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FINAL REPORT

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ABSTRACT

Coshocton wheel samplers, ISCO pumping samplers, and single stage samplers were compared on each of three small (5-6 ha), forested watersheds in the Ouachita Mountains of central Arkansas. The objective of the comparisons was to evaluate the performance of each sampling method in providing reliable samples for measuring concentrations of total suspended solids (TSS). H-flumes and water level recorders provided stream discharge data; a network of recording and non-recording raingages provided preciptation measurements. Rainfall and storm discharges during the study period were unusually low. No samples were collected by the single stage samplers. They appear unsuited for use on small ephemeral headwater streams in the Ouachita Mountains because only unusually large storms will provide the depth of flow required to fill the sample bottles. A few of the Coshocton Wheel samples provided eradic and unpredictable measurements of TSS; however, there was generally good agreement between the Coshoston and pumped samples. The ISCO pumping samplers provided data that were more consistent and predictable than that of the Coshocton wheel. The small number of storm events during the study precludes a definite conclusion as to which sampling method is "best". Measurements are continuing.

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INTRODUCTION

Numerous efforts have been made to develop a stream sampling system that can be effectively used on small natural streams, experimental watersheds, or runoff plots. A reliable sampler must (1) provide a small volume of streamflow which can be conveniently stored, collected, and processed; (2) operate automatically to avoid logistic problems associated with manual sampling; (3) provide either a proportional composite of streamflow or a series of discree samples throughout the hydrograph; and (4) provide a representative depth-intergrated sample that accurately reflects vertical stratification of stream quality parameters, especially sediments. Parsons (1954) did much of the early work in designing and testing Coshocton wheel samplers which are driven by energy supplied by water flowing through flumes or other metering devices. The most common Coshocton wheels extract samples roughly proportional to .33%-1.00% of total stormflow. However, even this size aliquot can require several cubic meters of sample storage space on small ephemeral streams. Coote and Zwerman (1972) developed a divisor to reduce the 1% Coshocton wheel sample to 0.1% or 0.2% of the gross runoff. Their device which attaches directly to the Coshocton wheel base plate consists of a series of small 60° "V" notches which divides flow from the Coshocton outlet into ten equal portions, eight or nine of which are discharged to waste. The remaining notch(es) discharge into the sample storage basin. Although this type of divisor functions adequately for small agricultural runoff plots, the sample percentage is still too high for larger watersheds.

Laflen (1975) described a multiweir divisor system which used two flumes in tandem separated by a weir plate with thirteen 22.5 degree "V"-notch weirs.

The center weir discharges into the second flume; the other 12 weirs discharge to waste. The lower flume discharges in a tank from which a proportion of the overflow discharges through one or more circular orifices into a second tank. The system, designed for streams with small (71 l/sec) but prolonged flow, is elaborate and requires expensive sheet metal fabrication and precise leveling.

Single stage samplers are among the simplest automatic devices available. They have been extensively tested and modified in order to optimize their precision and efficiency. These devices consist of a bottle with two tubes protruding through a two hole rubber stopper. One tube is the intake which projects into the stream channel at the desired sampling depth. The second tube is the vent which extends into the streamflow path above the intake tube. Stream water enters the bottle as the water stage exceeds the highest point in the intake tube. Flow into the bottle ceases when the water stage reaches the vent tube opening. Because single stage samplers usually fill only on the rising limb of the hydrograph, the recession limb is ignored. Another disadvantage of single stage samplers is that the sample is usually not proportional to flow. Sartz and Curtis (1967) modified the single stage sampler for use with H-flumes. Intake tubes are secured flush with the flume wall at desired stages. The vent tubes extend above the expected high water mark on the flumes. Intake ceases when the water level in sample bottles reaches the lower end of the vent tubes. Knisel, et al. (1971) combined single stage samplers, also attached to H-flumes, with a mechanically driven automated-recession sampler. The single stage samplers sampled the rising stage; the recession sampler activated by a water level recorder then engaged to sample the falling stage. The devices apparently operate well on single-peak storms but require considerable modification to sample more complicated multi-peak storms.

Automatic pumping samplers have been extensively studied in recent years (Miller, et al. 1969; Johnson, et al. 1078; Beschta 1980; Walling, et al. 1971; Welch, et al. 1971). Fredriksen (1969) described a battery powered proportional stream sampler which offers the advantage of extracting samples that are proportional to flow rate. This is accomplished by a streamflow sensing unit, coupled to the water level recorder in a gaging station, which divides the expected range of discharge rates into 20 equal increments. The number of samples pumped for the maximum flow rate class is 20 times that for the lowest flow rate class. The number of samples pumped for each flow rate class increases linearly from the lowest to the highest thereby assuring proportionality of sampling. The large number of samples pumped during a storm requires that a storm composite sample rather than discrete samples be collected. Consequently, this apparatus is not well suited for evaluating changes in water quality constituents throughout a storm runoff even. Even though most other pumping samplers reported in the literature do collect discrete samples throughout a storm, the samples are not proportional to discharge.

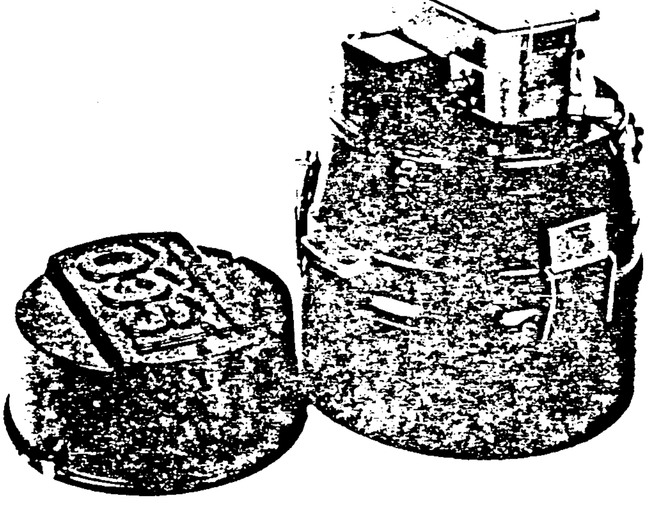
Advantages and disadvantages can be stated for each of the many stream sampling systems reported in the literature. The purpose of this paper is to compare three of the most common types of stream sampling systems (1) Coshocton wheel samplers with proportional splitters (2) single stage samplers, and (3) pumping samplers. The comparisons are based on concentrations of total suspended solids (TSS).

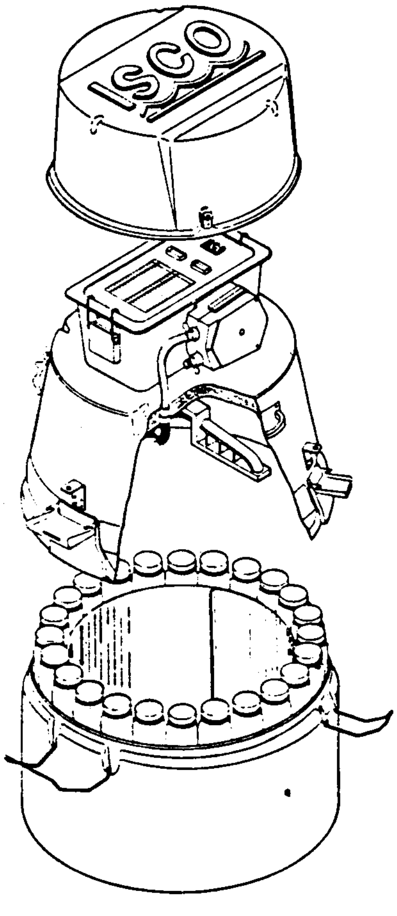
METHODS

Nine forested experimental watersheds in the Ouachita Mountains in central Arkansas were equipped with .9 meter H-flumes, concrete wing walls and approach sections, water stage recorders, Coshocton wheel samplers, sediment traps, water spitters, and a network of rain gages. The primary objective of the study was to measure the effects of forest management practices on selected water quality constituents. During the summer and fall of 1980 three watersheds were clearcut and site prepared by brush chopping and broadcast burning. Three watersheds were selectively logged to develop an uneven-aged stand. The remaining three watersheds were preserved in an undisturbed state to serve as controls. The clearcut watersheds were replanted with pine seedling in early winter 1981. However, in order to evaluate the Coshocton wheel samplers in comparison with alternative sampling methods, three contiguous watersheds, each with a different treatment, were equipped with two other sampling devices. Instrumentation Specialties Company (ISCO) pumping samplers were installed with the intake approximately 2 cm from the approach section floor. A styrafoam float near the intake activates a mercury switch when water stage reaches a preset level. The switch engages the pump which collects a maximum of 28 descrete samples (500 ml) at preset time intervals throughout the storm runoff event. A microswitch activates a solenoid and pen arm on the water stage recorder which marks a line on the chart each time a sample is pumped. Therefore, each sample represents a given segment of the hydrograph.

A battery of three single stage samplers (Figure 1) was installed in the natural stream channel a short distance upstream from each gaging station. The design of the intake tubes requires that water stage be at least 15 cm above the intake opening before water will flow into the first sample collection bottle. Two additional intakes are spaced 5 cm apart.

The Coshocton wheel set below the flume extracts roughly .5% of total stormflow. The sampled portion flows into a 20 liter polyethelene sediment trap where the larger sediments and organic debris are removed. Overflow discharges




ISCO

through a slotted splitter from which a 2% and 8% aliquot are collected and stored for amalysis. The 8% sample is utilized for analysis unless the collection container overflows, in which case the 2% sample is used.

Total suspended solids was determined by vacuum filtration through .45 micron filters and the evaporation method and expressed as mg/l concentrations. Weighted average TSS for the pumped samples for each storm was calculated by the following equation:

$$\overline{TSS} = \frac{\sum_{i=1}^{n} TSS_i Q_i}{Q_T}$$

where n = the number of samples=number of hydrograph segments.

TSS_i = Total suspended solid concentration (mg/l) for segment "i" of the hydrograph.

Q_i = Discharge volume (l) for segment "i" of the hydrograph.

Q_T = Total discharge for the storm.

The numerator of the above equation is equal to the mass (mg) of total solids which consist mainly of sediments. Mass of total solids by individual storms for the Coshocton samplers was computed by mulitplying TSS concentrations (mg/l) by total storm discharge (l) and converting to kg. Mean TSS concentrations for all six storms for each sampler were calculated by dividing total mass of solids by total discharge (l) for the six storms.

A split plot experimental design with an analysis of variance was used to satistically evaluate differences in TSS concentrations by individual storms for the Coshocton and pumping samplers.

RESULTS AND DISCUSSION

Rainfall during the study period was unusaully low; consequently, storm runoff events on the experimental watersheds were few and relatively small. Maximum stage recorded at any of the watershed flumes was only .35 m which corresponds to an instantaneous peak discharge of 94 l/sec (3.32 cfs).

No samples were collected by the single stage samplers during the study period. They appear to be unsuited for use on small ephemeral headwater streams in the Ouachita Mountains where only unusually large storms generate the depth of flow required to fill even the lowest sample bottle. It might be possible to locate the samplers in extremely narrow stream sections or in depressions where samples could be collected during smaller storms. Under such conditions higher streamflow velocities often result in higher rates of channel scouring; therefore, samples collected may not be truly representative of streamflow.

Pumping samplers and Coshocton wheel-spitter systems functioned well in collecting samples during all but the smallest flows. The pumping samplers functioned at lower flow rates than the Coshocton samplers. A storm that occurred on 27 October 1980 was sampled by the pumping units on all three watersheds; no samples were collected by the Coshocton units. This could be remedied by moving the slotted wheel of the Coshocton sampler closer to the lip of the flume so that the slot will intercept all flows. However, such a positioning causes a sample dilution problem on runoff events with extended recession limbs because the low flows are comparatively clean. On balance it is better to miss a few small storms (maximum flow rates < .93 l/s) than to have all samples diluted by low flows. A comparison of TSS concentrations (Table 1) revealed considerable variation both among and within sampling methods, watersheds, and storms.

An analysis of variance of the data (Appendix Tables 1 and 2) revealed no statistical differences even though mean sediment concentration for the Coshocton systems was numerically higher than that for the pumping samplers.

There appeared to be more consistency in the pump samples than in the Coshocton samples (Table 1). Concentrations of TSS were consistently highest

Table 1. Storm discharge, TSS concentrations, and total sediment losses by individual storms.

STORM DATE	WS TMT	STORM DISCHARGE	MEAN PRECIP.	TURBIDITY (COSH.)	TTS CONCENTRATIONS		SEDIMENT LOSSES	
					COSHOCTON	PUMP	COSHOCTON	PUMP
		$1x10^3$	mm	NTU	mg/l		kg	
10/16-17/80	Selection	191	52.1	19	53	11	10.2	2.1
	Control	109		44	58	7	6.4	.8
	Clearcut	142		--	61	29	8.6	4.1
11/14-17/80	Selection	631	77.8	16	41	19	26.1	7.5
	Control	279		8	14	12	3.8	2.6
	Clearcut	902		--	47	30	42.6	20.4
12/8-9/80	Selection	1,729	57.4	41	524	12	906.2	36.4
	Control	1,338		20	153	10	204.8	18.7
	Clearcut	1,969		25	18	23	36.3	287.7
1/31-2/1/81	Selection	1,033	47.0	50	89	21	92.1	4.9
	Control	912		17	32	14	29.5	2.4
	Clearcut	1,155		59	116	146	133.5	45.6
2/9-10/81	Selection	1,253	43.0	34	71	5	87.8	7.1
	Control	1,115		23	75	3	83.7	6.0
	Clearcut	1,247		57	29	40	36.3	25.2
2/28-3/1/81	Selection	650	33.0	--	7	6	4.7	4.2
	Control	656		--	6	5	3.9	4.7
	Clearcut	909		--	12	20	11.3	16.2
	TOTALS				---	---	1,727.8	496.7
	MEANS				106	31	-------	-----

for the selection watershed were consistently, though only slightly, higher than those for the control watershed. It should be noted that the statistical analysis showed no significant differences between treatments. Six storms do not constitute an adequate data base upon which to evaluate forest practices and such was not the objective of this report. However, the consistency of measurements from the pumping sampler lends a degree of credibility to the data. The consistency of measurements from the Coshocton samplers was not so apparent. In fact, two TSS values for the storm of 8-9 December 1980 appear to be grossly exaggerated. Total suspended solids for the selection and control watershed were 524 and 153 mg/l, respectively. In contrast, TSS for the clearcut watershed was 18 mg/l. Turbidity values for the Coshocton samples for that particular storm (Table 1) are in better agreement with the pumping sampler TSS values than with the Coshocton TSS values. In the Ouachita Mountains, stream turbidities have been found to correlate 1:1 with TSS concentrations for the 1-50 NTU turbidity range. Above 50 NTU's the correlation breaks down (Dr. Edwin Miller-Personal Communication). This further supports our belief that the two questionable Coshocton TSS concentrations are obvious anomalies.

Mean TSS concentration for all six storms was 106 mg/l for the Coshocton samples and 31 mg/l for the pump samples.

Total mass (kg) of suspended solids, primarily sediments, were computed by storm for each sampling method. The storm values were then totaled to provide a measurement of total sediment losses for the six storms. Total sediment loss was 1,728 kg for the Coshocton samplers and 497 kg for the pump samples. However, if the questionable Coshocton TSS values for the storm of 8-9 December 1980 and their corresponding pump values were deleted, the total sediment losses for the Coshocton and pumping samplers would be 617 kg and 442 kg, respectively. The mean TSS concentrations would change to 47 mg/l and 34 mg/l for the Coshocton and pump samples, respectively.

It would be inadvisable to draw farreaching conclusions about the reliability of sampling methods based on only 6 storms. In a normal year there are from 20 to 30 runoff producing storms on small headwater basins. With a large number of storm events the impact of one or two anomalous measurements is lessened. This study will be continued in order to more fully evaluate the comparative performances of the three sampling systems.

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APPENDIX

Table 1. Analysis of variance table for the split plot experimental design.

Source	d.f.	S.S	M.S.	F
Main Plots (STMXTMTS)	17	124,552.7	7,326.6	
Storms (6)	5	71,861.1	14,372.2	3.29^{ns}[1]
Treatments (3)	2	9,057.3	4,528.6	1.04^{ns}
Error (a)	10	43,634.1	4,363.4	
Sub plots	35	283,842.4	8,109.8	
Samplers	1	29,209.5	29,209.5	4.04^{ns}
Tmt. x Samp.	2	21,663.1	10,831.6	1.50^{ns}
Error (b)	15	108,417.2	7,227.8	

[1] "ns" denotes a non-significant (P=.05) difference for the F-values.

Table 2. Totals of TSS concentrations by treatments and sampling methods for the analysis of variance.

TREATMENT	SAMPLERS		TREATMENT TOTAL
	COSH	PUMP	(T_T)
Clearcut	283.5	274.9	558.4
Selection	785.2	60.7	845.9
Control	338.3	45.9	384.2
SAMP. TOTALS	1,407.0	381.5	1,788.5