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Sediment measurement techniques used by the Soil Conservation Service of New South Wales, Australia

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ABSTRACT A range of sediment samplers and supplementary equipment used by the Soil Conservation Service of New South Wales is assessed and discussed. The main sampler selection criterion is the object of each experiment. Consequently, samplers developed in the 1940's are still being used as well as more recently developed instruments. Geib multislot divisors and storage tanks are used to estimate total sediment yield, on an event basis, from small plots. Pomerene wheels and H flumes are used in small basins. When discrete samples are required for soil erosion process research, or from medium to large basins, pumping sediment samplers are used. The sampler intake point is located downstream of a turbulent section of flow or a depth integrating tube is used to obtain representative samples. The flow measuring structures used with pumping samplers are either sloping crest Crump weirs or H flumes with 14% sloping drop boxes.

Techniques de mesure des sédiments employées par le Service de la Conservation du Sol de New South Wales, Australie

RESUME Une série d'appareils pour échantillonner les sédiments et d'équipements complémentaires employés par le Service de la Conservation du Sol de New South Wales est évaluée et discutée. Le critère principal pour choisir l'appareil pour échantillonner les sédiments est le but de chaque expérimentation. En conséquence, les appareils qui ont été mis au point pendant les années 1940 sont employés encore aussi que des instruments mis au point plus récemment. Le partiteur Geib multislot et des réservoirs de stockage sont employés pour évaluer le produit total de sédiments des petites parcelles. Les roues Pomerene et les canaux jaugeurs H sont employés pour les petits bassins versants. Quand des échantillons discrets sont nécessaires pour les recherches sur le processus de l'érosion du sol, pour des bassins versants grands ou moyens on utilise des pompes pour échantillonner les sédiments. Le point d'entrée de l'appareil est situé à l'aval d'une section turbulente de l'écoulement ou on utilise un tube qui intégre suivant la profondeur pour obtenir des échantillons représentatifs. Les structures pour éstimer l'écoulement employées avec les pompes pour échantillonnage sont des déversoirs à crête Crump inclinées ou des canaux jaugeurs H avec des cuves dotées d'une pente de 14%.

INTRODUCTION

Sediment monitoring is undertaken by the Soil Conservation Service (SCS) of New South Wales, Australia, as part of hydrological evaluation of land management strategies, including soil erosion control measures.

In New South Wales sediment concentration in runoff is not constant with time, it fluctuates widely both between and during events (Australian Water Resources Council, 1969; Edwards, 1980). Thus, a major difficulty in sediment monitoring is the impracticability of the operator being present for every event. Consequently, instruments must be used to provide the otherwise missing data.

Two instrument systems are used by the SCS. The first system uses a sediment sampler to provide an estimate of both sediment concentration and total runoff. Total runoff is determined by dividing the volume of stored runoff by the known proportion of runoff flow the sampler extracts. The second system uses a sediment sampler to give an estimate of sediment concentration and a supplementary instrument to give the total runoff estimate. In both systems the sediment concentration per unit volume of runoff is applied to the total runoff amount for computing total sediment yield for a runoff period. The runoff period can be part of or, the entire, runoff event.

The selection of a sediment sampling system and sampler depends on the objects of specific programmes. Sediment monitoring from basins is only undertaken as a part of a research project so the aim of that research will dictate the sampler and sampling system requirements.

Research into sediment rates was begun by the SCS in 1946 with the establishment of 0.1 ha plots, to measure sediment and runoff from a range of land use treatments, on an event basis. The most suitable equipment available at that time for this object was the Geib multislot divisor and storage tanks. In the early 1950's research into the hydrological effects of land treatment in small basins (10 ha) was started, the aim being to compare total soil loss and runoff between treatments. A Pomerene wheel sampler is used in these studies. In the late 1960's and early 1970's SCS research began to involve larger basins, up to 500 ha. Initially single stage sediment samplers were used to obtain runoff samples. These were replaced by pumping samplers. When high sediment concentrations are anticipated pumping samplers are used in conjunction with a sloping crest Crump weir or H flume with a 14% sloping drop box.

These systems are discussed below using the following criteria (Parsons, 1954; Willis *et al.*, 1969): (a) capacity, (b) sample, (c) accuracy, (d) reliability, (e) cost and (f) hydraulic head.

The sampler must have sufficient *capacity* for measuring relatively large runoff events.

The size of the *sample* should be small, yet large enough to be analysed if only a small flow occurs. The sample must be *representative of runoff from both large and small runoff events.* There should be no variation between the sediment particle size distribution of the sample and that of the total runoff.

The type of sample collected and stored by the sampler will determine its suitability. A sampler which collects a composite sample for each runoff event would be suitable for a simple basin treatment comparison study, but, for soil erosion process research, discrete samples on a time or discharge rate basis are needed.

The *accuracy* of runoff measurement is higher than for sediment yield determinations. Maximum allowable error is the larger of 0.5-1.0 mm or 5-10% for runoff compared to 112 kg ha^{-1} or 25% for sediment yield (Parsons, 1954). Thus, the requirements for an apparatus to measure both parameters are more difficult to meet than the requirements for an apparatus to measure only one parameter (Parsons, 1954).

The sampler must be capable of *dependable*, automatic operation between inspection visits.

Ideally, the *cost* per satisfactory measurement of sediment rate should be as small as possible. This cost should include both installation and maintenance costs.

The *hydraulic head* is a site factor, some samplers require a greater hydraulic head to operate and would be unsuitable for use on very flat terrain. The smaller the hydraulic head required by a sampler the better, provided the other criteria are satisfied.

SAMPLERS USED BY THE SCS

Geib multislot divisor and storage tanks

The SCS use this sampler in conjunction with storage tanks on small plots and as a secondary sampler in small basins. The installation system is based on plans and specifications supplied by the USDA Soil Conservation Service (Wiltshire, 1947, 1948). The basic components are a collecting sill which concentrates runoff, a sludge tank in which heavy soil material and trash are retained, a Geib multislot divisor to divide outflow from the sludge tank into 11 equal aliquots and a storage tank to hold one of the 11 aliquots for further subsampling and analysis.

This system has good storage capacity. The sludge tank holds 3 mm of runoff and the storage tank holds the equivalent of 100 mm of runoff. The divisor is able to sample a flow of 0.009 m^3 s^{-1}.

The comparison of total sediment and runoff from different arable and pasture regimes is the object of this research, so the composite sample provided by this system is quite satisfactory for estimating total sediment yield.

A multislot divisor similar to the one used by SCS is claimed (Mutchler, 1963) to achieve an accuracy of about 1% in runoff estimation. This is well within accuracy limits imposed by these experiments. The main reason for this accuracy is the use of a sludge tank so that the divisor only handles water and suspended sediment in a smooth flow.

The reliability of the divisor system is good because there are no moving parts nor does it require attention whilst operating. The use of screens to filter out floating debris minimizes blockage of the slots.

The multislot divisor and tanks are comparatively inexpensive, but the slots must be accurately machined.

The height of the storage tanks and the gradient required to ensure that the collecting sill, connecting flumes and divisor are self cleaning, mean a reasonable hydraulic head is required.

Pomerene wheel

This wheel sampler is used by the SCS to obtain sediment samples from small basins, of about 20 ha. The 0.6 m diameter sampler is mounted below a H flume, which is used to measure total flow. The sample collected is stored in a storage tank providing a reasonably large sample from smaller flows. When this tank has been filled, the excess flows through a Geib multislot divisor and an aliquot is stored in a second tank.

This system is used in a research programme to compare runoff and sediment yield from basins under different land use regimes. A composite sample, composed of a number of discrete samples of runoff, for sediment determination is satisfactory.

The number of discrete samples is dependent on the discharge because the greater the discharge the greater the number of samples, so, the composite sample collected is representative of average runoff.

However, the ponding and decrease in runoff velocity which occurs in H flumes allows coarse sediment to settle in the flume. This effects the sediment concentration of the discharge that reaches the sampling wheel. Flows high in coarse sediment will be affected more than flows high in fine sediment.

Runoff from the basins monitored by SCS is generally not high in coarse sediment but there is still noticeable sediment deposition in the flume despite the use of a 2% sloping drop box. Deposited sediment is collected and added to the total sediment yield for each event. This reduces the error involved in sediment estimation but does not reduce the error involved in runoff estimation caused by the sediment deposition altering the rating curve of the flume.

The wheel being driven by gravity flow of runoff has no pumps or valves to clog or stick, especially with high sediment loads. Thus, it is capable of continuous operation for the entire duration of the flow. The wheel is inexpensive, but, the added cost of a runoff measuring structure to provide the large hydraulic head to operate the wheel must also be considered.

Single stage sediment sampler

The design of this sampler is simple and is described in US Inter-Agency Committee on Water Resources, Subcommittee on Sedimentation (1961). This sampler is designed to collect a sample from a point near the water surface. A volume, 500 ml, is siphoned into the container as soon as a predetermined head of water above the intake tube is reached and maintained. The location of the sampler intake near the surface means that intensive sampling is needed to relate sample sediment concentration to total sediment concentration. The sampler operates reliably provided the intake or the outlet tube is not blocked by insects or debris. The simplicity of design ensures that it is inexpensive. The SCS has only used this sampler to provide data prior to installation of a more accurate system.

Pumping samplers

The sampler used by SCS is the *Gamet* water sampler produced by Gamet Equipment Australia*. It is a self contained, transportable, battery operated machine, which will pump and store water samples from a source at regular, preselected time intervals. In some units sampling is governed by discharge.

Twenty-four discrete samples can be collected during each sampling cycle. The volume of each discrete sample can be varied up to 500 ml. They can be stored in individual bottles or as a composite sample in one large container. A special valve is necessary to prevent blockage by high sediment concentrations or coarse sediments which together with a flushing period before each sampling ensure that inter-sample contamination is minimized.

Sampling efficiency is maximized in SCS experiments by locating the sampling point just downstream of a hydraulic jump to ensure good mixing of the sediment (Walling & Teed, 1971; Hansen, 1966). Alternatively a depth integrating tube is located in the deepest section of flow. The depth integrating tube (Ciesiolka, personal communication) is a length of tube of 12 mm internal diameter and 10% longer than the expected maximum depth of flow. The intake hose from the sampler is attached to one end of the tube which is hinged to a rigid support. A float attached to the other end of the tube causes the tube to rise and fall as the depth of flow varies. Intake holes drilled along the length of the tube ensure a depth integrated sample is taken.

The most common malfunction is due to power failure, but, use of solar panels to keep batteries fully charged has overcome this problem making pumping samplers a reliable system for monitoring programmes even at relatively remote sites.

A pumping sampler system is expensive to establish. The sampler costs $ Aust. 2000 and the cost of the accompanying runoff measuring structure can easily double this figure. A hydraulic head is not required to operate the sampler, but, a head is involved in creating the turbulence necessary to ensure mixing of sediment and runoff.

Flow control structures

The side sloping crest Crump weir and a H flume with a 14% sloping drop box are now used in conjunction with pumping samplers because of their ability to handle high sediment concentrations. The

** The inclusion of trade and company names is not an endorsement by the Soil Conservation Service of NSW but is done for convenience to the reader.*

Crump weir, a triangular profile weir proposed by Crump (1952) has been used extensively for measurement of flow in alluvial channels where the Froude number does not greatly exceed 0.3.

The side sloping crest Crump weir is an inexpensive structure, requiring a very low hydraulic head and is accurate over a wide range of discharges (Bonham, 1972). When flow distribution of the natural channel matches the flow distribution of the weir the sloping crest Crump weir profile will tolerate high discharges and high sediment loads without undue scour or accretion.

A pumping sampler intake is located on the downstream slope to sample runoff water for sediment concentration. At this point all sediment is in suspension and it is representatively sampled using a depth integrating tube.

H flumes are used because of their sensitivity and proven performance. However, to achieve this accuracy and sensitivity throughout the flow range a relatively large head and slow approach velocity are required. These conditions are conducive to sediment deposition upstream of the flume and in the flume itself. To overcome this problem drop box approaches have been used.

Early drop boxes had a floor gradient of 2% in the direction of flow, but this has proved unsatisfactory. A new box design with a uniform floor gradient of 14% between the entrance to the box and the entrance to the measuring flume is now used (W. Gwinn, personal communication). This approach creates a hydraulic jump on the sloping floor for all flows. The turbulence in the jump helps to keep sediment in suspension and provide mixing for water quality measurements. The sediment sampling point for pumping samples is located in the side of the flume.

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