FEDERAL INTERAGENCY SEDIMENTATION PROJECT
PROPOSAL FORM

Proposal Title:	Using close-range remotely-sensed multispectral imagery to quantify the effects of particle size distribution on instream turbidity
Project Chief:	Kurt Spicer (krspicer@usgs.gov), PI: Adam Mosbrucker (amosbrucker@usgs.gov)
Project Chief Location:	USGS Cascades Volcano Observatory, Vancouver, WA
Proposed Start Date:	December 2013
Proposed End Date:	November 2014
1-Year Funding Request:	$8,140

1. **Relation to FISP goals** –

Quantifying suspended-sediment concentration (SSC) using continuous instream turbidity is rapidly becoming common practice within sediment monitoring programs. Sediment-surrogate technologies are increasingly viewed as more accurate and cost-effective than traditional physical sample-based methods (Gray and Gartner, 2009; Landers and others, 2012; Landers and Sturm, 2013). However, hysteresis in the relationship between turbidity and SSC has been attributed to changing particle size distribution (PSD) (Landers and Sturm, 2013; Uhrich and others, in prep). Temporal variation of PSD causes increased uncertainty in simple linear turbidity-SSC regression equations, due to the changes in nephelometric reflectance off the varying grain sizes in suspension. This discrepancy will then decrease the accuracy of the real-time SSC computations. To overcome this, concurrent and independent measurements of PSD (presently only obtainable using expensive LISST technology) could increase accuracy of turbidity-based SSC records. Following a 1-year investigation, this work could provide an immediate benefit to on-going operational monitoring programs using turbidity-SSC regressions in rivers with significant variation in PSD.

2. **Scientific Merit and Relevance** –

Remote sensing is a rapidly growing subdiscipline in river science due to its ability to answer complex spatial and temporal questions; cost-effective data acquisition, processing and analysis; and the increasing participation of hydrologists in geospatial technology (Marcus and Fonstad, 2010). River remote sensing has become a broad field. While active remote sensing has been used to map and assess geomorphic characteristics of river environments for decades, passive optical remote sensing using reflected solar radiation in the visible and near-infrared spectrum has been successfully used to estimate water discharge (Bjerklie and others, 2004; Xu and others, 2004); and depth (Lyon and others, 1992; Winterbottom and Gilvear, 1997; Fonstad and Marcus, 2005; Bustamante and others, 2009; Legleiter and others, 2009).

The relationship of turbidity and SSC to spectral response has been well documented for large rivers, estuaries, and reservoirs using imagery acquired by aircraft or satellite sensors (Curran and Novo, 1988; Aranuvachapun and Walling, 1988; Li, 1993, Mertes and others, 1993; Doxaran and others, 2001; Bustamante and others, 2009). Research using satellite imagery found that shorter wavelengths (450-590 nm) were better correlated with lower turbidity, while longer wavelengths (630-900 nm) better predicted higher turbidity (Curran and Novo, 1988; Doxaran and others, 2002; Bustamante and others, 2009). Accuracy compared to physical measurements was ±22-35% for a SSC up to 2,000 mg/L.

The purpose of this study is to develop methodology to continuously monitor PSD using multispectral imagery in order to apply several different turbidity-SSC regression equations tuned to a range of PSD and selected in real-time using a simple piecewise defined function. This should increase the accuracy of real-time estimates of SSC, which is vital to sediment program cooperators dependent on these data. Our methods use off-the-shelf and relatively inexpensive equipment and software to measure spectral response at similar wavelengths but with as much as 1,000 times greater spatial resolution. This study would add significant value to a key monitoring project on the North Fork Toutle River near Mount St. Helens where hysteresis caused by variation in PSD has caused increased uncertainty in turbidity-SSC regression equations.

3. **Methodology** –

We propose an approach to develop a relationship between multispectral imagery and PSD that is novel and innovative in that it uses a digital camera mounted in a robust housing within tens of feet above the river surface. The camera sensor and lens is optimized for maximum spatial and spectral resolution. Three bands capture wavelengths in the visible spectrum (400-700 nm), but can easily be modified to include near infrared (up to 850 nm). Though the camera sensor is passive, the system can be active with the addition of two small strobes. Reflected light can be further modified by polarization or custom filters designed to further discretize selected bands.

Digital image processing includes normalization to account for variation in natural light (radiance, incident angle, etc.), and mathematical operations to individual bands or proportions of bands (also known as spectral indices) to produce a unique value that corresponds to a range of PSD. Once processing methodology is resolved, the entire process will be automated by programming batch processing scripts.

PSD will be measured by collecting depth-integrated suspended-sediment samples concurrent with image capture. Sampling schedule will focus on capturing the full range of PSD. Once lab results are obtained, image processing methods will be evaluated in an iterative manner to determine the best relationship to particle size. Funding from FISP would cover capital investment, initial research, and development of the methodology. If feasibility is proven, then CVO would likely fund the development and installation of additional instrumentation to allow real-time image acquisition, processing, and integration with turbidity-SSC regression equations through a real-time piecewise defined function.

This study will be conducted at an existing surface water discharge and daily sediment monitoring station on the North Fork Toutle River below the sediment retention structure near Kid Valley, Washington (14240525). The site is about 8 miles downstream of the 3 billion cubic yard debris avalanche emplaced in the basin by the May 18, 1980 eruption of Mount St. Helens. The river continues to transport an average of 3 million tons of suspended-sediment per year; daily average SSC ranges from 31 mg/L to 79,800 mg/L (WY 2007-2012). Particle size ranges from clay- to sand-size grains, with bed material dominantly sand. Annual mean water discharge is 786 cfs (WY 1990-2012). The USGS gage is collocated with a fish collection facility operated by the Washington State Dept. of Fish & Wildlife. Infrastructure at the USGS gage includes 20 to 30-foot tall concrete walls, a bank-operated cableway, and two gage houses with AC power and USB backup. Instrumentation includes two non-submersible pressure transducers, two 780-900 nm turbidity sensors (a FTS DTS-12 and a Hach Solitax), two Teledyne Isco automatic pumping samplers, a water temperature sensor, a tipping bucket rain gage, and a DCP with GOES telemetry. The U.S. Army Corps of Engineers, the cooperator for this gage, has funded the development of a turbidity-SSC regression and continues to fund continuous daily water and suspended-sediment discharge as these data are a key component to their monitoring and flood abatement efforts.

4. **Timeline, budget (Feasibility), and partners –**

TIMELINE –

Project timeline is briefly described in the table below. Instrumentation will be installed in January, and data collection will occur during field site visits until June. Particle size samples will be submitted to the lab for analysis as they are collected. Similarly, digital image analysis will take place on an ongoing basis as iterative capture methodology is worked out. The final product for this project will be a peer-reviewed report.

Schedule	**FY2014**
Instrumentation design and installation	December-January
Field data collection	January-June
Particle size analysis – CVO sed. Lab	February-August
Digital image analysis and regression	February-September
Prepare peer-reviewed report	September-October
Submit final draft to USGS publishing center	November

BUDGET –

Project expenses are greatly minimized by shared infrastructure and field site visits. FISP funding will cover a little more than half of the total expected cost of this initial study. Expenses are summarized in the table below.

Expense	**FISP**	**CVO**
Salaries, benefits, and indirect costs	$3,200	$2,400
Camera and mounting bracket Purchase	$3,400	$200
Image capture and processing software	$140	$2,500
Travel to field site	$400	$2,800
Sample particle size lab analysis	$1,000	
Total	**$8,140**	$7,900

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