Protocols Part 1: Set Up
Riparian Buffers Affect Stream Temperature (RBAST)
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Contents

Introduction

This document contains some of the protocols that should be followed by all participants. Adherence to the protocols will ensure that all of the data are collected in a uniform manner so that direct comparisons can be made among data from different sites. That is one of the strengths of this project. If you find that a protocol is not written clearly or that you have a situation at your location that is not addressed in a protocol, please contact the Project Coordinator, Jeff Simmons (simmons@msmary.edu).

Instrumentation Needed

I am recommending the use of sensors and dataloggers from Onset Computer Corp. (www.onsetcomp.com) based on their durability, reliability and data quality. Instruments from other sources are acceptable provided they have similar specs to those listed in the table below. Funding for some of this instrumentation has been provided by the EREN group through their RCN grant.

Table 1. List of instrumentation for low-intensity sites.

Item	Quant.	Unit Price	Cat. No.	Minimum Specs for comparable instruments
HOBO Pro v2 Water Temperature Data Logger	3-4	$123	U22-001	Accuracy: 0.2°C over 0° to 50°C; Resolution: 0.02°C at 25°C; data storage > 1 month at 30 min. logging interval
Optic USB Base Station (for interfacing computer with datalogger)	1	$120	BASE-U-4	
HOBOware Pro software (for communicating with dataloggers)	1	$ 99	BHW-PRO-WIN or BHW-PRO-MAC	
PVC pipe, 2" diam., 14 cm length	3-4	$5		
Paving Stone, 6" x 8"	3-4	$2		
Nylon rope, braided, 1m	1	$2		
Eyebolt with nuts, 4", ¼" diam.	3-4	$1		
Total		**$583-706**		

Table 2. Optional items and additional items for high-intensity sites.

Item	Quantity	Unit Price	Cat. No.	Minimum Specs for comparable instruments
Air Temp datalogger	1	$163	U23-001	Accuracy: 0.2°C over 0° to 50°C; Resolution: 0.02°C at 25°C; data storage > 1 month at 30 min. logging interval
Air Temp Smart Sensor, 12-bit, 2 m cable	1	$ 95	S-TMB-M002	
PAR Light Smart Sensor, 3 m cable	1	$220	S-LIA-M003	0 to 2500 umol/m2/sec; wavelengths of 400 to 700 nm
Solar Radiation shield (for housing air temp. sensors)	2	$ 59	RS3	
HOBO Micro Station Data Logger (for logging light, Air temp and humidity)	1	$220	H21-002	
PAR sensor bracket and arm	1	$29		
Total		**$845**		

Recommended Schedule

Table 1 below summarizes the measurements that should be made at low-intensity and high-intensity sites and when they should be made. The measurements marked optional do not have to be performed. However, if you would like your site to be one that is computer-modeled then you should complete the optional measurements.

Table 1. Summary and timing of measurements for low-intensity and high-intensity sites.

Measurement	Protocol	Timing	Locations
Low-Intensity Sites			
Stream water temperature	B, C	Every 15 min. (by datalogger)	Beginning and end of forested and open reaches.
Latitude, Longitude, Elevation	E	Once	For each datalogger location
Channel Length, Ave. Width, Ave. Depth	F	Once	Forested reach and open reach
Air Temperature	G	4 times, on clear sunny days at 14:00 to 15:00 hrs	Forested reach and open reach midpoints
Riparian Vegetation Description	H	Once	Forested reach and open reach
Canopy Shade (optional*)	I	Once, on a clear sunny day near noon	Forested reach and any open area
Discharge (optional)	J	Once	Forested reach and open reach
Meteorological Parameters (optional)	K	4 times, on the same days as Air Temperature	Local weather station
Photos *(take some photos of your stream and send them to Jeff Simmons)*		Once	Forested reach and open reach
High-Intensity Sites			
Stream water temperature	B, C	Every 15 min. (by datalogger)	Beginning and end of forested and open reaches.
Latitude, Longitude, Elevation	E	Once	For each datalogger location
Channel Length, Ave. Width, Ave. Depth	F	Once	Forested reach and open reach
Air Temperature	D	Every 15 min. (by datalogger)	Forested reach and open reach midpoints
PAR	D	Every 15 min. (by datalogger)	Open reach midpoint
Riparian Vegetation Description	H	Once	Forested reach and open reach
Canopy Shade	I	Once, on a clear sunny day near noon	Forested reach and any open area
Discharge	J	4 times (minimum), on the same days as meteorological parameters	Forested reach, open reach and any major tributaries

Meteorological Parameters	K	4 times minimum, on the same days as discharge	Local weather station
Photos *(take some photos of your stream and send them to Jeff Simmons)*		Once	Forested reach and open reach

Protocol A: Site Selection

1. Each stream reach must be no less than 80 m and no more than 200 m in length. The ideal length would be 200 m (without any tributaries or large groundwater inputs). If these inflows are present, then a shorter reach without any inflows would be preferable.

2. "Forested" stream reach should have mature tree canopy cover along 90% of length on both sides of stream (within 5 m of channel). Reaches with less than 90% coverage will likely be acceptable (contact Jeff Simmons) but they complicate the experimental design.

3. "Open" stream reach should have mature tree plus shrub cover along less than 10% of stream length (within 5 m of channel). Grasses, herbs, sparse shrubs, bare soil are all acceptable for the remaining 90+% (the less shade the better).

4. Ideally, the two reaches will be contiguous; that is, the forested reach will be directly upstream of the open reach or vice versa. The next preferred option is that the two reaches are on the same stream but separated by a short distance. The last option is to have the two study reaches on different streams of similar size and character located within about 5 km of each other.

5. The landuse within the watershed is not that relevant for this study. We will be measuring <u>change</u> in stream temperature over distance, so the absolute temperature is not as important. Similarly the land use within the watershed (with the exception of 5 m on either side of the channel) is not important at this fine spatial scale (<200 m) that we are using.

6. Stream must be 1st, 2nd or 3rd order with a preference for 2nd and 3rd order.

7. You should obtain landowner permission for conducting the research. If you are considering a longer-term study, it is best to have a landowner that is an agency or organization (county or state government, University, not-for-profit) to minimize the chance of the property being sold.

Protocol B: Stream Datalogger Installation

There are three steps to perform to calibrate the Water Temp Pro v2 dataloggers: 1) calibrate the dataloggers, 2) launch the dataloggers and 3) install the dataloggers. Note: do NOT calibrate air temperature dataloggers as they are not built to tolerate submersion.

1. Calibration
- If your dataloggers were shipped to you by Jeff Simmons at Mount St. Mary's University, then they have already been calibrated and you can skip to step 2. If you purchased them yourself, then you should perform this calibration procedure.

- Fill a plastic bin, small ice chest or small bucket with ice. Add tap water to just cover the ice.

- Follow the "Launch" procedure outlined in the following step (#2) to launch all of your dataloggers but choose a logging interval of 1 minute.

- Submerge all of the dataloggers in the ice bath. Make sure they are completely submerged. You can weight them down with a heavy object if necessary. If you have a NIST-certified thermometer, place it in the bath as well (if not, assume the water temperature is 0°C)

- Let them sit for <u>at least 30 min</u>. recording the thermometer temperature at 30 minutes (Table B-1) then remove them and dry them off.

- Download the data from the dataloggers following the instructions in the Protocol C. In Table B-1 below record the temperatures reported by each datalogger at 30 min. or the average of three temperatures when it has reached an equilibrium (approximately constant temperature). Round all temperatures to the nearest 0.1°C.

- Calculate the Correction Factor for each datalogger as described in the Table. Send a copy of this table to Jeff Simmons (simmons@msmary.edu) **by 1 August 2011**.

Table B-1. Calibration data for Water Temp Pro v2 dataloggers.		
Datalogger Serial No.	**Temp. at equilibrium (°C)**	**Correction Factor* (°C)**
NIST Thermometer^		

*Correction Factor = (Datalogger Temp at Equilibrium) – (Thermometer Temp.)
^If a NIST thermometer is not available, write in "0" for the Temp in this row.

2. Launch the Dataloggers
- What follows is a short-hand version of the procedure. Refer to the instructions that came with the software and with the datalogger if you have questions.

- Open the HOBOware Pro software program on a computer. Before using it for the first time, go to File/Preferences…. Then, under Export Settings, check the box next to "Separate date and time into two columns".

- Connect the Optic Base Station to your computer with the USB cable. Insert the base station into the black coupler labeled "U22/U24" (your Water Temp Pro v2 datalogger has the item # of U22). Then insert a Water Temp Pro v2 datalogger into the other side of the coupler, aligning the arrows on the coupler and datalogger.

- At the bottom of the HOBOware Pro window on the computer, you should see "Dev: HOBO U22-001Water Temp Pro…" once the computer identifies the datalogger. You should also see the green status light on the base station illuminate as the computer "talks to" the datalogger. Select Device/Launch… from the drop-down menu.

- In the Select Device dialog box select your datalogger and click [OK].

- The Launch dialog box will appear. It's a good idea to write down the datalogger's serial number so that you can use it to distinguish the dataloggers if labels fall off or the units get mixed up. I usually just use the last four digits of the number.

- In the Launch dialog box,

  o Verify that the battery level is "Good".

  o Type in a name or location for the datalogger under "Description"

  o Select the "Temperature 10K Thermistor" channel

  o Select a sampling interval of 15-min. (Note that at that interval size the logger has enough memory to record for about 450 days).

  o Select a "Delayed Start" and then enter a date and hour <u>so that the first log time will be on the hour</u> (e.g., 10:00, 15:00).

- Click on "Launch" and follow the prompts to unplug the device.

- Place a calibrated datalogger into a PVC protector and attach it using the 4-inch eyebolt and nuts. Thread the bolt through one hole in the plastic pipe, through the datalogger and out through the opposite hole in the pipe. Secure with two nuts or a locking nut (Figure A-1).

- Tie the PVC pipe securely to a 12" x 12" paving stone using ¼" nylon rope. The rope can be threaded through the other holes in the pipe body and/or through the eyebolt. It is possible to drill holes through the paving stones using a special masonry drill bit. Then the rope can be threaded through these holes.

Two ¼"hex nuts

5/16" to 3/8" diameter holes, ¾" from end

Eyebolt (4" long, ¼" diameter)

4 holes, at corners of a 1¼" square, 3/8" to ½" diameter

¼" nylon rope, about 1 meter in length
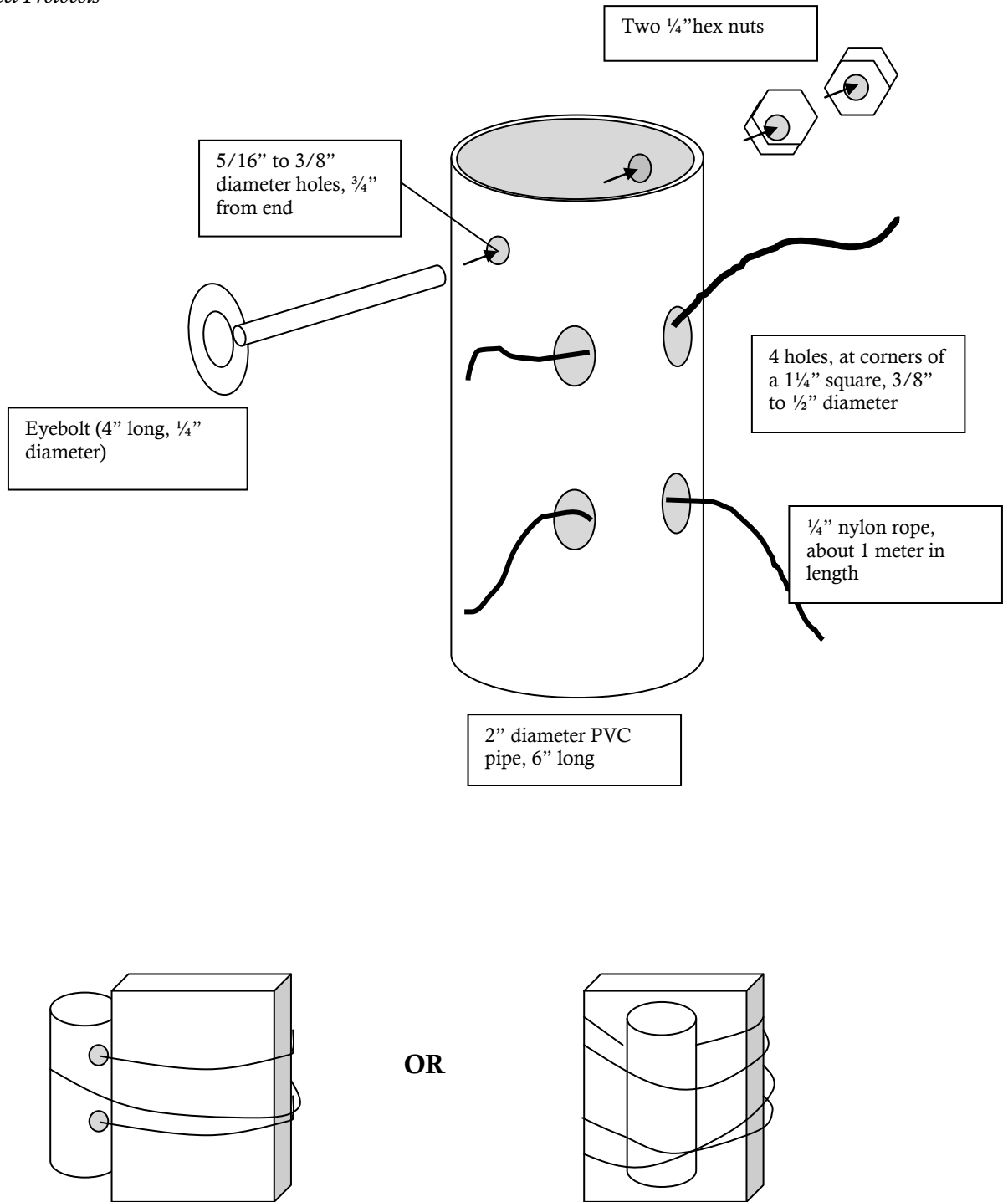
2" diameter PVC pipe, 6" long

OR

Figure A-1. Diagram of the construction of the stream datalogger protector from 2" PVC pipe and its attachment to a paving stone.

3. Install the dataloggers

- Take the paving stones with dataloggers out to the sampling locations. Submerge the stone and datalogger so that they rest in flowing water in a relatively deep portion of the stream where they are likely to remain submerged even during the dry time of year. Yet they should not be placed in a deep or stagnant pool where temperature changes will be sluggish. Orient the PVC pipe so that water flows in through the end with the eyebolt and out the other end.

- Mark the location of the dataloggers with flagging tape or pin flags on the stream bank. Take a photo of the location as well. Note the date and time of installation in Table B-2. Fill out Table B-2 every time the dataloggers are removed from the water. **By 15 October 2011** send a copy of Table B-2 to Jeff Simmons (simmons@msmary.edu).

Table B-2. Log of activity of dataloggers during the study period. Make note anytime the dataloggers are removed from the water. Also make notes of any time the dataloggers are moved or relocated or disturbed by flood.										
Datalogger Serial No.	Installation Date/ Time	Removed Date/ Time	Reinstalled Date/ Time	Removed Date/ Time	Reinstalled Date/ Time	Removed Date/ Time	Reinstalled Date/ Time	Removed Date/ Time	Reinstalled Date/ Time

Protocol C: Retrieval and Download of Stream Dataloggers

1. If you launch the dataloggers as described above, they will be able to record for the entire 4-month duration. However, you are strongly encouraged to download the dataloggers monthly, so that if something should happen to one of the dataloggers during the study period, no more than one month's data would be lost.

2. Create a **field notebook** for the project that is carried with you to the site each time you go. Make notes of all of the following events: dataloggers removed for download, dataloggers reinstalled in the stream, dataloggers moved, dataloggers not submerged, dataloggers moved or partially covered by sediment due to high water event, etc.

3. Follow manufacturer's instructions for downloading data. What follows is a condensed version.

4. In order to offload the data from the dataloggers, the dataloggers must be connected to a computer running the HOBOware Pro software. The quickest way is to bring a laptop computer to the field. If this is not possible, then remove the dataloggers from the stream, bring them back to your lab/office for offloading, and then return them to the stream ASAP.

5. Boot up the computer and start the HOBOware Pro software.

6. Wipe off the round window at the end of the datalogger so that it is clean and dry (the datalogger communicates with the base station via blinking lights that shine through this window). Attach the datalogger to the Optic Base Station using the appropriate coupler. Plug the Base Station into the computer. A green light should illuminate on the Base Station and the name of the device should appear at the bottom of the HOBOware Pro window.

7. Select Device/Readout… from the drop-down menu.

8. A dialog window will ask if you want to stop the logging of the datalogger. Select "Don't Stop" if you plan to redeploy the logger soon. Select "Stop" if you are going to store the datalogger or if you want to change the settings on it. (Note: if you stop the logging of the datalogger, you will need to "Launch" it again before deploying it).

9. After a lengthy wait a "Save" window will appear. Choose a location for the file and descriptive file name. At a minimum the file name should include: 1) either the site location or logger ID, 2) the current date, and 3) the word "temp". Click [SAVE].

10. The Plot dialog window will appear. You can just click on [Plot] or you can adjust some of the settings if you wish first.

11. The data file has been saved (?) as a .dtf or HOBO file. Next you need to export it as an Excel file. Go to File/Export table data…

12. An Export Options window will appear. Click on [Export].

13. After a lengthy wait, a Save dialog window will appear. Choose a location for the file and a descriptive file name. At a minimum the file name should include: 1) either the site location

or logger ID, 2) the current date, and 3) an acronym for your institution (e.g., MSMU, MC). Click [SAVE].

14. Send the Excel files to Jeff Simmons (simmons@msmary.edu) **by 15 October 2011**.

Protocol D: Installing Instrumentation at High Intensity Sites

Purpose: We want to be able to document any difference in air temperature between open and forested sites. For computer modeling, air temperature can be a main driver of stream temperature.

1. Materials Needed:

    *   2 mounting poles – You can purchase a real weather station tower or tripod or you can purchase a piece of galvanized metal conduit pipe (1" diameter, 6 ft. long). A section of 1" x 1" pressure treated lumber will work too (saw one end to a point).

    *   Sledge hammer or pole driver – for pounding the mounting pole into the ground

    *   Tools – screwdrivers, wrenches, pliers, measuring tape, etc.

    *   Level – to make sure the poles and PAR sensor are plumb and level.

    *   Duct Tape – hey, you never know when you'll need duct tape!

2. Sampling Locations - You will be setting up two sampling stations near the midpoint of each reach. One will be along the open reach and will monitor air temperature and PAR. The goal is to get the locate the sampling pole as close to the stream channel as possible while minimizing the chances of the sensors being submerged or washed away in a large flood. You'll have to use your best judgment for identifying the "flood zone". I recommend 0.5 to 2 m from the stream channel. The air temperature sensor should be mounted 0.5 m above the ground. The PAR sensor should be mounted between 0.5 and 1m above the ground.

    The second sampling station will be along the forested reach and will measure air temperature only. As in the open reach, the pole should be 0.5 to 2 m from the stream channel and out of the "flood zone". The air temperature sensor should be mounted 0.5 m above the ground. Try to avoid locating the pole right in or under a large shrub. Also it should be in a location that has canopy cover that is representative of the reach in general (i.e., avoid canopy gaps).

3. Test Run – Put the instruments together in the lab and test them all first. Connect the sensors to the Microstation and the microstation to the computer. Launch them and collect data for an hour or a day. Then download the data and make sure it all checks out and that you are getting readings. Don't attach anything to the mounting poles until AFTER they have been inserted into the ground (the pounding will dislodge anything on the pole).

4. Read the manufacturer instructions for operating and maintaining the instruments. This protocol will give just a brief overview.

5. Setting Up in the Field:

    *   Install the mounting pole first. Try to get it as plumb (vertical) as possible using a level.

    *   Attach the air temperature sensor to the solar radiation shield, then mount the shield to the pole so that the sensor is 0.5 m above ground level.

- In the open reach, attach the arm bracket to the pole just above the solar radiation shield and point it south (so you won't get a possible shadow from the pole). Attach the PAR sensor to the end of the bracket arm about 0.5 to 1.0 m above ground level. Make the PAR sensor as close to level as you can by adjusting the mounting screws on the bottom.

- Attach the Microstation to the pole above the other sensor mounts and facing north (to reduce overheating in the sun).

- Connect the sensor cables to the Microstation. Wrap them around the pole and arm or secure them with tape or cable ties.

6. Launching the Microstation and Sensors – Connect your laptop to the Microstation with the cable. Open HOBOware Pro and select Device/Launch… Set the datalogger to sample every minute and to log at 15 min. intervals (at 0, 15, 30 and 45 minutes past the hour). With this configuration air temperature and PAR will be measured every minute, and the 15-minute average will be recorded after 15 minutes. You can use the <delayed start> option to start the logging right on the hour.

Protocol E: Latitude, Longitude and Elevation

Purpose: To record the exact location of the study site and each datalogger.

1. In Table D record the latitude and longitude of each datalogger in decimal degrees (dd.ddddd°) and elevation in meters using a GPS unit.

2. Submit Table E to Jeff Simmons (simmons@msmary.edu) **by 1 August 2011**.

Table E. Data table for latitude, longitude and elevation of each sampling location.					
Site Name or ID	**"Treatment"**	**Datalogger Serial Number**	**Latitude (decimal degrees)**	**Longitude (decimal degrees)**	**Elevation (m)**
	Forested Upstream				
	Forested Downstream				
	Open Upstream				
	Open Downstream				

Protocol F: Stream Channel Length, Width, Depth

Purpose: Quantify the mean width and depth of the stream as well as its length for descriptive purposes and for use in the computer model.

1. Using a tape measure, measure the actual channel length (in meters) of the forested stream reach and the open reach. The measurement should follow all the curves of the channel.

2. At 5 points along the forested reach and the open reach, measure the wetted channel width (i.e., from water line to water line). Points may be selected randomly or at regular intervals.

3. At the same locations at which width is measured lay out a transect across the stream channel and measure the water depth with a meter stick or ruler at 6-8 equidistant points along the transect. Average these to obtain the mean depth at that point in the stream.

4. Calculate the average depth and the average width for each reach.

5. Measure the slope of your two stream reaches using a sight level or clinometer. If the slope changes a lot within a reach, measure it at a few locations and take an average. The slope should be calculated as vertical drop / horizontal distance * 100%.

6. Record all results in Table F and submit to Jeff Simmons (simmons@msmary.edu) **by 1 August 2011**.

Table F. Data table for stream reach length, width, depth and slope. The slope should be calculated as vertical drop / horizontal distance * 100%.					
Site Name or ID	**"Treatment"**	**Channel Length (m)**	**Ave. Channel Width (m)**	**Ave. Channel Depth (cm)**	**Stream Channel Slope (%)**
	Forested				
	Open				
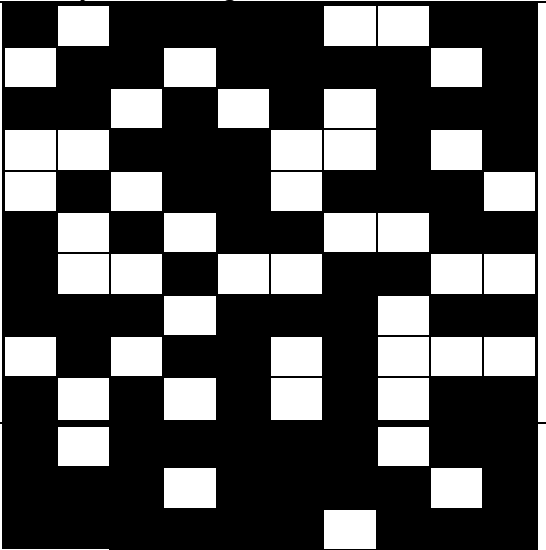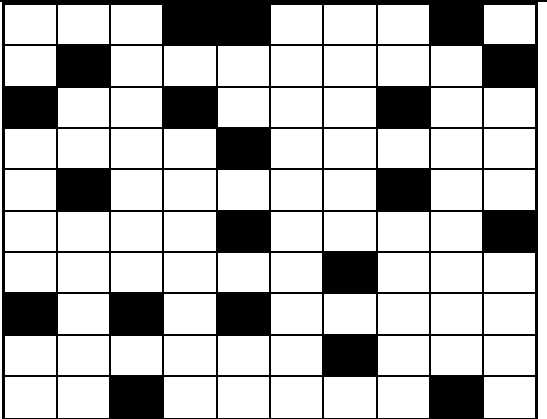
Protocol G: Air Temperature

Purpose: To provide an estimate of the maximum daily air temperature on a few clear, sunny days to verify that there is a difference in air temperature between the two reaches and for use in computer modeling.

1. If air temperature dataloggers are not being used, record air temperature at each reach just above the stream (0.5 m) about once a month (4 times total) on a clear, sunny day near the time of highest temperature (2:00 to 3:00 pm). Measure it near the midpoint of each reach and measure the two air temperatures as close to concurrently as possible.

Table G. Afternoon air temperatures at the midpoint of each reach on four dates during the summer of 2011.			
Location	**Air Temperature (°C)**	**Date**	**Time**
Forested			
Open			
Forested			
Open			
Forested			
Open			
Forested			
Open			

Protocol H: Riparian Vegetation Description

1. For each of the two reaches make estimates of the amount of forest (tree and shrub) coverage as follows.

2. Establish 8 transects across the stream in both the forested and open reaches. The transects will extend 5 m away from the <u>edge</u> of the stream channel (either the water line or the edge of an obvious channel) on both sides. Walk the transect from one end to the <u>center</u> of the stream and estimate the average % coverage of leaves overhead along the entire 5+ m transect.

3. Score each transect using the categories in Table G-2. Table G-3 shows illustrations of various amounts of percent cover. Record the scores in Table G-1.

4. Make a separate score for the same transect on the other side of the stream.

5. Make a list of the dominant or most abundant plant species present in the 5m-wide buffer zone along the forested reach and the open reach. This list does not need to include every species present nor their relative abundances. If species names are not known, broad taxonomic groups are acceptable ("grasses", "mosses", "vines", etc.).

Table H-1. Data table for recording % cover of the forested and open stream reaches.

Reach (*Forested or Open?*)	Location of Transect	Side of the Channel (*N, S, E, W*)	% Cover Score

Table H-2. Scores used to quantify the percent cover by overhead vegetation in riparian zones.

Score	0	1	2	3	4	5
Percent Cover	0%	1 – 20%	20-40%	40-60%	60-80%	80-100%

Table H-3. Examples of percent cover distributions using randomly selected squares in a 10 x 10 box.

0%	(No leaves or branches to very few leaves or branches)	60%	
20%		80%	

40%		**100%**	
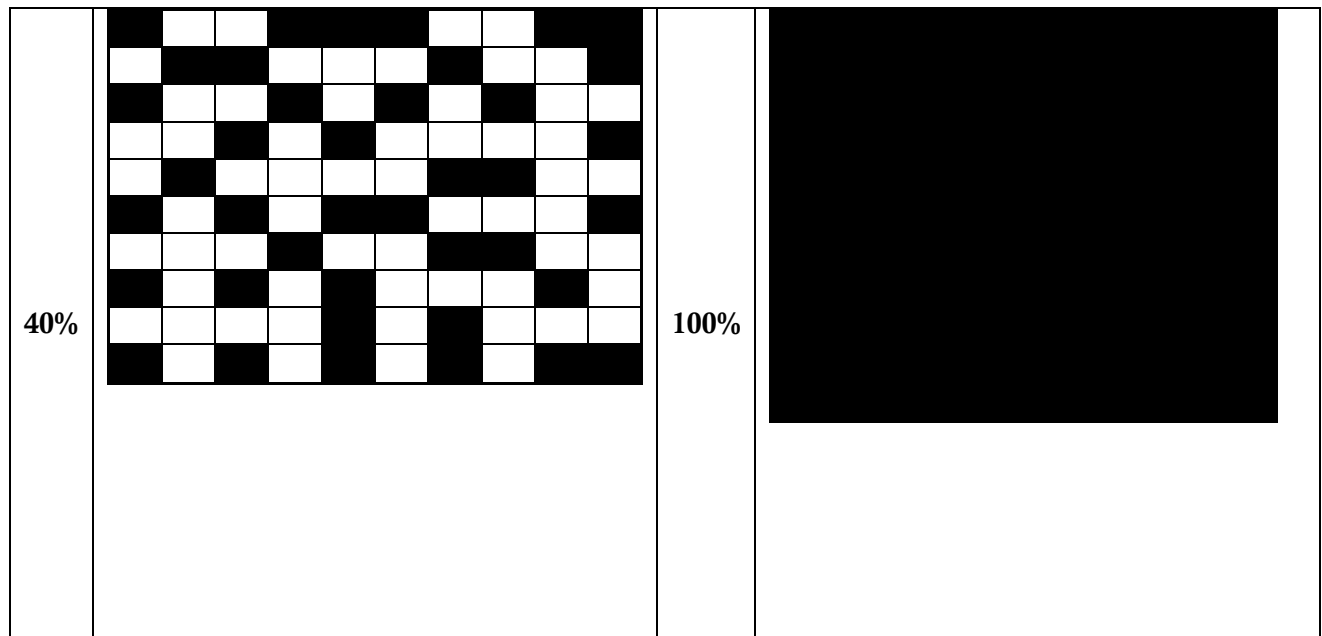
Protocol I: Canopy Shade

- For the stream model we will need a measure of the relative difference in light level between forested and open reaches. The light level is measured using a light meter. We have two light meters (model EA30 from Extech Instruments, Inc.) that can be shipped among our sites so that everyone can take a set of readings. Alternatively, you can purchase your own. The main criterion for purchasing a light meter is that it measures mainly from 350 to 700 nm (the visible spectrum). The EA30 mentioned above has silicon photodiode with a spectral response filter that transmits visible wavelengths. Because the variable of interest is the <u>relative</u> amount of shade compared to the open site, consistency in instrumentation and accuracy are not that critical.

- The model defines the variable "Shade Quality" as

  Shade quality = $1.0 - (E_i / E_o)$

  where E_i = light level in the forested reach at midday

  E_o = light level at the open reach at midday

- Both E_i and E_o should be measured as close to concurrently as possible because light levels change continuously as the sun moves across the sky. To avoid changes in irradiance due to clouds, measurements should be made on a clear day with few clouds (and make sure you only take readings when the sun is not obscured by clouds) near midday when the sun is high in the sky (between 10:00 am and 2:00 pm). You will take several readings along the forested and open reaches because light levels can vary tremendously under a forest canopy due to sun flecks.

- You will measure the incident light level at 0.5 m above the ground (or water) surface at 21 points along a 20-m stretch of stream within each reach. To prevent delays between measurement of the two reaches, mark the two 20-m stretches with flags or stakes before you start. You can either walk in the stream or along the stream bank to take the measurements.

- The following instructions pertain to the EA30 Extech light meter. If you have a different meter, follow the manufacturer's instructions.

  o Stand at one end of the 20-m stretch that you have marked.

  o Turn on the light meter by pressing the power button. Remove the protective cap from the light sensor. Press the [lux] button so that the readout is in lux.

  o Kneel or squat down and hold the light sensor out at arm's length at about 0.5 m height above the ground or stream surface. By squatting or kneeling, you reduce the amount of shade created by your body. Try to hold the sensor as level as possible. If the reading is out of range, "OL" will be displayed. Press [Range]to change the range of the meter until you get a viable reading. Record the reading in lux (or kilolux) in Table I-1.

- Move one meter downstream or upstream towards the other end of the stretch you have marked and take another reading as described in the previous step. Take measurements every 1 m along the 20-m stretch.

- As soon as you finish with the first reach proceed to the next reach so that the irradiance does not change too much and repeat this procedure.

- When done, calculate the average E_i and the average E_o. Calculate Shade Quality as described above using the average E_i and E_o values. Submit this information including your raw data to Jeff Simmons (simmons@msmary.edu) by 1 September 2011.

Table I-1. Data table for light intensity data. The forested and open reaches should be sampled on the same day. For "Time Range" write in the start and end times of sampling.
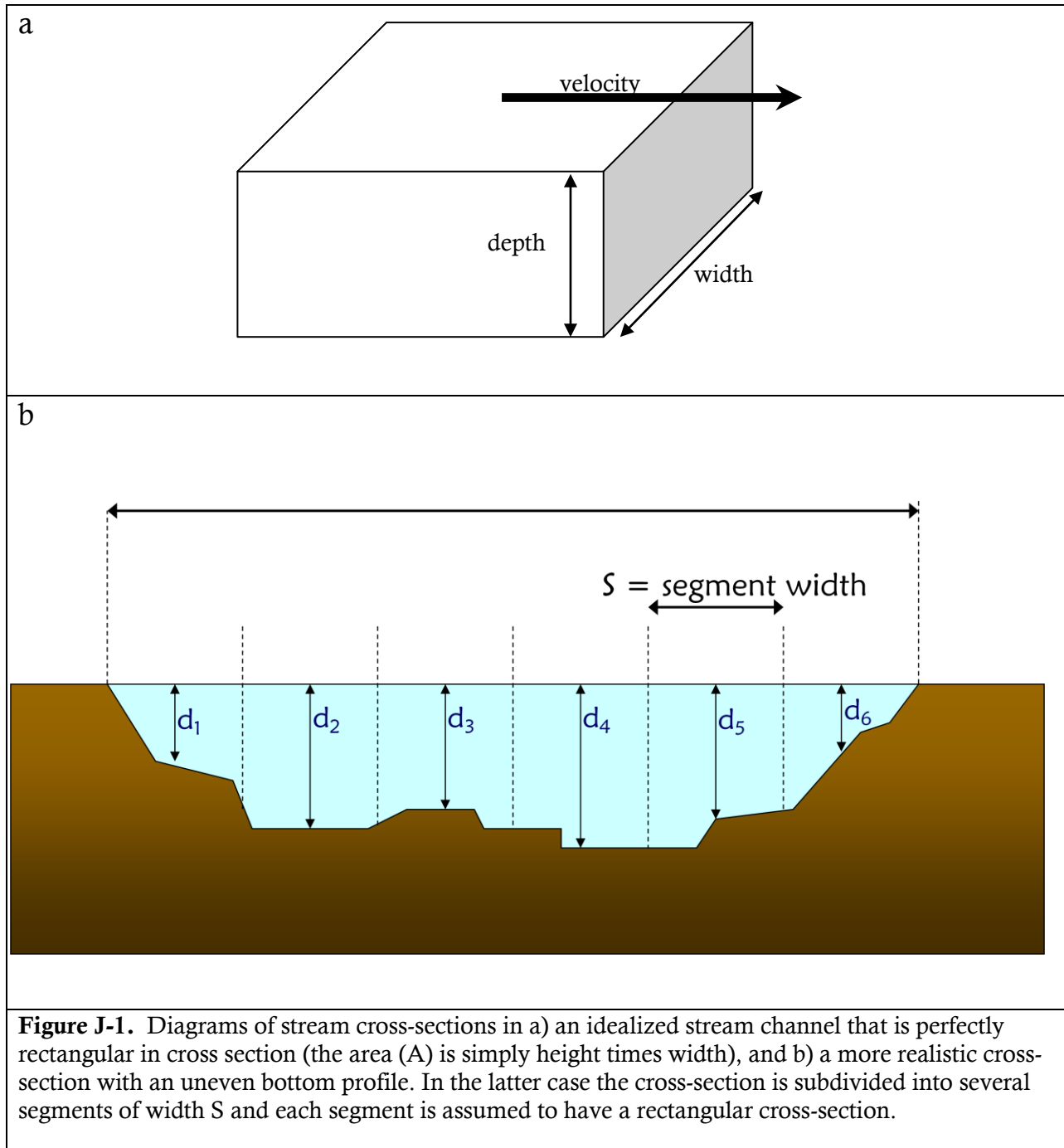
Date:				
Forested Time Range:			**Open Time Range:**	
Forested			**Open**	
Transect Location	**Light Intensity (lux)**		**Transect Location**	**Light Intensity (lux)**
0 m			0 m	
1 m			1 m	
2 m			2 m	
3 m			3 m	
4 m			4 m	
5 m			5 m	
6 m			6 m	
7 m			7 m	
8 m			8 m	
9 m			9 m	
10 m			10 m	
11 m			11 m	
12 m			12 m	
13 m			13 m	
14 m			14 m	
15 m			15 m	
16 m			16 m	
17 m			17 m	
18 m			18 m	
19 m			19 m	
20 m			20 m	
21 m			21 m	
Mean:			**Mean:**	
St. Deviation:			**St. Deviation:**	

Protocol J: Discharge

Discharge will be measured at the high-intensity sites on at least 4 dates encompassing a range of flow rates. Also measure wetted channel width and average depth at the point where discharge was measured. Low-intensity sites are encouraged to measure discharge at least once to give an idea of the size of the stream. If the two study reaches are adjacent or relatively close, only one discharge measurement may be necessary. However, if the study reaches are some distance apart or if a major tributary enters between the two reaches, then discharge should be measured in both reaches. Any major tributaries to the stream within the study reaches should be measured for discharge as well.

There are several methods and instruments available for measuring discharge, each with its own degree of accuracy and precision. Because flow meters can be expensive and because discharge is not a key variable, consistency among all participants is not essential. That is, you can use whatever method you are familiar with or whatever method you can afford. The method described here is the Area-Velocity Method that requires a flow meter to measure the velocity of the flowing water. A good summary of the method has been published by our own Frank Kuserk at Moravian College (The American Biology Teacher, Vol. 51, No. 2 (Feb., 1989), pp. 100-102).

1. Materials: Velocity meter (like a Marsh-McBirney, electromagnetic meter or a propeller-type meter), wading rod or yardstick, tape measure, stakes, hammer, clipboard, data sheet.

2. The principle behind this method lies in the simple equation $Q = A * v$, where Q is the discharge (m^3 s^{-1}) moving past a point in the stream, A is the cross-sectional area of the wetted stream channel at that point (m^2) and v is the velocity of the water at that point. In an ideal stream channel that has a perfectly rectangular cross-section, the area, A, will be simply depth times width (Figure J-1a).

Figure J-1. Diagrams of stream cross-sections in a) an idealized stream channel that is perfectly rectangular in cross section (the area (A) is simply height times width), and b) a more realistic cross-section with an uneven bottom profile. In the latter case the cross-section is subdivided into several segments of width S and each segment is assumed to have a rectangular cross-section.

3. In a more typical stream channel the cross-section shape is more irregular; therefore, the channel is subdivided into 10-20 segments of equal width (S). Each segment is assumed to be rectangular in shape. This assumption is most valid with many, very narrow segments. The depth of each segment, D_i, is measured at the center of the segment (Figure 1b). The velocity, v_i, is also measured in the center of each segment.

4. Then, the discharge, Q_i, is calculated *for each segment* ($Q_i = A_i * v_i = \{S*d_i\} * v_i$). The total discharge for the whole channel, Q, is then the sum of all the Q_i values.

5. Select a section of the channel that is relatively straight for at least 2 m, free of major boulders or other large flow blockages, and at least 4 cm inches deep in <u>some</u> places. Try to avoid sections that have an island or gravel bar. Also avoid very slow-moving or deep pools and avoid riffles where the water surface is very uneven.

6. Pound in a stake on either side of the stream channel and attach the tape measure to each stake so that it is suspended just above the water line. The tape measure marks the transect across the channel. When locating this transect try to avoid, to the extent possible, large underwater obstacles like boulders or logs (these will introduce additional error into your calculation because they interfere with laminar flow). It is OK to relocate these obstacles in the channel before taking your measurement.

7. Record the total wetted channel width (from water's edge to water's edge in meters) using the tape measure.

8. Divide the channel into 10 to 20 segments of equal length. For example, if the channel is 160 cm in width, then you might select 16 cm (10 segments) or 10 cm (16 segments) as the segment length, S. Record S (in cm) on your data sheet.

9. Starting at one end of the transect, identify the first segment (S_1) on the measuring tape, locate the midpoint of that segment. Measure and record the depth (D_1) at the midpoint in cm. Using your flow meter, measure velocity at the midpoint at a depth equal to 60% of the total depth. For example, if the depth, D_1, is 20 cm, velocity should be measured 12 cm from the water's surface. (This depth is used because it should approximate the *average* velocity over the entire depth profile). This is where a wading rod is really handy. It allows you to measure depth and velocity at the same time and it automatically "calculates" the correct depth for the probe.

10. Repeat the previous step for each segment across the channel.

11. If the water depth at the midpoint of a segment is less than 4 cm, you may not be able to get a velocity reading. In this case, assign that segment a discharge of zero. The error introduced by omitting that segment is very small.

12. When done, remove the measuring tape and stakes.

13. Calculate Q_i for each segment. Remember to convert cm to m. Calculate Q for the stream channel.

$$Q_i \ (\text{m}^3 \ \text{s}^{-1}) = \{S \ (\text{cm}) * d_i \ (\text{cm}) \ / \ 10{,}000 \ (\text{cm}^2 \ \text{m}^{-2})\} \ * \ v_i \ (\text{m} \ \text{s}^{-1})$$

$$Q \ (\text{m}^3 \ \text{s}^{-1}) \ = \ \sum \{Q_i \ (\text{m}^3 \ \text{s}^{-1})\}$$

14. Report the <u>discharge</u>, <u>average velocity</u> and the <u>wetted channel width</u> to Jeff Simmons (<u>simmons@msmary.edu</u>) by **15 October 2011**.

Date/Time	Forested or Open Reach?	Discharge $(m^3 \, s^{-1})$	Total Wetted Channel Width (m)	Average Velocity $(m \, s^{-1})$
Table J-1. Data table for discharge measurements				

Field Data Sheet for Discharge (Area-Velocity Method)

Discharge $(Q, \text{m}^3 \text{ s}^{-1}) = \sum [\text{Area } (A_i, \text{m}^2) * \text{Velocity } (v_i, \text{m s}^{-1})]$

Segment #	1	2	3	4	5	6	7	8	9	10
Segment Width (cm)										
Depth (cm)										
Area (m²)										
Velocity (m s⁻¹)										
Q (m³ s⁻¹)										

Segment #	11	12	13	14	15	16	17	18	19	20	Total
Width (cm)											
Depth (cm)											
Area (m²)											
Velocity (m s⁻¹)											
Q (m³ s⁻¹)											

$1 \text{ m}^2 = 10^4 \text{ cm}^2$

Protocol K: Meteorological Information

- In order to use the computer model SSTemp on your site, we will need several meteorological values. If you are a high-intensity site, you are already collecting most of these data. Because SSTemp simulates just a single day it is best if you can <u>collect all of these data on the same date or dates</u> and on the same days that you measure air temperature and/or discharge so that all data will be temporally consistent.

- Locate the weather station that is nearest to you. Check Weather.com and Weatherbug.com as well as the National Climate Data Center. Obtain the following information for the day or days that you would like modeled. Note that some sources, like Weatherbug.com, will report real-time data that you can access that day (and only that day). Other sources like the NCDC will have a time lag of 3 – 6 months before the data are publicly available so you will have to wait until the data are published before you can obtain the data.

- The data you will need for each day are:

  - Daily mean air temperature (°C)

  - Daily maximum air temperature (or 3:00 pm air temperature in °C. This is optional if you have measured this parameter at your site already)

  - Daily mean relative humidity (%)

  - Daily mean wind speed (mph or kph)

  - Mean annual air temperature for 2010 (°C). This value is needed to estimate ground and groundwater temperature (which tends to be strongly correlated with mean annual air temperature).

  - Elevation of weather station and distance from your site (or lat/long of the weather station). This info will allow us to correct for elevational differences in air temperature and humidity between the weather station and your site.

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Date	Daily Mean Air Temperature (°C)	Daily Maximum Air Temperature (°C)	Daily Mean Relative Humidity (%)	Daily Mean Wind Speed (mph or m/s)

Table K-1. Meteorological information obtained from local weather station.

Table K-2. Regional weather station information.			
Weather Station Name or ID	**Elevation (m)**	**Distance from site (or latitude/longitude)**	**Mean Annual Air Temperature for 2010**

Protocol L: Additional Information

Some additional information about the participants is needed for reporting purposes to the EREN collaboration. Please answer the following questions and submit the answers to Jeff Simmons (simmons@msmary.edu) **by 15 March 2012**.

1. How many students participated in the RBAST project as research assistants, work study students, lab technicians or as part of an independent study or research experience?	
2. Did a class participate in the project (either in field or lab work or by making use of the data)? If so, please give the course title, course number, semester taught, and enrollment.	
3. How many faculty participated in the RBAST project at your site?	
4. How many students from questions 1 and 2 were minority students?	
5. How many faculty from question #3 were minority students?	