Progress report #2: Thermal scour-deposition chain

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Executive summary

A new thermal scour-deposition chain instrument is currently under development. The device will be capable of measuring scour and deposition in a stream bed in real time using temperature differences induced by diurnal temperature variation. The goal for June was completion of laboratory tests, collection of sufficient data for proof of concept, and completion and installation of field scour monitoring probes. To accomplish this goal, the work was broken down into three major tasks:

1. Complete assembly and verify that the model functions as designed.
    a. Select and grade sand for use as sediment
    b. Add sand to the model
    c. Run the model under various water flux/signal conditions
2. Run a successful laboratory model and collect data for evaluation
3. Develop and install a field application scour-deposition probe

Task number 1 began successfully until attempting modeling under upward water flux conditions, where air entrainment plugged system flow. Multiple attempts were made to remove air from the system until finally designing a new water sourcing system, including a pump and water heating system. With task 1 accomplished, task 2 provided good time series plots of predicted versus imposed sediment bed elevation in the model tank. Task 3 resulted in a modular field temperature probe/data logger system, with an installation in the South Fork Boise River.

Future goals include the following:

1. Additional laboratory data analysis under multiple imposed model conditions
2. Time series bed elevation plots of the streambed in the South Fork Boise River
3. Development of additional field probes with capability of wireless data collection
4. Complete the final project report

The total expenditure has been $35,258 so far with a budget burn rate of $3,918 per month, placing the project on track for spending at this time.

An application is under review for funding and collaboration with the Idaho Department of Transportation for an extension of this SBOE project, which would include wireless scour monitoring at an in-stream bridge.

Patent application status is unchanged from the previous report information as of December, 2013.

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Thermal scour-deposition chain progress report. June 2014. University of Idaho.

Introduction

A new thermal scour-deposition chain instrument is currently under development. The device will be capable of measuring scour and deposition in a stream bed in real time using temperature differences induced by diurnal temperature variation. A common method of measuring scour-deposition is the scour chain. This device can provide maximum scour and deposition for an event or a time frame of installation but cannot provide time series data of scour-deposition. This new thermal scour-deposition chain aims to provide an improved and inexpensive method to provide necessary stream data useful in water resource management practice.

A laboratory model has been assembled and run to calibrate the temperature scour chain theory and provide design basis for product development. The lab model is a scaled system that attempts to replicate hyporheic flow into and out of a stream bed and can measure temperature data throughout the sediment layer in the tank. A sinusoidal wave temperature source mimics naturally occurring daily temperature variation in a stream. Temperature data is logged over time and plotted to provide values necessary for calculating sediment scour or deposition.

A prototype for the field application temperature scour-deposition chain is under development, and the first beta testing version has been installed in a live stream for testing.

This report provides information on the recent quarterly goals, designs and accomplishments, budget, future goals, and patents/business inquiries or applications.

Project goals and accomplishments

Using the previously completed sinusoidal temperature source, sediment tank, temperature probe, and computer data logging system, laboratory tests have been run under multiple conditions of sediment depth and groundwater flux. This report section describes goals and the associated tasks for their completion.

The project goal for June was completion of laboratory tests, collection of sufficient data for proof of concept, and completion and installation of field scour monitoring probes. To accomplish this goal, the work was broken down into three major tasks, with subtasks continuing from the project beginning:

1. Complete assembly and verify that the model functions as designed.
    a. Select and grade sand for use as sediment
    b. Add sand to the model
    c. Run the model under various water flux/signal conditions
2. Run a successful laboratory model and collect data for evaluation
3. Develop and install a field application scour-deposition probe

The following subsections describe selected designs for each above item and steps/setbacks that occurred in accomplishing their completion.

Task 1

The previous problem in December associated with the temperature feedback sensor in the laboratory model was successfully resolved with a new sensor, and the model performed well during follow up testing.

Sand-gravel substrate with grain size ranging from approximately 0.5 mm to 4.0 mm was placed in the tank to a total depth of approximately 45 cm. The model was run with downward groundwater flux, followed by upward flux. Figure 1 displays an image of the complete functioning system. During upward flux conditions, the gravity feed water flow hoses would airlock, and air/gas bubbles were filling the tank bottom, nearly plugging the flow grid. The source of air/gas was traced to the water itself from the building tap water system. This pressurized water has entrained air that releases once exposed to lower atmospheric pressure. Several attempts were made to remove the gas from the water prior to entering the model system, including a siphon system, sand filter, and a wire mesh filter. After approximately one month of such attempts, the model was moved to a different location in the lab, where water was sourced from the large flume pool and air entrainment is not an issue. A pump and heater system was designed to provide the forced water temperature cycling source.

Figure 1. Functioning laboratory model.

Project delays totaled approximately 3 months, due to the entrained air problem and associated redesign. After redesign, the model was successfully run under upward flux conditions, as well as downward flux and static conditions.

Task 2

Various sediment depths were induced and modeled under both sinusoidal and saw tooth temperature signals. This section describes model results and plots.

Temperature plots obtained from the model demonstrate excellent respective desired sinusoidal and saw tooth temperature forcing (Figure 2 and Figure 3). One can see as sediment depth increases in the tank, temperature signal amplitude decreases and the phase of the signal peak is delayed.

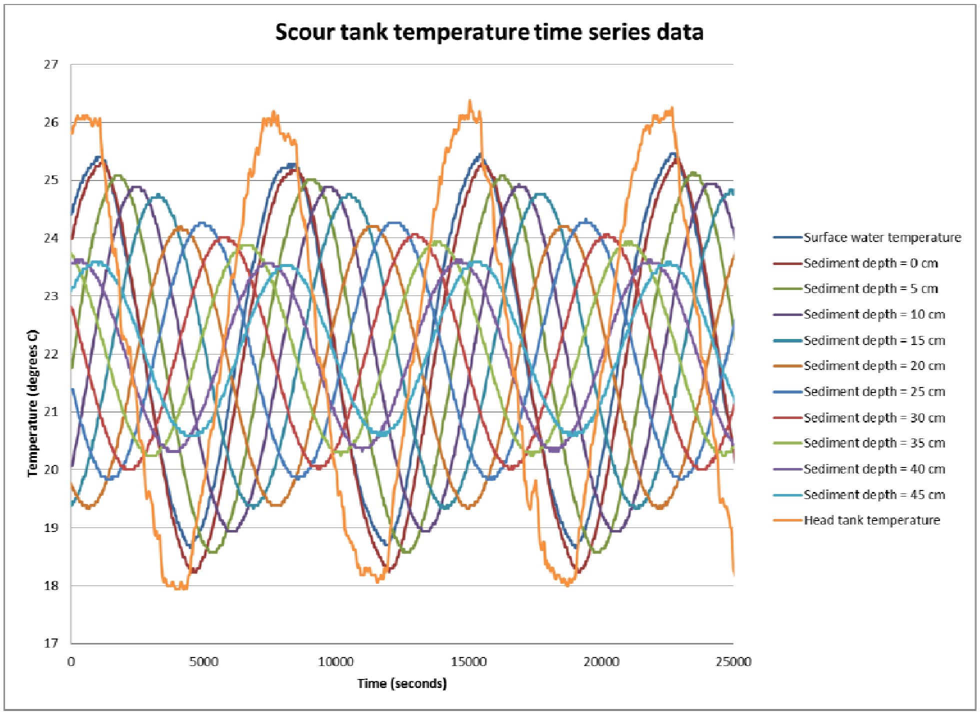

Figure 2. Laboratory model sinusoidal temperature time series plot.

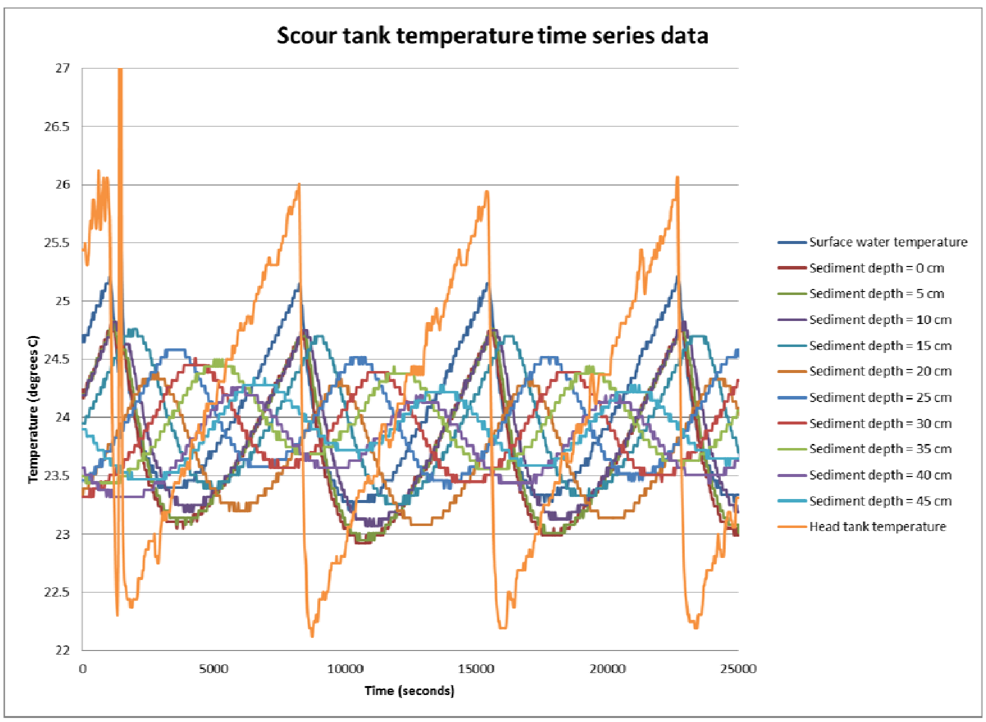

Figure 3. Laboratory model saw tooth temperature time series plot.

Model scour elevation plots were obtained through data analysis in R, an open source environment for statistical computing and graphics. A preliminary R program for analyzing scour via temperature was provided to me by Dr. Daniele Tonina; however it was necessary to invest some training time in R to upgrade the programming to compile multiple scour tank data files and provide continuous plots of model scour over time. One example of such analysis is shown in Figure 4. This figure demonstrates success in predicting streambed elevation compared to actual values.

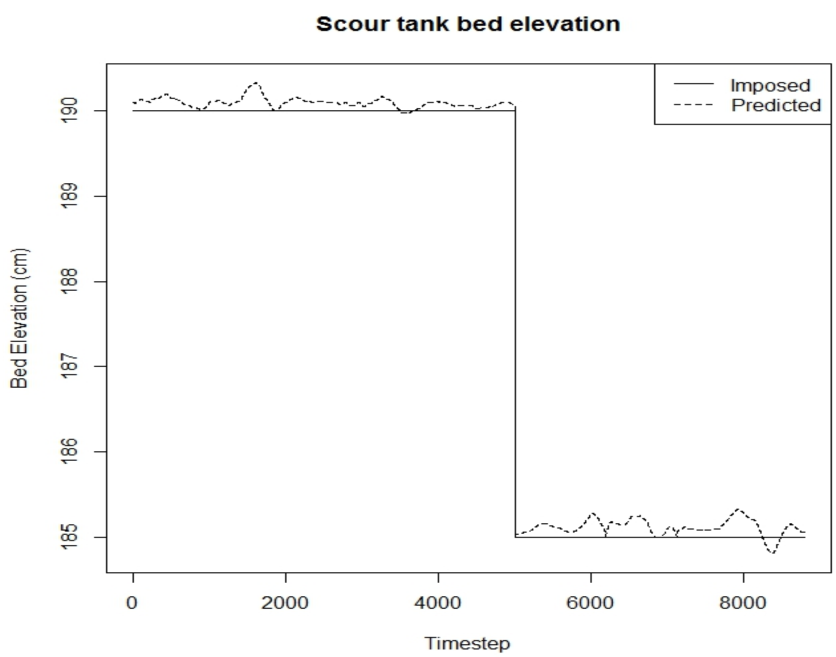

Figure 4. Laboratory model time series scour plot.

Task 3

In-stream temperature scour chain (temperature probe) design for temperature data collection was centered on two major elements: the temperature sensor and data storage. A modular system was desired, where one probe design could be utilized whether data is collected via wireless communication or simply stored in memory at remote locations with no wireless connectivity. Thus, a temperature sensing probe and a data logger were designed as separate modular devices. Design elements for each respective device follow.

Probe design:

Probe design elements include the following: (1) placement approximately 1 meter deep in a streambed (2) withstand impact from large debris in the channel (3) extremely low temperature conductivity of the material to avoid mixed or averaged temperature measurements (4) a rigid stem retaining sensor locations during scour condition, but not too hard or brittle (5) small diameter for ease of insertion into the bed.

UHMW (Ultra High Molecular Weight) plastic tube was selected to house temperature sensors as it meets all of the above design criteria. DS18B20 temperature sensors from Dallas Semiconductor were selected for temperature measurement. Temperature data from each sensor is collected via serial data. For proper analysis, the particular sensor location along the probe must be known. This is accomplished by referencing the unique serial address of an individual sensor to its location along the probe. The 1 inch long sensors are placed at a 45 degree angle to allow a smaller diameter tube. Three wires from each sensor are connected in a parallel star network, allowing one three wire sleeved bundle to exit the top of the probe with a connector for connection to a data logger. This connector provides the advantage to connect the probe to an attached data logger or to run longer wires and connect multiple probes to one central wireless communication device which transmits data to an office or laboratory location. Figure 5 displays the field probe, with sensors along the vertical and a single wire connector extending from the top.

Figure 5. Field temperature probe.

Data logger design:

Data logger design elements include the following: (1) waterproof housing connecting directly to the temperature sensing probe to avoid exposing sensitive wiring to floating debris (2) ability to disconnect from the probe during deployment to upload data or replace batteries (3) as small in size as possible, given time and cost restraints (4) resistant to damage from debris in the channel (5) battery life of six months or greater (6) high capacity for data (7) house a microprocessor and memory capable of collecting data from the DS18B20 sensors.

Multiple housing designs were explored including utilization of existing waterproof cases or electrical junction boxes. To achieve an economical and waterproof housing, 1 ½ inch PVC fittings and pipes were used. The device houses an open source Arduino based microprocessor, micro SD card, and batteries. One 3 wire bundle exits the waterproof case through a waterproof cable gland and has a waterproof connector on the end for connection to the sensor probe. Figure 6 demonstrates the final assembled data logger, with one waterproof wire for connecting to the probe.

Figure 6. Field temperature probe data logger.

Field probes were placed in the South Fork Boise River in the May, 2014 (Figure 7). Initial bed elevations were surveyed using DGPS equipment. The probes are currently monitoring streambed erosion/deposition associated with dam release flows and high sediment loads from multiple fire related debris flows in the system.

Figure 7. Field temperature probe installation, South Fork Boise River.

Future goals

Additional laboratory data analysis is anticipated for inclusion in the final project report, including scour-deposition under multiple groundwater flux conditions.

South Fork Boise River field data analysis results are anticipated by September, 2014. Time series bed elevation plots will be compared with actual surveyed elevations obtained periodically during probe deployment.

During the months of June through September, multiple additional field probes with added wireless communication abilities are planned to be assembled and installed at in-stream bridge pier locations. The additional graduate student salary has been funded through a stipend from the Hydro Research Foundation (HRF), and the associated results are planned for inclusion in the final report for this field portion of the SBOE funded project due to unanticipated delays.

The final report for the SBOE thermal scour-deposition chain project will be complete by the final deadline in September, 2014. This report will include complete analysis of the laboratory data and some analysis of field data.

Budget

The total expenditure has been $35,258 so far with a budget burn rate of $3,918 per month. The project burn rate was calculated based on the starting day of September 1st when the graduate student started working on the project. Additional project materials will be purchased within the next 7 days, totaling approximately $3,500. The project including current and future spending is within the budget constrain shown by the current budget projection shown in Table 1.

Table 1. Project budget.

BUDGET:		FLK403-FY14	KDJ 06/12/2014	BALANCE AS OF:	13-Jun-14
TITLE:		ISBOE Thermal Scour-Deposition		PROJECTED THROUGI	15-Jun-14
PRINCIPAL INVESTIGATOR:		Tonina, Daniele		PREPARED BY:	Kellie
TERMINATION DATE:		30-Jun-14		START DATE:	1-Jul-13
ALLOCATION:				FISCAL YEAR 13 STARI	1-Jul-13
		BUDGETED	ACTUAL EXP	AVAILABLE	COMMITTED EXP
01	Salaries	25,800.00	20,484.00	71.20	25,728.80
02	Fringe Benefits	1,400.00	1,147.43	76.41	1,323.59
03	Irregular Help	0.00	0.00	0.00	0.00
04	Travel	3,176.00	288.30	2,850.49	325.51
05	Other Expense	6,000.00	3,964.76	2,035.24	3,964.76
06	Capital Outlay > $5K	0.00	0.00	0.00	0.00
07	Capital Outlay < $5K	0.00	0.00	0.00	0.00
08	Reserve	0.00	0.00	0.00	0.00
09	Overhead*	0.00	0.00	0.00	0.00
10	Trustee/Benefits	9,374.00	9,374.00	0.00	9,374.00
	TOTAL	45,750.00	35,258.49	5,033.34	$ 40,716.66
			Total days	364	
			Days remaining	17	
			% remaining:	11.00%	

Patent/Collaboration information

An application for funding from and collaboration with the Idaho Department of Transportation is currently under review. This work would be an extension of this SBOE project and would include wireless scour monitoring at in-stream bridge infrastructure and could continue one year or more from now.

Patent application status is unchanged from the previous report information as of December, 2013.