Progress report: Thermal scour-deposition chain

Tim DeWeese
Graduate Research Assistant
Daniele Tonina
Center for Ecohydraulics Research
University of Idaho, Boise
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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 project goal for December was a working laboratory model and base level time series temperature data for scour comparison. To accomplish this goal, there were five major tasks:

1. Provide an automated sinusoidal wave water temperature source.
2. Select a data logging system for recording time series temperature data, separate from the automated temperature source.
3. Design and construct the sediment tank and related hydraulic plumbing.
4. Complete assembly and verify that the model functions as designed.
5. Run a successful model and collect data for evaluation

Task number 1 required the greatest amount of time, due to the complexity of programming a constantly varying set point. As a result, programming and parts were complete and ready upon the first week in December. Task 3 was designed in October and constructed in November. Task 2 was complete and ready for operation by November 30. Task 4 is currently in progress and will require a new control temperature sensor for completion. Task 5 has not yet been performed due to delays in task number 4 and extended time required for task 1.

Future goals include the following:

1. Temperature control source validation
2. Obtain scour-deposition laboratory data
3. Compile and analyze data
4. Complete design of an in stream temperature sensing device ad deploy in a live stream with high spring run-off flow rates.
5. Compile and analyze in stream data
6. Complete a final project report

The total expenditure so far has been $13, 632 and the budget burn rate is $4,544 per month placing the project on track for spending at this time.

Patent applications have been submitted U.S. Patent Application No. 13/890,919 for METHOD AND APPARATUS FOR MONITORING WATERBED ENVIRONMENT USING TEMPERATURE MEASUREMENTS; U of I Ref. No. 12-009, KS Ref. No. 7832-91088-01.

Business contacts for additional product development include CH2M HILL and the Idaho Department of Transportation, for both stream restoration and bridge scour monitoring.

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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 lab model is under development to calibrate the temperature scour chain theory and begin to provide a design 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.

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

The goal for December was a working laboratory model and base level time series temperature data for scour comparison. To accomplish this goal, the work was broken down into five major tasks, with subtasks:

1. Provide an automated sinusoidal wave water temperature source.
    a. Design and select a scaled method for provision of sinusoidal temperature automation
    b. Determine necessary components to run the selected temperature control method
    c. Program computer control equipment to run with only daily user input
2. Select a data logging system for recording time series temperature data, separate from computer controlled temperature source.
    a. Select and design method for data logging

   b. Select temperature sensors which may be used in submerged locations and provide near point temperature readings
   c. Program the interface device for communication and data logging with PC
3. Design and construct the sediment tank and related hydraulic plumbing.
   a. Size and select materials for the scour tank and hydraulics
   b. Design the hydraulic system for tank water inflow and outflow, as well as upwelling and downwelling hyporheic flow
   c. Order/purchase materials
   d. Construct the tank and hydraulic system
4. Complete assembly and verify that the model functions as designed.
   a. Install automation controls
   b. Test the temperature control system
   c. Select and grade sand for use as sediment
   d. Assemble entire model including sand and sensors
   e. Run the model and address start up issues
5. Run a successful model and collect data for evaluation

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

Task 1

Provision of a constantly varying, sinusoidal wave form, water temperature source was selected as the first task due to its complexity and time requirements. Design was complete and parts ready for install in the first week of December.

Programming a constant temperature set point for a thermostatically controlled water source would have been simple, but in this case the set point is constantly varying. We first discussed using an on demand water heater to provide a controlled temperature source but learned that a varying temperature set point would be difficult to add to existing water heater controls. Another option discussed was a source tank with a computer controlled heating element. It was determined that the volume of water in a tank would not be able to respond fast enough to constant temperature change demands. Ultimately, an automated temperature mixing valve was selected for its quick response time, and it is designed specifically for providing a desired water temperature in similar applications. We contacted a local electrical engineering company, which specializes in computer automation processes in various municipal and agricultural management systems. John Bolen, an employee of this company, volunteered his time to program a programmable logic controller (PLC) to operate the actuator on a mechanical mixing valve. With John’s assistance, we selected the Honeywell MN7505 Temperature control actuator and VBN3 temperature mixing valve and the Omron CP1L-EL20DR-D PLC (Figure 1).

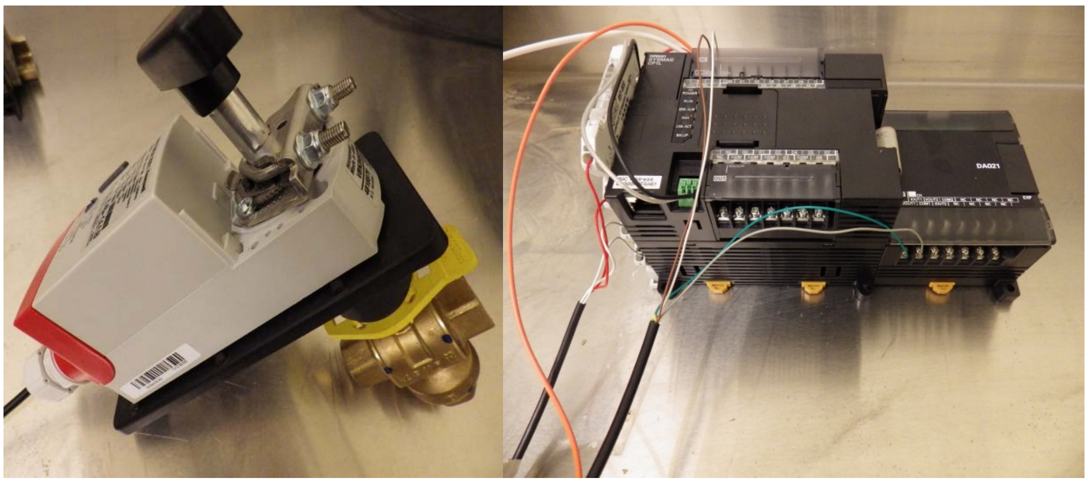

Figure 1. Left: Honeywell MN7505 Temperature control actuator and VBN3 temperature mixing valve. Right: Omron CP1L-EL20DR-D PLC.

Task 2

Data logging system design and implementation ran concurrent with the controlled temperature design. Programming and initial system validation were complete the first week in December.

Data logging is designed such that it is separate from the temperature control system for redundancy and improved stream bed and bridge scour sensor development. Several temperature sensing and data logging methods were considered, with resolution, reliability, and cost as selection criteria. Selected is use of an Arduino board (an electronics prototyping platform) integrated with Dallas Semiconductor waterproof digital temperature sensors (DS18B20) (Figure 2). These sensors provide 0.625 degree Celsius resolution and 750 millisecond sampling capability, more than capable of providing quality data for analysis. The Arduino board provides an interface between the lab PC and the sensors, with appropriate programming. Arduino is also capable of incorporating wireless communication for remote sensing potential and could be integrated as part of the new sensor device for remote monitoring and collection capabilities.

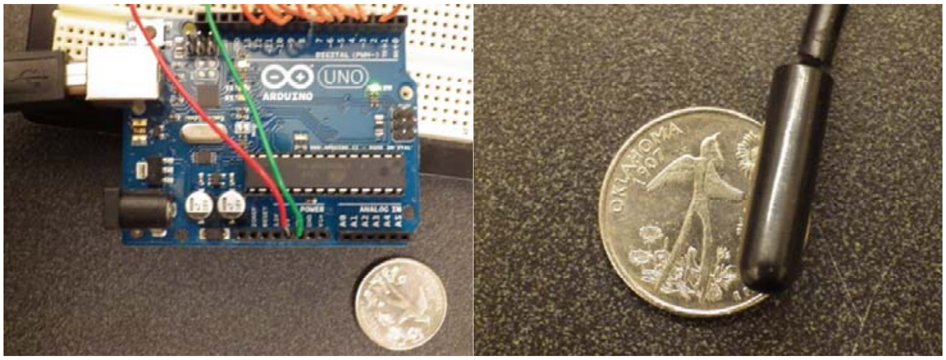

Figure 2. Left: Arduino board. Right: Temperature sensor.

Eleven sensors were placed every five centimeters along a plastic strip for vertical placement in the center of the tank (Figure 3, pictured horizontal). Each sensor is connected individually to the Arduino board. An additional sensor is placed at the temperature source to log the controlled temperature for monitoring purposes. Temperature data is currently logged every 30 seconds and written directly to a text file.

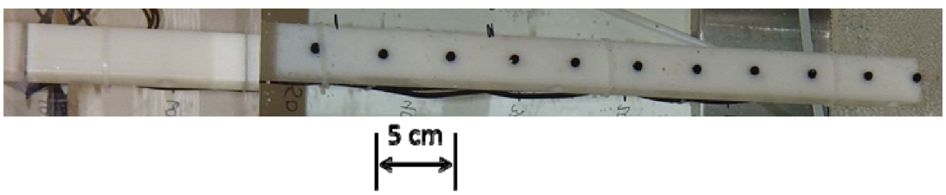

Figure 3. Temperature sensing strip.

Task 3

The tank design was complete in early October and was constructed in early November. Final hydraulic plumbing was completed upon receipt of all system components in early December.

Clear cast acrylic was the selected material for tank construction. Cast was selected for its machinability, which would allow drilling and tapping for pipe thread connections. A 4' by 8' sheet was purchased from a local supplier and cut per our request, allowing immediate assembly upon receipt of the materials. Clear poly (3/8" OD, 1/4" ID) tubing was selected for the hydraulic system for its ease of assembly and availability of various connectors.

Figure 4 demonstrates the assembled tank. Flow rate control is accomplished through use of a constant head supply tank, fed by the controlled temperature mixing valve, shown in Figure 6. Plumbing is set up such that down welling or upwelling flow may be induced to mimic flow in the hyporheic zone.

Task 4

During the control temperature validation procedure in week 2 of December, there was a problem with the feedback temperature signal, causing the system to command full cold and a constant temperature feed. An improved replacement sensor is on order at this time. Figure 5 provides an example of a plot from data logged during validation, and one can see that the actuator is adjusting temperature, but is not yet successful at a sinusoidal wave due to the failed control temperature sensor.

Figure 4. Assembled tank.

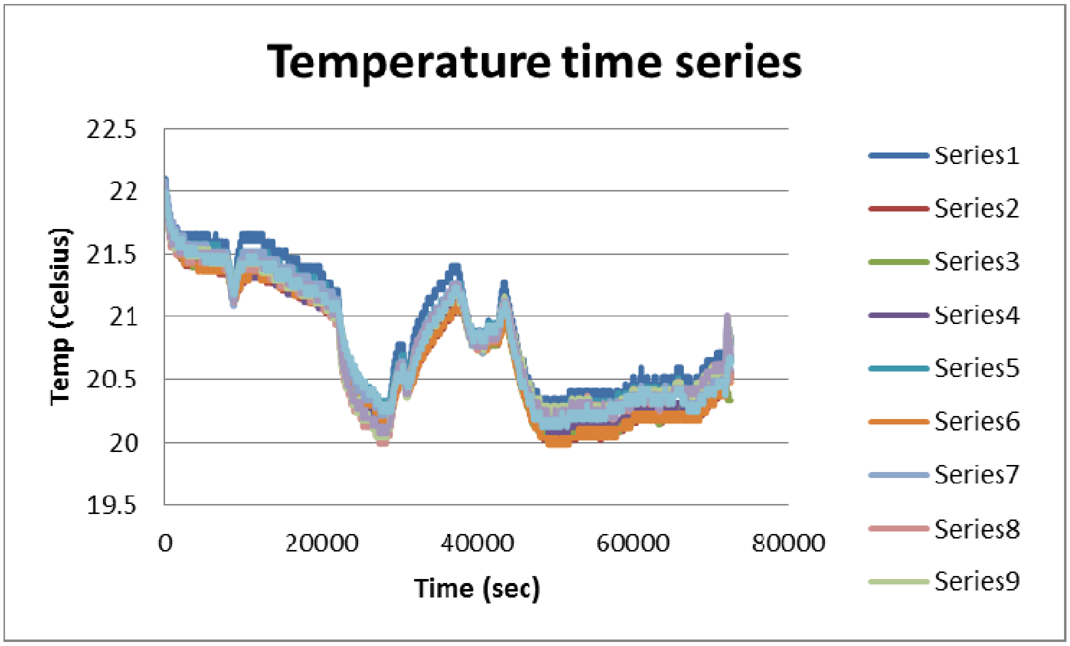

Figure 5. Example time series temperature data plot.

Figure 6 provides a view of the laboratory set up and labelled components for visual reference.

Figure 6. Complete laboratory layout.

Task 5

This task is not yet underway due to time requirements of previous tasks.

Future goals

Sand selection and grading will occur in the first week of January, as well as repair of the failed temperature reference sensor and temperature control source validation. By end of January, it is anticipated that several plots of laboratory data will be completed, including base level and scour-deposition data. Laboratory data analysis is planned during the months of March and April.

An in stream sensor design will be complete and ready for material purchase and assembly by early February. The sensor device should be tested and validated by end of February for in stream placement, in time for spring run-off, where a sensor will be placed in a nearby live stream known to experience significant scour-deposition during high flows. Stream data will then be analyzed during the month of May.

A final report will be completed during the month of June. The report will compile the laboratory and stream device designs, along with the associated data and analysis, and provide detailed expenditures associated with the project.

We have been working with University of Idaho students in the marketing and business to develop a business plan for the product.

Budget

The total expenditure has been $13,632 so far with a budget burn rate of $4,544 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. The project is within the budget constrain shown by the current budget projection shown in Table 1.

Table 1: Budget, budget cost and budget projection.

BUDGET:		FLK403-FY14		BALANCE AS OF:	27-Dec-13
TITLE:		ISBOE Thermal Scour-Deposition		PROJECTED THROUGH	15-Jun-14
PRINCIPAL INVESTIGATOR:		Tonina, Daniele		PREPARED BY:	Kellie
TERMINATION DATE:		30-Jun-14		START DATE:	1-Jul-13
ALLOCATION:				FISCAL YEAR 13 START:	1-Jul-13
		BUDGETED	ACTUAL EXP	AVAILABLE	COMMITTED EXP
01	Salaries	25,800.00	7,966.00	(1,512.00)	27,312.00
02	Fringe Benefits	1,400.00	293.60	108.16	1,291.84
03	Irregular Help	0.00	0.00	0.00	0.00
04	Travel	3,950.00	0.00	3,950.00	0.00
05	Other Expense	6,000.00	686.14	5,313.86	686.14
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	8,600.00	4,687.00	3,913.00	4,687.00
	TOTAL	45,750.00	13,632.74	11,773.02	$ 33,976.98
			Total days	364	
			Days remaining	185	
			% remaining:	25.73%	

Patent information

CH2M HILL and the Idaho Department of Transportation have been contacted regarding further product development for both stream restoration and bridge scour monitoring. Patent applications have been submitted U.S. Patent Application No. 13/890,919 for METHOD AND APPARATUS FOR MONITORING WATERBED ENVIRONMENT USING TEMPERATURE MEASUREMENTS; U of I Ref. No. 12-009, KS Ref. No. 7832-91088-01.