Evaluation of Percent Flow Captured by a Small In-Field Runoff Collector

D. H. Franklin, M. L. Cabrera, J. L. Steiner, D. M. Endale, W. P. Miller

Abstract. *Increased environmental concern about nutrient loadings in runoff and surface water has heightened the need for evaluation of management practices at the field scale. Thus, there is a need for small in–field runoff collectors to assess nutrient migration at the field scale on various land management systems. A runoff sampler previously designed for the relatively flat terrain of the Coastal Plain was modified to accommodate steeper slopes (5% to 12%), larger flow rates, and channelized flow common in the Southern Piedmont. We conducted a laboratory study with the modified sampler to evaluate the effect of flow rate (1 to 5.5 L min^{-1}) and slope (5% and 12%) on percent flow capture. Our results show that slope and flow rate had little to no effect on the percent flow capture of the modified runoff collector. The 95% confidence interval for percent flow capture in a single observation was 10.4 ±2.5% for the 10x splitter and 2.0 ±1.7% for the 100x splitter. Because of the potential errors for single observations, several runoff collectors should be used if runoff volume needs to be quantified. The use of this small in–field runoff collector would be fairly unobtrusive, inexpensive in different management systems, and could help further our knowledge of migration of nutrients, pesticides, microorganisms, and sediments from fields into streams.*

Keywords. *Runoff collector, Nutrient management, Field scale assessment, Water quality, Nonpoint–source pollution.*

Increased environmental concern about nutrient loadings in runoff and surface water has heightened the need for evaluation of management practices at the field scale. A better understanding of nutrient concentrations in runoff from fields under various management practices will assist policy makers in developing realistic guidelines and will help land managers optimize nutrient use. Nutrient concentrations vary with landscape type, position, and use. The high cost of instrumenting watersheds with full–size runoff collection systems limits the number of sites that can be evaluated. Thus, there is a need for small in–field runoff collectors to assess nutrient migration at the field scale in order to evaluate a greater number of land management systems. These runoff collectors should be economical, unobtrusive, and impose little alteration of the landscape. In addition, these runoff collectors should be able to measure intermittent runoff and/or rill runoff.

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Several runoff studies have used sophisticated instrumentation to measure and sample runoff from pastures at the field scale (Vervoort et al., 1998; Moore et al., 1998). While these approaches give more detailed information on runoff, they are often too imposing and costly to use when working with farmers and with small budgets. In another runoff study, Ulen (1997) collected runoff from cropped fields using collection troughs at the bottom of delineated slopes, closely following procedures detailed by Gerlach (1967). Runoff water was pumped out and collected from a protected vessel on a weekly basis. Though less imposing in size and cost, this method may result in added denudation of the landscape where slopes tend to be steeper, as is the case in the Southern Piedmont. Slot–type samplers using multislot divisors collect a known portion of the runoff and provide a storm–integrated or discharge–weighted sample. The early samplers (Brakensiek et al., 1979) reduce the amount of runoff that must be stored, but they are costly and obtrusive in many landscapes, and they require too much space to be placed in multiple fields for one or more landowners. Sheridan et al. (1996) designed a low–impact flow event (LIFE) sampler to minimize disturbance and cost. This sampler was designed to quantify nutrient concentrations in runoff flowing through riparian buffers in the Coastal Plain, where slopes are gentle and sheet flow is likely.

We modified the LIFE sampler to accommodate steep slopes (5% to 12%), larger flow rates (with the addition of the 100x portal), and channelized flow, which are common in the Southern Piedmont. The basic design and percent recovery can be found in Franklin (1999). However, that study does not elaborate on the design, installation, or protectors, nor does it have statistical comparison of the lab data. The objective of this article is to describe the modified sampler in greater detail and present the results of statistical analysis of a

laboratory study to evaluate the effect of flow rate and slope on the performance of the small, in–field collector.

Materials and Methods

Description of Runoff Collector

The runoff collector is approximately 305 mm × 762 mm and consists of two sets of sample splitters (10 splitters for each set) with a collection port for each set (fig. 1). The collector is made of 16–gauge stainless steel on the bottom and 20–gauge stainless steel for the splitters and cover. The collector body sits on a stabilizing frame made of 25.4 × 25.4 × 0.16 mm stainless steel angle stock, which extends 2.5 cm out from the sides (fig. 2). These extensions have leveling eyelets to accommodate threaded rods, which are cemented into the earth at least 45 cm and project upward. Nuts are placed on the threaded rods above and below the eyelets to level the runoff collector laterally and to allow the collector slope to be adjusted to equal the land slope. Fabrication specifications of the frame include stainless steel angle stock around the perimeter as well as two additional lengths of angle stock under the splitters, which are perpendicular to the flow direction. These fabrication specifications were made to prevent warping and to ensure that the collector remained level.

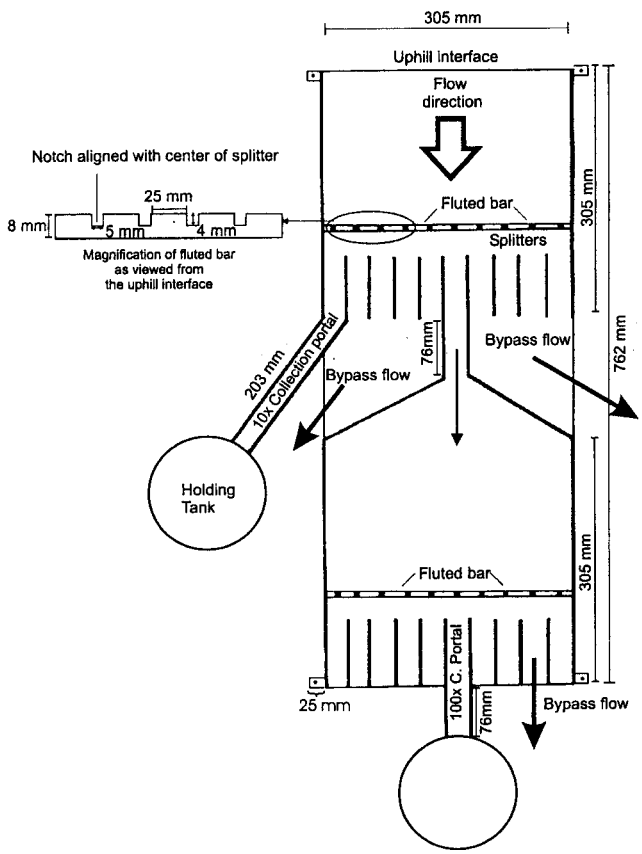

Figure 1. Plan view and dimensions of small, in–field runoff collector.

Water flows into the uphill interface of the collector (fig. 1) and encounters a fluted bar, which builds up hydraulic head until the water rises to the bottom of the notches (one notch for each splitter). Water then flows through notches and into the first set of ten splitters at equal rates. One tenth of the flow enters the 10x collection portal and is collected in the 10x holding tank (fig. 3). Eight tenths flow out and away from the collector. The remaining tenth flows into the second chamber (100x), encounters a second fluted bar, and is again split into ten parts. One hundredth flows through the 100x portal into the 100x holding tank. The remaining water flows out of the collector and into the field.

Field installation was initiated using a template. Holding tank and edge positions of the runoff collectors were marked. Excavations for holding tanks were completed, making sure to stay within the template markings. Runoff collectors were embedded into the earth (~50 mm) until the uphill interface was flush with the soil surface. Threaded rods were cemented into the earth to a depth below potential freezing. Leveling was done at installation and then again after the cement had thoroughly cured (24 to 48 hours).

When placed in grazed pastures or in areas where visibility was poor, runoff collectors were shielded from animals and farm equipment with a protector. This protector was made of 16–gauge angle iron, which extended 21 cm into the ground at each corner and covered the runoff collector from the uphill interface to the 100x collection portal. Two

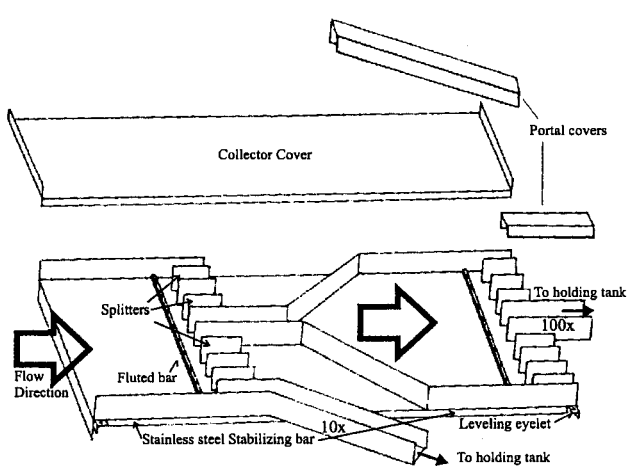

Figure 2. Three–dimensional view of runoff collector.

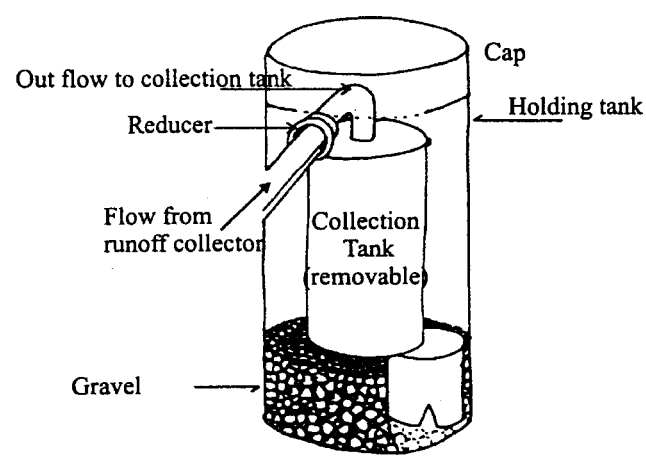

Figure 3. Cross–sectional view of holding tank.

protector legs were hinged opposite the 10x holding tank to facilitate access to the removable collection tank.

Holding and Collection Tanks

Both the holding tanks and the collection tanks are made of polyvinyl chloride irrigation pipe (fig 3). Holding tanks are connected to the runoff collector at the end of both the 10x portal and the 100x portal (fig. 1). Tank volume was determined by the amount of runoff expected for each contributing area of interest. The holding tank (20.3 cm diameter × approximately 61 cm deep) acts as a protector and stabilizer for the collection tank. The bottom of each holding tank is sealed with a flat cap, which leaves a lip that acts as a barb for securing the tank in the ground. The removable collection tank (15.2 cm diameter × 40 cm height; 7.26 L capacity) sits on top of approximately 5 cm of gravel. Samples are taken only from the collection tank, which can be cleaned after each sampling.

The main modifications made with respect to the LIFE sampler are the fluted bar, removal of the baffle, addition of a leveling system, combining 10x and 100x into one system, stainless steel fabrication, and an in–ground collection system with removable collection tanks.

In the Southern Piedmont, concentrated flow or rill flow of runoff is common. The fluted bar converts rill flow into sheet flow, allowing the splitters to be more accurate. Runoff collectors have to be laterally level if the splitters are to be effective. Level surfaces are difficult to locate in pastures and fields, especially in the Southern Piedmont where slopes are often concave or convex. The leveling system allows for lateral leveling while maintaining the natural longitudinal slope. The in–ground collection system with removable collection tanks minimizes the area taken out of production and facilitates measuring sample volume, collecting samples, and cleaning the collector.

Laboratory Evaluation Process

Runoff collectors were set up in a laboratory on 5% and 12% slopes to determine their effectiveness at splitting and capturing ten percent (10x) and one percent (100x) of the flow encountered. An even–flow distributor (not shown) controlled flow distribution entering into the collector at flow rates between 1.0 and 5.5 L min^{-1}. Assuming an average capture area of 9 m^2 (0.3 m × 30 m slope length), flow rates of 1 to 5.5 L min^{-1} represent runoff rates of 0.11 to 0.60 L m^{-2} min^{-1}, which are values observed during winter in the Southern Piedmont (Hoogenboom, 1998). Most runoff occurs in the Southern Piedmont during the winter months when soil moisture is often just below field capacity and evaporation is minimal.

Six runoff collectors were evaluated at three flow rates (1 to 2, 2.1 to 3.5, and 3.6 to 5.5 L min^{-1}) and two slopes (5% and 12%). Each test lasted three minutes and was repeated three times. Fisher's LSD was used to determine statistically significant differences between flow rates and slopes.

Results and Discussion

Slope did not affect the percent capture by the 10x splitter. There was, however, an effect of flow rate, with the smaller rate showing a larger percent capture (11.1%) than the other two rates (9.9% and 10.1%), as shown in table 1. The percent capture at the smaller flow rate was significantly larger than the expected value of 10%, but since this difference is small, we pooled all the data to calculate confidence intervals. The 95% confidence interval for the percent capture of the 10x splitter was 10.4 ±0.4% for the mean (n = 36) and 10.4 ±2.5% for a single observation.

Table 1. Effect of flow rate on percent flow captured by 10x and 100x portals in small, in–field runoff collectors.

Flow Rate (L min^{-1})	10x Splitter	100x Splitter
	(% Capture of Runoff)	
1.0 to 2.0	11.1a[a]	2.0a
2.1 to 3.5	9.9b	2.1a
3.6 to 5.5	10.1b	2.0a

[a] Within a column, means followed by the same letter are not significantly different according to Fisher's LSD at p = 0.05.

Neither slope nor flow rate had a significant effect on the percent capture by the 100x splitter. The average recovery by the 100x splitter was 2.0%, which was significantly higher than the expected value of 1% (table 1). We believe that part of this excess capture was caused by a slight concave warping of the fluted bar found just above the 100x splitter. As a result of this warping, the fluted bar was approximately 2 mm higher on the outer edges than in the middle. Another possible reason for the 2% instead of 1% capture is that the runoff's flow rate is lower after it has been split by the 10x splitter. Therefore, due to low flows (lower than 1.0 L/min), the second splitter can be significantly affected by surface tension forces, which would make the water velocity faster at the center of the fluted bar than at the ends. The 95% confidence interval for the percent capture of the 100x splitter was 2.0 ±0.3% for the mean (n = 36) and 2.0 ±1.7% for a single observation.

Summary and Conclusions

Our results show that slope and flow rate had little to no effect on the runoff percent capture of the 10x and 100x splitters of the modified runoff collector. The 95% confidence interval for percent capture in a single observation was 10.4 ±2.5% for the 10x splitter and 2.0 ±1.7% for the 100x splitter. These values could be used to obtain upper and lower boundary estimates of runoff volume if the runoff contributing area is known. However, because of the potential errors for single observations, several runoff collectors should be used if runoff volume needs to be quantified. The use of this simple runoff collector in different management systems could help further our knowledge of migration of nutrients, pesticides, microorganisms, and sediments in fields and into streams.

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