Response to FISP FY2015 call for proposals

Analysis of lower limits of densimetric measurements of stream water as a surrogate for suspended-sediment concentration in the Rio Grande, New Mexico

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Project Chief Location: U.S. Geological Survey New Mexico Water Science Center, Albuquerque, New Mexico
Proposed Start Date: October 01, 2014
Proposed End Date: September 30, 2016

Relation to FISP goals

A previous FISP funded study examined differential-pressure derived densimetric measurements of stream water as a surrogate for suspended-sediment concentration (SSC). The study found that stream water density correlated well with SSC (preliminary results found R^2 of 0.78), and was a significant improvement of the previously assumed relation of SSC and streamflow. However, effective lower limits of SSC are not well known with this instrument *in situ*. This study examines the viability of densimetric measurements of stream water as a surrogate for suspended-sediment concentration in the Rio Grande at Albuquerque, NM (USGS 08330000), which represents much lower SSC than did the previous study at the Rio Puerco. This study directly relates to the first general FISP goal to "…identify, develop, or test emerging surrogate technologies or methodologies…" A densimetric method for continuously monitoring high-to-hyperconcentrated streamflows has been tested since July 2012 in New Mexico, with increasingly compelling results (Figures 1and 2). Although the densimetric technology focuses

on a sedimentological regime that no other surrogate technology seems to address – high and hyperconcentrated streamflows, determination of the viability at lower SSCs will allow for more ubiquitous use. Such high-to-hyperconcentrated streamflows are spatially limited, therefore, determination of lower limits of SSC where the densimetric method will function are critical for increasing the applicability of the surrogate technology. If the relatively inexpensive, simple, and robust dual orifice bubbler technology proves as tractable as a surrogate for lower amounts (<1,000mg/L to 20,000 mg/L) as it did with large suspended-sediment concentrations (>20,000 mg/L), continuous and quantifiably accurate data would be obtainable in a wider range of streams.

Scientific Merit and Relevance

Purpose and Niche: The purpose of the study is to collect stream water density and SSC data at the Rio Grande at Albuquerque, NM sediment gage to determine the efficacy of the density surrogate technology at lower suspended-sediment concentrations (approximately 250 mg/L to 15,000 mg/L). The study would inform the scientific and water-management communities to the efficacy and availability of the densimetric technology at a wider range of SSC than was proven with the previous study at the Rio Puerco. Currently, there is no knowledge of the lower operable limits of SSC for this density technology *in situ*. The study would also describe the methods (physical and analytical) used to compute daily suspended-sediment records from the pressure-difference signals, and calibration of the pressure-difference SSC record to SSC data obtained using standard methods as described in Edwards and Glysson, 1999. Relevance of the study is to better understand the lower limits of the densimetric method using the dual orifice bubbler, which may appreciably increase its applicability in streams and rivers worldwide, particularly where other surrogate technologies become ineffective at mid to high sediment concentrations.

Capabilities and Methodology

The densimetric technology requires two vertically-arrayed precision pressure sensors, separated by a given distance (usually between 0.3 and 0.7 meters) in a stream vertical (Figure 2). Each pressure sensor measures pressure head at each in-stream sensor orifice so that pressure head at two depths in the water column are associated with a single measurement of stream stage. Mean fluid density is derived by solving simultaneous equations using pressure data as measured by the two sensors. The methodology assumes a well mixed stream with no vertical density gradient in the water column. Because of the high SSC values and fresh-water source, density values greater than that of fresh water can be attributed to the presence of suspended sediment, and density variations can be quantitatively attributed to SSC variations. Issues related to the assumptions listed above, specific to the Rio Grande, include 1) the existence of a vertical density gradient in the water column, specifically within the orifice spacing, that may shift with channel morphology, and upstream SSC contribution, and 2) failure to accurately obtain simultaneous, equivalent water surface pressure readings due to turbulence. The former is likely to be problematic during baseflow and snowmelt runoff, yet approach a very well mixed stream during periods of monsoon storm event flows. The latter presents great difficulty in determining the signal (the differential pressure value assumed to represent sediment) from the noise (sensing different water surfaces due to turbulence at the water surface, among other factors) due to low SSC during baseflow and snowmelt runoff. Despite these issues, the benefit of the study is the ability to collect data across a wide range of SSC and particle size distribution resulting in determination of operable conditions for the dual orifice bubbler surrogate.

The Rio Grande at Albuquerque, NM, is unique in the variability of sediment due to source. At times, the relation of SSC with streamflow is invalid as values of SSC may change orders of

magnitude with little or no increase in stage. During periods of baseflow and snowmelt runoff, suspended-sediment is composed primarily of sand-sized particles. Whereas, during precipitation events (summer monsoonal storms) elevated concentrations of fine grained particles are observed in the water column, likely a result of streamflow in ephemeral channels that contribute flow to the Rio Grande. The dynamic conditions of this site may allow for definitive ranges of SSC for which the densimetric method will perform within an acceptable uncertainty. Additionally, the perennial nature of the Rio Grande will allow for more frequent, long term data than did the previous study on the more flashy, ephemeral Rio Puerco.

Studies analyzing differential pressure to estimate SSC data have been successful in the laboratory setting (Lewis and Rasmussen, 1999, Hsu and Cai, 2010). Differential pressure sensing to estimate SSC *in situ* has, however, been tested at limited locations and with limited success including northeastern Georgia (Calhoun, 2001), Paria River, Arizona (Hornewer et al., unpublished data, 2004-2006), Rio Caguitas, Puerto Rico (Larsen et al, 2001), and Rio Puerco, New Mexico (Brown, in review). The installation and attempt to correlate density data from differential pressure lines to values of SSC at the Rio Puerco near Bernardo, New Mexico, proves densimetric surrogate as an effective *in situ*, yet the minimum level of SSC required for successful operation of the densimetric method is unknown.

The New Mexico Water Science Center (NMWSC) has a long history of sediment-data collection in the Rio Grande. Mean daily SSC data have been collected at the proposed study site, the Rio Grande at Albuquerque, NM, since 1969. Suspended-sediment concentrations at this site typically range from 250 mg/L to 3,000 mg/L during baseflow and spring runoff, and as high as 10,000 mg/L to 50,000 mg/L during summer monsoon storm events. Calibrating the dual orifice bubbler with the pump-sampler data and hydrographer cross-section samples should yield

high quality, high resolution surrogate SSC data. The study consists of SSC and density data collection and analysis. Data collected from the double bubbler unit will be statistically analyzed to test for viability of the surrogate technology at lower ranges of SSC in the range of 250 mg/L to 10,000 mg/L.

Timeline, budget (feasibility), and partners

The timeline for the proposed project is not to extend beyond fiscal year 2016 (Table 1). Data collection is able to begin on October 1 2014 and will likely continue until the end of the monsoon season (~September 2015) in order for the data to sufficiently represent variability in SSC transport over different hydrologic regimes. The proposed timeline allows for one year of sample collection, ample time for data analysis, report writing and review (report to be determined).

The total budget for FY2015-16 is $59,500 (Table 2). The Bureau of Reclamation currently funds the daily suspended sediment discharge program at the Rio Grande at Albuquerque sediment gage, which includes SSC sample collection and analysis of SSC data to generate a mean daily suspended-sediment discharge. The NMWSC will invest in equipment and personnel to implement the dual orifice bubbler setup and will provide funding and support to allow for data collection and analysis. Continued collection of daily SSC data at this site to augment analysis of this surrogate technology will continue through FY2015. Following the success of the previous FISP project, the current FISP contribution sought is limited to $15,000 for data-analysis efforts in determination of the lowest operable SSC of the densimetric surrogate technology.

References

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Edwards, T.K., and Glysson, G.D., 1999, Field methods for measurement of fluvial sediment: Techniques of Water-Resources Investigations of the U.S. Geological Survey, book 3, chap. C2, 89 p. [http://pubs.usgs.gov/twri/twri3-c2/].

Hsu, Y.S., Cai, J.F., 2010, Densimetric monitoring technique for suspended-sediment concentrations: Journal of Hydraulic Engineering-ASCE, v. 136 no. 1, p. 67-73 [http://ascelibrary.org/doi/pdf/10.1061/(ASCE)HY.1943-7900.0000132].

Larsen, M.C., Figueroa-Alamo, C., Gray, J.R., and Fletcher, William, 2001, Continuous automated sensing of streamflow density as a surrogate for suspended-sediment concentration sampling: Proceedings of the 7th Federal Interagency Sedimentation Conference, Reno, Nevada, March 25-29, Vol. I, III-102 to III-109.

Lewis, A.J., Rasmussen, T.C., 1999, Determination of suspended sediment concentrations and particle size distributions using pressure measurements: Journal of Environmental Quality, v. 28, p. 1490-1496 [https://www.soils.org/publications/jeq/abstracts/28/5/JEQ0280051490].

Federal Fiscal Year (Oct. – Sept.)	FY 2015												FY 2016											
Month	**O**	**N**	**D**	**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**	**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**
Data collection																								
Data analysis																								
Initial draft																								
Review																								

Table 1. Timeline for completion of tasks in fiscal years 2015 and 2016.

Federal Fiscal Year	**2015**	**2016**
FISP	$15,000	
NMWSC	$10,000	$10,000
BOR	$24,500	$0
Total	**$49,500**	**$10,000**

Table 2. Financial contributions by the New Mexico Water Science Center (NMWSC), Bureau of Reclamation (BOR), and those requested of the Federal Interagency Sedimentation Project (FISP).

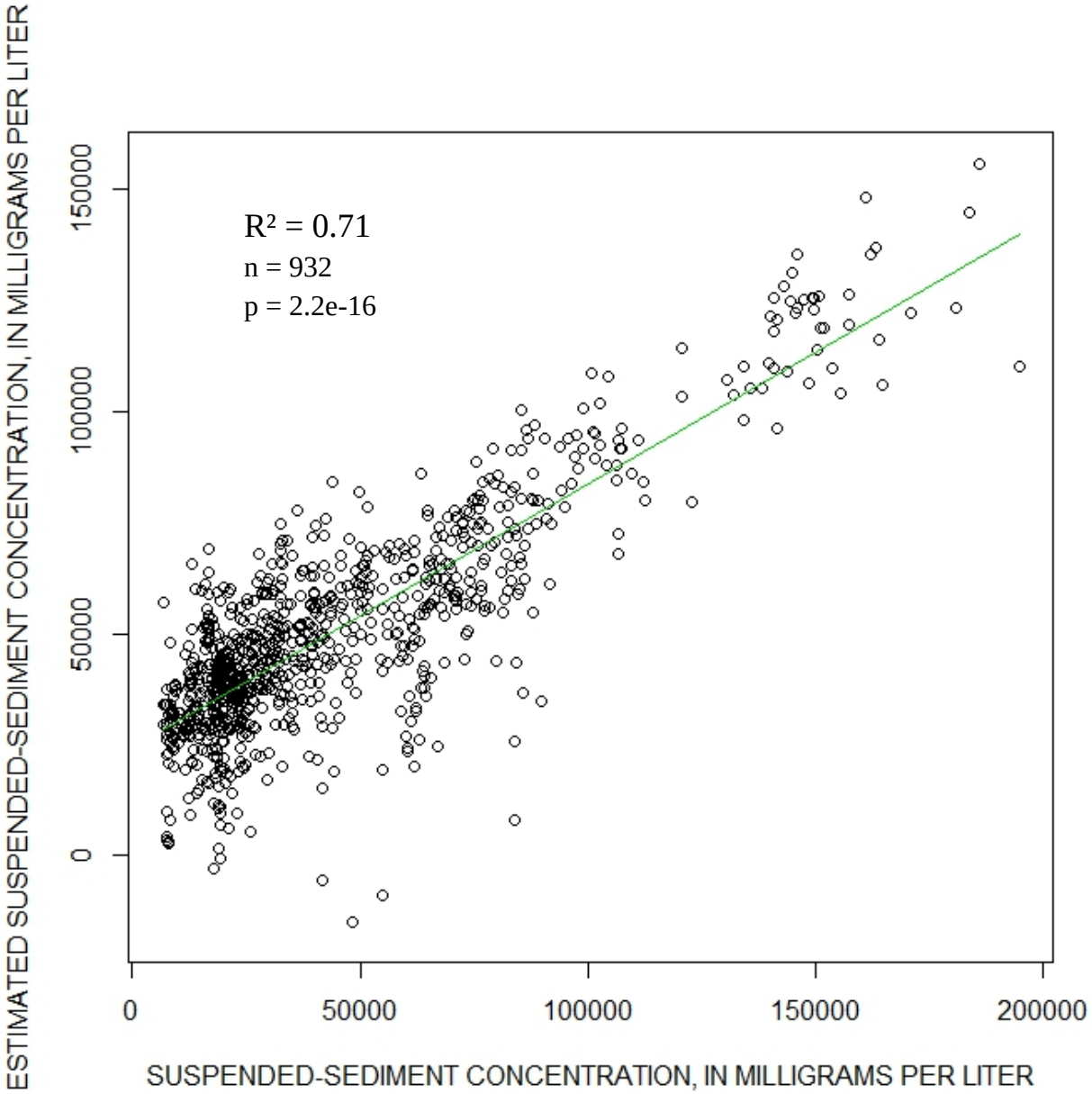

Figure 1. Comparison of estimated suspended-sediment concentration from differential pressure derived density data versus observed suspended-sediment concentration at the Rio Puerco near Bernardo, NM, sediment study site for water year 2013. Addition of streamflow into a multiple linear regression model improves the relation to R^2 = 0.78 (n = 791, p = 2.2e-16), with a variation inflation factor of 1.15, removing the possibility of multicolinearity.

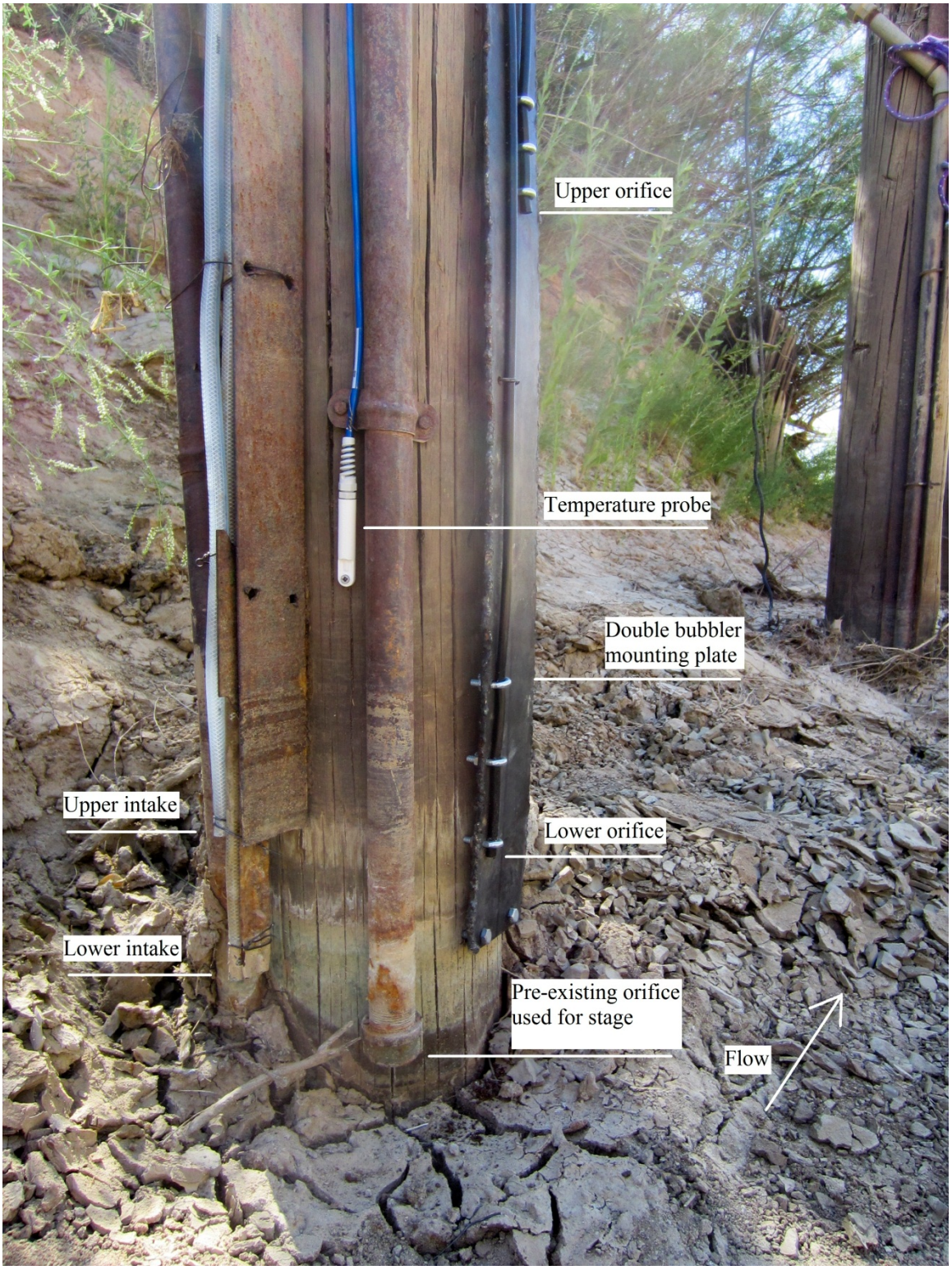

Figure 2. Installation of the two orifices, temperature probe, and automatic pump sampler intake lines at the Rio Puerco near Bernardo, NM. Installation at the Rio Grande at Albuquerque, NM, sediment gage will closely resemble this installation.