Mountainous Regions. I - Hydrological Measurements; the Water Cycle, IAHS Publication No. 193, International Association for Hydrological Science, Proceedings of two Lausanne Symposia, August 1990, pp. 247–254.

Hongve, D. 1987. A revised procedure for discharge measurements by means of the salt dilution method. Hydrological Processes 1:267–270.

Johnstone, D.E. 1988. Some recent developments of constant-injection salt dilution gauging in rivers. Journal of Hydrology (New Zealand) 27:128–153.

Mellina, E., R.D. Moore, S. Hinch, S. Macdonald, and G. Pearson. 2002. Stream temperature responses to clear-cut logging in British Columbia: the moderating influences of groundwater and headwater lakes. Canadian Journal of Fisheries and Aquatic Sciences 59:1886–1900.

Moore, R.D. 2004a. Construction of a Mariotte bottle for constant-rate tracer injection into small streams. Streamline Watershed Management Bulletin 8(1):15–16.

Moore, R.D. 2004b. Introduction to salt dilution gauging for streamflow measurement: Part I. Streamline Watershed Management Bulletin 7(4):20–23.

Story, A.C., R.D. Moore, and J.S. Macdonald. 2003. Stream temperatures in two shaded reaches below cut blocks and logging roads: downstream cooling linked to subsurface hydrology. Canadian Journal of Forest Research 33:1383–1396.

Construction of a Mariotte Bottle for Constant-rate Tracer Injection into Small Streams

R.D. (Dan) Moore

Liquid tracers are commonly injected into streams to measure streamflow, hydraulic characteristics, and rates of nutrient uptake (e.g., Webster and Ehrman 1996; Story *et al.* 2003). A Mariotte bottle, based on a device developed by the French physicist Edme Mariotte in the 17th century, provides a simple method for injecting tracer at a constant rate. This article describes the construction and application of a Mariotte bottle appropriate for injecting tracer into small streams.

Construction

A simple Mariotte bottle can be constructed from a carboy fitted with a spigot (Figures 1 and 2; Table 1). A 10-L carboy holds a sufficient volume of tracer for gauging small streams at low flow, and fits into a large backpack for transport to remote field sites. We have measured flows as low as 1 L/s and as high as 100 L/s using a Mariotte bottle (e.g., Mellina *et al.* 2002; Story *et al.* 2003).

D. Moore

Figure 1. Materials required to construct Mariotte bottle. From left to right: 10-L carboy, pipette tip, Quick Disconnect Connector, rubber stopper with Plexiglas tube inserted.

To construct the Mariotte bottle, the screw-on cap is replaced by a size 13½ one-hole rubber stopper with a length of Plexiglas tube inserted to a level about 10 cm higher than the spigot level. The tube should be inserted such that it remains below the surface of the tracer fluid (as shown in Figure 2) throughout the measurement period; otherwise, tracer solution will not discharge at a constant rate. The tube allows air to enter as water drains, thereby maintaining a constant water pressure at the spigot, resulting in a constant outflow rate. The lower end of the tubing should be cut on a bevel, to facilitate bubbling.

The spigot is fitted with a tubing connector and pipette tip with the end cut off. The non-tapered end of the tubing connector fits snugly into the spout of the carboy, and the pipette tip is slid over the tapered end of the connector. This set-up "steps down" the outflow rate, and allows the spigot to be opened fully for delivery of tracer while controlling the injection rate. Several pipette tips with a range of hole diameters allow for a range of injection rates. It is important that the outflow be a continuous stream rather than discrete drips. If the water drips out, air will enter and create an inconsistent outflow rate.

Application

The Mariotte bottle can be set up on a square of plywood fixed to the top of a tripod, to provide a stable base for the bottle. If the stream is narrow, it may be possible to have the tripod legs span the stream.

After setting up the Mariotte bottle, open the spigot to begin injection. When the spigot is first opened, the

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Table 1. Equipment list

Item
10-L carboy (Nalgene no. 2318-0020)[1]
Quick Disconnect Connector (Nalgene no. 6150-0010)[1]
Pipette tip (100- to 1000-L volume)
13½ one-hole rubber stopper
40 cm length of Plexiglas tubing (5 mm outside diam.)
Tripod with plywood square

[1]Nalgene part numbers provided purely for reference. No specific endorsement of Nalgene parts relative to alternative manufacturers is intended or should be implied.

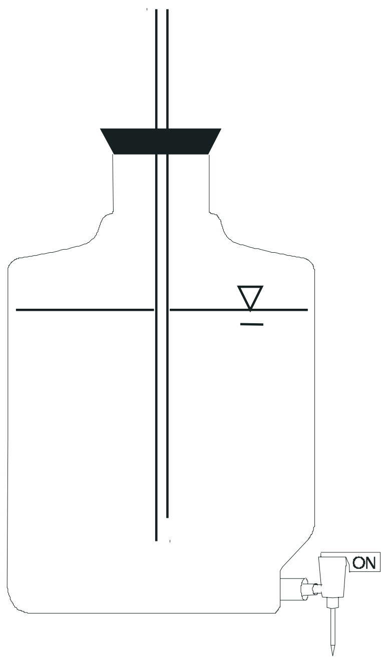

Figure 2. Schematic of assembled Mariotte bottle.

injection rate will be higher than the ultimate steady-state rate until air begins bubbling through the air entry tube. Once "bubbling" begins, the injection rate will be constant. Bubbling can be detected by listening for the distinctive "gurgling" sound that occurs every few seconds. Because the Mariotte bottle will initially drain at a rate higher than the steady-state constant rate, the measured tracer concentration in the stream (e.g., as measured by electrical conductivity for salt injection) may initially overshoot and then settle down to the steady-state value. To avoid this, a bucket can be used to catch the injection solution until constant flow is established.

The injection rate (q) can be measured using a 100-mL graduated cylinder and a stopwatch. It is important to measure q in the field, since the injection rate via the pipette tip varies with temperature. In addition, the outflow rate is influenced by the orientation of the pipette tip, which depends on the inclination of the support base for the Mariotte bottle, and on the height of the lower end of the bubbler tube. Several trials should be conducted to obtain an average outflow rate. Repeated measurements also allow estimation of the uncertainty for use in error analysis.

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References

Mellina, E., R.D. Moore, S. Hinch, S. Macdonald, and G. Pearson. 2002. Stream temperature responses to clear-cut logging in British Columbia: the moderating influences of groundwater and headwater lakes. Canadian Journal of Fisheries and Aquatic Sciences 59:1886–1900.

Story, A.C., R.D. Moore, and J.S. Macdonald. 2003. Stream temperatures in two shaded reaches below cut blocks and logging roads: downstream cooling linked to subsurface hydrology. Canadian Journal of Forest Research 33:1383–1396.

Webster, J.R. and T.P. Ehrman. 1996. Solute dynamics. In Methods in Stream Ecology. F.R. Haver and G. Lamberti (editors). Academic Press, Toronto, Ont.

Profile

Dr. Markus Weiler: A New Face in B.C. Hydrology

How and when do hillslopes contribute to streamflow in watersheds? How does residence time of water draining a watershed affect flow pathways and storage as well as water quality? How do natural and human disturbances in forested watersheds change the properties of soils and hence infiltration characteristics and flow paths of water? These are some of the questions that Dr. Markus Weiler, Assistant Professor in the Departments of Forest Resources Management and Geography at the University of British Columbia (UBC), and FRBC Chair in Hydrology since January 2004, is currently investigating.

Dr. Weiler completed his Ph.D. at the Swiss Federal Institute of Technology (ETH) in Zurich, Switzerland in 2001. His dissertation dealt with the experimental identification and numerical modelling of flow in natural soils, to evaluate the effects of macropore flow on runoff generation and to predict flow pathways in watersheds. While at ETH, Markus also collaborated on various consulting projects related to stochastic hydrology, flood hydrology, and impacts of environmental changes on surface and subsurface hydrology.

Weiler spent the last two years in the United States as a postdoctoral researcher in the Department of Forest Engineering at Oregon State