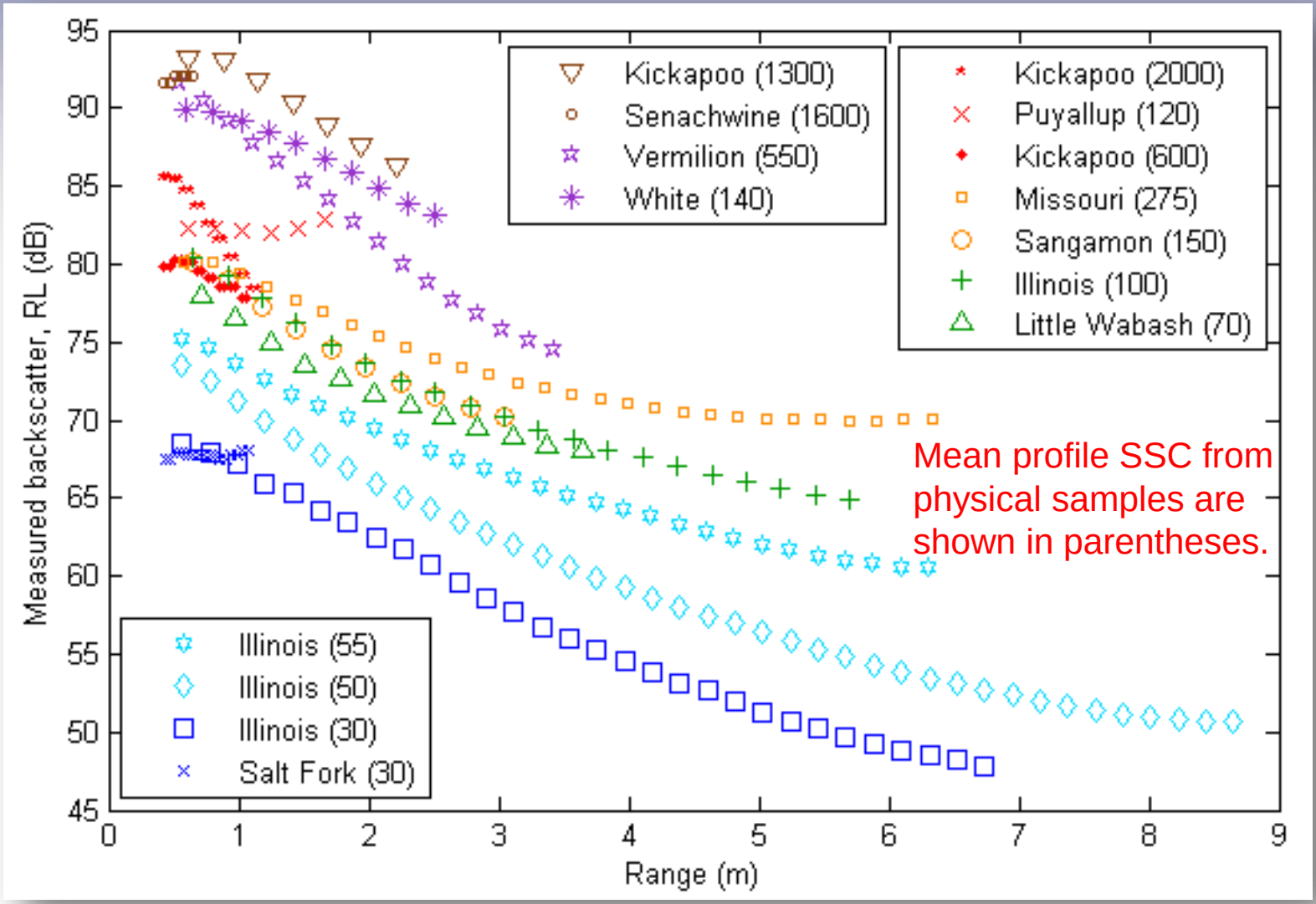
1:40 pm : SSC = 2,020 mg/L

5:05 pm : SSC = 576 mg/L



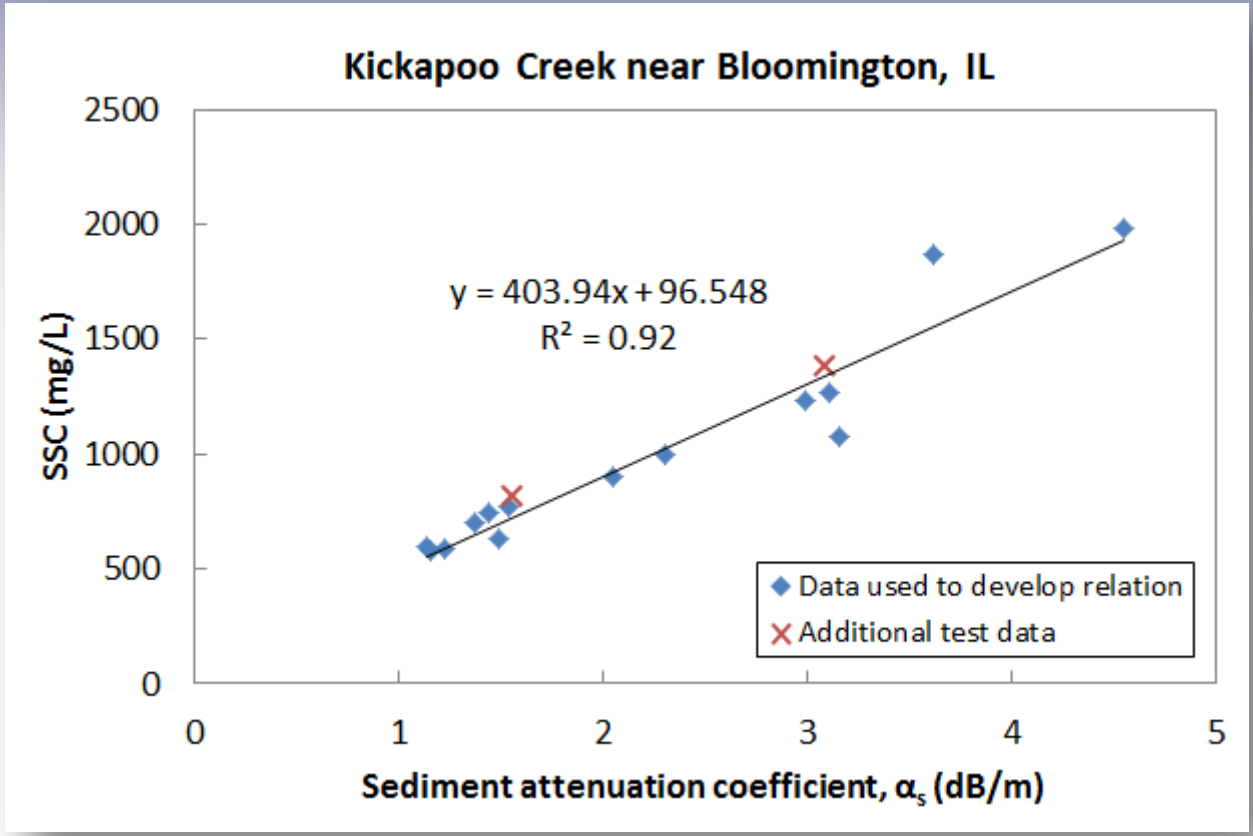
Provisional data subject to revision

Data from 13 sites



Provisional data subject to revision

Kickapoo Creek near Bloomington, IL

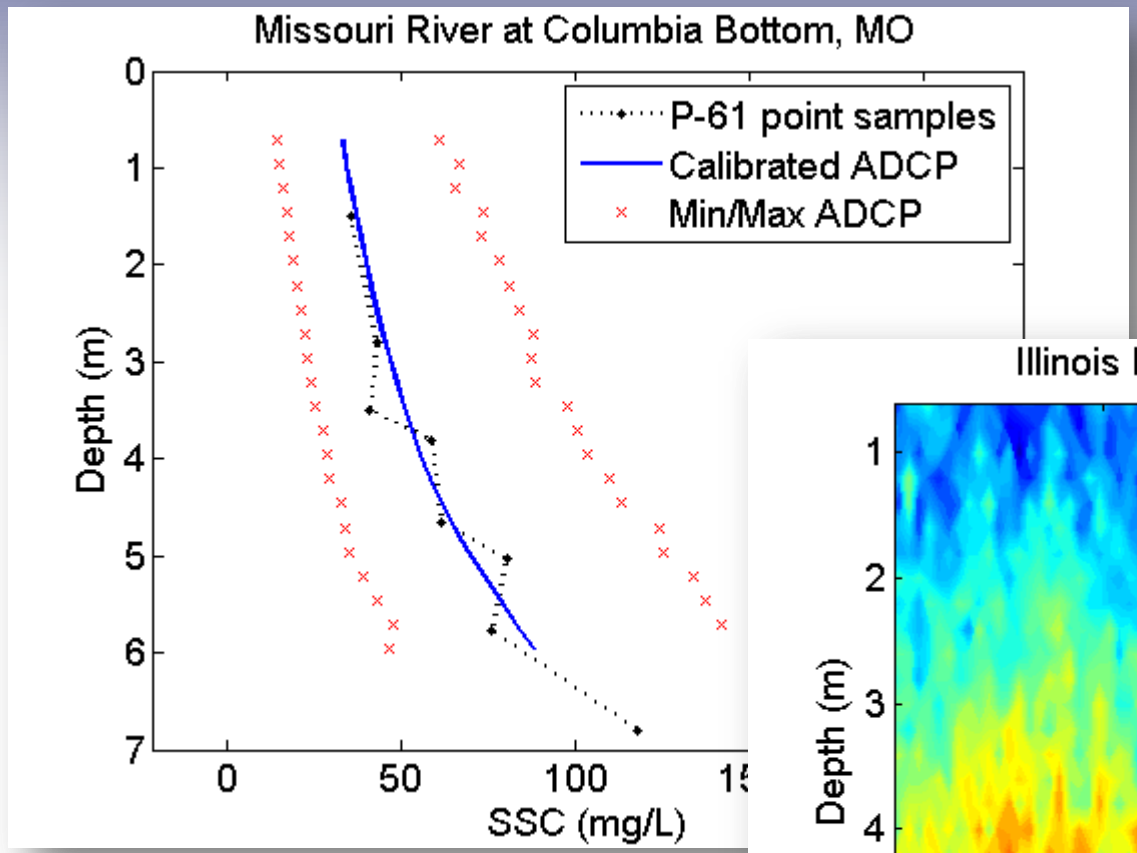


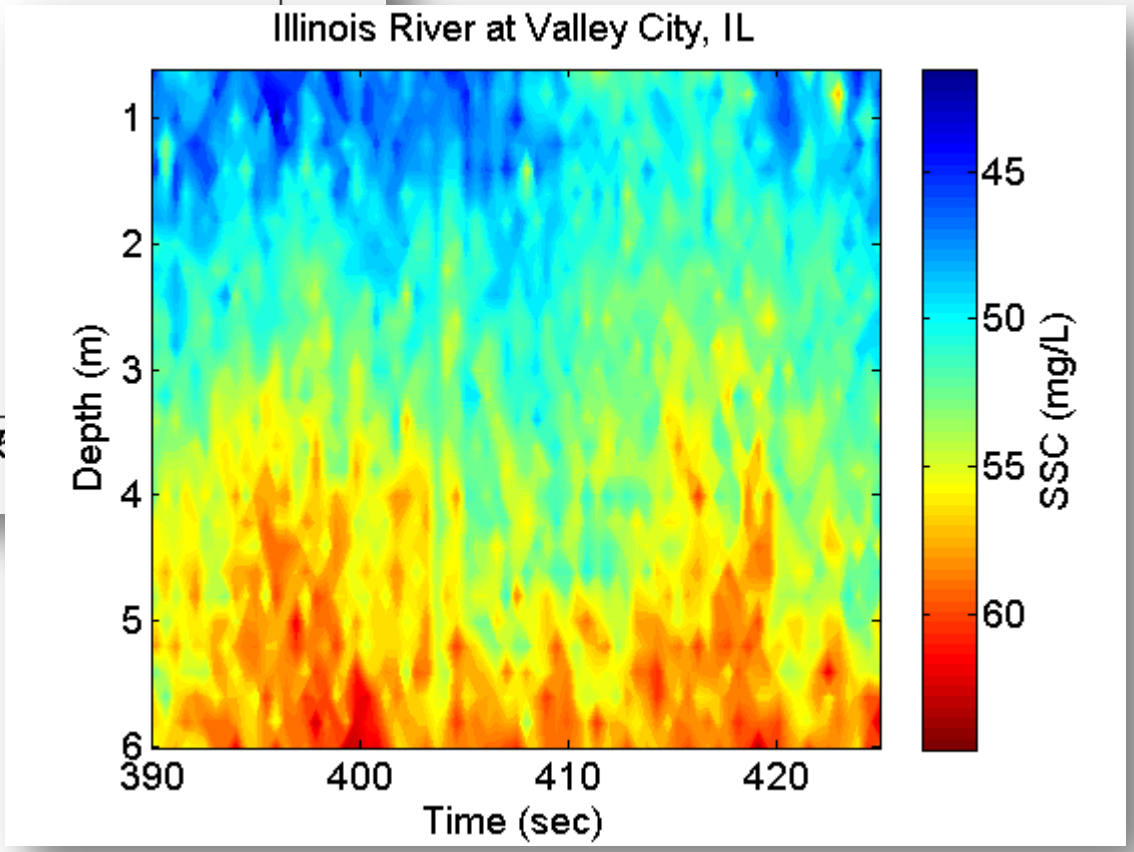
	Meas. SSC (mg/L)	Pred. SSC (mg/L)	% error
p01	1380	1345	-2.6
p02	817	727	-11.1

Provisional data subject to revision

Hydro Acoustics USGS

Data Display

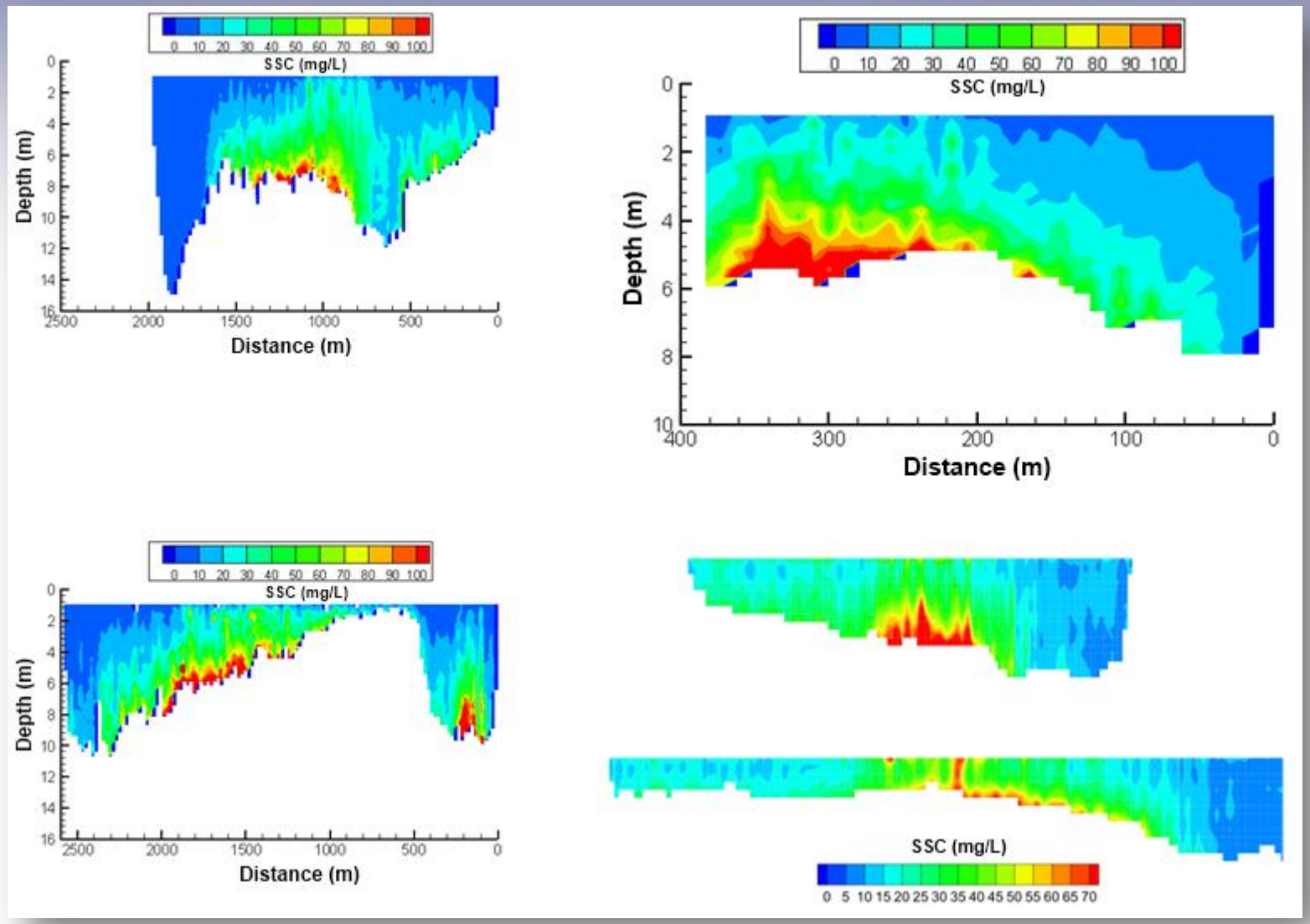




Provisional data subject to revision

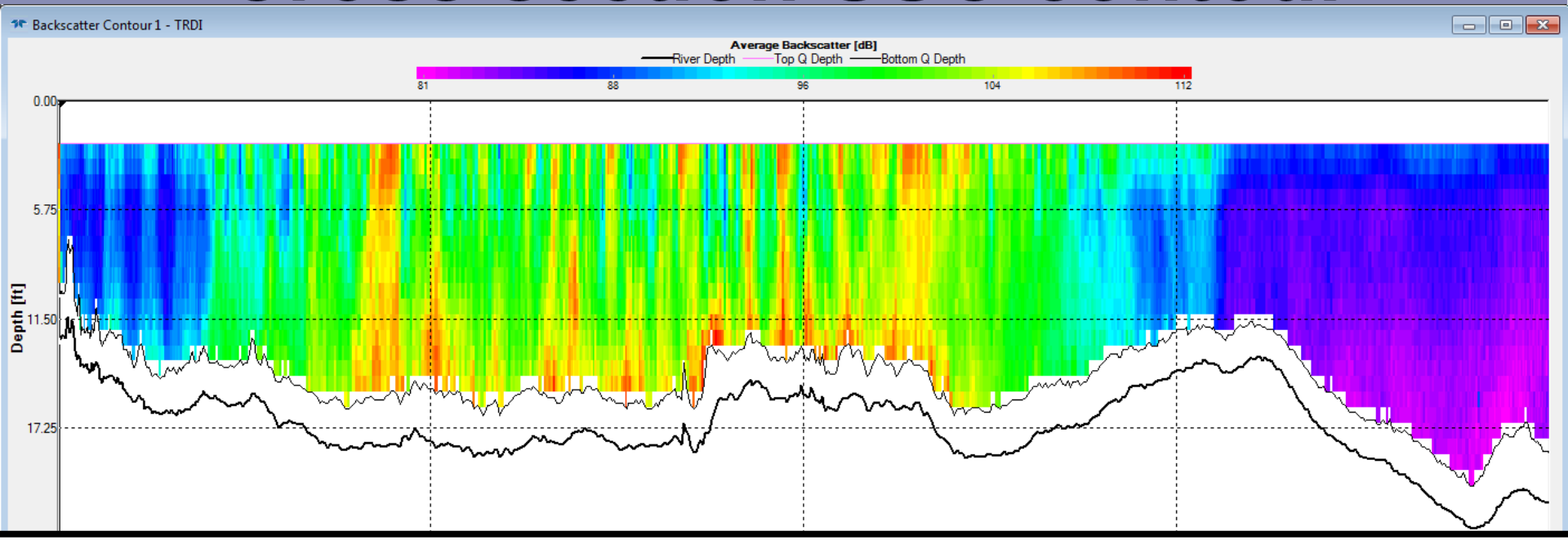
Hydro Acoustics USGS

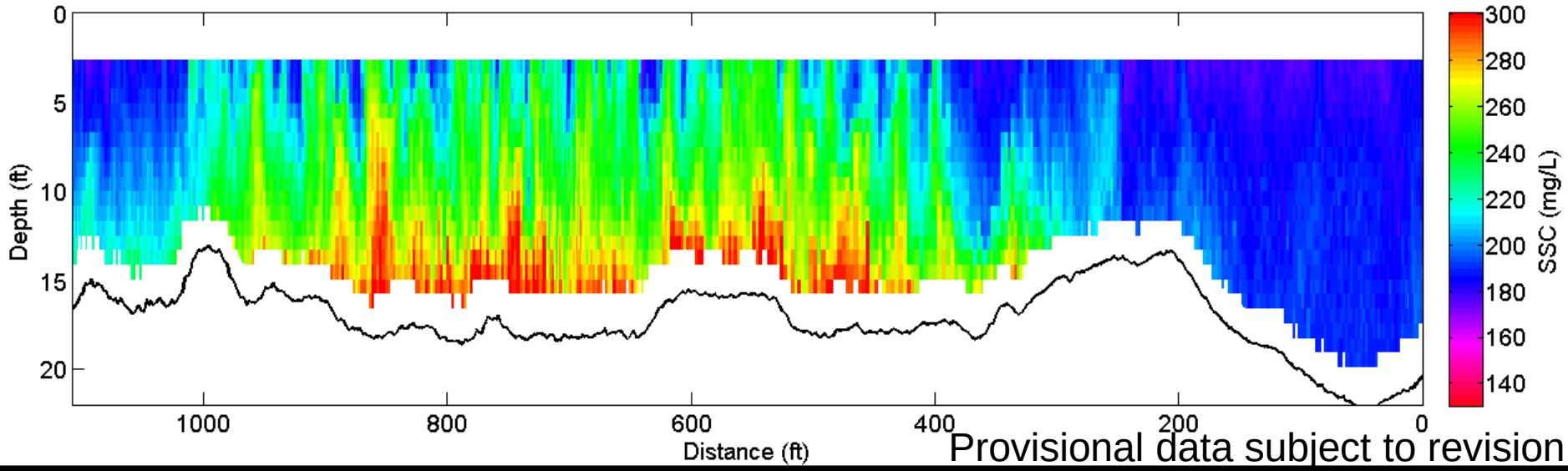
Cross section SSC contour



Plots courtesy of R. Szupiany.

Cross section SSC contour





Provisional data subject to revision

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Delivery to FISP

- Memo describing data package
- WA ADCP/LISST/SSC data
- HMEM papers and presentations
- This summary presentation
- Brief methods/analysis/summary

Future Publication Direction

- LISST
  - SSC vs VSC
  - PSD
  - Conc. at vertical
  - High resolution spatial distribution
- ADCP
  - Processing tool
  - Sediment attenuation
  - Stationary velocity/SSC
  - High resolution spatial and temporal distribution

HMEM References

- Straub, T.D., Curran, C.A., Czuba, J.A., and Domanski, M.M. (2012) Field testing comparing the stream-lined laser in-situ scattering and transmissometry (LISST-SL) surrogate technology with physical samples of suspended-sediment concentration from rivers in Washington and Illinois. *Proceedings of Hydraulic Measurement and Experimental Methods Conference*, Snowbird, Utah, August 12-15, 2012.
- Boldt, J.A., Czuba, J.A., Straub, T.D., Curran, C.A., Szupiany, R.N., and Oberg, K.A. (2012) Calibration procedure and MATLAB-based tool to estimate suspended sediment concentration from down-looking acoustic Doppler current profilers. *Proceedings of Hydraulic Measurement and Experimental Methods Conference*, Snowbird, Utah, August 12-15, 2012.