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Cropp River: data to test concepts of channel network and river basin heterogeneity – Data note

R.D. Henderson, R.P. Ibbitt and M.J. Duncan
(NIWA, P.O. Box 8602, Christchurch, New Zealand)
(Email: r.henderson@niwa.cri.nz)

Abstract

The paper describes data collected in the Cropp River basin, Westland, New Zealand, for testing hypotheses underpinning the optimal channel network concept. Access details are given on a World Wide Web page (http://www.niwa.cri.nz/hydrology/cropppage.htm), for the use of other researchers. The basin is a steep, high altitude mountain basin with an area of 13 km^2 and runoff in excess of 11 m/yr. On 26th February 1996, flow was measured at 53 sites, channel properties at 47 sites, and elevation by Global Positioning System (GPS) at 41 sites. The basin flow was steady at a value exceeded approximately 60% of the time. This Data Note describes measurement procedures and error analysis.

Introduction

Recent proposals that river channels assume an optimum form (Ibbitt, 1997 and references therein) contain testable hypotheses relating to the exponents of the downstream hydraulic geometry relationships and the variation in longitudinal slope. To test these hypotheses, measurements are needed of flow and channel properties at many locations across a basin while the flow is steady. This Data Note describes catchment-wide data collected for this purpose on 26 February 1996 at 53 sites in the Cropp River catchment in Westland, New Zealand, during a one-day period with near-median flows. It briefly describes the data collection methods, indicates how the data may be accessed, and explores the applicability of the data for testing the optimal channel network model.

The data comprise flow, channel properties and Global Positioning System (GPS) elevation measurements at 53 sites along the channel network, in ASCII format. Associated data are the stream channel network in PostScript format for the basin, as shown on the N.Z. Infomap 260 (1:50 000) maps for the basin. Details for accessing the data are given on a World Wide Web page: http://www.niwa.cri.nz/hydrology/cropppage.htm

Basin Description

The basin selected for this study was the Cropp River above the stream gauge at Cropp Hut (station number 90607). This basin, a tributary of the Hokitika River, which drains the central Southern Alps, lies at latitude 43° 5′ S, in the South Island of New Zealand. It was selected because it is in the zone of highest rainfall in New Zealand, and is tectonically and erosionally active; it provides a contrast to the basins described by McKerchar *et al.* (1998) and Ibbitt *et al.* (1998). The elevation range of the basin is from 860 m to 2000 m, and the slopes are steep (70% between 26° and 35°, 30% greater than 35°). Two long-term automatic raingauges (Cropp Hut and Waterfall) operate within the basin. Mean rainfalls at these two gauges are 10.5 and 11.3 m/yr respectively. There is seasonal snowfall and some winter snow accumulation. Mean discharge, as measured at the streamflow recorder over the 17 year period 1979-1999 (with 8% missing record) is 4.84 m^3/s, representing an average runoff rate of 11.7 m/yr from the basin. The discrepancy between rain and runoff may be accounted for by an assumption of 13% losses at the rain gauges due to wind and snow.

The Cropp basin is underlain by extensively faulted, tilted and shattered schist, and the overlying soil mantle is thin. The basin is natural sub-alpine to alpine in character, unmodified by human activity. The vegetation ranges from tall (c. 1500 mm) sub-alpine shrub species through c. 900 mm native tussock grassland to low alpine vegetation and bare rock.

Geology, rainfall and hydrology of the area are more fully described by Chinn (1979), Griffiths and McSaveney (1983a and b) and Henderson (1993).

Data acquisition

Site selection

Sites were chosen to sample an even size distribution of catchment areas and sub-areas where possible (Fig. 1), but for practical purposes were generally located immediately above and below stream junctions, as shown on the topographic map. Six teams of two were dropped at the highest altitude sites by helicopter, and proceeded on foot where possible to the sites downstream. One team needed to resolve major differences between the map and the terrain where a debris flow had affected 11% of the basin area. These differences were such that more detail was gathered in the altered area, and planned measurements for a group of sites in the centre of the basin were missed.

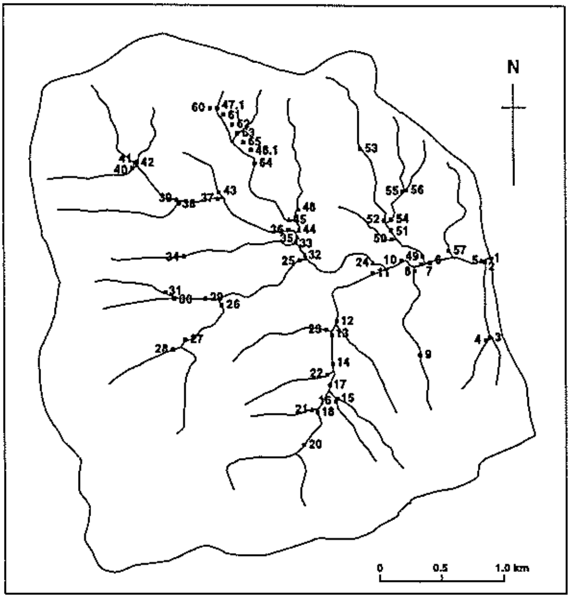

FIGURE 1 – Location of measurement sites in the Cropp basin above the stream gauge at Cropp Hut (stream gauge no. 90607). Sites for which flow measurements were obtained on 26 February 1996 are marked with squares, and those with no field flow measurement are marked with triangles.

Measurement techniques

Location

The location of each site was estimated in the field using 2x-enlarged laminated field copies of the relevant section of the 1:50,000-scale map sheet (Infomap 260-J34). Portable GPS units were also used where terrain permitted independent measurements of location. This proved of great benefit in areas where there were differences between the mapped and actual stream network, particularly in the sub-basin eroded by a debris flow, where locations were difficult to determine because of the altered drainage pattern and valley bottom shape. GPS coordinates were obtained at 41 of the 53 sites at which flows were measured, topographic interference preventing GPS measurements at the remaining 12 sites.

Elevation

GPS measurements were used wherever possible to obtain elevation data. Map estimates were used for those sites without GPS readings.

Flow and hydraulic parameters

Flow was measured using standard methods and equipment (Rantz *et al.*, 1982). Of the 47 current meter gaugings, 25 were by Pygmy, 3 by Gurley, and 19 by Small Ott meters. Channel width, mean depth and mean velocity are also provided by these measurements. Standard errors in the current meter flow measurements were calculated using methods outlined in Henderson and Rodgers (1993) in accordance with standards in ISO (1983). The 6 volumetric gaugings and the single field-estimated flow were estimated to have a standard error of 8%.

Channel width

Channel width was measured 10 m upstream or downstream of gauging sites. These measurements were made to check the representativeness of the gauging site for use in estimation of basin hydraulic geometry parameters. The ratios of these widths to the width of the measured section range from 17% to 775%, with a mean 92% and a standard deviation 111%.

Reach type

Reach types in the categories of waterfall, chute, rapid, riffle, run, pool and combinations of these were observed (Padmore *et. al.*, 1998).

Substrate

Across each measured section estimates were made of the percentage of substrate within the following classes: sand and silt, fine gravel, gravel, small cobble, large cobble, boulder and bedrock (Chow, 1964).

Stability of discharge during measurements

The catchment outlet (the site furthest downstream) was gauged only at the end of the day, so a continuous record of flow during the exercise is not available. However no rain fell on the day the measurements were made, and flow records from a downstream site, Hokitika River at Colliers Creek (site 90604), and from a site in the adjacent Taipo catchment (site 91103) show a steady flow recession (104% to 98% of the mean flow on that day). The nearest measured site to the south of the Cropp (Whataroa at State Highway Bridge, site 89301) showed some effects of snowmelt in the late afternoon, but flows still did not vary by more than 3% during the day. The flows at these sites and their exceedance percentiles are given in Table 1. Records for these stream gauges are available on request from the authors.

Data Checks

Various measured and derived data were subject to checks on consistency.

a) For each cross-section processing of the velocity-area gaugings provides

TABLE 1 – Flows recorded at nearby sites, and their exceedance percentiles.

Site no.	Site name	Area	Length of record	Missing record	Median flow	mean flow on day	Exceedance Percentile
			km^2	years	M^3/s	m^3/s	
90607	Cropp	13	17.1	8%	2.45	2.00 (gauging)	62
90604	Hokitika	352	16.7	2%	61.9	60.7	51
91103	Taipo	181	18.7	1%	29.0	26.6	56
89301	Whataroa	445	11.1	2%	79.5	55.6	69

the channel width, cross section area, mean velocity of flow and mean channel depth. Internal consistency was checked and each cross-section and velocity distribution was plotted for visual assessment by an experienced hydrologist.

b) Measured and estimated flows (see below) were checked for consistency. A single requirement was imposed that no between-site increment of flow would be less than zero in the downstream direction. Flows for 15 sites were adjusted to achieve this result. Of these 15 flow values, 7 were altered by less than ±1 standard error (se), 6 by between ±1 and ±2 se, and 2 by between ±2 and ±3 se. The size of adjustments is consistent with a normal distribution of gauging errors. There remain between-site specific discharges that are unrealistically large, but these could be attributed to small differences in large areas or small differences in large flows.

c) Global Positioning Satellite (GPS) data are claimed by the manufacturer to yield standard errors of ± 2.5 m for horizontal measurements and ± 7.5 m for elevations. Since map elevations are at 20 m resolution with a standard error of at least ±10 m, discrepancies between map and GPS elevation were resolved in favour of the corrected GPS reading.

d) Channel slopes for the 29 sites with another site upstream were calculated from the ratio of the altitude gain to the plan distance along the channel between sites. For 27 headwater streams, slopes were calculated from the ratio of the gain in altitude to the distance along the channel between the measurement site and the end of the stream marked as a blue line on the map. For six sites with no blue line on the map, a plan distance of 200 or 300 m was selected and the corresponding altitude gain was measured from the map.

Derivation of estimated flows

For nine sites where flow measurements were planned, no measurements were actually made for reasons of access, physical constraints, or time.

For these nine sites, flows were estimated for analysis using the following logic:

- the flow at a site should be less than the nearest downstream main stem flow minus intervening measured tributary flows;
- the flow at a site should be greater than the sum of the nearest upstream flows; and
- the flow at a site should be close to the product of specific discharge at the nearest site and the basin area of the site in question.

Because of the steep slopes, thin soil mantle and closeness of bedrock to the channels in the Cropp basin, losses to or gains from ground water between sites are unlikely.

Example of use of data

Figure 2 shows two cumulative discharge curves for the Cropp and the cumulative area curve. The cumulative discharge curves have been derived in two ways: firstly from the measured and estimated flows, and secondly

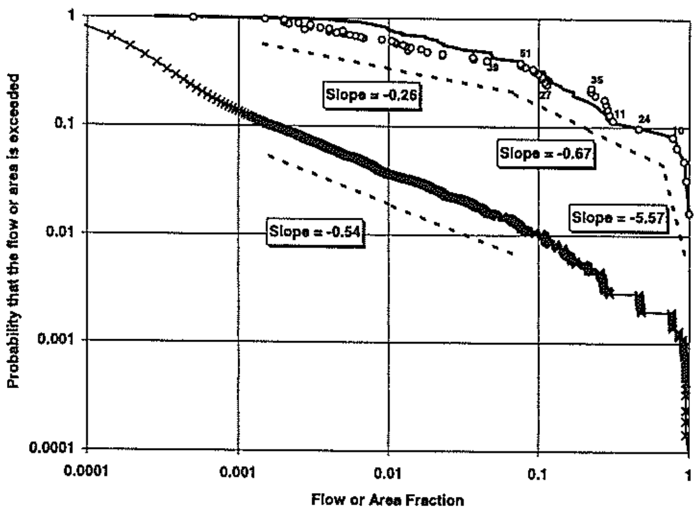

FIGURE 2 – Cumulative distribution of flow in the Cropp basin (circular symbols), the cumulative flow curve derived from the areas of the sampled sites by assuming a constant specific discharge across the basin equal to the mean discharge on the day of measurement (bold solid line) and a cumulative area curve derived from a digital elevation model (crosses). The dashed lines define lines of constant slope - see text for details. Numbers with circular symbols refer to the site at which the flow determining the position of the circle was measured.

by using the contributing area at each measurement point and assuming a constant specific discharge across the basin. The cumulative area curve is derived from a digital elevation model at 25 m resolution. Discontinuities within, and dissimilarities between, the three sets of cumulative data are evident.

The three linked dashed lines of constant slope marked on Figure 2 close to the flow data points were derived by successively fitting linear regressions to each end of the curve so as to maximise the regression coefficients of each end segment. A line of slope -0.67 was fitted to the remaining middle points. A similar line near the cumulative area curve shows the slope of the straight central portion, and its extent.

Dissimilarities between the curves are attributable to spatial variations in specific discharge within the basin. A major tributary draining from the north-facing slopes (sites 11 to 23 on Figure 1) had much higher specific discharge and measured flows than the rest of the basin, possibly due to a contribution from snowmelt.

Discontinuities along the cumulative discharge curves are caused by the small size of the basin. Some flow ranges cannot be sampled, because the basin has no sub-basins with flow in that range. These major discontinuities are also present in the cumulative area curve. Other discontinuities, such as between sites 35 and 27, or sites 51 and 39, do not appear on the cumulative area curve, and could have been smoothed by sampling between stream junctions. However the terrain and time constraints of the exercise did not allow this.

Downstream hydraulic geometry relationships derived from the data, which express channel width, depth and velocity and slope as functions of discharge raised to an exponent are listed in Table 2. These results are clearly different from those used in the generation of optimal channel networks, and raise questions about the applicability of the optimal channel network concept to New Zealand drainage basins (Ibbitt, 1997). Henderson and Ibbitt (1996) present hydraulic geometry exponents for a number of other New Zealand basins.

TABLE 2– Exponents from basin-wide log-log relations between flow and width, depth and velocity at gauging cross-sections.

Basin-wide exponents	Cropp Data	Ashley Data	Optimal channel network values
Velocity V, exponent 'm'	0.22 ± 0.04	0.318 ± 0.018	0.0
Width W, exponent 'b'	0.47 ± 0.04	0.440 ± 0.016	0.5
Depth D, exponent 'f'	0.31 ± 0.03	0.242 ± 0.014	0.5

It is clear from Figure 2 that the slope of the cumulative flow curve for the Cropp channel network does not approach the optimal value of -0.45. The analysis presented here also shows that the Cropp is not 'similar' to the Taieri and Ashley, as initially suggested by Henderson and Ibbitt (1996). The cumulative flow diagram shows slopes that deviate markedly from the optimal channel network expected value of -0.45, and discontinuities that are matched by detail in the cumulative area curve derived from a 25 m digital elevation model. The tectonically active Cropp basin was not expected to satisfy the requirements for an optimal channel network. The field exercise shows that it is possible to collect data that differentiate a real basin's properties from those of an optimal channel network.

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