science for a changing world

Prepared in cooperation with the Tennessee Department of Transportation

A Modified Siphon Sampler for Shallow Water

Scientific Investigations Report 2007–5282

U.S. Department of the Interior
U.S. Geological Survey

Cover photograph. U.S. Geological Survey Station 034336392 (Slick Rock Hollow Creek near Pewitt Chapel, Tennessee). Photograph taken by Shannon D. Williams, April 7, 2005.

A Modified Siphon Sampler for Shallow Water

By Timothy H. Diehl

Prepared in cooperation with the Tennessee Department of Transportation

Scientific Investigations Report 2007–5282

U.S. Department of the Interior
U.S. Geological Survey

U.S. Department of the Interior
DIRK KEMPTHORNE, Secretary

U.S. Geological Survey
Mark D. Myers, Director

U.S. Geological Survey, Reston, Virginia: 2008

For product and ordering information:
World Wide Web: *http://www.usgs.gov/pubprod*
Telephone: 1-888-ASK-USGS

For more information on the USGS—the Federal source for science about the Earth, its natural and living resources, natural hazards, and the environment:
World Wide Web: *http://www.usgs.gov*
Telephone: 1-888-ASK-USGS

Suggested citation:
Diehl, T.H., 2008, A modified siphon sampler for shallow water: U.S. Geological Survey Scientific Investigations Report 2007–5282, 11 p.

Contents

Abstract.....1
Introduction.....1
Acknowledgment.....3
Design and Operation.....3
Comparison to DH-48.....5
Summary.....10
References Cited.....10

Figures

1–3. Diagrams showing—
1. Features of the U-59A, one model of the siphon samplers developed by the U.S. Geological Survey in the 1950s.....1
2. The siphon sampler of Gray and Fisk (1992), after Bent and others (2001).....2
3. One modified siphon sampler bottle showing intake and air vent.....3
4–7. Photographs showing—
4. Two views of a modified siphon sampler with three pairs of bottles mounted to a tall crest-stage gage.....4
5. Modified siphon sampler mounted on boards bridging the channel.....6
6. Modified siphon sampler mounted on a steel frame.....7
7. Modified siphon sampler mounted on a vertical steel rod.....8
8–9. Graphs showing—
8. Turbidity of paired samples collected with the DH-48 isokinetic sampler and with the modified siphon sampler.....9
9. Suspended-sediment concentration of paired samples collected with the DH-48 isokinetic sampler and with the modified siphon sampler.....9

Table

1. Suspended-sediment concentration and turbidity of paired samples collected with the DH-48 isokinetic sampler and with the modified siphon sampler.....8

Conversion Factors, Abbreviations, and Acronyms

Multiply	By	To obtain
	Length	
centimeter (cm)	0.3937	inch (in.)
millimeter (mm)	0.03937	inch (in.)
meter (m)	3.281	foot (ft)
	Volume	
liter (L)	33.82	ounce, fluid (fl. oz)
liter (L)	0.2642	gallon (gal)
liter (L)	61.02	cubic inch (in^3)
	Flow rate	
meter per second (m/s)	3.2808	foot per second (ft/s)
millimeter per second (mm/s)	0.0032808	foot per second (ft/s)

Concentrations of constituents in water are given in milligrams per liter (mg/L).

Acronyms

CSG Crest-stage gage

NTRU Nephelometric turbidity ratio unit

SSC Suspended-sediment concentration

USGS U.S. Geological Survey

A Modified Siphon Sampler for Shallow Water

By Timothy H. Diehl

Abstract

A modified siphon sampler (or "single-stage sampler") was developed to sample shallow water at closely spaced vertical intervals. The modified design uses horizontal rather than vertical sample bottles. Previous siphon samplers are limited to water about 20 centimeters (cm) or more in depth; the modified design can sample water 10 cm deep. Several mounting options were used to deploy the modified siphon sampler in shallow bedrock streams of Middle Tennessee, while minimizing alteration of the stream bed.

Sampling characteristics and limitations of the modified design are similar to those of the original design. Testing showed that the modified sampler collects unbiased samples of suspended silt and clay. Similarity of the intake to the original siphon sampler suggests that the modified sampler would probably take downward-biased samples of suspended sand. Like other siphon samplers, it does not sample isokinetically, and the efficiency of sand sampling can be expected to change with flow velocity. The sampler needs to be located in the main flow of the stream, and is subject to damage from rapid flow and floating debris.

Water traps were added to the air vents to detect the flow of water through the sampler, which can cause a strong upward bias in sampled suspended-sediment concentration. Water did flow through the sampler, in some cases even when the top of the air vent remained above water. Air vents need to be extended well above maximum water level to prevent flow through the sampler.

Introduction

Siphon (or "single-stage") samplers provide an inexpensive, reliable way to collect samples automatically from rising water at predetermined stages. Such samples have historically been used by the U.S. Geological Survey (USGS) for suspended-sediment analysis, but can be analyzed for turbidity and dissolved constituents as well. Each sampler includes a sample container—typically a 0.5- to 1.0-liter (L) bottle—an intake tube, and an air vent (fig. 1). When water rises to the approximate level of the top of the intake tube, it flows into the sample container until the inner end of the air vent is submerged. An air bubble trapped in the upper part of the air vent prevents water from flowing through the sampler. Multiple samplers typically are used at a site and are spaced vertically to collect samples across a range of stages.

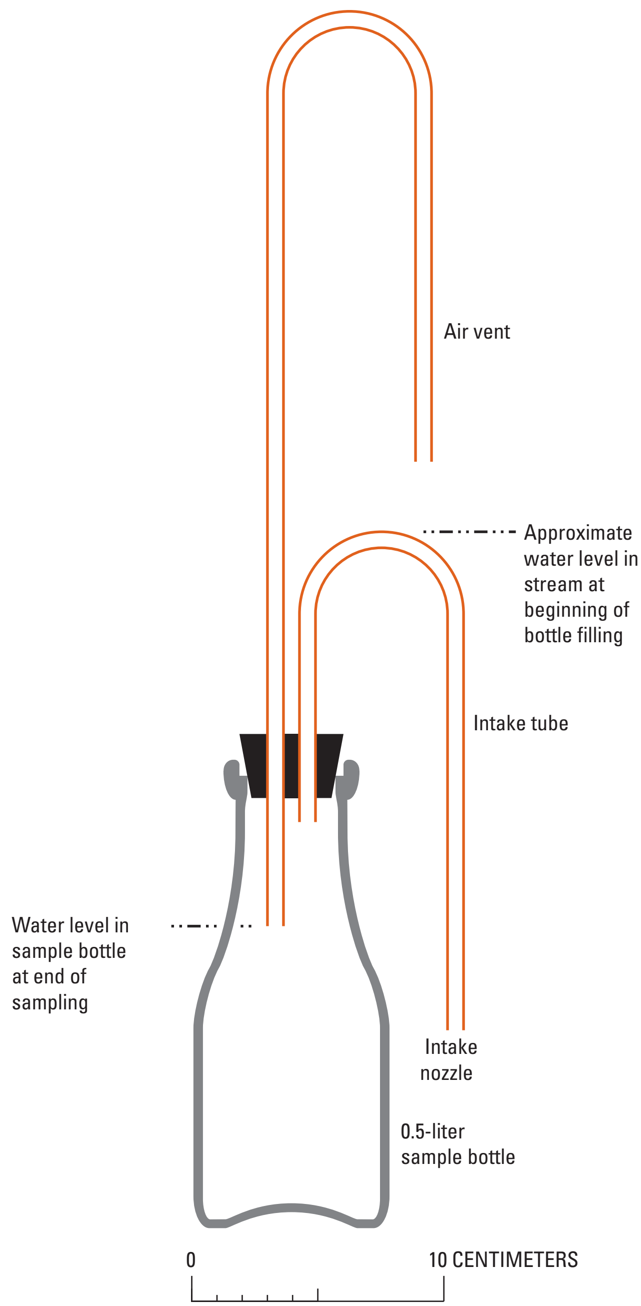

Figure 1. Features of the U-59A, one model of the siphon samplers developed by the U.S. Geological Survey in the 1950s.

The siphon sampler was developed in about 1954 by the USGS as a low-cost means of automatically collecting water samples for suspended-sediment measurement (Inter-Agency Committee on Water Resources, Subcommittee on Sedimentation, 1961; Edwards and Glysson, 1999). Siphon samplers are useful where site remoteness, rapid hydrologic response, or the need to sample many sites preclude the use of pumping samplers or manual sampling (Edwards and Glysson, 1999; John, 2000; Lurry and Kolbe, 2000; Bent and others, 2001; Burton and Pitt, 2002). Siphon samplers have been used to monitor suspended sediment and other water-quality properties in several studies, most of them involving multiple sites on small streams (Gray and Fisk, 1992; Lewis, 1998; Savidge, 1998; Graczyk and others, 2000; Freihoefer and others, 2001; Ely, 2004; Carter, 2005; Garn and others, 2006).

Several limitations affect the use of siphon samplers (Edwards and Glysson, 1999). The stage at which sampling begins varies with intake orientation and the velocity and turbulence of the stream. The time at which the sample is taken is unknown; if the sampler is paired with a continuous stage recorder, the uncertainty in the sampling time corresponds to the uncertainty in the stage at which sampling begins. The efficiency of sand sampling changes with intake nozzle orientation (facing upstream or downward) and water velocity; samples can contain significantly higher or lower sand concentrations than the stream. The sample represents concentration at a single point; the sample concentration's relation to the mean concentration in the stream can only be verified with manual sampling along multiple vertical lines. If the sampler is mounted in the main channel to get a representative sample, it is exposed to debris impact, debris accumulation, and strong hydraulic forces.

In rapid flow, transitory pressure surges at the intake nozzle may be large enough to force the air bubble out of the air vent tube of the original (U-59) siphon sampler. Water then can flow through the sampler and can enrich a sediment sample many times greater than the concentration in the stream. When the water level drops below the air-vent opening, the water drains out of the air vent tube, and definite evidence of the loss of the air bubble remains. The original design included several versions of samplers with tall air vents to minimize this problem, but Gray and Fisk (1992) found it necessary to extend all air vents well above maximum flood stage (fig. 2).

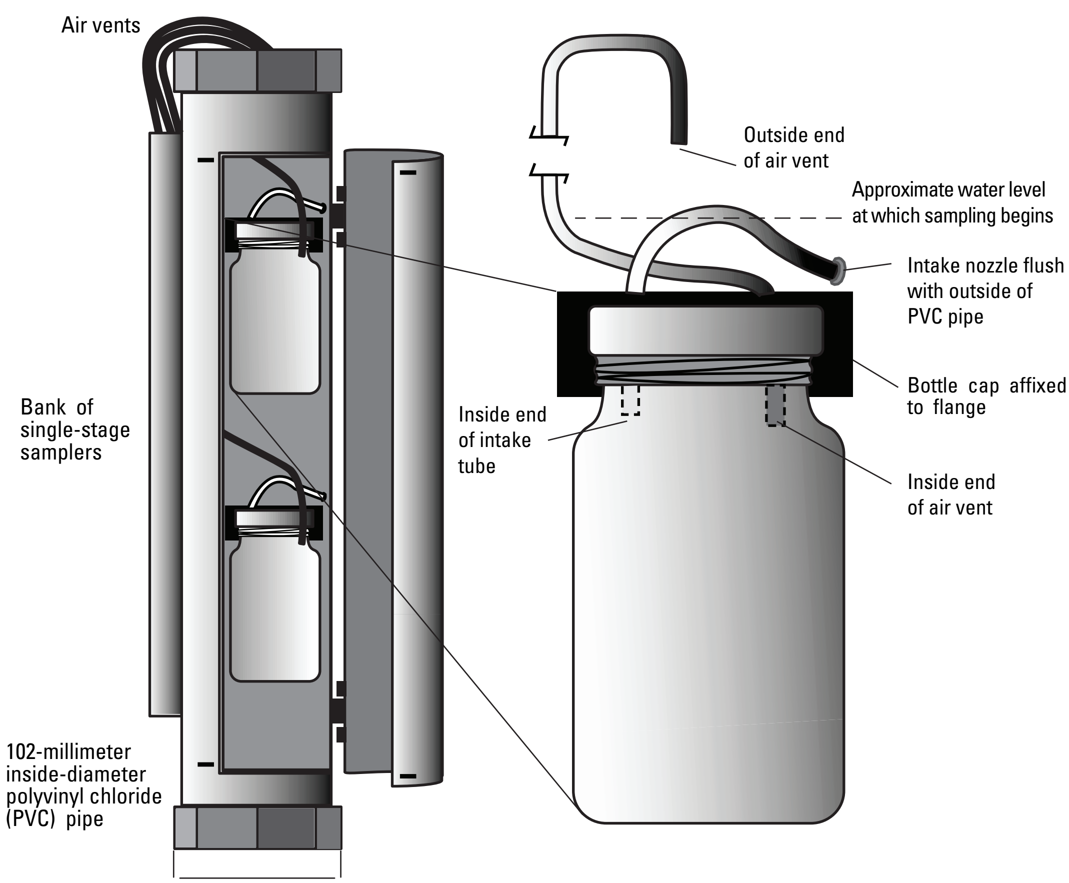

Figure 2. The siphon sampler of Gray and Fisk (1992), after Bent and others (2001).

Siphon samplers collect a water sample when water rises about to the level of the top of the intake. The minimum stage for sampling into a vertical container is about 3 centimeters (cm) above the top of the container, typically 19 to 21 cm for a 0.5-L container. Many sites on ephemeral channels and small headwater streams that would otherwise be suitable for siphon samplers are shallower than 19 cm during most storms. In a study of suspended-sediment concentration in Middle Tennessee (Diehl and Williams, 2006), most of the sampling sites had shallow, rapid flow over bedrock or riprap beds. Excavating the bed to allow use of a typical siphon sampler was impractical. As a result, a modified siphon sampler was developed that could sample water 10 cm deep and be mounted on bedrock. This report describes the design and operation of the modified siphon sampler and the results of a comparison between this modified sampler and an isokinetic point sampler, the DH-48.

Acknowledgment

The development and initial use of the modified siphon sampler was funded by the Tennessee Department of Transportation.

Design and Operation

The main modification to the siphon sampler was to turn the sample bottle on its side. This reduces the minimum depth for sampling and permits more closely spaced sampling depths (fig. 3). The water intake tube extends upstream from the sampler and is turned downward to sample 5 cm below the water surface (fig. 4). The air vent combines short sections of copper tube connected by flexible vinyl tubes. The inner end of the air-vent tube is below the inner end of the water intake at a level that limits the sample volume to less than about 90 percent of the volume of the bottle to allow for the expansion of frozen samples. Bottles are mounted side by side in pairs, with intakes offset vertically to sample at 5-cm intervals. Each pair of bottle caps is attached to a single assembly that supports and protects the intake and air vent tubes and incorporates a curved shield that guides flow smoothly around the bottles. Leakage around the tubes is prevented by a soft rubber gasket. The assembly is fastened around the pipe of a crest-stage gage (CSG) with a pipe clamp (Sroka, 2003). One to three pairs of bottles were stacked vertically on each pipe, providing a sampling range of 5 to 25 cm.

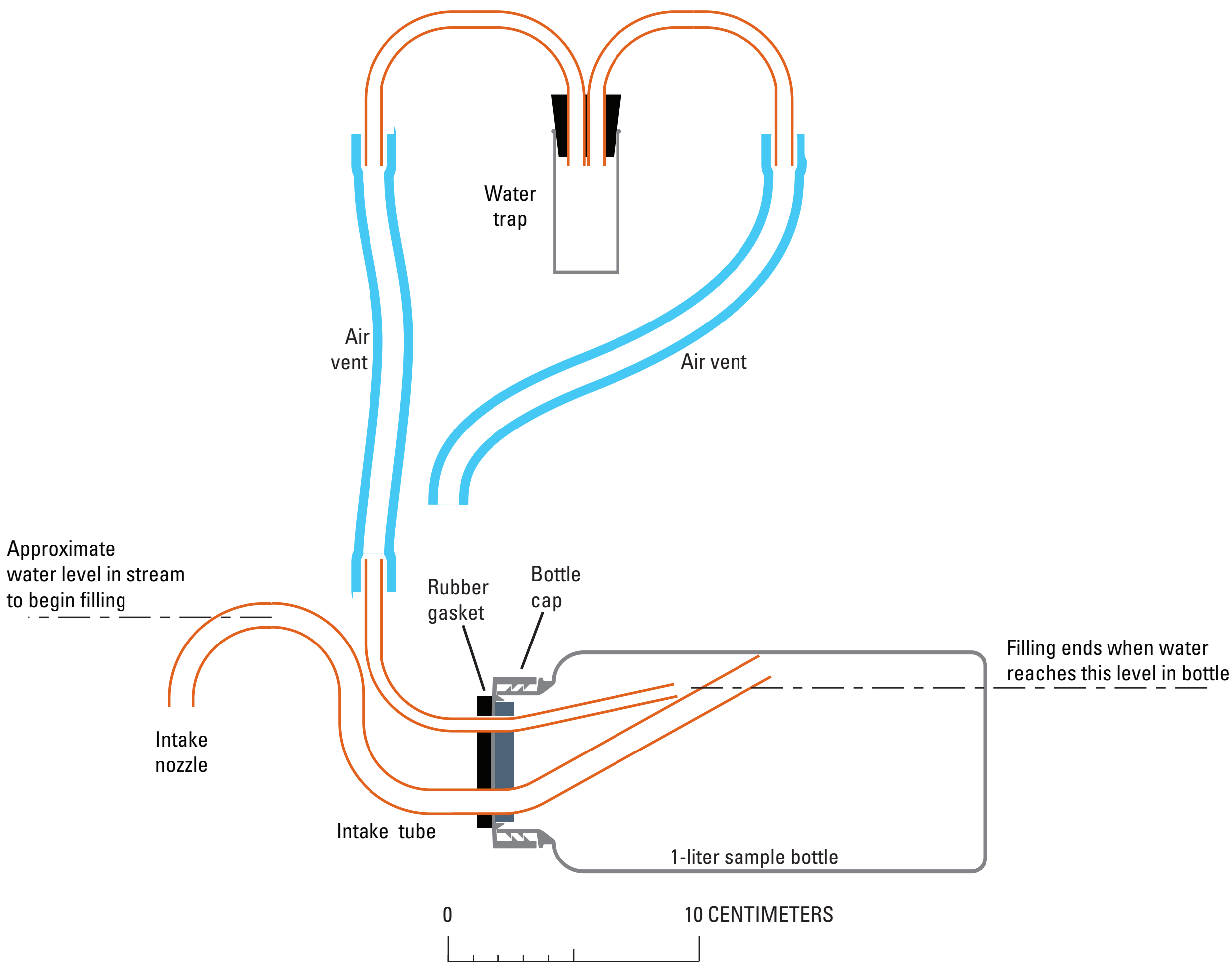

Figure 3. Schematic diagram of one modified siphon sampler bottle showing intake and air vent.

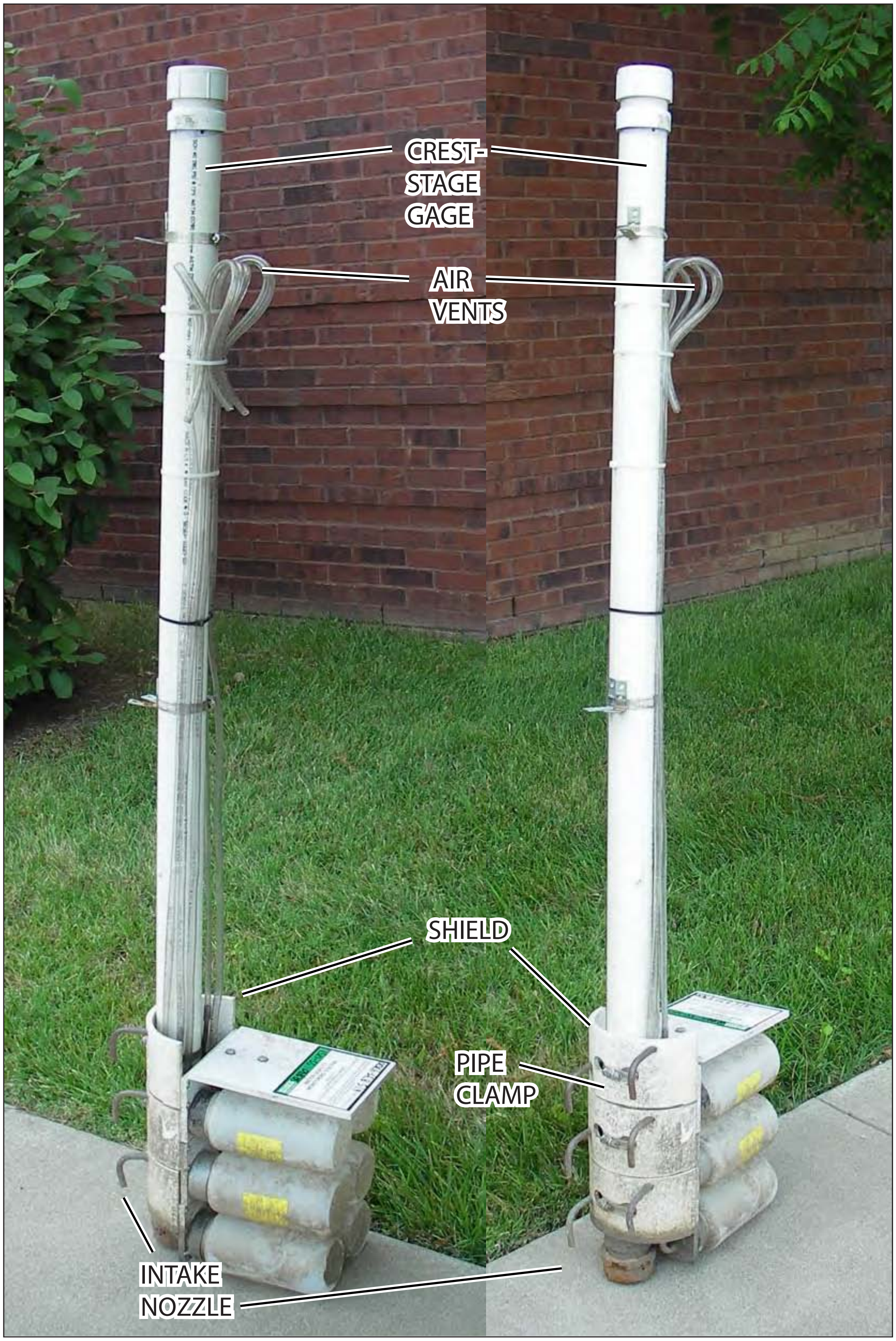

Figure 4. Two views of a modified siphon sampler with three pairs of bottles mounted to a tall crest-stage gage.

The modified siphon sampler has its intake nozzle directed downward like the U-59A and is likely to undersample suspended sand like the U-59A does, while both samplers collect unbiased samples of silt and clay (Inter-Agency Committee on Water Resources, Subcommittee on Sedimentation, 1961). A sample of 0.8 L is taken in about 2 minutes, with a corresponding intake velocity of about 200 millimeters per second (mm/s). The fall velocity of coarse (0.062-millimeter diameter) silt ranges from about 2 to 4 mm/s depending on water temperature (Vanoni, 1975), or about 1 to 2 percent of intake velocity. Finer particles fall even more slowly. The high ratio of intake velocity to fall velocity suggests that the bias in sampling silt concentration is small for the modified sampler, as it is for the U-59A (Inter-Agency Committee on Water Resources, Subcommittee on Sedimentation, 1961), despite the fact that this modified sampler does not sample isokinetically.

In the modified design, several means have been used to detect water flowing through the air vent or to keep water from flowing through the air vent. A CSG was incorporated into the modified siphon sampler to record whether water rose above the top of the air vent. Most of the modified samplers included water traps in the air vents. If water flowed through the air vent, the water trap retained water until the sampler was serviced, recording the flow through the air vent and indicating potential bias in the sample. These traps sometimes filled even when the top of the air-vent tube remained a few centimeters above the water surface.

Three options were developed for mounting the sampler in the middle of the channel to avoid areas out of the main flow that may have unrepresentative suspended-sediment concentration (SSC). The first method was to drive fenceposts on both sides of the channel, bolt two boards across them above the maximum anticipated water level, and attach the CSG to the boards (fig. 5). This method has the advantage of minimizing effects on the channel, can be used to suspend the sampler over a mobile particulate bed, and is the easiest way to incorporate air vents that extend well above the maximum flood elevation. This mounting method has the disadvantages of being cumbersome, visually obtrusive, and excessively flexible if the fenceposts are more than 4 meters apart. The second and third methods involve only a short CSG that may or may not reach the maximum flood elevation. In the second method, the CSG is mounted to a steel framework anchored to the stream bed, which must be approximately level (fig. 6). In the third method, suitable only for firm beds, a fencepost is driven into the bed or a steel rod is inserted into a drilled hole, and a narrow pipe attached to the upstream side of the CSG is slipped over it (fig. 7). The second and third types of samplers are ballasted to keep them stationary on the bed. Regardless of the method of mounting the sampler, streams with flood depths greater than 0.5 meter and velocities greater than 1.2 meters per second tended to wash away the samplers. Problems with accumulation of woody debris also increased with the size of the stream.

Servicing the modified sampler involves more tasks than servicing the original (U-59A) design. Before recovering the samples, the water traps are examined and the maximum water level is read from the CSG. To recover the samples, the entire sampler, including the CSG and bottles, is removed from the stream and rotated to turn the bottles upright. Then, as with older designs, full bottles are unscrewed from their caps, which remain attached to the CSG. The sampler is rinsed and empty bottles are screwed hand-tight into the caps. Air is blown into the intake nozzle through a short flexible tube, first with the air vent open to check for free flow, then with the air vent covered to check for leakage. The sampler is then turned upright and put back in the stream.

Comparison to DH-48

A hand-held version of the modified siphon sampler was compared with the DH-48, a hand-held, isokinetic sampler with a horizontal intake nozzle (Edwards and Glysson, 1999; Lane and others, 2003). Testing took place in shallow, rising, rapid, and turbulent flow conditions similar to those that the modified siphon sampler is designed to sample. The two sampler intakes were immersed simultaneously to the shallowest depth at which the modified siphon sampler would sample, and held side by side at points about 8 cm apart while sampling. The DH-48, sampling isokinetically in rapid flow, always finished sampling before the siphon sampler filled its larger bottle. Testing was performed first at one of the field sites (USGS Station 03601630, Locke Branch near Bending Chestnut, Tennessee), but it proved difficult to reach the site in time to sample the first flush. Testing continued at a site nearer the Tennessee Water Science Center office with easy foot access to a gravel bar with swift, shallow flood flows (USGS Station 03433040, Little Harpeth River at Edwin Warner Park near Bellevue, Tennessee). This second site was similar to the project study area, with karst geology and soils developed in clayey residuum, but was more extensively disturbed by residential, commercial, and road construction.

Fifteen pairs of samples were collected using the DH-48 and the modified siphon sampler. All pairs of samples were analyzed for turbidity using a Hach 2100AN turbidimeter, and 13 pairs were analyzed for SSC by the USGS Kentucky Sediment Laboratory (table 1). Samples covered a range of turbidity and SSC similar to stormwater samples from the study area, from 26.2 to 1,587 nephelometric turbidity ratio units (NTRU) and from 58 to 1,520 milligrams per liter (mg/L) of suspended sediment. The Wilcoxon signed-ranks test was used to determine the significance of differences between the two samplers in SSC, turbidity, and the ratio of SSC to turbidity (Bhattacharyya and Johnson, 1977). Samples from the DH-48 tended to have higher SSC and turbidity than the corresponding siphon samples, but this difference was not statistically significant ($p = 0.147$ and $p = 0.174$, respectively). The average ratio of SSC to turbidity was higher for DH-48 samples ($p = 0.015$). The paired samples with the largest discrepancy in SSC (178 mg/L DH-48, 58 mg/L siphon) also had the highest ratios of SSC to turbidity (table 1), suggesting relatively coarse samples. Small-scale eddies of variable turbidity were observed in the stream during the sampling; temporal and spatial variability in SSC seems a plausible explanation for the degree of scatter observed (figs. 8, 9).

Figure 5. Modified siphon sampler mounted on boards bridging the channel.

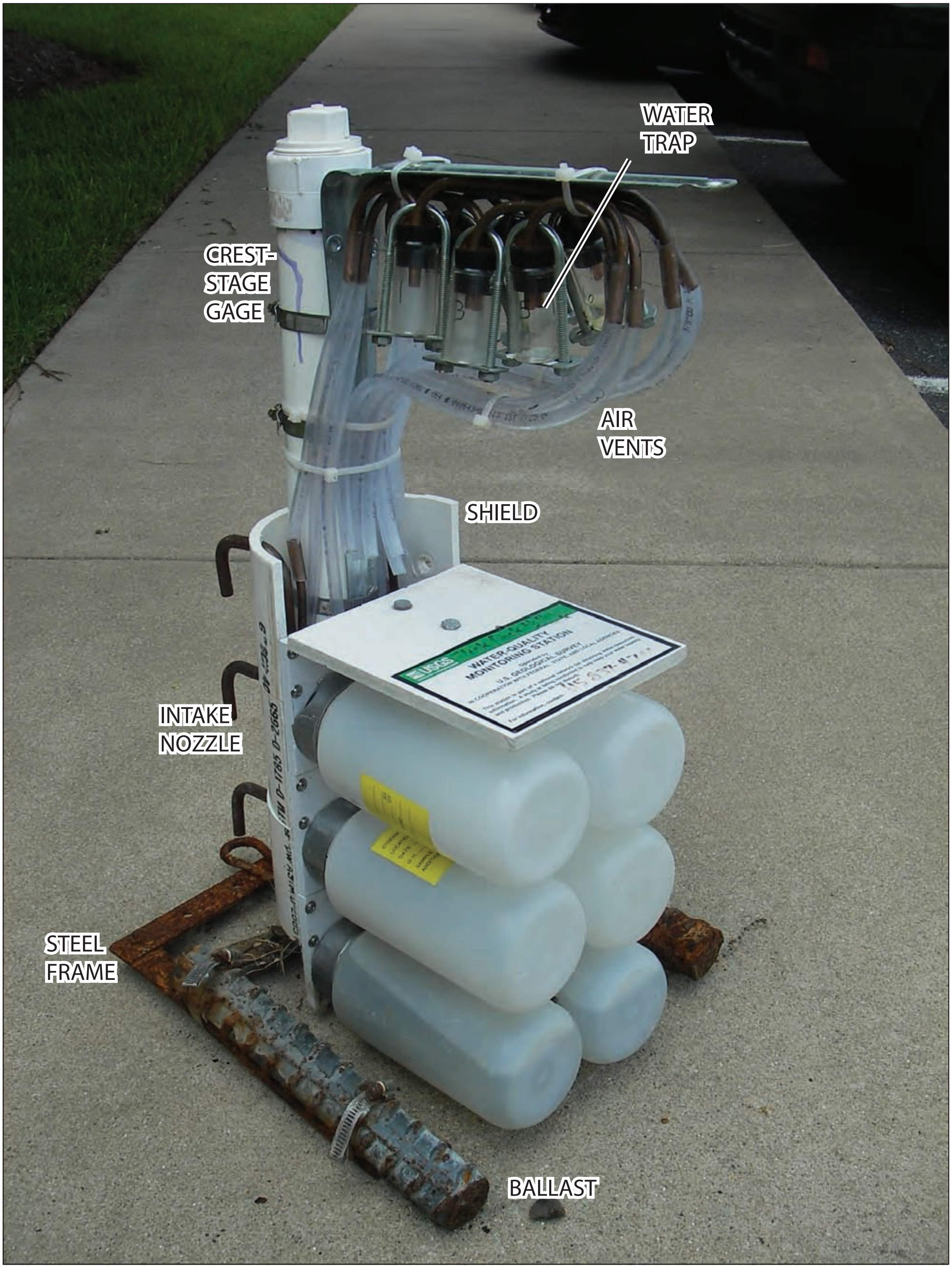

Figure 6. Modified siphon sampler mounted on a steel frame.

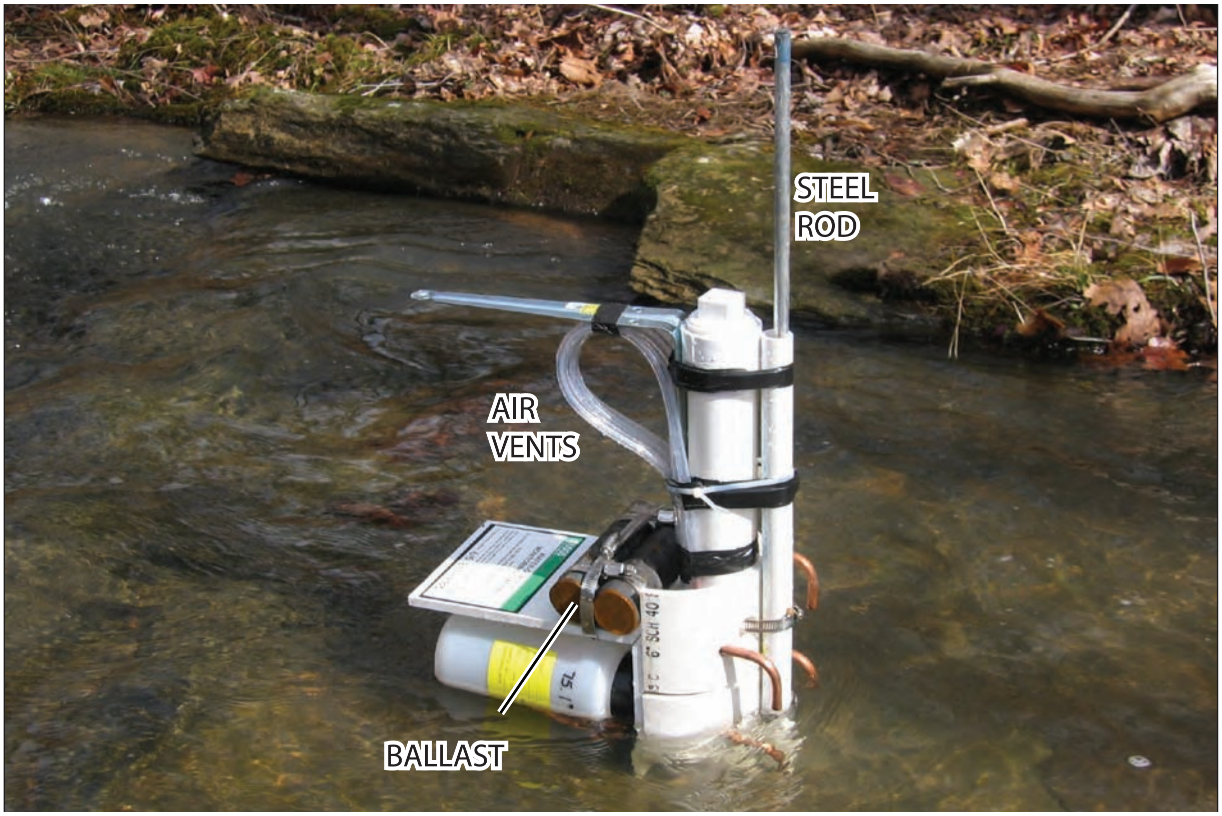

Figure 7. Modified siphon sampler mounted on a vertical steel rod.

Table 1. Suspended-sediment concentration and turbidity of paired samples collected with the DH-48 isokinetic sampler and with the modified siphon sampler.

[USGS, U.S. Geological Survey; SSC, suspended-sediment concentration; mg/L, milligrams per liter; NTRU, nephelometric turbidity ratio units; —, no data; Little Harpeth R., Little Harpeth River at Edwin Warner Park near Bellevue, Tennessee; Locke Branch, Locke Branch near Bending Chestnut, Tennessee]

Sample date and time (yyyymmddhhmm)	Sample location in Tennessee	USGS station number	SSC, in mg/L		Turbidity, in NTRU		Ratio of SSC to turbidity	
			DH-48	Modified siphon sampler	DH-48	Modified siphon sampler	DH-48	Modified siphon sampler
200604021645	Little Harpeth R.	03433040	1,490	1,520	1,277	1,587	1.2	1.0
200604021655	Little Harpeth R.	03433040	1,130	1,110	1,196	1,198	0.9	0.9
200604021707	Little Harpeth R.	03433040	488	507	306	307	1.6	1.7
200604021719	Little Harpeth R.	03433040	—	1,270	1,145	1,043	—	1.2
200604021742	Little Harpeth R.	03433040	1,240	1,150	712	683	1.7	1.7
200604210941	Little Harpeth R.	03433040	178	58	49	26.2	3.6	2.2
200604210949	Little Harpeth R.	03433040	160	201	122	149	1.3	1.3
200604210959	Little Harpeth R.	03433040	196	204	164	181	1.2	1.1
200604211007	Little Harpeth R.	03433040	213	196	182	180	1.2	1.1
200604211013	Little Harpeth R.	03433040	—	—	164	163	—	—
200604211021	Little Harpeth R.	03433040	151	149	134	132	1.1	1.1
200604211027	Little Harpeth R.	03433040	127	124	115	112	1.1	1.1
200508171901	Locke Branch	03601630	176	113	62	59	2.8	1.9
200508171931	Locke Branch	03601630	119	96	57	53	2.1	1.8
200508171946	Locke Branch	03601630	95	96	49	50	1.9	1.9

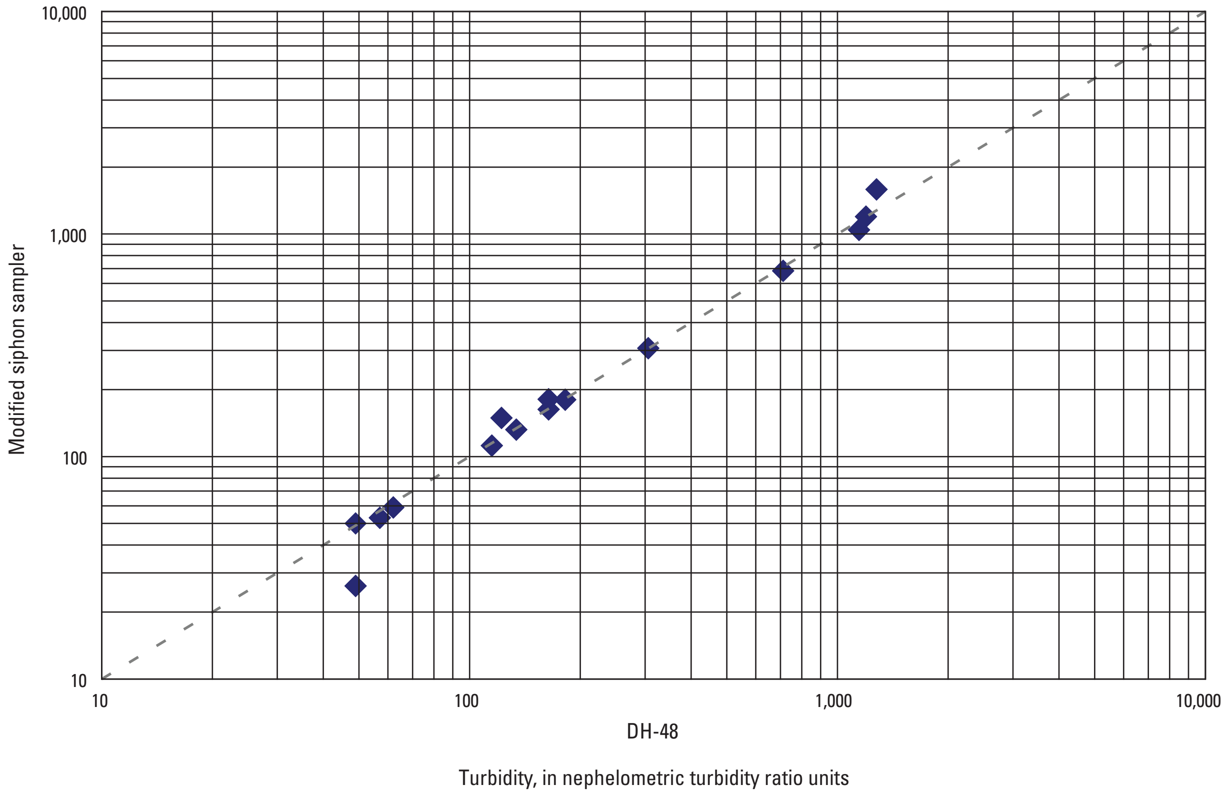

Figure 8. Turbidity of paired samples collected with the DH-48 isokinetic sampler and with the modified siphon sampler.

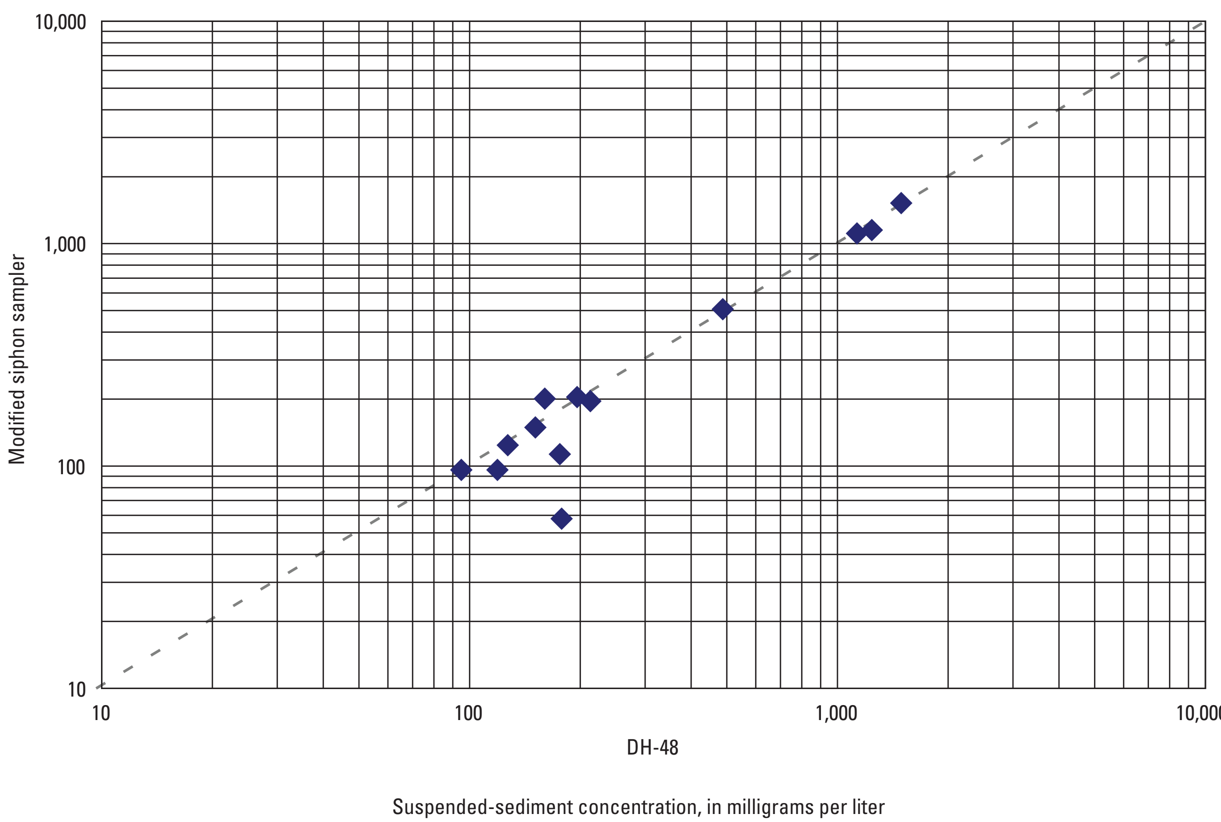

Figure 9. Suspended-sediment concentration of paired samples collected with the DH-48 isokinetic sampler and with the modified siphon sampler.

Summary

The modified siphon sampler with horizontal sample containers meets the need for a reliable siphon sampler for shallow water. Several means of mounting the sampler are effective and produce minimal alteration of the channel bed and banks. Based on a comparison with simultaneous isokinetic point samples, the modified design produces unbiased samples of suspended silt and clay. The good correspondence between simultaneous paired samples suggests that the scatter in the paired samples of Graczyk and others (2000) may have been due to differences in the timing of the samples, as they conjectured.

The modified design has several limitations in common with other siphon samplers. Flow through the sample containers occurs in versions of the modified sampler with air vents that do not extend above the maximum water level. The inclusion of a water trap in the air-vent tube prevents compromised samples from being analyzed but does not improve the sampler's ability to collect valid samples. The need for air vents above the water surface limits mounting options in large streams that carry floating debris. Other limitations include biased sampling of suspended sand and uncertainty about the time and water level of sampling.

References Cited

Bent, G.C., Gray, J.R., Smith, K.P., and Glysson, G.D., 2001, A synopsis of technical issues for monitoring sediment in highway and urban runoff: U.S. Geological Survey Open-File Report 00-497, 51 p., accessed March 29, 2004, at *http://ma.water.usgs.gov/fhwa/products/ofr00497.pdf*

Bhattacharyya, G.K., and Johnson, R.A., 1977, Statistical concepts and methods: New York, John Wiley & Sons, 639 p.

Burton, G.A., and Pitt, R.E., 2002, Stormwater effects handbook; a toolbox for watershed managers, scientists, and engineers: Boca Raton, Florida, CRC Press, accessed June 19, 2007, at *http://www.epa.gov/ednnrmrl/publications/books/handbook/chp5b.pdf*

Carter, M.D., 2005, Stream assessment and constructed stormwater wetland research in the North Creek watershed: Raleigh, North Carolina, North Carolina State University, accessed June 19, 2007, at *http://www.lib.ncsu.edu/theses/available/etd-03142005-103836/unrestricted/etd.pdf*

Diehl, T.H., and Williams, S.D., 2006, Spatial and temporal variability of turbidity and suspended sediment in southwest Williamson County, Tennessee [abs.], *in* Tennessee Water Resources Symposium, 16th, Burns, Tennessee, April 19–21, 2006, Proceedings: Tennessee Section of the American Water Resources Association, p. 1C-3.

Edwards, T.K., and Glysson, G.D., 1999, Field methods for measurement of fluvial sediment: U.S. Geological Survey Techniques of Water-Resources Investigations, book 3, chap. C2, 80 p., accessed June 19, 2007, at *http://pubs.usgs.gov/twri/twri3-c2/pdf/TWRI_3-C2.pdf*

Ely, Eleanor, 2004, Low-cost storm event sampler: The Volunteer Monitor, v. 16, no. 2, Summer 2004, p. 11, accessed March 29, 2004, at *http://www.epa.gov/owow/monitoring/volunteer/newsletter/volmon16no2.pdf*

Freihoefer, A., Turyk, N., and Shaw, B., 2001, Water quality assessment of the Plover River watershed, Langlade, Marathon, and Portage Counties, Wisconsin: Stevens Point, Wisconsin, Environmental Task Force Program, University of Wisconsin–Stevens Point, accessed June 19, 2007, at *http://www.uwsp.edu/cnr/watersheds/Reports_Publications/UWSP%20Plover%20River%20Water%20Quality%20Study%202002.pdf*

Garn, H.S., Robertson, D.M., Rose, W.J., Goddard, G.L., and Horwatich, J.S., 2006, Water quality, hydrology, and response to changes in phosphorus loading of Nagawicka Lake, a calcareous lake in Waukesha County, Wisconsin: U.S. Geological Survey Scientific Investigations Report 2006-5273, 53 p., accessed June 19, 2007, at *http://pubs.usgs.gov/sir/2006/5273/pdf/SIR_2006-5273.pdf*

Graczyk, D.J., Robertson, D.M., Rose, W.J., and Steuer, J.J., 2000, Comparison of water-quality samples collected by siphon samplers and automatic samplers in Wisconsin: U.S. Geological Survey Fact Sheet FS-067-00, 4 p., accessed March 29, 2004, at *http://wi.water.usgs.gov/pubs/FS-067-00/FS-067-00.pdf*

Gray, J.R., and Fisk, G.G., 1992, Monitoring radionuclide and suspended-sediment transport in the Little Colorado River Basin, Arizona and New Mexico, USA, *in* Erosion and Sediment Transport Monitoring Programmes in River Basins: Oslo, Norway, Proceedings of the International Symposium, August 24–28, 1992, IAHS Publication No. 210, p. 505–516.

Inter-Agency Committee on Water Resources, Subcommittee on Sedimentation, 1961, The single-stage sampler for suspended sediment: Washington, DC, U.S. Government Printing Office, Report 13 of series "A Study of Methods Used in Measurement and Analysis of Sediment Loads in Streams," 105 p., accessed June 15, 2007, at *http://fisp.wes.army.mil/Report%2013.pdf*

John, F.B., 2000, Collecting water-quality samples for dissolved metals-in-water: U.S. Environmental Protection Agency, Region 6, accessed June 19, 2007, at *http://www.epa.gov/earth1r6/6pd/qa/qadevtools/mod5_sops/surface_water_sampling/low_level_metals/r6wtr-sampling-metals.pdf*

Lane, S.L., Flanagan, Sarah, and Wilde, F.D., 2003, Selection of equipment for water sampling (ver. 2.0): U.S. Geological Survey Techniques of Water-Resources Investigations, book 9, chap. A2, accessed September 13, 2006, at *http://water.usgs.gov/owq/FieldManual/Chapter2/Chapter2_V2uncompressed.pdf*

Lewis, J., 1998, Evaluating the impacts of logging activities on erosion and sediment transport in the Caspar Creek watersheds, *in* Ziemer, R.R., ed., Proceedings of the conference on coastal watersheds: the Caspar Creek story: General Tech. Rep. PSW GTR-168, Pacific Southwest Research Station, Forest Service, U.S. Department of Agriculture, 149 p., accessed June 19, 2007, at *http://www.fs.fed.us/psw/publications/documents/gtr-168/07-lewis.html*

Lurry, D.L., and Kolbe, C.M., 2000, Interagency field manual for the collection of water-quality data: U.S. Geological Survey Open-File Report 00–213, accessed June 19, 2007, at *http://pubs.usgs.gov/of/2000/ofr00-213/pdf/ofr00-213_eng_v2.pdf*

Savidge, Tim, 1998, Management of protected freshwater mussels with regard to North Carolina Department of Transportation highway projects, *in* Evink, G.L., Garrett, P., Zeigler, D., and Berry, J., eds., Proceedings of the International Conference on Wildlife Ecology and Transportation (ICOWET), February 10–12, 1998, Fort Myers, Florida: Tallahassee, Florida, Florida Department of Transportation, 263 p., accessed June 19, 2007, at *http://www.icoet.net/downloads/98paper19.pdf*

Sroka, B.N., 2003, Collecting peak-flow data in Ohio through the use of crest-stage gages: U.S. Geological Survey Fact Sheet FS-059-03, accessed June 8, 2007, at *http://oh.water.usgs.gov/reports/fs-059-03.pdf*

Vanoni, V.A., ed., 1975, Sedimentation engineering: New York, ASCE Task Committee, American Society of Civil Engineers, ASCE Manual 54, 745 p.

Prepared by:
USGS Publishing Network
Raleigh Publishing Service Center
3916 Sunset Ridge Road
Raleigh, NC 27607

For additional information regarding this publication, contact:
Timothy H. Diehl, Hydrologist
USGS Tennessee Water Science Center
640 Grassmere Park, Suite 100
Nashville, TN 37211
phone: 615–837–4751
email: thdiehl@usgs.gov

Or visit the USGS Tennessee Water Science Center website at:
http://tn.water.usgs.gov/

USGS Diehl—**A Modified Siphon Sampler for Shallow Water**—Scientific Investigations Report 2007–5282