Proposal Title: Acoustic bedload monitoring using hydrophones at Vance Creek, WA

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Additional Investigators: Scott Anderson (USGS-Washington Water Science Center), Chris Curran (USGS-WAWSC), Kris Jaeger (USGS-WAWSC)

PI Location and Study Location (if different): PI Location: Sacramento, California;

Study Location: Vance Creek, Washington

Introduction:

This proposal directly supports the 2016 FISP research focus area: *Surrogate Bedload-Transport Monitoring*. The USGS California Water Science Center has been involved in multiple acoustic bedload monitoring projects using hydrophone at a range of study sites. The overall objective of this work is to develop the methods and techniques for scientists and field technicians to use for bedload monitoring. However, additional field testing and validation is needed from a variety of sites before this can be an accepted method. We need to test this method in a variety of locations and stream types to understand the method's strengths, limitations, and best practices to transition to an established method within the USGS.

Passive acoustic technology has been an emerging surrogate technique used to monitor coarse bedload sediment transport. Collecting physical bedload measurements is expensive and time-consuming (Gray, 2010) and often does not capture the temporal variability of sediment transport (Gomez, 1989; and Figure 1). Therefore, technological advances in sediment monitoring can improve estimates of sediment transport while reducing the time and expense associated with physical bedload measurements.

Background:

Hydrophone technology has been tested in both lab and field settings to use as a surrogate method for monitoring sediment transport in gravel-bedded rivers for decades (e.g. Thorne, 1986; Barton et al., 2010, Geay et al. 2017). Common limitations for many of these previous studies was the absence of physical bedload samples, and/or lack of long-term acoustic data. In recent years, the USGS-CAWSC has developed a low-cost acoustic recording system that is capable of long-term monitoring. This system has been tested and refined in a variety of studies (Marineau and others, 2015; Marineau and Wright, 2016; Marineau et al. 2017; also see example data in Figure 3.

Table 1 also provides a summary of passive acoustic bedload field studies led by Matt Marineau over the last 8 years. To date, the approach has shown the most success in large, gravel-bedded rivers and has had mixed success in smaller creeks. During flood events, underwater noise in large-gravel bedded rivers is dominated by sediment-generated noise (SGN) rather than flow- or turbulence-related noise. This was determined qualitatively by listening to audio recordings and quantitatively relating SGN to bedload measurements. Another study by Geay et al (2017), in a large gravel-bedded river also verified that hydrophones *were* detecting sediment-generated noise and can be used as a surrogate. In smaller creeks, however, the bed-material type and slope can have a large effect on the dominant noise type. At acoustic bedload monitoring sites in steep cobble-boulder streams in the Catskills Mountains (NY), for example, noise is dominated by water turbulence, rather than sediment transport.

Another gap in research is knowledge of sound propagation in shallow water (the term shallow here refers to rivers and creeks). A simple question such as *"How far can hydrophones detect?"* has not been adequately answered. This is an important question too, because that information can be used in designing a surrogate bedload monitoring program. This gap is being addressed field experiments by USDA-ARS, as well as by the USGS-CAWSC (through an internal research grant). The work performed by the USGS-CAWSC will revisit four Trinity River sites which were monitored using hydrophones in WY2016. Acoustic propagation will be mapped to see how acoustic propagation characteristics may have impacted the bedload prediction accuracy. This information can also qualitatively inform site selection for hydrophones at other future sites.

Table 1. Summary of acoustic bedload monitoring experiments led by WAWSC and CAWSC

Site	WY	River/creek size/type	Bed-material	Bedload sampled?
Cedar River, WA	2011	Large, regulated, low-grade	Sand-cobble	N
San Joaquin River, CA	2012-2016	Large, regulated	Sand-cobble	N
Gunnison River, CO	2015	Large, regulated	Sand-cobble	N
Shinumo & Bright Angle Creeks, AZ	2016	Small, shallow, unregulated	Sand-boulders	N
Trinity River, CA	2015-2017	Large, regulated, gravel-bedded	Sand-cobble	Y
Sauk River, WA	2018	Large, unregulated	Sand-cobble	Y
Stoney Clove & Birch Creeks, NY	2017-present	Small, shallow, steep, unregulated	Gravel-boulders	Y
Arroyo de los Pinos, NM	2018-present	Small, ephemeral, unregulated	Sand-gravel	Y
Vance Creek, WA(proposed)	2019	Medium, unregulated	Sand-gravel	Y

Purpose and Scope:

The primary goal of this study is to test the hydrophone-based acoustic monitoring method in a *medium-sized* gravel-bedded creek. Vance Creek fills the gap between the two end points of large gravel-bedded rivers, and smaller ephemeral or mountainous streams. This also gives us another calibration data set to compare to existing sets. Finally, the cooperator desires bedload data to help inform restoration management plans; therefore, providing a continuous surrogate-based data set will add value to the project itself.

Vance Creek acoustic monitoring will leverage an existing bedload monitoring study providing an opportunity collect paired acoustic and physical bedload data sets. This will help us move closer to making hydrophone-based acoustic bedload monitoring into an established surrogate method.

Technical Requirements:

This proposal will be a surrogate add-on for an existing bedload study. The bedload study at Vance Creek will be performed by the USGS Washington Water Science Center and is funded by Mason County Conservation District. The FISP would fund equipment, data analysis and results publication for the acoustic surrogate component.

Acoustic data related to sediment-generated noise will be collected during storm events. A water-level sensor will trigger the system to start recording 1-minute of audio data at 15-minute intervals (or shorter if flashier events are found to occur at this site). At that recording interval, the system can record for up to 2 months before batteries need to be replaced. During sampling, however, the system will be manually switched over to "continuous" mode, so it will record every minute of data. This is to capture any short-term temporal variability in transport (such as bedform migrations) and improve correlation with the physical samples. The recording system has an internal real-time clock and all files will have a timestamp relating to when it was recorded.

The bedload sampling protocol will also be modified to accommodate acoustic data collection. Conventional bedload sampling involves compositing the entire cross-section into a single measurement. Since a pair of hydrophones will be used (one on each bank), bedload subsamples (often referred to as "verticals") would be weighed separately before compositing. If observations of particle-size distribution show substantial lateral variability (and funding allows), then the group of subsamples may be composited into a left and right half, or into thirds rather than into a single measurement. By obtaining bedload mass and PSD data from each side of the river, each partial bedload measurement can be related independently to the acoustic recordings on the nearest side. Then, the two partial bedload records can be summed to generate a continuous bedload estimate that comprises the entire channel.

Deliverables:

Processed acoustic data and bedload estimates would be archived in internal USGS databases and made publicly available through the USGS NWIS website. Methods for processing and analyzing this data would be published in a peer-reviewed USGS report or journal article.

Bedload data and a separate interpretive report for those data will be published but those deliverables will not be funded through the FISP.

Timeline:

Task and description	Oct-Dec	Jan-Mar	Apr-Jun	Jul-Sep
Task 1. Purchase equip., build & install	■			
Task 2. Data Collection and sampling		■	■	
Task 3. Process, analyze, and archive data			■	■
Task 4. Publish results				■

Budget:

The budget below is for the building, installing, servicing the instrumentation (task 1), data collection (task 2), and analyzing and publishing the data (task 4). Bedload sampling and processing will be funding under an existing agreement. In addition, some costs are reduced by reusing and upgrading equipment from an older project.

Task	Description	Gross cost
1	Equipment costs for new acoustic instruments	$3,100
1	Build systems (labor)	$4,800
1	Field work for installation (labor)	$2,700
1	Misc. field supplies	$100
2	Data collection – service instruments	$4,000
2	Bedload sampling – in kind contributions	$0
3&4	Analyze and Publish (labor)	$20,000
Subtotal		$34,700
Acoustic equipment re-use from previous project; reduces labor and equipment cost for building new instruments		($4,700)
Total requested from FISP, FY2019		**$30,000**

Unique Qualifications:

Mathieu Marineau:

- Designed, built and installed dozens of field-based acoustic recorders
- Eight years of experience with acoustic bedload monitoring projects in multiple states (WA, CA, CO, NM, NY, AZ)
- Leading technical expert in the USGS for passive acoustic bedload monitoring
- Established the first USGS long-term acoustic bedload monitoring site (Trinity River above Lewiston Turnpike Bridge, Lewiston CA; Station number 11525525); https://waterdata.usgs.gov/nwis/inventory/?site_no=11525525&agency_cd=USGS

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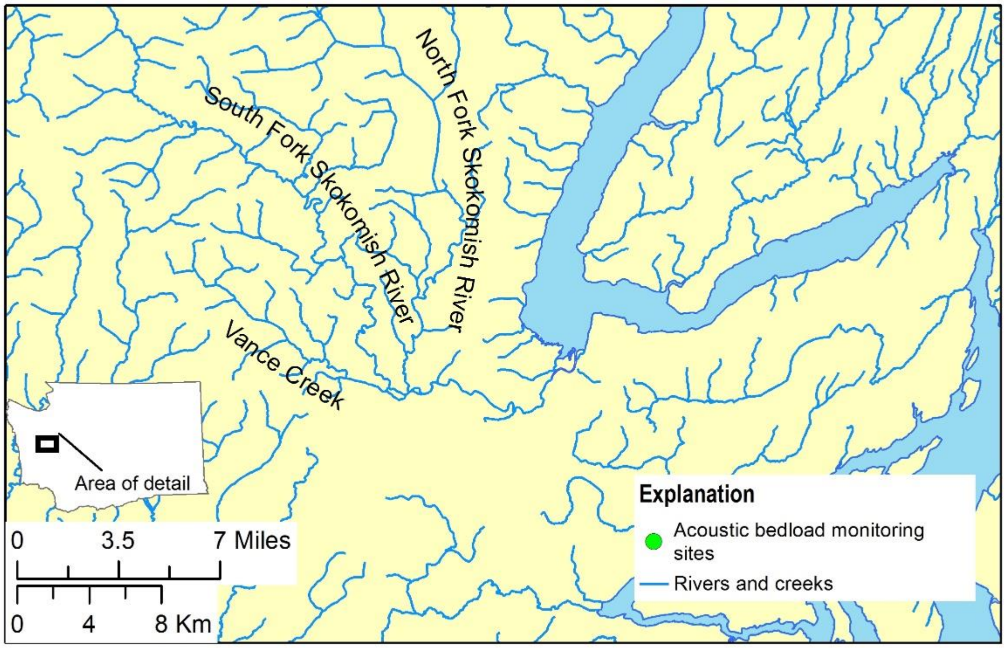

Figure 1. Map of study area. Vance Creek is a tributary to the Skokomish River

Figure 2. Photograph of Vance Creek at study site. Creek generally runs dry in summer time.

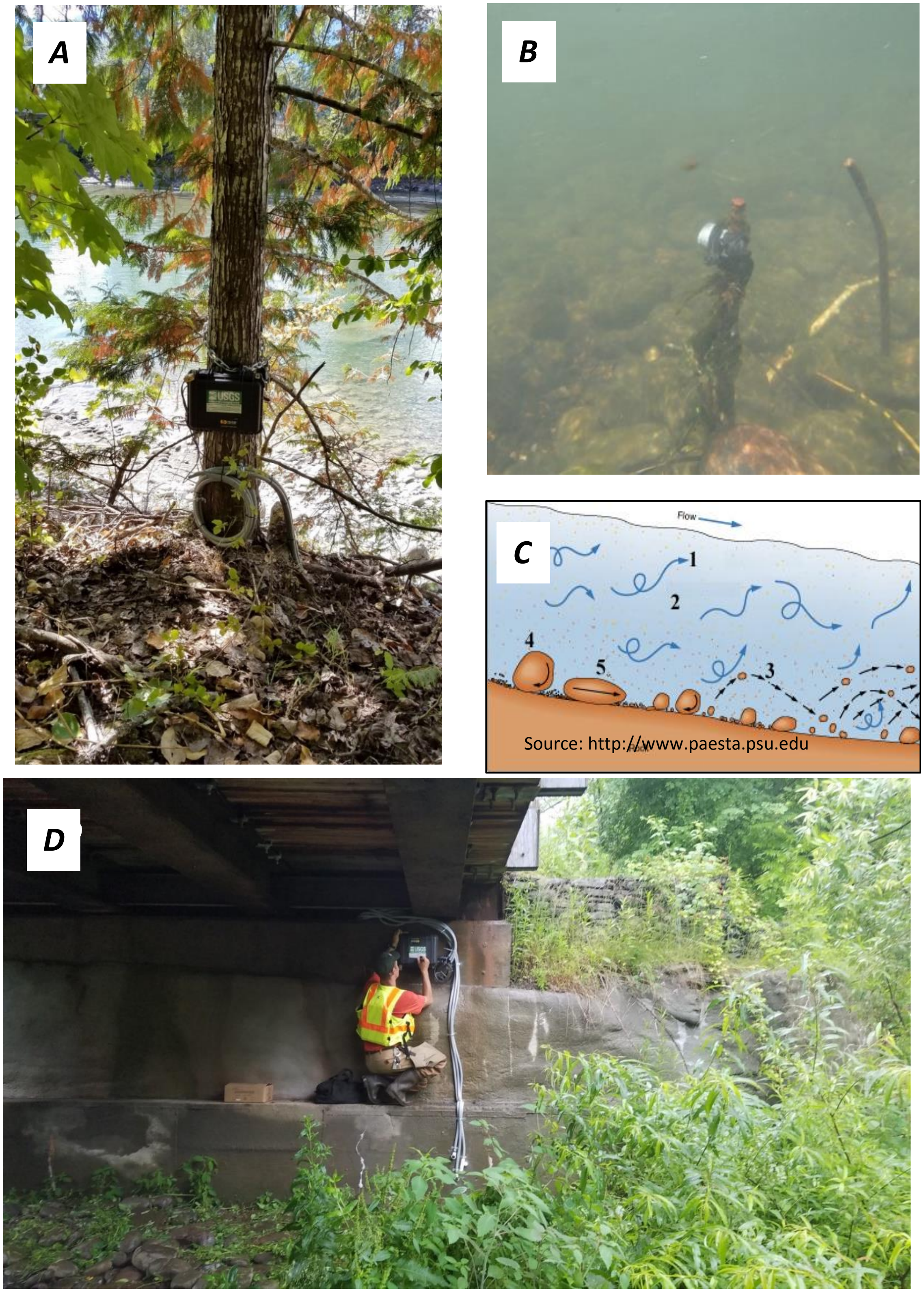

Figure 3. (A) Short-term hydrophone installations on the Sauk River, Washington; (B) submerged hydrophone; (C) typical modes of suspended and bedload sediment transport; and (D) hydrophone installations at Stoney Clove Creek in Upstate New York.

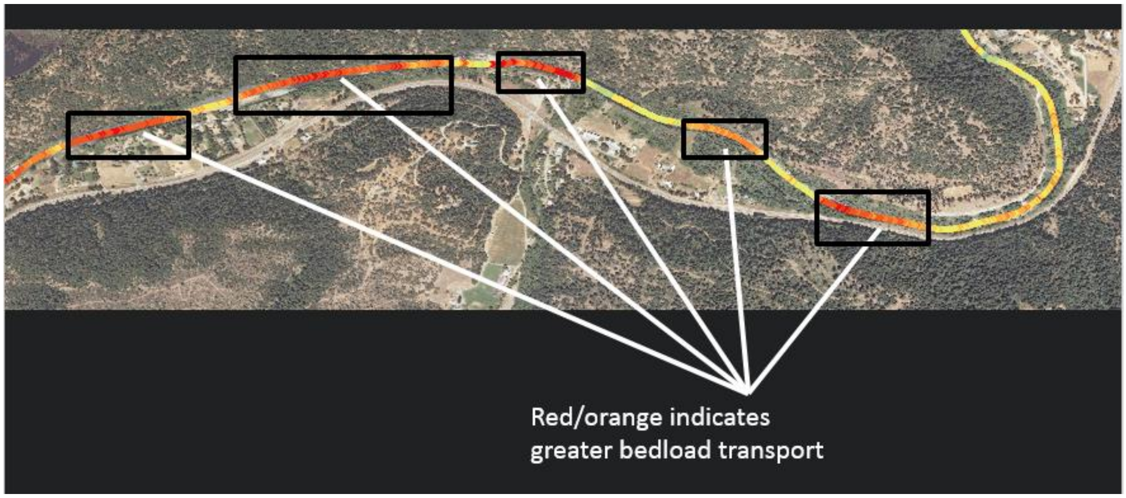

Figure. 4. Spatial mapping of bedload estimates made using boat-mounted hydrophones. The aerial image above is of a 2.25-mile reach of the Trinity River with longitudinal acoustic bedload data overlaid. The orange/red areas are areas which transport is occurring, while the yellow areas are quiescent areas.

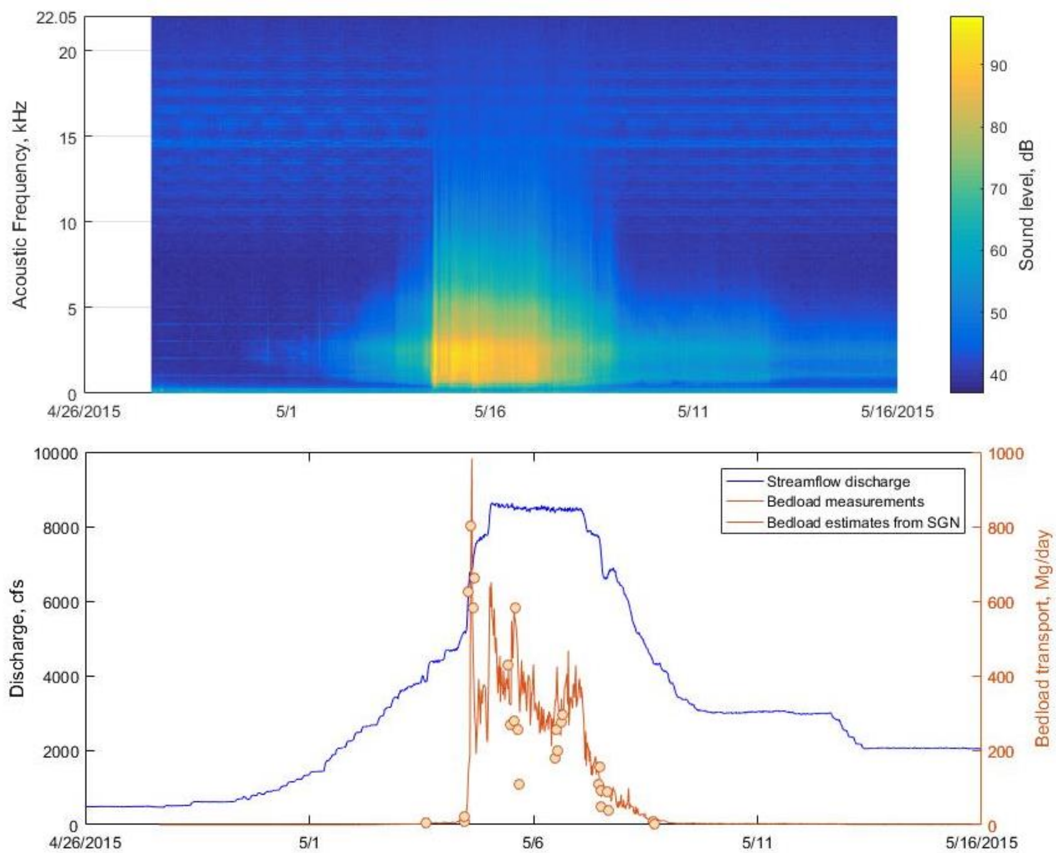

Figure 5/. Spectrogram at one site during reservoir releases on the Trinity River in May 2015 (top panel), time series of streamflow discharge with bedload measurements and acoustic-based estimates of bedload overlaid on discharge plot (bottom panel).

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