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EVALUATION OF A DEPTH PROPORTIONAL INTAKE DEVICE FOR AUTOMATIC PUMPING SAMPLERS[1]

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ABSTRACT: A depth proportional intake boom for portable pumping samplers was used to collect suspended sediment samples in two coastal streams for three winters. The boom pivots on the stream bed while a float on the downstream end allows debris to depress the boom and pass without becoming trapped. This equipment modifies point sampling by maintaining the intake nozzle at the same proportion of water depth regardless of stage. Data taken by pumping samplers with intakes mounted on the boom were compared with depth integrated hand samples. Pumped samples showed higher concentrations than depth integrated hand samples. Results suggested that cross-sectional sampling can give high precision with proper placement and calibration of a boom mounted intake.
(KEY TERMS: pumping sampler; water quality; suspended sediment; statistics; sampling.)

INTRODUCTION

Portable automatic pumping samplers, originally designed for waste water sampling, are being used increasingly to collect suspended sediment samples from small streams. Such equipment is advantageous because many sampling locations are remote, storms arrive at random times, and fewer field workers are required. The logistics of collecting sufficient suspended sediment samples during the large, infrequent hydrologic events that are of major interest can be simplified to some extent by the use of these machines. They can be operated at equal time intervals or, with flow integrating equipment, at equal flow intervals. But automatic samplers used to collect suspended sediment data pose several major problems. One of these is the proper placement of the nozzle in the stream channel. A common installation is to place the waste water intake nozzle towards the edge of the active channel and directly on the streambed. Depending on stream conditions, this practice can result in either "starvation" or "enrichment" of the sample.

This report describes and evaluates an apparatus that maintains the nozzle at a depth proportional to stage. It also provides data that compare suspended sediment measured with this device with reference samples measured with a depth integrated sampler.

THE PROBLEM

Although steep gradient mountain streams usually provide adequate mixing of suspended solids (Federal Inter-Agency Sedimentation Project, 1948), depth of bedload transport generally increases with rising stage. Mixing of suspended solids in moderate to low gradient streams is often incomplete, resulting in variations in concentrations within the cross section. Concentrations generally increase with depth, and can vary across the stream (FIASP, 1940). Intake nozzles at fixed levels collect samples from different portions of the vertical sediment profile during different flow regimes.

The hand held DH-48 sampler (FIASP, 1963) is commonly used to collect depth integrated samples. A major feature of these samplers is that they sample isokinetically. That is, the sample enters the nozzle at the ambient velocity, thus avoiding either starvation or enrichment of the sample. The isokinetic property of the sampler, when operated from equally spaced "verticals" and at constant vertical transit rates, ensures that concentrations will be weighted according to discharge. Proper use of depth integrated samplers is generally considered a standard technique for estimating the average cross-sectional concentration. Pumping samplers, however, collect "point" samples. Given this limitation, the placement of the nozzle within the cross section becomes a major consideration.

McGuire, *et al*. (1980), tested the effect of vertical intake position on the concentration of several water quality parameters. They used two pumping samplers to collect simultaneous samples from an intake mounted near the floor of a control section and from one at midstage. The midstage intake was mounted at the middle of an arm with its upstream end pivoted at the floor of the control section. The downstream end was supported at the water surface by a float made from plastic containers. The sampler hose trailed downstream from the intake. For the three events sampled the concentration of suspended sediment was consistently higher from the floor mounted intake.

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Beschta (1980) experienced clogging of pumping sampler intakes with organic debris during high flows in the Oregon Coast Range. He used a free swinging bent metal rod, supported upstream by a plank or cable across the channel to solve this problem. This arrangement allowed the nozzle to swing up out of the way of passing debris. With this device the intake samples from its resting position near the streambed except when the stream velocity is sufficient to lift the rod above the bottom. The intake samples from a different proportion of depth depending on flow.

DEPTH PROPORTIONAL INTAKE BOOM

To avoid the problems of sampling at a fixed depth, we designed a depth proportional sampler intake device for use in field conditions that satisfies these criteria:

- minimal susceptibility to trapping debris;
- functional under high flows; and
- reasonable material and fabrication costs; low incidence of maintenance.

Our solution was a "boom" similar to that used by McGuire, *et al.* (1980), hinged upstream to an anchor driven into the streambed. We attached a float to the downstream end of the rod, and an intake nozzle to a bracket that can be adjusted along the rod (Figure 1). Debris can depress the rod and pass above it.

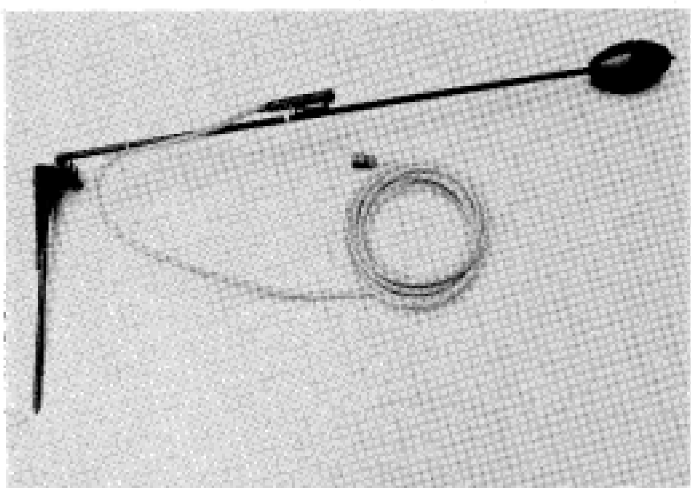

Figure 1. The Boom and Streambed Anchoring Device, Showing the Nozzle Intake and Sampling Hose.

Suppose the boom has length L and that the nozzle is placed a distance pL from the float. Two similar triangles are formed by the boom, the streambed, a horizontal line passing through the nozzle, and a vertical through the float (Figure 2). (The height of the pivot and any slight slope of the bed are ignored.) Then,

$$\frac{D}{L} = \frac{d}{pL},$$

or

$$d = pD.$$

That is, d is the same proportion p of any total stream depth D. By adjusting the value of p, therefore, the user can govern the proportion of depth from which samples are taken.

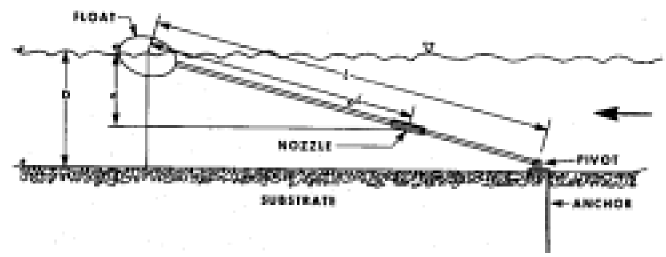

Figure 2. Intake Boom and Mounting Mechanism.

Our boom is 152 cm long. The length should be determined by the maximum expected stage to maintain a "low" angle between the boom and the streambed. Our rule of thumb was that the boom should be at least twice as long as the maximum expected stage. This length prevents depression of the boom at high flow velocities and allows debris to pass easily. We use a swimming pool float to support the downstream end of the rod and a hinge bearing made of nylon. (Detailed plans for constructing the boom and anchor are available upon request to the authors.)

We set our nozzle bracket so that p = 0.6. This is one of several acceptable depth settings for point sampling (FIASP, 1948). The intake hose is attached to the boom with nylon fasteners and led along the boom upstream where it is anchored to the bed with steel hooks. The hose then crosses the stream perpendicular to the flow and connects to the pumping sampler.

We have used this intake boom and a previous prototype for three winters in two coastal streams in Northern California. Two booms were left in place for up to six months and subjected to stream velocities exceeding 1.5 m/s without serious functional or maintenance problems. We have experienced good results and have met the design criteria.

INSTREAM MEASUREMENTS

To compare pumped samples obtained by a boom mounted intake with depth integrated hand samples, we collected simultaneous measurements at Janes Creek near Arcata, California, a 61-hectare watershed with an overall gradient of 13 percent. The hand samples were taken from a small bridge located just downstream from the boom at approximately five positions spaced 15 cm apart across the narrow channel. A model DH-75 sampler was used that has sampling characteristics similar to the more common DH-48 (Hindall, Steven H., April-June 1974; New Suspended Sediment Sampler for Winter Sampling; WRD Bulletin, U.S. Geological Survey, Water Resources Div., internal publication 24-25). The pumped samples were taken with a Manning 54050 portable pumping sampler and the standard waste water intake nozzle. (The use of trade names in this paper does not constitute endorsement by the U.S. Department of Agriculture.) Samples were taken during several storm periods covering flows from 0.069 to 0.12 m^3/s. Samples were actually taken with two pumping samplers and two intakes mounted, one on each side of the boom. In addition to the waste water nozzle, an open tube with inside diameter equal to that of the hose and pointing *downstream* was used. Differences observed between any combination of nozzle, position, or sampler were not statistically significant at the 0.05 level.

Figure 3 is a plot of the simultaneously collected depth integrated hand samples and pumped samples with the waste water nozzle. The data are fit well by the regression

$$y = 8.25 + 0.921x$$

in which x is the concentration in mg/1 determined by the pumped sample and y is an estimate of the cross-sectional concentration in mg/1 measured by a depth integrated hand sampler. The overall test for regression is highly significant with an R^2 of 0.98 and standard error of estimate of 14.9.

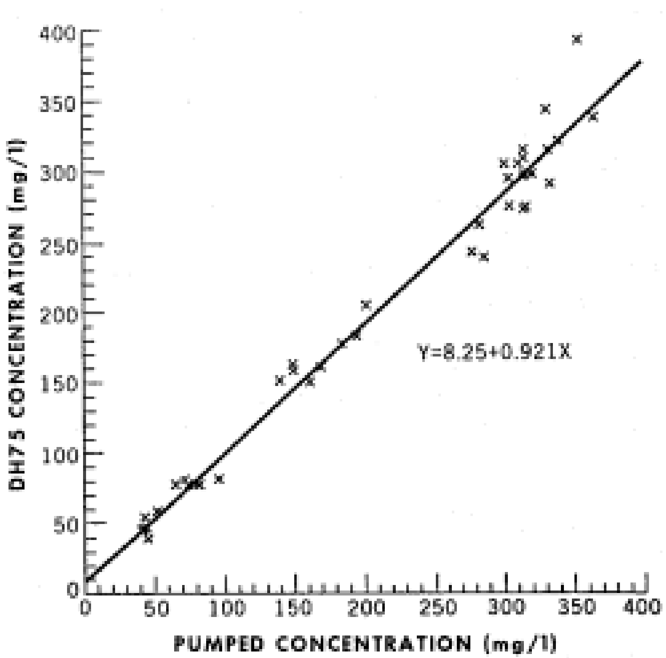

Figure 3. Simultaneous Concentrations of Pumped and Depth Integrated Hand Samples of Janes Creek, Near Arcata, California.

If the pumped samples measured exactly the same quantity as the depth integrated samples, the points should lie close to the line y = x. An F-test of the hypothesis that the regression line is actually y = x gives a value of 16, with 2 and 46 degrees of freedom. This value implies rejection at any reasonable level of significance. The sample regression line has a slightly lower slope than the "ideal" line, which indicates that the pumped concentrations are higher compared with the hand samples for concentrations above approximately 100 mg/l. Eight other measurements taken at the same station for a different study ranged up to 2000 mg/1. These data were not included in this analysis because they were not collected under identical conditions, however, they indicate the same pattern.

Eleven similar data points were collected at Miller Creek in Redwood National Park near Orick, California, a 232-hectare watershed with an overall gradient of 17 percent. These data points align more closely with the line y = x for concentrations up to 1000 mg/1 than the data points from Janes Creek.

The expected effect of lack of isokinesis with the waste water nozzle was not observed. The filaments of water and sediment must turn at approximately right angles to enter the holes around the surface of this nozzle. Particle momentum implies that some of the higher density sediment would leave the filament during the turn resulting in starved samples. This effect should be more pronounced for higher concentrations (which have larger particles and higher velocities) because pumping velocity remains constant. Although these data do not address this problem directly - since the depth integrated measurements were made throughout the cross section - the effect is not supported by the data (Figure 3). Evidently, the higher concentrations to be expected in the center of the stream overwhelm any such isokinetic effect.

Because pumped samples are essentially point samples, it is unlikely that their concentrations would be identical to those of simultaneous cross-sectional samples. It seems reasonable, however, that there may be points at which the concentration behaves much like the cross-sectional average over a range in flow conditions. Such points can be located by trying different mounting positions across the channel and by selecting different values for p. At Janes Creek, the boom was located over the thalweg.

As long as a pumped sample installation is calibrated to a depth integrated sampling procedure, the exact form of the relationship is not critical. It is advantageous, however, to have a simple relationship (e.g., linear) and especially one with low and uniform variance over the range in stage that will be sampled.

These data indicate that measurements of concentrations made with a depth integrated sampler can be estimated with a pumping sampler having a boom mounted intake. Of course, the relationship will be different for different stream conditions, so calibration to a depth integrated standard will still be necessary. The relationship appears stable at Janes Creek; however, it may be permanently changed by a major flow that alters the cross-sectional geometry. The calibration should be checked periodically to uncover such changes.

Most importantly, mean concentration in a stream cross section was estimated with good precision. The 95 percent confidence half interval for predicting one additional observation is small - at x = x = 206.4 it is 30.3 and when x is 150 units above or below x, it is 30.8. This means that the error is similar throughout the range of data. This confidence band is not strictly correct for measuring error when repeated predictions are made, but it gives some sense of precision. Although our experience is confined to two locations, hydraulic principles suggest that with proper placement and calibration, a sample taken with a pumping sampler having a boom mounted intake can yield a good estimate of the average concentration in a stream cross-section.

ACKNOWLEDGMENTS

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