Federal Interagency Sedimentation Project

FY2023 Call for Ideas

Idea Title: An examination of the LISST-ABS and turbidity pairing factor (AOBS) to improve continuous estimates of suspended-sediment concentrations in rivers.
Principal Investigator (PI): Jason Alexander
Additional Investigators: Jeb Brown (NMWSC), Paul Diaz (ORWSC), Joel Unema (AZWSC), Jason Siemion (NYWSC).
PI Location: Wyoming-Montana Water Science Center, Cheyenne, WY
Study Location: Laboratory; Shoshone River, WY; Animas River, NM; Columbia River, OR/WA; Cowlitz River, WA; Willamette River, OR; Colorado River, AZ; West Branch Neversink River, NY.

Introduction: This study supports the FISP mission to develop standardized, consistent, and accurate quantification of sediment characteristics and transport in the Nation's rivers. The objective of the proposed research is to improve estimates of suspended-sediment concentrations using the pairing capability of Sequoia's LISST-ABS (ABS) and turbidity (OBS) sensors. Sequoia Scientific developed the pairing technology (referred to as 'AOBS' or 'Super Turbidity' by Sequoia) to increase sensitivity to a broader range of suspended sediment grain sizes in continuous monitors. The new research will leverage existing laboratory data and continuous data from laboratories and rivers in Wyoming, New Mexico, Oregon, Washington, Arizona, and New York to develop guidance for use of the pairing value to improve accuracy of continuous monitoring of suspended sediment using the AOBS method.

Background: Sequoia Scientific's LISST-ABS sensor was developed as an alternative to turbidimeters (optics) for estimating suspended-sediment concentrations (SSCs) in surface waters. The ABS sensor emits an 8-megahertz (MhZ) acoustic signal into the water column and measures the backscatter signal intensity returning to the instrument. The acoustic backscatter intensity measured by the ABS is translated directly to a sediment concentration via relation of the scattering intensity, which is nearly constant beyond the Raleigh limit at the 8 MhZ frequency for grain sizes larger than about 60 microns (µm; Agrawal and others, 2019)

After development and testing, Sequoia Scientific recognized the need for pairing the ABS and turbidity (OBS) signals to increase sensitivity to a wider range of suspended grain sizes, particularly particles less than 60 µm suspended as washload. To meet this need, they developed a so-called 'pairing factor' between OBS and ABS sensors, which they defined as the ratio of the signal from the ABS to the OBS signal measured in a standard suspended sediment mixture:

$$\gamma = \frac{ABS}{OBS}$$

Where **γ** is the so-called 'pairing factor', ABS is the output from the LISST-ABS (typically in units of mg/L and OBS is the output from a turbidity monitor deployed simultaneously (units of NTU or FNU). Sequoia recommends using a relatively high concentration mixture (1,000 mg/L or greater) to obtain the pairing factor in a laboratory setting. The pairing factor is then used in the following simple linear equation whereby γ is the rate of change in the ABS signal relative to the OBS signal:

$$AOBS = ABS + \gamma OBS$$

where $AOBS$ is a unitized concentration of suspended particles in units of milligrams per liter.

Sequoia treats the pairing method as proprietary information and has charged the USGS for use of their pairing methods in the past. Likewise, Sequoia charges customers to generate a pairing value for instrument combinations sent to them. As is obvious in equation 2, Sequoia's recommended pairing method treats γ as a constant, but recent laboratory experiments performed by the USGS WY-MT WSC indicate that the pairing value can vary widely depending on standard concentration, suggesting γ be treated as a free variable (fig. 1).

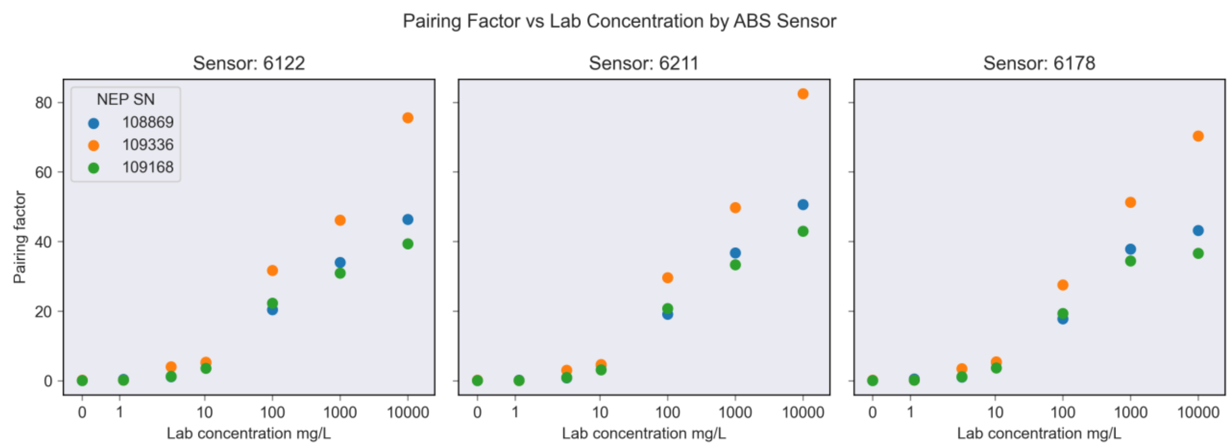

Figure 1. Scatter plots showing AOBS pairing factor as a function of standard concentration in the laboratory for different combinations of LISST-ABS and NEP-5000 turbidity sensors. Colors indicate different turbidity sensors while each plot represents a single LISST-ABS sensor.

Recent testing of the pairing method in the Shoshone River indicates that treating γ as a free variable improves the predictive relationship relative to OBS or ABS alone for a river with complex mixtures of suspended sand and mud (fig. 2C).

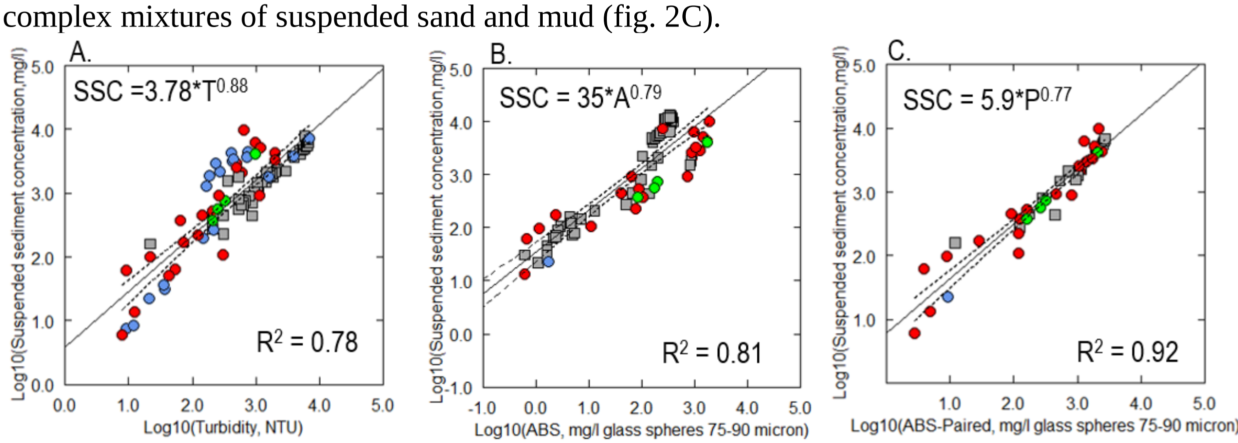

Figure 2. Scatter plots showing relations between surrogate values from sensors and suspended sediment concentrations (SSC) in the Shoshone River below Willwood Dam, near Ralston, WY (06284010). (A) Relationship between turbidity and SSC; (B) relationship between acoustic backscatter (ABS) and SSC; (C) relationship between paired turbidity and ABS (AOBS) and SSC. The location has complex, unpredictable mixtures of sand and mud due to Willwood Dam sluicing sediment to retain storage capacity in the live pool.

The model relation shown in figure 2C was created using an iterative procedure whereby γ was varied by steps of 0.01 over a realistic range of values (0 to 100) in a logarithmic version of equation 2. The model in figure 2C was created with value of γ that resulted in the maximum coefficient of determination (fig 3). That model resulted in a γ value of 0.36. The model in figure 2C used two of the ABS and NEP sensors shown in figure 1 which, based on methods proposed by Sequoia, should have a value of γ in the range of 30 to 50. Figure 3 shows that models using γ values in the range of 30 to 50 would explain substantially less of the variance in the data than those with values between 0.1 and 1.0. This is likely due to a combination of grain size differences between the standards and those observed in the Shoshone River, but nonetheless suggest that γ should not be treated as a constant.

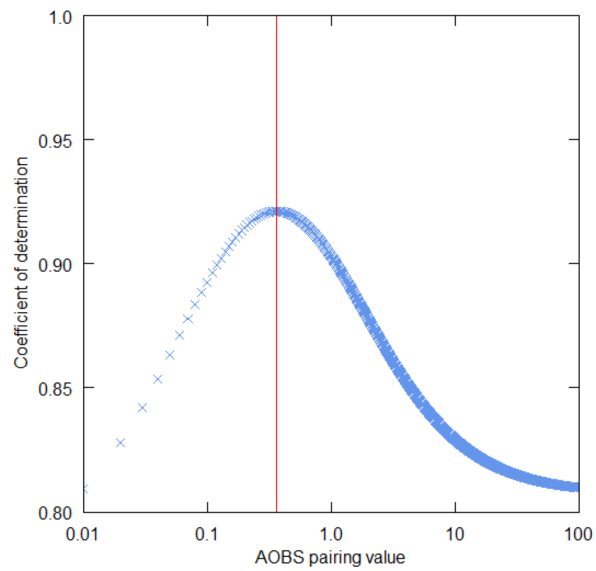

Figure 3. Scatterplot showing change in coefficient of determination for different AOBS values in a log-log model between LOG(AOBS) and LOG(SSC) for the Shoshone River below Willwood Dam near Ralston, WY (06284010)

The analysis shown in figure 3 demonstrates that a multiple regression approach is more likely to be successful than treating γ as a constant, and that users will likely not benefit from using Sequoia's proprietary methods, nor from paying Sequoia to obtain a constant value of γ. This also suggests a need for improved understanding and user guidance on use of AOBS technology to predict SSC in rivers.

Purpose and Scope: The purpose of this study is to develop guidance for using paired ABS and OBS signals to improve continuous estimates of SSC in the nation's rivers. The study will gather existing AOBS datasets (pairs of OBS and ABS values and associated SSC samples) from several rivers across the United States and use these data to: (1) examine differences between suspended sediment predictive models using pairing values (γ) developed in the laboratory and/or field using Sequoia's method and those developed using field data and a multiple regression approach; (2) examine behavior of pairing values for different combinations of instruments in the same river and between rivers.

Technical Requirements: The proposed study would leverage existing laboratory and field datasets (table 1), with additional laboratory-based data collection as necessary. These data would be used to generate predictive models of SSC using the standard Sequoia method (supplied by Sequoia to the PI) and using a multiple regression framework following the methods of Rasmussen and others (2009). Pairing values generated from both methods will be compared across rivers in different fluvial settings (table 1) to make inference on the variability and stability of γ for different grain size distributions and mixtures.

WSC/State	Waterbody	Station ID	Length of record	Sensors
WY-MT	Shoshone River	06284010; 06283995	3/1/2019 - 10/31/2021	NEP5000/ABS
WY-MT	Laboratory	NA	NA	9 combinations of NEP5000/ABS
OR-WA	Columbia River	14144700, 14246900,	12/04/19 - Current 11/14/19 - Current	DTS-12/ABS
OR	Willamette River	14211720	10/29/19 - Current	EXO/ABS
WA	Cowlitz River	14243000	10/29/20 - Current	NEP5000/ABS
AZ	Colorado River	09429500	1/27/2022- Current	Turner Designs Turb+/ABS
AZ	Colorado River	330131114364101	1/27/2022- Current	Turner Designs Turb+/ABS
AZ	All American Canal at Colorado River	09429490	1/27/2022- Current	Turner Designs Turb+/ABS
NM	Animas River	09363500	12/01/21- Current	NEP5000/Turner Designs/EXO2/ABS
NY	West Branch Neversink River at Claryville NY	01434498	08/08/2019- 04/01/2022	NEP5000/ ABS

Deliverables: A formal presentation during FISP's annual research results meeting is the proposed deliverable. This study also provides an opportunity to transfer these assets to other regional and early-stage sediment-related projects by other Federal agencies such as the Bureau of Reclamation, the Bureau of Land Management and the U.S. Environmental Protection Agency.

Timeline: The proposed timeline for the project is 12 months. The major activities and scheduled completion dates are presented in table 1.

Table 1. Timeline of major activities and completion dates.

Activities and Components	**Completion Date**

1. PI and co-PI inventory data and generate models for individual sites using Sequoia and multiple regression methods with paired ABS and OBS data.	April to July 2023
2. Analysis and comparison of pairing models by fluvial setting and sediment mixture.	July to September 2023
3. Generate figures and tables to summarize collective models and analysis	October – November 2023
4. Complete presentation and present to FISP	December 2023-January 2024

Budget: The proposed budget is dedicated entirely to partially support PI and co-PI salaries to diffuse costs to meet, organize data, generate models, perform collective model analysis, generate presentation(s), and attend virtual FISP meetings as needed.

Table 2. Itemized budget.

Budget Category	Cost FY 21	Explanation and Comments
Jason Alexander (WY-MT WSC)	$10,000	Project lead and coordination; model development and analysis
Jeb Brown (NM WSC)	$4,000	Model development and analysis
Paul Diaz (ORWSC)	$4,000	Model development and analysis
Joel Unema (AZWSC)	$4,000	Model development and analysis
Jason Siemion (NYWSC)	$4,000	Model development and analysis
Total Project Costs	$26,000	FISP funding

Unique Qualifications: USGS staff assigned to this project will be Jason Alexander, PhD, as principal investigator. Jason is the sediment specialist at the Wyoming-Montana Water Science Center and has 20 years of experience in fluvial geomorphology studies, including the use of optical and acoustic surrogate technologies to monitor fluvial suspended sediments.

Joel Unema is a hydrologist in the Arizona Water Science Center with experience in single and multi-frequency acoustics and sediment records on the Colorado River and its tributaries. He currently works with the Grand Canyon Monitoring and Research Center acoustic sediment program and leads suspended sediment studies on the lower Colorado and Verde rivers.

Paul Diaz is a Hydrologist in the Oregon Water Science Center and has over 20 years of experience using hydroacoustic instrumentation for a variety of applications, including single and multi-frequency side looking and down looking systems for use in sediment modeling. Currently he is principal investigator on a complex sediment acoustic project on the Lower Columbia River, where single and multi-frequency acoustic instrumentation is being utilized to generate real-time sediment models and various other sediment related products.

Jeb Brown is a USGS hydrologist in the New Mexico Water Science Center with research focuses in emerging technologies for hydrologic application, suspended sediment and metals transport, and suspended sediment surrogate instrumentation. He has 17 years of experience with fluvial sediment data collection, analysis, and instrumentation experience.

Jason Siemion is USGS Physical Scientist in the Watershed Research Section of the New York Water Science Center. His research focuses on suspended and bedload transport in streams of the northeastern US, including development of surrogate relationships between turbidity, ABS, and suspended sediment concentrations.

Principal Investigator Contact Information: Jason Alexander, phone: 307.287.1836, jalexand@usgs.gov

References:

Rasmussen, P.P., Gray, J.R., Glysson, G.D., and Ziegler, A.C., 2009, Guidelines and procedures for computing time-series suspended-sediment concentrations and loads from in-stream turbidity-sensor and streamflow data: U.S. Geological Survey Techniques and Methods book 3, chap. C4, 53 p.