TRANSPORT OF SEDIMENT IN MOUNTAIN STREAMS: PERFORMANCE OF A MEASUREMENT SYSTEM DURING A TWO YEAR STORM (NOTE)

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INTRODUCTION

Dry Acheron Stream, a small subtributary of Rakaia River, drains a 21 km² area of eastern Southern Alps, New Zealand (Fig. 1). Alpine and montane grassland, scrub, bare rock and scree occupy the mountainous portion of its catchment except for a 0.6 km² area of hardwood forest (Nothofagus), near the basin centre. Altitude ranges from 650 to 1540 m and mean annual rainfall is approximately 2000 mm. Within the upper basin the stream channel is deeply entrenched, and is characterised by a pool-and-riffle geometry defined by channel boundaries of boulders and cobbles. Average stream gradient is 0.167.

To provide quantitative assessments of sediment yields and transport patterns, a water and sediment discharge recording station was recently constructed just downstream of where the stream exits from its mountainous upper catchment (6 km²) (Fig. 1).

The station comprises three structures: (1) a weir to furnish a stable, rated, water discharge record and a convenient site to sample sediment load; (2) a debris-retention dam to trap most of the sediment load; and (3) a platform on the downstream side of the dam to allow sampling of material escaping through or over the dam (Fig. 1).

The purpose of this note is to describe the operation of the station and to present results from a recent flood which provided a test of the measuring system.

MEASUREMENT TECHNIQUES AND STRUCTURES

Sediment transport rates and yields are measured using conventional techniques at each of the three structures of the recording station. Inflows of water and sediment to the system are determined at the weir, which is constructed of reinforced concrete in the Flat-Vee Crump-style (see, for example, Herschy et al., 1977): it is rectangular in plan (6 × 5.6 m) with a raised floor of complex geometry and side walls 2 m in height—details of the modified design are specified in Griffiths (1978a). The weir is positioned to correspond to a natural riffle in the streambed. Its design

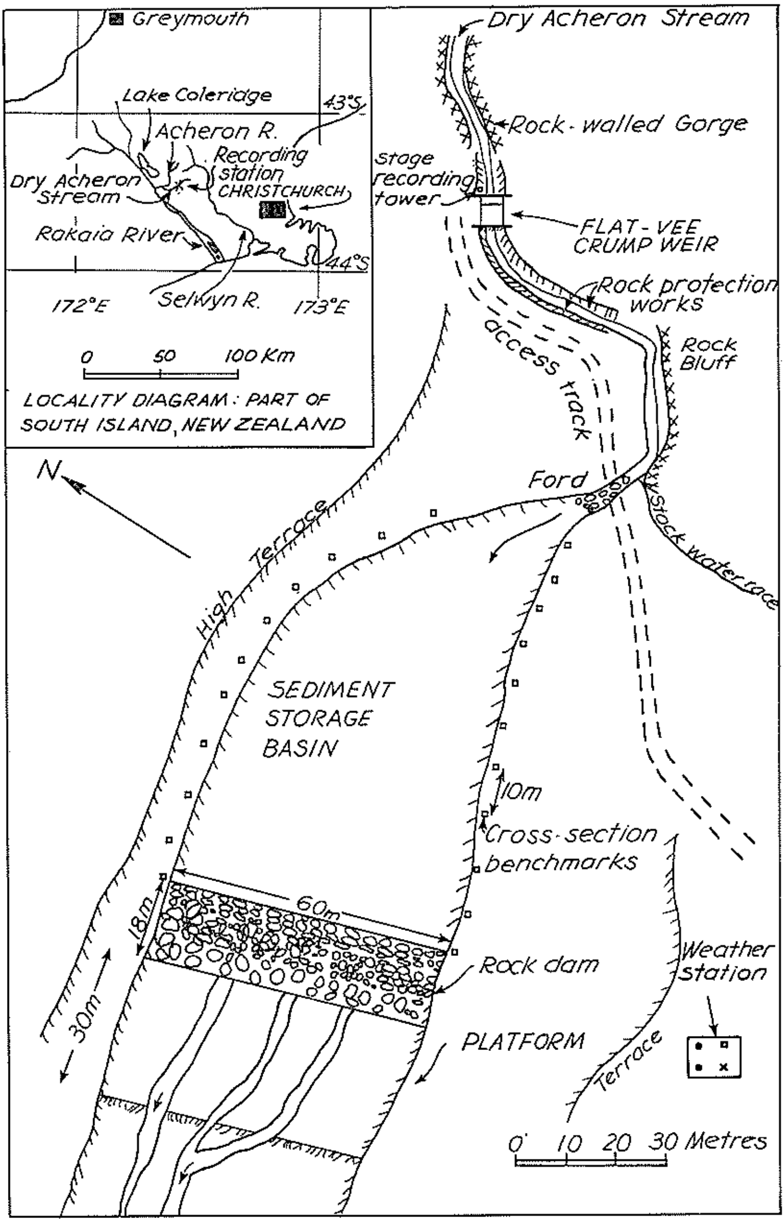

FIG. 1—Sketch plan of Dry Acheron Stream water and sediment discharge recording station (Ministry of Works and Development Site No. 68529—Map Reference = NZMS1, Sheet 74, 147730).

is intended to allow unimpeded passage of sediment and debris, and to provide sensitivity to changes in waterlevel at low flows. Stage or water-surface elevation in the approach section to the weir is recorded, every 15 minutes, within an adjacent tower (see Waugh and Fenwick, 1979). These values, in combination with a stage-discharge relationship, are used to derive a continuous record of water flow. Suspended sediment is sampled from a bridge across the weir using a USDH48 depth integrating sampler, in the manner described by Guy and Norman (1970). Material moving along the streambed is sampled with a Helley-Smith Bedload Sampler as detailed by Emmett (1979) (Plate 1). The orifice of the Helley-Smith sampler is 0.077 m square, so it also collects suspended material, moving in the vicinity of the streambed, that is not sampled by the USDH48 device.

PLATE 1—View from upstream of operation of Helley-Smith Bedload Sampler from bridge across weir, Dry Acheron Stream, New Zealand.

The permeable dam bounding the sediment retention basin at its downstream end is a trapezoid in cross-section, and is constructed of large streambed-derived boulders. It is 60 m long and 3 m in height, with upstream and downstream batters of 2:1 and 3:1 repectively—details of the design are specified in Griffiths (1978b) (Fig. 1 and Plate 2). The volume of sediment deposited, over some interval, in the storage area is determined from changes in area of basin cross-sections spaced uniformly and parallel to the dam face (Hicks, 1980). The mass is estimated from volume, using a mean value of density deduced from measurements of the density of the deposited material. Storage basin capacity is about 5000 m^3. At appropriate intervals the basin is cleared mechanically and the sediment returned to the streambed below the dam.

PLATE 2—View from downstream of sediment storage basin, rock dam and platform, Dry Acheron Stream, New Zealand.

Fine suspended material, not trapped by the dam, flows through and over the structure, depending on water discharge. This sediment is sampled with a USDH48 sampler, by wading, on a horizontal platform (60 x 30 m) excavated on the downstream side of the dam (Fig. 1 and Plate 2).

The constraint of continuity requires that, for the same period, inflow minus outflow equals change in storage. As two of these three independently determined variables are ascertained by different measuring techniques, an assessment of the accuracy of the recording station is possible.

RESULTS FROM A FLOOD IN APRIL 1980

On 9 through to 11 April 1980, Dry Acheron catchment was subjected to a southerly storm of moderate intensity. The concomitant flood reached a single peak of 4.2 m^3/s at 1100 hours on 10 April. Total storm rainfall was 110 mm, with 85 mm falling in 48 hours. A continuous record of rainfall intensity is not available, owing to recorder malfunction at the weather station (Fig. 1). From annual series derived by Tomlinson (1980) the deduced recurrence interval for this storm is about two years. The adjacent Selwyn River (Fig. 1) reached a mean-annual flood (recurrence interval of 2.3 years), which also peaked on 10 April. Measurements made at the three structures during the storm allowed the computation of a sediment budget for the flood (Table 1). Sediment yields at the weir and platform were determined by integrating measured transport rates with time.

Estimates of precision (standard error of mean) are noted in Table 1: precision limits would probably have been smaller had inflows and outflows been sampled more frequently, together with a larger number of density tests in the sediment storage basin. The precision of the sediment yield measurement system is high (Table 1) and, by implication, so is that of instantaneous transport rates. Size distribution and quantity of the transported material, sampled at each structure, is given in Table 2. Most of the sediment is of gravel size, in contrast to channel boundary material, and moved as bedload through the weir. Within the precision limits of measurement the dam is nearly 100 percent efficient at trapping material coarser than silt.

TABLE 1—Sediment budget for April 1980 flood—Dry Acheron Stream, South Island, New Zealand.

INFLOW Estimated at weir (tonnes)		DEPOSIT Recorded at sediment retention basin (tonnes)	OUTFLOW Estimated at dam platform (tonnes)
USDH48 sampler	Helley-Smith sampler	Volume from cross-section surveys, density from in situ tests	USDH48 sampler
421 ± 53	2563 ± 366		
2984 ± 370		2901 ± 464	153 ± 36

Sources contributing sediment to the stream channel were almost exclusively riparian (Whitehouse and McSaveney, 1980). Whitehouse (pers. comm.) estimates source input (neglecting bank erosion) of the order of 2570t (assuming a density of 1.8 t/m^3) which suggests a figure of the order of 330t, for changes in streambed sediment storage and bank erosion input.

TABLE 2—Size distribution of material transported during April 1980 flood—Dry Acheron Stream, South Island, New Zealand.

	INFLOW Recorded at weir (tonnes)		DEPOSIT Recorded at sediment retention basin (tonnes)	OUTFLOW Recorded at dam platform (tonnes)
	USDH48 Sampler	Helley-Smith Sampler		USDH48 Sampler
Gravel	17 (4%)	2435 (95%)	2437 (84%)	0
Sand	173 (41%)	128 (5%)	348 (12%)	17 (11%)
Silt/Clay	231 (55%)	0 (0%)	116 (4%)	136 (89%)
Total	421 (100%)	2563 (100%)	2901 (100%)	153 (100%)
Mean size (mm)	0.044	13.4	9.10	0.01
Median size (mm)	0.043	15.0	10.0	0.01
Mode (mm)	0.088	13.2	14.3	0.009
Std. deviation of distribution (Folk, 1968)	10.90	2.56	3.05	4.41

CONCLUSIONS

1 Results from a single storm confirm the accuracy of a sediment yield measuring system in a mountain stream during a flood of about 2 year recurrence interval. Performance for floods of lower frequency remains to be tested. This is an encouraging result given the vigorous environment.

2 Measurements made with conventional samplers of within-flood variations in sediment transport rates are likely to be reliable in Dry Acheron Stream.

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