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A procedure for characterising river channels

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by M. P. MOSLEY

Christchurch Water and Soil Science Centre
Ministry of Works and Development
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Christchurch Water and Soil Science Centre, Ministry of Works and Development, Christchurch.
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The evaluation of the potential impacts of water resource development upon instream uses such as recreation and fisheries requires in the first instance a large amount of information on the character and environment of the river channels involved. A review of the various methods already in use for evaluating instream flow needs indicates, that, despite a wide diversity of approaches, there are many data requirements in common. Indeed, it is apparent that the intrinsic characteristics of a river may be described independently of the particular human use of concern; in principle, description of the physical appearance of a river is a relatively simple, though time-consuming, matter.

A data collection procedure is proposed which will provide all the data needed by a specialist to assess the value of a given channel for instream uses. Data fall into the following groups; (i) Geographic location; (ii) Channel environment and setting; (iii) Channel hydraulic geometry; (iv) Sediment characteristics; (v) Streamflow and water quality; (vi) Riparian vegetation. As an example the procedure is applied to the Ashley River, Canterbury.

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Contents

Introduction

Use of New Zealand's water resources for irrigation, hydro-electricity generation, dilution of pollutants and other purposes may modify the hydrologic regime of and sediment transport along a river, and hence cause changes in the form and behaviour of the channel. This in turn may affect the value of a river for such instream uses as water-based recreation and fishing, as well as modifying the aesthetic quality of the river environment.

As part of the process of planning for water resource development, it is necessary to have full information on the characteristics of a river channel in its undisturbed state, its value for any instream uses, and the likely impact of development on these. In the past, efforts to provide this type of information have usually been inadequate, primarily because of a lack of awareness of the precise information required. Those personnel who have been involved in data collection are not trained in specific disciplines such as fisheries biology and recreation resource management, and cannot be expected to intuitively know what parmeters are of importance and should be measured; even the specialists are not always certain what to measure, nor how to measure it.

An alternative to collecting information needed by specific user groups is to collect data that will characterise a river's present form and environment, its instream values, and its likely response to development independently of these uses, and which will provide all the information that will be needed by any user group. A review of existing literature in a wide range of disciplines indicates that there is in fact a substantial overlap in information needs, and that a properly designed general procedure for data collection will provide the information required by all. For example, information on the appearance and condition of a river bank will provide data needed by a fish biologist to assess the amount of cover available to fish, by a recreation resource manager to assess the aesthetic quality of a riverscape as seen by a canoeist, or by a wildlife biologist to assess the amount of habitat available for terrestrial birds, mammals, and other animals. Looked at in another way, it seems that the characteristics of a river which control its suitability for a variety of instream uses are intrinsic to the river, and may be measured or defined whether or not those uses actually occur. In essence, a river may be viewed as a three-dimensional body of water whose dimensions (length, widths, depths) and other characteristics (velocities, temperature, chemical characteristics) can be measured, just as for a block of wood. The surfaces of the body of water (between the water and atmosphere above it and between the water and the stream bed sediment below it) and the edges where those surfaces join (the stream bank) can similarly be measured and described, just as for the block of wood. Of course, a river is a very complex entity, far more so than a block of wood, so that its description is by no means a simple problem of geometry. Nevertheless, there seems no reason why a procedure cannot be developed for measuring, independently of the uses to which it is put, the characteristics of a river, in the same way that the character of a block of wood can be measured, whether it be used as firewood or turned into a piece of furniture.

Purpose

The purpose of the present guidelines is to propose a general procedure for data collection that can be applied to any river that is under consideration for water resource development. The procedure is intended to describe in some detail the appearance and other characteristics of the river and its environment, so that the present and potential value of the river for any instream use may be defined, and changes in its characteristics and instream values resulting from development may be predicted.

Because specialists in the relevant scientific disciplines such as fish biology are limited in number, data collection must be by technical staff, such as staff of catchment authorities or the Ministry of Works and Development, who are untrained in these specific fields. The data will be used by the specialists and other user groups such as canoe clubs to make estimates of the value of the river for their own areas of concern; the data must therefore be in a comprehensible and readily used form, and must provide all the information needed by the specialists and user groups. The procedure is not intended, however, to provide the type of detailed information on the hydrologic characteristics of a river that is required for water resource planning; where this is needed, as for example for preparation of a water allocation plan, much additional data will have to be collected.

The procedure is based partly upon consideration of the best way of describing and measuring a three-dimensional body of water and its boundaries, and partly upon a synthesis of procedures already developed by workers in several disciplines, particularly fish biology, recreation resource management, and geomorphology. Because information needs in these areas have been defined in most detail, the procedure may show some bias towards them, and characteristics of river channels that are significant for other possible uses may not yet have been recognised. These guidelines are therefore exactly that; the procedure will undoubtedly require future modification.

A general data collection procedure like the one proposed herein may provide some information that is redundant for specific, immediate purposes. It is possible to omit those parts that are clearly irrelevant in a given circumstance, but on the other hand use of the whole procedure will ensure that a body of compatible, consistent data is built up which will permit future analysis for other purposes. While this is not the immediate aim, such analyses would immensely enhance our ability to manage New Zealand's rivers in the most efficient way.

Review

Data to describe river channels have been collected by workers in a wide variety of fields, and for many different purposes. To arrive at a basis for a general data collection procedure it has been necessary to carry out an extensive review of the type of data collected and the uses to which they have been put. The major points are brought out in this review.

Factors to be Considered

River engineers and geomorphologists have for many years routinely measured the physical characteristics of river channels. A number of variables have been used (Hey 1978; Leopold *et al.* 1964); in a study of rivers in the South Island of New Zealand, Mosley (1981a) considered the following variables as descriptors of the morphologic and hydrologic character of river channels:

Cross-section

Cross-sectional area A
Wetted perimeter (≃ width) P
Hydraulic radius (≃ mean depth) R = A/P
Maximum depth DX
Width-depth ratio P/R
Shape factor DX/R
Relative roughness R/d_{75}

Reach

Sinuosity
Water surface slope
Braiding index
Meander wavelength

Sediment in channel perimeter

Mean diameter of bed surface sediment
Median diameter of bed surface sediment d_{50}
Representative diameter of bed surface sediment d_{75}
(size at which 75% is finer)
Standard deviation of bed sediment diameter
Silt-clay percentage of bank sediment

Flood discharge variables

Mean annual flood
Standard deviation of annual floods
Maximum recorded flood
Bankfull discharge

Instantaneous flow variables

Mean discharge
Standard deviation of instantaneous flows
Median flow
Minimum recorded flow
Variability index $VI = \frac{(\ln(Q_{16}) - \ln(Q_{84})}{4} + \frac{(\ln(Q_5) -)\ln(Q_{95}))}{6.6}$

(where Q_{16} is the discharge equalled or exceeded 16% of the time, etc.)

Canonical correlation analysis indicated that, for the sample of 72 rivers, nearly 70% of variation in channel morphology, as indexed by the cross-section and reach variables, was accounted for by cross-sectional area, slope, and cross-section shape, even though measurements were generally obtained for only the bankfull channel at a single representative cross-section.

Although this type of data may adequately describe a river channel for the purpose of analysing the relationship between channel morphology and the controlling factors of water and sediment discharge, it does not provide sufficient information for such purposes as fish habitat evaluation. A recent workshop (Smith 1979) on the US Fish and Wildlife Service Instream Flow Group (IFG) methodology for evaluating instream flow requirements concluded that thirteen factors must be considered in evaluating a stream ecosystem. These were (in order of importance), depth, velocity, temperature, food supply, riparian cover, and competition, and (of lesser, unranked, importance) predation, substrate (bed material), dissolved oxygen, instream cover, nutrients, stream morphology, and sediment load. The precise ranking of these factors would not receive universal agreement, but they do appear to be sufficient to effectively characterise a given reach of river, at least for ecological/biological purposes. Recent work by Canadian hydrologists has gone some way to characterising river channels at a more detailed level than had formerly been attempted by hydrologists and geomorphologists. For example, in a report documenting channel characteristics at 108 gauging stations in Alberta, Kellerhals *et al.* (1972) assembled the following data:

1. cross-sections in the gauging station reach (3–4 cross-sections up and downstream, over a reach length of up to 50 channel widths);
2. water surface levels at each cross-section;
3. longitudinal profile of the streambed and water surface along the thalweg;
4. bed material samples;
5. descriptive notes on bank materials, vegetation, etc., and photographs of the reach.

Tabulated data included discharge, cross-sectional area, width, depth and mean velocity for the surveyed and bankfull discharge, descriptions of the character of the surrounding terrain, the valley, the stream channel itself (particularly channel pattern and bed and bank materials), and the relationship of the channel to its valley. In addition, extensive hydrologic data were tabulated to provide estimates of long-term, minimum and maximum flows, and flood frequency estimates. Neill and Galay (1967) and Kellerhals *et al.* (1976) have presented checklists of data requirements for characterising in a simple, qualitative fashion, a river channel and its associated valley and surrounding terrain.

Nevertheless, even this level of detail may be inadequate for evaluation of suitability for instream uses, because it excludes many less obvious factors which have been shown to be important (Stalnaker and Arnette 1976; Cortell and Associates 1977). Fisheries biologists in particular have examined the relationships between a variety of river channel characteristics and the suitability of those rivers for use by a large number of fish species, particularly salmonids and other sport fish, at different life stages. The knowledge thus gained has been incorporated into methods for predicting fish population abundance under a variety of conditions, and hence for predicting changes in fish populations in response to changes in flow regime due to water resource development. The most sophisticated approaches so far developed are the "incremental method" of the US Fish and Wildlife Service Instream Flow Group (Bovee 1978a) and the "Habitat Quality Index" (HQI) work of Binns and Eisermann (1979).

In the IFG method, the likelihood of a fish being present at a given point in a stream channel is considered to be a function of the water depth, mean velocity, water temperature, and bed sediment character (Bovee 1978b). The mean water depth, velocity and sediment type in a channel reach are therefore of little relevance to the total fish population in that reach, which is controlled by the precise distribution of depths, velocities and sediment types throughout. Bovee (1978b) provides tables of probability of use by a number of species and life stages of habitats with given values of depth, velocity and sediment type. By estimating the amount of habitat having different combinations of depth, velocity and sediment at a range of discharges, the user of the incremental method may estimate the total fish population in a reach at each discharge, and hence assess the effect of changing discharge on the population. This concentration upon only a small number of factors has been strongly criticised (Smith 1979); other studies that are closely related to the HQI work demonstrate that other factors such as the availability of cover (undercut banks, overhanging trees, aquatic vegetation, submerged logs and roots) (Nickelson 1976; Wesche 1976) or the minimum depth of a riffle (Thompson 1972; White 1976) are also important factors controlling fish populations. Binns and Eisermann (1979) measured, for a sample of 36 Wyoming streams, the following variables:

Physical

*Late summer streamflow
*Annual streamflow variation
*Maximum summer stream temperature
*Water velocity (mean in section)
Turbidity
*Percent cover
*Stream width
Stream depth
Stream morphology (?)
*Proportion of eroding banks
*Bed sediment character

Chemical

*Nitrate nitrogen
Total alkalinity
Total phosphorus
Total dissolved solids
pH

Biological

Stream bank vegetation
*Fish food abundance, diversity, type

Those marked with an asterisk were found to be significantly correlated with trout standing crop, and were combined into a habitat quality index which explained 96% of the variability in standing crop. Lewis (1969) determined that most of the variation in numbers of brown trout in 19 selected pools in a Montana stream was accounted for by current velocity and cover, and Glova and Mosley (in preparation) have found that the standing crops of a number of salmonid and native New Zealand fish species in a sample of riffles in the Ashley and Hurunui rivers also are related to the presence of instream cover (patches of "white water"), among other things.

Less work has been done on the requirements for other instream uses, but Cortell and Associates (1977) have provided a valuable review of the optimum conditions for a variety of water-based recreational activities, such as angling (wading and from the bank), boating (including tranquil water canoeing, white water kayaking, power boating, etc), swimming, rafting and tubing, and so on. Although water depths and velocities and channel widths are of fundamental importance for many activities a variety of other factors must also be considered when evaluating the suitability of a given river reach for recreation. For example, the height, stability and vegetation cover along streambanks influence a river's suitability for bank angling and swimming or diving, while the occurrence of riffles and rapids, overhanging vegetation and obstructions in the channel controls suitability for various types of boating.

In addition, the aesthetic quality of the riverscape has received some consideration (Hamill 1974; Leopold 1969; Morisawa 1971). Hamill (1974) presented a matrix of factors to be considered and rankings to be assigned to each at a given study site:

Physical factors

Low flow water surface width
Low flow depth
Velocity
River pattern
Bed material
Bed slope
Drainage area
Stream order
Width of valley flat
Height of nearby hills

Water Quality factors

Water colour
Turbidity
Water condition (?)
Amount of algae
River fauna
Pollution evidence
Litter

Human use and interest factors

Land flora diversity and condition
Presence of artificial control
Accessibility

Diversity of local scene
Confinement of view and presence of vistas
Land use, degree of urban and industrial development
Presence of special views or historic features

Apart from the physical factors, which can be readily placed into classes on the basis of simple measurement, the other factors are all ranked subjectively; the rankings may then be combined into a overall "evaluation number" for a given site. Morisawa (1971) showed that the results of this type of objective evaluation were closely related to subjective assessments of scenic quality by members of the public.

Site Selection

The type and location of site selected for data collection has varied from study to study, depending on the specific objectives, but three general approaches are commonly followed.

Selection of a specific site of interest

Kellerhals *et al.* (1972) collected data along river reaches in Alberta in which stream flow gauging stations had been established, while Drage and Carlson (1977) considered locations in northern Canada at which pipeline river crossings were planned. Data might be required at a specific location because, for example, a dam, reservoir, irrigation offtake, bridge or other structure is planned.

Selection of a representative reach

Where information is required for a whole river, data may be collected for a reach that is regarded as being representative of the "average" character of the river. This procedure has been followed by, among others, Cochnauer (1976), Collings *et al.* (1972), Dooley (1976) and Waters (1976). An alternative to subjectively selecting a representative reach is to randomly select study sites from aerial photographs (Platts 1979) or to make measurements at sites located at some pre-determined regular interval along the river—¼ mile in the case of Herrington and Dunham (1967). Such sites are considered to be an unbiassed sample of all possible sites in the river, and therefore are representative of the average condition and the range of conditions found therein.

Selection of a critical reach

A number of studies have collected data at locations that are in some way critical controls on the instream use under consideration. For example, White (1976) collected data on a shallow, diagonal riffle to evaluate changes in ease of passage for sturgeon with changing discharge, Lewis (1969) and Cooper (1976) made measurements in pools used by adult trout for resting and feeding, and Swank and Phillips (1976) concentrated on locations regarded as good habitat for fish spawning, rearing, and food production. Use of the IFG computer-based method for predicting water surface profiles at a range of flows requires at least one cross-section to be at a critical hydraulic control point at which the depth-discharge rating curve can be established (Dooley 1976; Jowett and Wing 1980).

Basis for Data Collection

Most studies have relied upon cross-sections or transects as a basis for data collection, but detailed procedures vary widely. Herrington and Dunham (1967) collected data for a single cross-section at each site. Platts (1979) used five cross-sections spaced 15 m apart at each site, while at the other end of the scale, Jowett (1980) used 23 cross-sections at 25 m intervals in an application of the IFG incremental method to the Clutha River. Other studies have used a varying number of cross-sections, commonly between 4 and 10 (Cochnauer 1976; Dooley 1976; Waters 1976; White 1976). Collings *et al.* (1972) used their four measured cross-sections as a basis for drawing maps of their study reaches, while other workers have taken this procedure to its logical conclusion and have prepared highly detailed maps of their study reaches (Keller and Tally 1979; Mosley 1981b; Swanson and Leinkaemper 1978).

Uses of Data

The data provided by the various procedures referred to above have been used in a variety of ways, but basically there appear to be two fundamental objectives:

1. to describe the present characteristics of a river, that is, to provide an inventory procedure;
2. to provide a basis for estimating the characteristics of a river under a set of conditions that do not exist at the time of data collection, that is, to provide a predictive tool.

Thus, as an example of the first case, Herrington and Dunham (1967) required data to "permit land managers and fisheries biologists to evaluate the fishery potential of selected streams and diagnose basic deficiencies in fish habitat", and to "be used as a benchmark to determine the magnitude of future changes that may occur", whereas in the second case the IFG incremental method allows "quantification of the amount of potential habitat available for a species and life history phase, in a given reach of stream, at different streamflow regimes with different channel configurations and slopes" (Bovee 1978a).

It is important to distinguish between these two broad objectives because the data collected for one will frequently be inappropriate for the other. The IFG and related "incremental methodologies" which use a computer model to predict conditions in a selected reach at a range of discharges, using data collected at only one discharge, can be applied to only a relatively short reach, unless the river is unusually uniform in character. This is because the incremental methodology, when it uses a computer program such as the US Bureau of Reclamation Water Surface Profile (WSP) program, requires a number of closely spaced cross-sections to adequately define the shape of the water surface and stream bed. The more irregular the channel, the more cross-sections are necessary. Clearly, then, without a massive investment of effort in cross-section surveys, the reach that is used for incremental analysis is more or less unrepresentative of the river as a whole. In fact, the more irregular or variable the river, the shorter and more unrepresentative must the study reach become, as the cross-sections become more closely spaced. On the other hand, cross-sections spaced at wide intervals along a river that are intended simply to describe the full range of river environments are most likely too widely spaced for extrapolation between them, and so cannot be used in the IFG incremental methodology. In some circumstances, for instance in a major river with a flat sandy bed and constant width, cross-sections established for one purpose may be usable for the other, but in most cases this is unlikely, particularly in New Zealand, where rivers tend to be highly irregular in shape and bed profile.

Another distinction between the two approaches is in the type and quantity of data required. The various versions of the incremental method concentrate to a large extent on intensive measurement of depths, velocities and bed sediment character at closely spaced points along the cross-sections; although some other information is collected, for example a description of the bank material and vegetation (Dooley 1976), it is very much subordinate to the hydraulic data. As already noted, this has been a fundamental criticism of the IFG incremental method, but it is not easy to see how other less easily quantified factors can be incorporated into the method. On the other hand, those procedures intended primarily to describe a reach of river may provide a large amount of information on present conditions which cannot be used to predict conditions at other discharges. Such factors as the amount of vegetation overhanging the water surface or the number of dead limbs in the water cannot be included in the incremental approach to prediction, and virtually no research has been carried out to show how they change with changing discharge.

For the purpose of predicting changes in channel character, the "incremental method" is becoming more and more widely used. A variety of procedures have been used; Waters (1976), Swank and Philips (1976), Bishop and Scott (1973), and Collings *et al.* (1972) made measurements of hydraulic conditions at a range of discharges and computed the area usable at each discharge for a particular use. Usable area was then plotted against the measured discharges, to allow prediction of areas at other discharges. This procedure may be called the 'regression method' of incremental analysis, and has been most recently applied in New Zealand by Mosley (1981 d) to the Ohau River.

Bartschi (1976) made measurements at a single "index" discharge at sample cross-sections; the water surface at index discharge was drawn on the plotted cross-sections, as well as additional water-levels from bankfull to zero flow. For each of these the discharge was calculated using the Manning equation, and wetted perimeter measured on the plotted cross-sections. Again, usable area (proportional to wetted perimeter) was plotted as a function of discharge. The most sophisticated version of the incremental method is the IFG method described by Bovee (1978a) and used in the Tekapo and Clutha Rivers by Jowett and Wing (1980) and Jowett (1980). Measurements of cross-section shape, water depth and velocity, water surface slope and bed roughness at one discharge are used by a computer program to predict, at other target discharges, the water surface profile and thence other hydraulic characteristics. Information on fish preferences may then be used to estimate usable areas at each discharge.

The regression and IFG methods of incremental analysis require apparently similar information, but data collected for one are unusable for the other. The regression method requires information at several discharges at a small number of representative cross-sections, whereas the IFG method needs more detailed information at a larger number of closely spaced cross-sections, but at only one discharge. Each method appears most appropriate under certain conditions. Rather obviously, the IFG method requires access to a computer system on which a water surface profile program is available or can be accommodated (in New Zealand, most likely the Ministry of Works and Development (1978) RIVERS-ROADS program package). This implies that the river involved is of national or major importance, and/or that the project involves sufficiently large expenditure that the expense of using a computer-based predictive model is justified. Strictly speaking this type of model may be applied only to rivers which conform to a number of more or less restrictive assumptions, the most important of which is that flow is uniform. The ideal river would be a large, rather straight, single-thread channel with an even bottom, and no large scale bed features like skew riffles to cause deviations in the flow from the straight-downstream course. The most inappropriate case would be a braided river in which flow is at all points converging and diverging in channels of constantly varying width, and branching and joining in a series of separate channels. The more the assumptions are violated, the less confidence can there be in prediction from the single measured discharge, and the less extrapolation is possible (Prewitt 1981).

The regression method appears to be most appropriate for: (1) smaller streams whose characteristics are highly variable from place to place, so that the closely spaced cross-sections required for the IFG method would not be representative of the full range of conditions present; (2) streams and rivers of any size in which flow is highly non-uniform (that is, in strongly meandering or braided streams, or those which have pronounced skew riffles and other large scale bed forms); (3) rivers which are not sufficiently important to justify expenditure on use of a computer-based predictive model, or for which data can rapidly and easily be collected over the range of discharges of interest.

In conclusion, it can be seen that data collection may be for one of three basic purposes:

1. to describe in detail the character of a river at the time the survey is carried out;
2. for use in the regression method of incremental analysis;
3. for use in the IFG method of incremental analysis.

In view of the criticisms levelled at incremental analysis (Smith 1979), it would appear that a full description of the river of interest should in any case be carried out, but because the information needs of the two methods of incremental analysis are different, a decision must be made as to which (if either) is to be used. Criteria to be used in making that decision are basically: (1) are staff and funds available for and does the project warrant use of a computer-based predictive model; (2) is access to a computer available; (3) do conditions conform to the assumptions that underlie use of a program to compute water surface profiles; (4) how much variability in form and how many different aquatic sub-environments are present in the river; (5) is it more feasible to collect data at several discharges at a small number of representative (or randomly chosen) cross-sections, or at one discharge at a larger number of cross-sections; (6) can data be collected at or near to the discharge(s) of greatest concern (e.g., proposed minimum flow after abstraction)? The final decision should be made in consultation with experienced users of the methods (e.g., staff of Ministry of Agriculture and Fisheries, or Ministry of Works and Development).

Discussion

A data collection procedure is proposed that is based on (1) a consideration from first principles of the information needed to describe a body of water and its surroundings and (2) a thorough review and synthesis of other work. These data will provide a detailed description of any river to which it is applied, and a basis for application of the regression method of incremental analysis, if data are collected at several different discharges. If the IFG method of incremental analysis is to be used, more data on hydraulic conditions will be required; these requirements are also dealt with. Even though the IFG method of incremental analysis does not explicitly use many of the data included in the present procedure, it is considered that for fully informed decision-making they must nevertheless be collected.

Selection of Study Reach

Where the impact of a proposed development such as a dam is under consideration, the site for study is automatically selected for the investigator. In most cases, however, water resource development affects a length of river which is too long to be studied in its entirety, e.g., a reservoir may submerge many kilometres of river channel, or abstraction for irrigation will significantly reduce flows from the site of the offtake to at least the next major confluence downstream. In this situation, the characteristics of only a fraction of the river can be documented; that is, the river must be sampled.

The river should first be divided into a series of internally homogeneous sections, using interpretation of aerial photographs to identify stretches of the river along which characteristics such as active channel width (both the average width and variability in width), degree of braiding, sinousity and radius of curvature of bends, and amount and kind of vegetation along the banks, remain constant (Mollard 1973). For example, the Ashley River, North Canterbury, may be divided into five homogeneous sections:

(1) from the mouth to 8 km upstream, in which the river is narrow, slightly sinuous with a single thread channel (often dry in summer) winding across a wide gravel bed, with banks lined with dense willow growth;

(2) from 8 km from the mouth to the confluence with the Okuku River, in which the river has a wide, unstable gravel bed with multiple, braided channels at low flow, and banks which are in places lined with willows but frequently are covered in grass, scrub, or scattered trees;

(3) from the confluence with the Okuku to the mouth of Ashley Gorge, in which the river is similar to section (2), but narrower;

(4) through Ashley Gorge, in which the river is generally single-thread, and with a course controlled largely by bedrock outcrops;

(5) above Ashley Gorge, in which the river has a steep, cobble bed with a tendency to braid, and erodible banks cut into fluvioglacial terraces with a cover of tussock and introduced grasses.

A study reach representative of each homogeneous section may be selected in a variety of ways. If each section is truly homogeneous, one reach should be as representative as another; the most convenient and probably most unbiassed method of selection is to find the easiest point of access to the river and designate it as the middle of the study reach, on the assumption that its precise location is unrelated to the form of the river and occurred "by chance". (This is obviously not the case with a bridge crossing. A bridge *should not*, therefore, be selected as the point of access, both because it may be sited at the narrowest crossing point, and because the bridge itself or any associated training works may affect the character of the reach. It might also be noted here that water level recorder sites should also be treated with suspicion, because of, for example, bedrock control).

The objection may be raised that data collected in a single study reach, even if the reach has been randomly selected, apply only to that reach, and that the investigator cannot determine his level of confidence that they are in fact representative of the whole section of river. If a statistically precise result is required, therefore, a sample of all possible study reaches must be drawn; in other words, data must be collected for more than one reach, so that between-reach variability can be assessed and confidence limits be assigned to the attributes that are measured. Depending on the degree of variability exhibited by these attributes, a sample of five or more study reaches may prove to be necessary (Waters 1976); the investigator may find himself surveying the whole river, and will certainly increase the cost of his survey in proportion to the number of study reaches selected. The precision gained seems unlikely to justify the extra cost involved in most cases.

In some circumstances, data may be required for a particular type of location, and selection of a study reach by a random or quasi-random procedure may have a low probability of including it. For example, the investigator may be particularly interested in the effect of changing discharge on salmonid spawning grounds in a given river, and knows the precise locations actually used for spawning. In this case, the most sensible selection procedure is to choose one (or preferably more) of the known spawning grounds for detailed study (the possibility that changing hydrologic regime may make suitable other locations not presently used for spawning must not be overlooked). In addition to this chosen "optimum" reach, however, it is advisable also to randomly or quasi-randomly select a reach that is representative of "average" conditions along the river.

During the process of selecting study reaches, representatives of all organisations involved with or interested in the study (MWD, catchment authority, Fisheries Research Division) should meet to ensure that the choice of reach is acceptable for all purposes; consultation with other interested parties (acclimatisation society, canoe clubs) is desirable. Agreement is also required on the timing of the study, the contribution of each organisation and the duties of individual staff, the number of different flows at which data would be collected, the number of cross-sections required, and other related matters.

Extent of Study Reach

The river attributes of interest—channel widths, degree of braiding, bank vegetation, and so on—differ widely from river to river in their degree of within-reach variability. It is therefore difficult to stipulate universal guidelines for the extent of study reach needed to include the full range of conditions found in the section of river which it represents. Where regularly repeating features such as riffles, pools or meanders are present, the reach should ideally include at least three; this implies a reach length of about 15 bankfull channel widths, since such features tend to be spaced at intervals of 5 channel widths. However, not all rivers have such repeating features, and to specify required reach length as, say, 15 bankfull widths might produce an impractically long reach. For example, for a wide, braided river like the Rakaia, a reach length equal to 15 bankfull channel widths would be over 20 km.

Instead, the investigator must define the limits of his study reach with the following guidelines in mind: (1) that all the geomorphic features or aquatic sub-environments (riffles, pools, etc.) present in the section of river are represented in the reach in proportion to their occurrence in the whole river section, and (2) that the reach encompasses at least two of each such feature. To avoid bias the reach length should be determined from study of aerial photographs of the river rather than in the field. The limits of the reach should be set at equal distances up and down river from the point of access chosen as the centre of the reach.

Data Requirement and Source Materials

To adequately describe the study reach and its environment, information is required in the following six groups:

I—Geographic location;
II—Channel environment and setting:

III—Channel hydraulic geometry;
IV—Bed sediment characteristics;
V—Streamflow and water quality;
VI—Riparian vegetation.

Specific requirements in each of these groups are detailed below. It is expected that a short report will be prepared for each site surveyed by the staff of the organisation carrying out data collection. If the IFG method of incremental analysis is to be used, additional data are required, and are dicussed later in the section on IFG information needs. As with any analysis of natural resources, consultation of other documents—particularly aerial photographs, geologic maps, and worksheets of the New Zealand Land Resource Inventory—is necessary both before and during data collection (see Cortell and Associates (1977) for a full discussion of the utility of such documents). However, the procedure is essentially field-oriented, and will require several man-days' field work to complete, the precise number depending, of course, on river size. Because so many factors other than river character and size—accessibility, weather conditions, number and experience of staff, etc.—are involved, no attempt is made here to indicate the amount of time required to conduct a reach survey. It is assumed that any staff instructed to organise a survey will already have sufficient experience of this type of work as to have no difficulty estimating labour requirements.

Data Collection

The precise procedure for data collection will depend to some extent on the objective of the survey, that is, whether it is to be used simply to objectively describe the river (for the purposes of research, perhaps) or to aid in evaluating the environmental impacts of a modification of hydrologic regime. However, in either case, all available hydrologic data should be reviewed first, and aerial photographs studied in detail. The field work is most appropriately carried out during the summer low flow period, because at present most concern appears to be focussed on the impacts of water resource development on low flow conditions. Channel survey work is also easiest and most pleasant at this time of year, and discharge is likely to be most stable.

A check list is appended (Appendix 1) which summarises the steps in the whole survey and suggests field equipment needed. Appendix 6 presents an example of the data collected by this procedure, for the Ashley River; reference to the example should clarify any questions arising from the text. If the regression method of incremental analysis is to be used to evaluate the impact of flow abstraction on the river environment, many of the data discussed below will need to be collected at several (three or four) different discharges. This is most effectively done on the falling stages of a small, late summer fresh. In this case, the study reach must be visited beforehand and cross-section lines clearly marked; other tasks such as collection of sediment samples may also be undertaken. When a suitable fresh occurs, the survey party must then visit the site and make those measurements which are dependent on water stage (that is, depth and velocity measurements, recording of the characteristics of channel sub-environments such as pools and riffles, measurements of bank overhang and other elements which constitute fish cover). Since this information must be related to a specified discharge, it must be collected as rapidly as possible so that discharge does not change excessively. A four-man team working for 1 day is therefore preferable to a two-man team for 2 days. After the stage-dependent data have been collected, the other tasks such as cross-section survey may be completed at leisure, although before another fresh is able to modify bed morphology.

Geographic Location

For each reach surveyed, a location map (based on the NZMS 18, NZMS 1 or NZMS 260 topographic maps) should be prepared, and the following information (obtainable from NZMS 1 maps) should be tabulated:

- Name of river and location of reach, and extent of the homogeneous section of river of which the reach is representative.

- Grid reference and latitude/longitude.
- Catchment area upstream of the centre of the reach.
- Elevation of the study reach.
- Distance from the sea and from the head of the catchment.
- Maximum catchment elevation, and elevation of the point halfway from the study reach to the head of the catchment.

Reach Environment and Setting

Appendix 2 presents a check list, based on variable lists suggested by Kellerhals *et al.* (1976), Leopold (1969), and Neill and Galay (1967), of information that documents the general environmental setting of the survey reach. In most cases, a code number is simply circled to indicate the character of the reach; in some cases more than one number should be circled, e.g., where more than one vegetation type is found on the flood plain. The check list may be largely completed in the field, and should require only a few minutes. Some factors will need to be obtained from other documents, e.g., the valley measurements, lithology and land capability classes. The measured reach parameters are obtained from aerial photographs, except for bed slope, which is obtained by field survey.

Most entries on the check list are self-explanatory; brief notes for the others are included in Appendix 2. In the final report, the checklist should be presented as completed, together with any narrative text considered necessary to enlarge on specific points, and with ground photographs (if possible, including some taken from nearby high ground) to provide a general view of the reach. If possible, a recent vertical aerial photograph should also be included.

Hydraulic Geometry

Cross-section layout

The basis of collection of hydraulic geometry data is a series of cross-sections established in the study reach. Because water depths and velocities and other morphologic attributes cannot be measured at every point in the reach, some sampling scheme must be used: although there are a number of possibilities, survey of and data collection along cross-sections is conventionally used, and has many advantages. It may be regarded as a form of stratified random sampling, if the cross-sections are established in such a way that no subjective bias is introduced in their selection (e.g., by avoiding deep pools because they cannot be waded, or by ensuring that a cross-section intersects a deep pool because "a deep pool ought to be included in the survey"). At least five, and preferably nine, cross-sections should be included in the study reach, to ensure that all sub-environments have a reasonable chance of being selected. The number of cross-sections must, of course, be controlled by the size of the river, the between-section variability and the number of man-days that can be committed to the survey. Unfortunately, no data are available to indicate the number needed to attain a specific coefficient of variation (CV) of any attribute such as channel width (CV = standard deviation/mean, and is a measure of the relative variability of the attribute). The only guideline that can be given is that the more variable the form of the channel, the more cross-sections are likely to be required, particularly when large-scale bed features such as riffles and pools are present.

When a decision has been made as to the number of cross-sections that can be surveyed by available staff, they should be laid out at equal distances (along one bank) through the length of the study reach, one at the centre (at the access point) and an equal number either side. There seems to be no reason to introduce the added complication of randomly locating the cross-sections; setting them at equal distances apart introduces no bias on the part of the investigator, and there is little likelihood that a repeating geomorphic feature (riffle, pool, etc.) will have a constant wavelength precisely equal to the cross-section spacing. There should be absolutely no effort to select favourable sites for surveying; the objective is to obtain a quasi-random picture of the overall morphometric character of the reach. Each cross-section should be established perpendicular to the bankfull channel, using aerial photographs (*not* field inspection, which may introduce serious error or bias). In many cases the cross-section will therefore cross the low water channel at an angle other than 90°, but this is not a drawback, as the objective is to use the cross-sections as a sampling grid for making point measurements of water velocity, etc.

Topographic survey of cross-sections

The end points of each cross-section should be established well back from the bankfull channel limits, marked with hardwood stakes on the ground, and also marked on a recent aerial photograph of the reach. A complete survey of the cross-section endpoints (relative elevation and locations) should be carried out and an accurate plan drawn, so that bed and water surface slopes through the reach may be computed. This survey should form the basis of a detailed sketch map showing the location of the cross-sections with respect to streambanks, low flow channels, islands, bars, etc., possibly with contours.

Topographic surveys, using standard survey procedures with level, theodolite or tacheometer, are required along at least five cross-sections (where more have been marked); but more are desirable to obtain a valid sample of the whole river bed area. On a narrow river where one cross-section may be surveyed in only 10–15 minutes, little time would be saved by reducing the number of cross-sections, but the value of the whole survey could be reduced significantly. Enough elevation readings should be taken to define the form of the river bed in some detail. The precise number will vary with size of channel, but significant changes in transverse slope along the section should be recorded. It takes little extra time to make more readings, so more should be made when in doubt, to avoid a return visit. Particular attention should be paid to defining the flood plain level and bankfull channel elevations at each cross-section, while in the field, as these may be difficult to identify back in the office. Note should also be taken of the edges of all low water channels (including pools and backwaters) that are intersected, and details such as type of vegetation (e.g., gorse/broom scrub; grassy flat; bare gravel) or geomorphic feature (e.g., island; low bar).

All surveyed cross-sections should be plotted at an appropriate scale to accompany the plan of the reach. In addition, for each cross-section, the following variables should be computed for the discharge at the time of the survey and for bankfull discharge:

Water surface slope S
Cross-sectional area A
Water surface width and wetted perimeter P
Mean depth and hydraulic radius R
Maximum depth
Mean velocity (discharge/cross-sectional area)

The bankfull channel may be defined simply by extrapolating from bank to bank on the plotted cross-sections, and bankfull discharge (Q_{bf}) estimated using the relationship (Mosley 1979)

$$Q_{bf} = 8.91\ A^{1.27}\ (P/R)^{-0.27} S^{0.32}$$

(This relation was developed for South Island rivers, and has not yet been verified in the North Island. It is, however, similar to one proposed by Williams (1978).)

The mean and standard deviation for each variable should be computed, and all data (individual values, mean, and standard deviation for each variable at the two discharges) tabulated.

Topographic survey of longitudinal profile

A longitudinal profile should be surveyed along the thalweg (line of maximum depth) of the low water channel in the study reach. Both stream bed and low water surface profiles should be plotted at an appropriate scale, and the bankfull water-level at each cross-section transferred from the cross-section drawings, so that the bankfull water surface slope may be drawn in. The survey of the longitudinal profile must, of course, be tied in with the survey of the cross-section end-markers, and may be done simultaneously.

Water velocities and depths

Along every cross-section line, water velocities and depths should be measured in *all* low flow channels (including backwaters and isolated ponds in which velocity is zero). Standard measurement techniques should be used, that is, current meter measurement at 0.6 depth where possible, or timing of floats where the water is too shallow or too deep for using a current meter. In some circumstances it may be desirable or convenient to measure velocity at a constant depth, e.g., 10 cm above the bed, as well as or instead of at 0.6 depth. It should be noted, however, that estimation is possible of velocity at one point in the vertical from the velocity measured at another, if water depth is known and velocities are assumed to be distributed logarithmically. The velocity measurements should be done *along the cross-section line* rather than perpendicular to the channel, as their objective is to provide a representative sample of water velocities in the reach, not to measure discharge. However, the angle that the current makes to the cross-section should be noted. A desirable number of measurements for the whole reach (all cross-sections combined) is at least 150; standard gauging procedure is to aim for at least 15 measurements per channel, but for present purposes there is little need to make measurements at points more closely spaced than 0.5 m. Measurements do not need to be at a constant spacing along all cross-sections, but the spacing must be measured.

Discharge should be measured at an appropriate location in the reach, using normal gauging techniques, to provide a reference to which all the other data may be related. If one of the established cross-sections provides a good gauging site, then the data collected there are sufficient.

If the survey is to provide a basis for application of the regression method of incremental analysis, the data in this and the preceding section (topographic survey of longitudinal profile) must be collected at several discharges.

A matrix of depth and velocity values should be prepared to show the relative frequency in the reach of water having different combinations of these two attributes. Each measurement point represents an area of water surface in the reach whose extent is equal to the product of the distance between cross-sections (a constant value through the reach) and the spacing of measurement points along the cross-sections (which may not be constant). For example, in a braided reach with cross-sections spaced at 100 m intervals measurements were made across the 20 m wide main channel at 2 m intervals. Each measurement therefore represents $100 \times 2 = 200$ m^2 of water surface. In a 5 m wide side channel, however, measurements were made every 0.5 m; each measurement represents $0.5 \times 100 = 50$ m^2 of water surface. If individual measurements are not weighted in this fashion, the true distribution of depth and velocity in the reach will be seriously distorted.

Each measurement should be assigned to a depth-velocity class, and the total areas in each class accumulated. Choice of the class boundaries depends to some extent on the maximum depth and velocity observed; where a maximum depth of 1.5 m is measured, depth class boundaries of 0–0.09 m, 0.1–0.19 m, etc., are convenient and give 15 classes. This procedure will also provide the information necessary to prepare independent frequency distributions of water depth and velocity; these distributions may be presented in the form of tables, histograms, or cumulative frequency curves (either as a percentage of the total water surface area, or as an actual estimated water surface area). Accumulation of all class totals will provide an estimate of total water surface area in the reach; this should be equal to the estimate given by computing the product of reach length × mean water surface width.

Character of the water surface

During the programme of velocity and depth measurements, information should be collected on the character of the water surface (still, wavy, broken, aerated (white), weed-covered) and on the occurrence of aerated water ("white water"), which may provide cover for fish (Fig. 1). The character of the water surface should be specified at each velocity measurement point, and the length of each segment of white water intersected by the cross-section line should be measured. By adding up the total length of the cross-section lines which cross white water and the overall length of water surface intersected by the cross-sections, the percentage of the total water surface area of the reach which is composed of white water may be estimated. The number (per hectare of water surface) of distinct patches of white water for the whole reach should if possible also be determined, although this may be somewhat difficult where, for example, large continuous areas of white water exist on major riffles.

The number of observations in each water surface type class (weighted for cross-section and measurement point spacings, as in the preceding section) should be accumulated, and the proportion of each in the study reach should be tabulated.

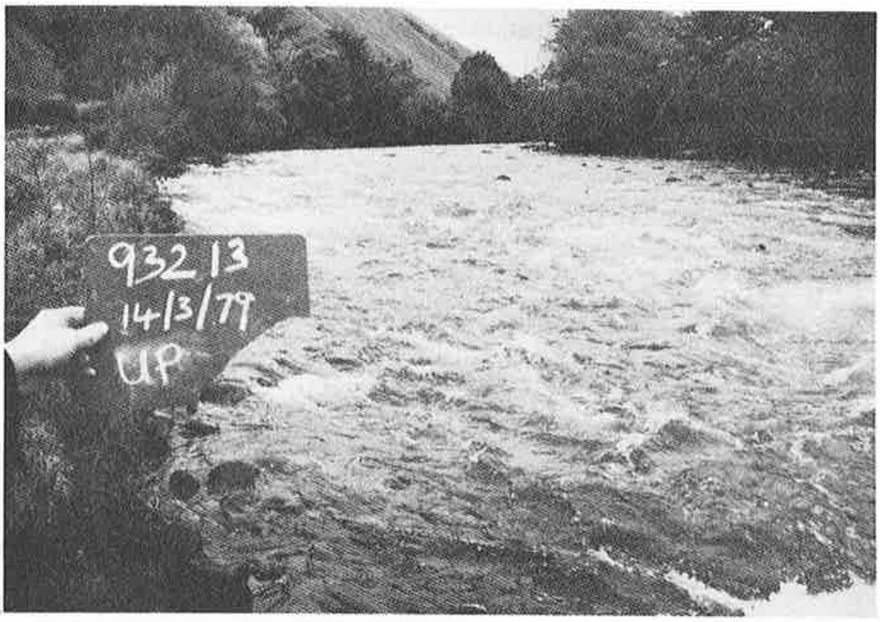

Figure 1 A section of the Glenroy River with numerous patches of white water, mostly associated with boulders that almost break the surface. The patches of white water and eddies below boulders constitute good cover and resting spots for fish.

Aquatic sub-environments

Each channel (including backwaters and ponds) intersected by the cross-section lines should be classified into type (riffle, pool, torrent, run, backwater, isolated pond—see below), and its width measured. The widths in each type should be accumulated, and multiplied by cross-section spacing to provide an estimate of the total area of the reach included in that type. The percentage of the total water surface area in the reach in each type should also be computed, and tabulated.

The cross-section surveys provide data for a quasi-random sample of locations within the channel. This results in the lumping together of different types of sites, e.g., in pools and riffles, but interest may for some purposes be concentrated on specific features. For example, to evaluate ease of passage for a "Canadian" canoe information is required specifically on depths over riffles, and available water surface width for a given depth.

Accordingly, such features must themselves be identified, sampled and characterised; the representative reach should be used for this purpose, with extension beyond its limits if an insufficiently large number of the features of interest are to be found in the reach. At least five samples of each feature should be examined to provide a reliable estimate of their average characteristics, and of their variability in the study reach. A number of channel sub-environments have been identified in a river—riffle, pool, backwater, isolated pond, run, and torrent (Fisheries Research Division, Freshwater Fish Survey card). It is difficult to precisely define these in such a way that any location in a channel may be assigned unequivocally to one type; in particular, drawing the boundary between two types may present problems. Of course, not all of these sub-environments are necessarily represented in a given section of the river.

Riffle Riffles are areas of shallow, usually broken and rapidly moving water, generally composed of coarse sediment (gravel-size particles and coarser). Frequently, riffles are angled across the channel (an alternative name is skew shoals) and form an abrupt step in the bed and water surface profile (Fig. 2). The downstream edge of the riffle is usually clearly defined, but the stream bed on the upstream edge often grades steadily from the pool next upstream to the head of the riffle and definition of the boundary is difficult. At low flows, much of a riffle may become emergent, and form a long boulder bank across the river with flow concentrated into a number of small chute channels over the bank (Fig. 3).

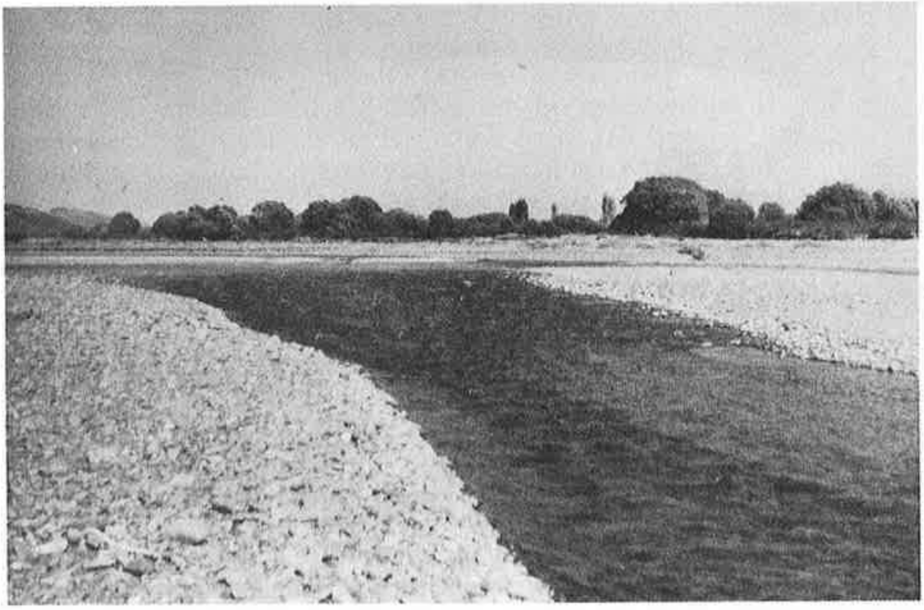

Figure 2 A small riffle in the Ashley River, looking upstream from beside a pool immediately below.

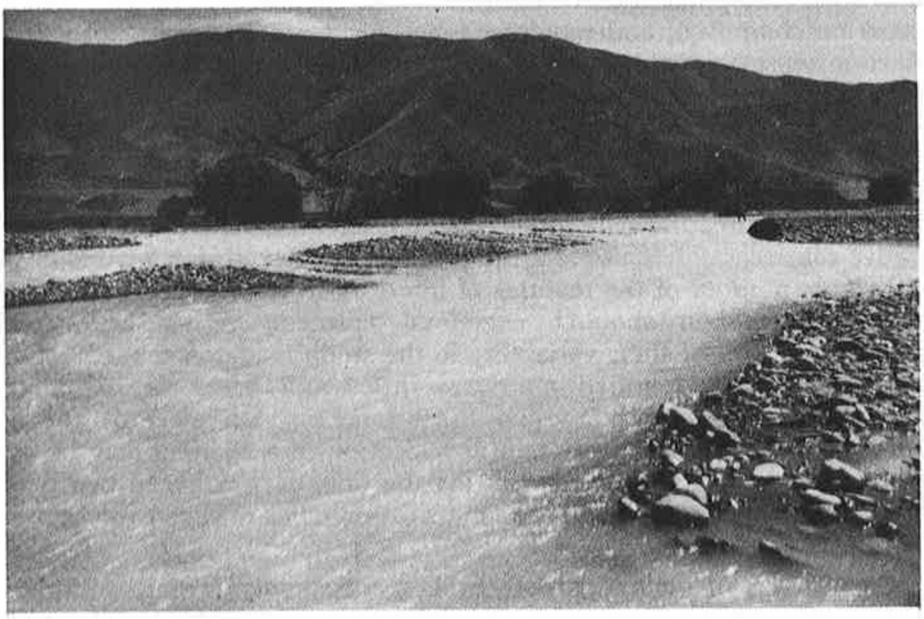

Figure 3 A riffle in the Ohau River. In places the flow is almost perpendicular to the overall channel direction, as water passes down chutes across the steep boulder bank that forms the riffle.

Pool Pools are areas of slowly moving water with greater than average depth, commonly found at meander bends or downstream from riffles (Fig. 4).

Backwater A backwater is an area of still water connected to but not part of the main low flow channel (Fig. 5). It is generally the location of a former course of the main channel, or of a channel that is active during flood stages only. Commonly, the backwater is connected to the main channel at its downstream end; water flows into it by seeping from the gravel of the stream bed, and flows into the main channel.

Torrent A torrent may best be described as a continuous riffle, in which the water is fast, highly turbulent, and commonly shallow, with emergent boulders (Fig. 6).

Run A run is any part of the channel which does not fall obviously into one of the other types; it is not distinctive in any way but is characterised by water moving at slow or moderate speed, with a calm or rippled surface and widths and depths which are close to the average for the channel as a whole (Fig. 7). Thus, while riffles and pools are extreme cases when considered in terms of velocity and depth, a run may be regarded as "average".

Isolated Pond An isolated pond is simply a body of standing water in the river bed which is not connected to nor accessible from the main channel.

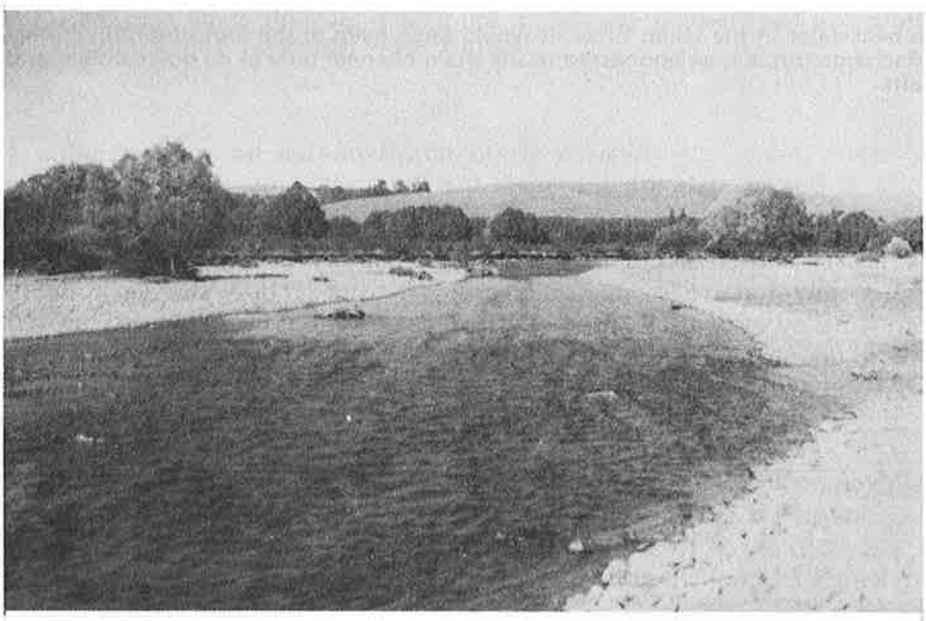

Figure 4 A pool in the Ashley River, distinguishable from the riffles up and downstream from the smoother and horizontal water surface. The riffles are steeper, shallower, and have a broken water surface.

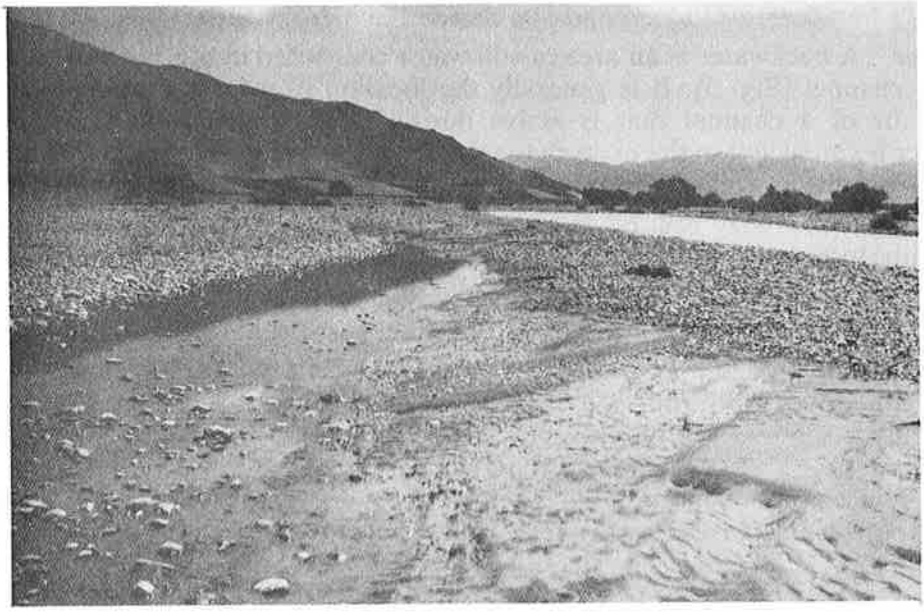

Figure 5 A backwater in the Ohau River. It would have been at the foot of a riffle during higher discharge but is now connected to the main channel only at its downstream end (lower left).

Examples of each sub-environment should be randomly selected; the easiest method is perhaps to select any that are located on a surveyed cross-section, starting at the middle of the reach and working outwards. If too few are selected, then those located between cross-sections may be taken, again starting at the middle of the reach and working outwards, if necessary, beyond the reach.

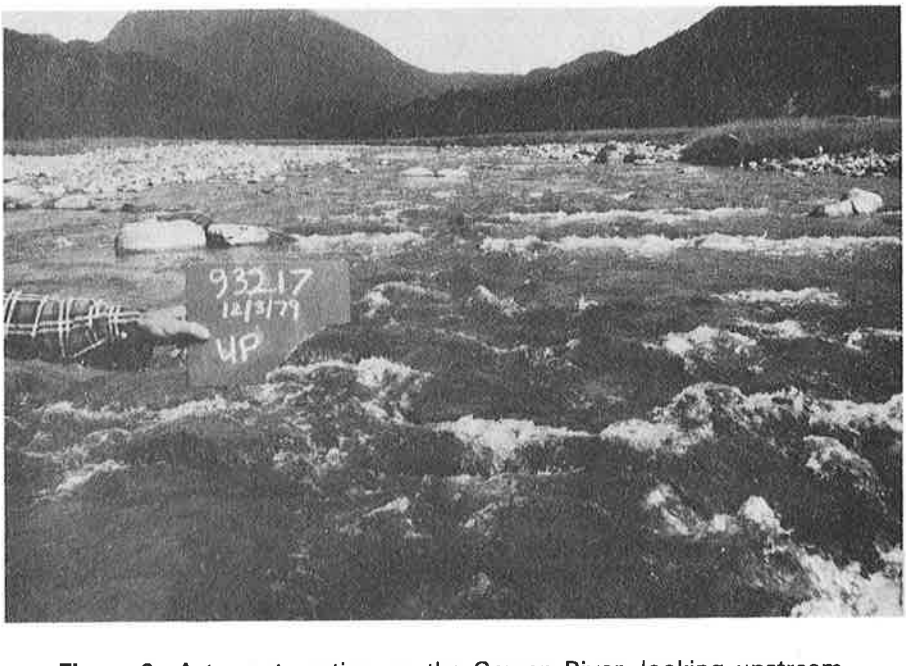

Figure 6 A torrent section on the Gowan River, looking upstream.

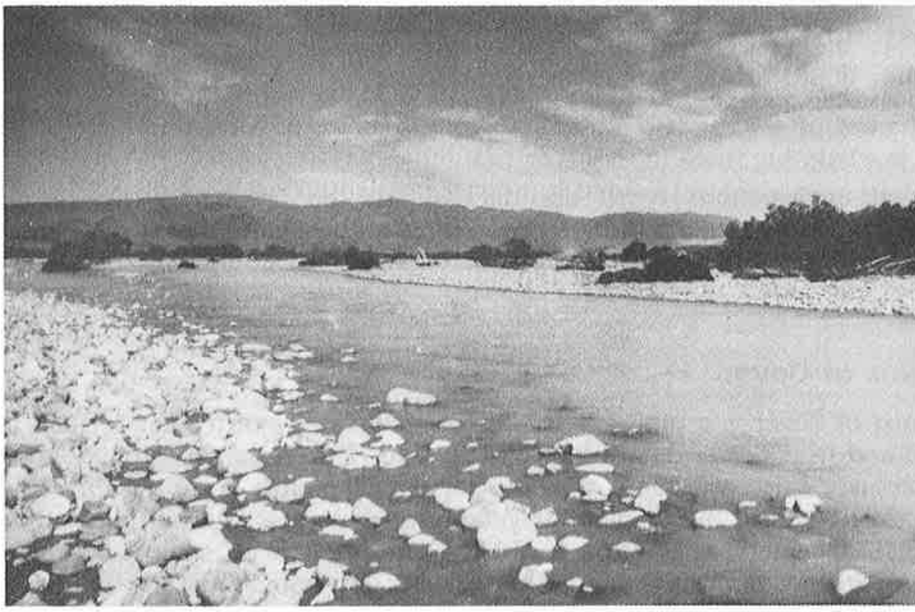

Figure 7 A run in the Ohau River, looking downstream. The water surface slope is approximately equal to the overall river bed slope, and the water surface is wavy to slightly broken. Depth is constant along the run; a pool has a distinctly bowl-shaped bed profile, and also a smooth, almost horizontal water surface.

Data collection for all sub-environments is basically the same; water depth, water velocity, water surface condition and bed sediment are determined at about 50 points within each example (of course, water velocity will be zero in pools and some backwaters, and bed sediment character and water surface condition may be the same throughout). Selection of points should be based on transects spaced at equal intervals through each selected feature; the process of laying out the transects provides measures of length, mean width and surface area of the features. Depending on the shape of each feature, from 4 to 10 transects, each with an appropriate number of measurement points, will be an adequate base. The transects should be perpendicular to the direction of flow at each point; neighbouring transects may therefore not be parallel.

For each sub-environment type, the following data are required:

1. Number per kilometre of channel (obtained by counting the number in the study reach).
2. Proportion of total water surface area (obtained using the lengths of each intersected by the reach cross-sections).

For each example surveyed, the following data should be obtained:

1. Frequency distributions (by percentage of total area covered) of depth, velocity and bed sediment, and a joint tabulation of depth and velocity.
2. Length, total water surface area, mean width.
3. Tabulation of water surface condition, and number of occurrences of white water.
4. Water surface slope (obtained by level survey).
5. Photograph.
6. If the data are to be used in the IFG incremental method (see this section on pp. 27–28), a plan of the end points of the transects and relative elevations of the water surface at each transect for those riffles, pools, and runs to be included in the anaylsis.

In addition, specific information is required for some sub-environment types:

Riffles At the head of the riffle, on the arc along which flow is shallowest, total water surface width (perpendicular to the flow lines at all points), maximum flow depth, mean flow depth, and width of water surface over which flow depth exceeds 0.1, 0.2, 0.3, 0.4, 0.5 m. These data are best obtained by measuring depth every 1 m along the head of the riffle, and provide information on the minimum depth of water available for passage by fish and boats.

Backwaters At the point where the backwater connects to the main channel, the maximum water depth in the shallowest cross-section.

Torrents Number of emergent boulders per square metre of torrent (which, of course, need not be a whole number).

For each sub-environment type, the data should be combined (i.e., frequency distributions for velocity, etc., are plotted on the same graphs; values for surface area, etc., are tabulated together and means and standard deviations computed for all features sampled).

Measurement of Cover

The presence of cover is a major determinant of the value of a river for fish habitat (Lewis 1969), and its accurate determination is therefore essential. A variety of different types of cover may exist: viz deep, slow-moving water; coarse bottom sediment; white water; overhanging banks; overhanging vegetation; submerged and partially submerged logs and branches; aquatic vegetation; turbidity. Information on some of these will be provided by the cross-section surveys and flow velocity determinations, but for others must be obtained specially.

Deep Water The proportion and amount of deep water in the study reach may be obtained from the cross-section surveys. A frequency distribution graph or histogram of water depths should be prepared, on the assumption that the water depths along the surveyed cross-sections are a representative sample of the whole reach. For example, Fig. 4 (Appendix 6) shows, for the Ashley River survey reach, that only 4% of the combined length of the surveyed cross-sections (hence by inference, 4% of the water surface area in the reach) has water deeper than 0.5 m. Given that the mean water surface width at the surveyed cross-sections is 47.5 m and the reach is 1640 m long, the total water surface area may be estimated as $47.5 \times 1640 = 77\,900$ m^2 (7.79 ha) and the area of water with a depth greater than 0.5 m as $77\,900 \times 0.04 = 3116$ m^2 or $3116/1.64 = 1900$ m^2 per 1 km length of channel. Presentation of the depth data in frequency distribution form permits similar computations for any other depth of interest.

Bottom Sediment Again, presentation in frequency distribution form of the sediment size distribution data obtained during velocity measurements (see section on Sediment Characteristics pp. 25–26) permits estimation of the proportion and absolute amount of the stream bed covered by material of a specified size. For example, Table 9 (Appendix 6) shows, for the survey reach in the Ashley River, that 36% of the combined submerged length of the cross-sections is covered by material of size small cobble or greater (>64 mm). Sampling and measurement of the sediment submerged in the channel, using the data form A in Appendix 4, provides similar but more detailed information. For example, Fig. 7 of Appendix 6 shows, for selected riffles in the same reach, that 56%–97% of the bed surface is covered by material coarser than 64 mm. These data are more precise and reliable than those collected during gauging, but are more difficult to obtain in deep or rapidly flowing water.

White Water Information on the proportion of the water surface composed of white water is collected during flow velocity measurement.

Overhanging Banks and Vegetation Over the full length of both banks of the survey reach, information should be collected on the characteristics of the banks and of the vegetation on the banks; the perimeter of islands should, of course, be included. Basic measurements to be made using a tape are:

1. Length of the survey reach.
2. Total length of bank in the reach.
3. Total length of bank in the reach at the foot of which there is water (i.e., low flow channel, backwater or pool).
4. Total length of overhanging bank.
5. Total length of eroding bank.

A data collection card has been designed for this purpose (Appendix 3); its use is self-explanatory and all terms are defined thereon.

Amounts of overhang are measured at intervals along the banks, using a staff, the spacing of the measurement points should be selected such that 50–60 measurements are made. Most will probably be zero (that is, the bank is vertical or slopes away from the river). Knowledge of the length of bank and the length of the reach permits computation of the absolute length of bank with a given degree of overhang, and the total area of water surface overhung by stream bank. For example, if measurements of overhang are taken every 5 m along a hypothetical section of bank 30 m long, then the area may be computed by:

Measurement Number	Width Over Water (m)	×	Length Over Water(m)	Area Over Water (m^2)
1	0.2		5	1.0
2	0.6		5	3.0
3	0.7		5	3.5
4	0.4		5	2.0
5	0		5	0
6	0		5	0
			Total	9.5 m^2

This gives a total estimated area of water surface of 9.5 m^2; similar computations for other sections of bank will give a total value for the whole reach, and these may be summarised in the form of a table or a graphical frequency distribution of width of overhang.

A procedure similar to that for overhanging bank should be followed for overhanging vegetation. Because vegetation varies greatly in canopy density, height above water surface, etc., it may be necessary to make separate computations for selected vegetation categories (Appendix 3). Only the total area of water surface in the reach overhung by vegetation of each type is of interest, and a frequency distribution of width of overhang is not needed.

Submerged and Partially Submerged Logs and Branches, etc. The number of occurrences and the total water surface area affected in the reach should be noted.

Sediment Characteristics

During the cross-section surveys, the staff-man should note (on the special form B of Appendix 4) at each set-up point within the limits of the bankfull channel the character of the stream bed. By making an entry in the appropriate class at each point (see below), totals for nine stream bed types can be simply obtained for each cross-section. A similar procedure should be employed during velocity measurements along the cross-sections and along the transects across each sub-environment example, except that the bed character should be specified, on the gauging card, for each measurement point. The same codes should be used. The bed character in the vicinity of, rather than precisely at, the measurement points should be classified.

The character class determinations may be used to obtain an estimate of the overall stream bed character in the reach (for the whole bed from the cross-section survey, and for only the low-flow channel bed from the velocity measurements). Each determination must be weighted according to the length along the cross-section of which it is representative, by multiplying by the measurement point interval. For example, in a large channel with velocity determinations made at 4 m spacing, each measurement point is representative of four times the stream bed width and area that is represented by determinations at 1 m spacing in a nearby minor channel. In the 'count' column on the data card B shown in Appendix 4, therefore, each determination should be entered not as a tick-mark or a one, but as the length across the cross-section that it represents. In the example above, the entry would be either 4.0 or 1.0. Once the cross-section has been completed, the values in the 'count' column for each type are summed in the 'total in class' column, to give the total width in metres characterised by that particular type. An overall total may then be obtained, and percentages of the overall total computed for each class. Where tacheometry is being used for a cross-section survey, this procedure is impracticable. However, in this circumstance the stream bed is probably extensive and a large number of staff set-up points will be used. These may be taken to be an acceptable representative sample of the stream bed, and character determinations may be made without weighting each for its representative width. Thus, a tick may be entered in the 'count' column, in the appropriate bed type class, for each determination, and these ticks summed in the 'total in class' column.

More detailed surveys of bed sediment should also be carried out for the examples of aquatic sub-environments selected, and also for selected emergent sub-environments such as gravel bars. The Wolman sampling method (Wolman 1954) is used, with the data form A in Appendix 4, to provide more detailed information than that given by the cross-section and transect surveys. Within each selected sub-environment (which must be delimited on the sketch map of the cross-sections), 60–70 particles are collected and their sizes estimated and noted on the data form A (Appendix 4). Collection is best done by pacing, with eyes closed, across the sampling area; at each pace, a finger is extended vertically to the ground surface and the first particle touched is selected. The particle size is then estimated by comparing it with square holes cut in an aluminium or plywood plate which have the same dimensions as the mesh of a set of sieves (from 8 mm square to 256 mm square; see C of Appendix 4). Photographs of the sampling locations should be taken; each photograph should include a small blackboard with pertinent information written on it and a staff to provide an indication of scale. In addition, a bulk sample of the sub-bed material should be taken and returned to the office for conventional sieve analysis. An effort should be made to ensure that the sample represents the "average" bed material load, although in a gravel-bedded river this is not easy.

Measurement of suspended sediment load and bed load as part of the present survey procedure cannot be justified, and the many equations that have been proposed overseas to estimate sediment loads have not been adequately tested in New Zealand rivers. However, many rivers do have suspended sediment concentration data available and filed on the MWD TIDEDA system; these data may be obtained from the MWD. Although data are unlikely to have been collected at a given survey reach, they may be available for a nearby site on the same river, and may thus give a general indication of the suspended sediment regime at the reach. All available New Zealand sediment load data are currently being analysed by staff of MWD, and general predictive equations appropriate to local conditions should result that are applicable to sites at which no data have been collected.

Streamflow and Water Quality

Discharge

A number of indices have been proposed to characterise the hydrologic regime of a river; most of these require a flow record from a water-level recorder. Where a study reach is near to a flow recorder with an acceptable length of record (preferably ten years), the following parameters give a good general indication of hydrologic regime:

Mean annual flood Q_{maf}
Standard deviation of annual floods Q_{afsd}
Mean discharge Q_{bar}
Standard deviation of instantaneous discharges Q_{sd}
Maximum recorded flow
Minimum recorded flow

In addition, a plotted instantaneous flow duration curve should be prepared.

Where no discharge data are available, some of the parameters may be estimated. Mosley (1979) presents equations to estimate, for South Island rivers, Q_{maf}, Q_{afsd}, Q_{bar}, and Q_{sd} from information derivable from the cross-section surveys, and Beable and McKerchar (1981) describe a procedure for estimating Q_{maf} and a flood frequency curve.

Water Temperature

Water temperature is an important consideration in evaluation of a river's suitability for fish habitat and recreational use. A large body of water temperature data is available for several hundred New Zealand gauging sites; data for a site near to and similar to the survey reach may give an indication of temperature regime at the reach. A general model of water temperature regime for the whole of New Zealand is in preparation by MWD: it will predict regime in terms of readily measured variables such as altitude and latitude (Mosley 1981c). Water temperature measurements may be taken at intervals during the field work, and in association with information on weather conditons may give a crude indication of the temperature regime of the reach. It seems unlikely that the type of analysis used by Hockey *et al.* (1980) for the Hurunui River could be justified in many situations to obtain information on water temperature regimes.

Chemical Water Quality

Chemical water quality, particularly as characterised by such parameters as pH, electrical conductivity (a surrogate for total dissolved matter), dissolved oxygen, and concentrations of nitrate and phosphate, is an important determinant of the biological productivity of a river and its suitability for a variety of uses. Information on water quality should therefore be included in a description of the survey reach, if facilities are available for its collection. The five parameters mentioned above are the most useful indices of chemical water quality, and several determinations of each should ideally be made. However, water quality parameters are so variable in time and space that a small number of samples, taken during the short period that a river survey is conducted, will have very limited meaning. Even where regular sampling over a period of many months is possible, interpretation of the results may present difficulties (Mosley and Rowe 1981).

Conductivity, dissolved oxygen and pH may be measured on site with portable meters. However, great care is needed to ensure proper calibration of the meters because large errors are possible if the incorrect data collection procedure is used, particularly for pH. Although nitrate and phosphate concentrations are undoubtedly important, their measurement presents severe difficulties. Field sampling is not simply a matter of collecting a bottle of water, as measures must be taken to ensure that concentrations do not change in the sample bottle due to biochemical activity. Solute concentrations are so variable in time and space that a few measurements may be of virtually no value; many organisations do not, in any case have the laboratory facilities necessary for proper analysis. In some cases, water quality data may already be available for a location near to the study reach; these may be presented to provide an indication of possible conditions at the study reach, particularly if some comparative data are collected there.

Riparian Vegetation

An important component of the river environment is the vegetation along the river banks and flood plain; the character of the vegetation influences the aesthetic quality of the environment, its suitability for recreation, and its suitability as habitat for wildlife and birdlife.

A survey card has been designed (Appendix 5) which may be used to provide an objective and quantitative picture of the character of the vegetation—the type of growth (bushes, trees, etc.), density, type, and species. Notes on the use of the card are included in Appendix 5. The survey may be rather time-consuming, such that it cannot be repeated sufficiently often in a given reach to give a statistically precise result. Therefore, care must be taken that the survey sites chosen are truly representative of the vegetation communities in which they are located.

IFG Information Needs

Application of a computer program to estimate water surface profiles and thence channel widths, depths, and velocities requires measurements at one discharge along closely spaced transects which are perpendicular to the water course. The cross-sections that are surveyed in the section above on channel hydraulic geometry (pp. 16–17) are in many (if not most) rivers inappropriate because they are too widely spaced and are perpendicular to the bankfull channel, not the low flow channel. Reduction of the spacing of cross-sections so that they may be used in a water surface profile computer model is not acceptable, because they would necessarily be sampling a shorter reach of river (unless the number of cross-sections is increased), and may not represent all conditions present in the whole section of river. It should be noted that closely spaced cross-sections are auto-correlated, that is, they are to some degree similar to each other, and do not provide independent samples of all conditions. The more widely spaced the cross-sections, the less they are auto-correlated, and the more independent is the information provided by each.

If, after careful consideration of the needs of the study and the resources available, use of the IFG method of incremental analysis is decided upon, data *additional to (not instead of)* those covered in the preceding sections, must be collected. The additional data are:

1. Measurements of water depth, velocity at 0.6 depth (= mean velocity) and/or at 20 cm above the bed, and the character of the bed sediment at points along a series of closely spaced transects.
2. Distance between each transect, a longitudinal profile of the water surface and stream bed, and a plan of the reach.
3. Where prediction to a discharge higher than the study discharge is required, topographic surveys to extend the transects across the ground that will be inundated.

In some circumstances, most of the information required for the IFG incremental method will be obtained when the aquatic sub-environments are sampled. For example, in a reach of river which has a single thread channel and a sequence of pools, riffles, and runs, the aquatic sub-environment sample may include all of these features, and hence cover the reach with a series of closely spaced transects. In this case, only a little extra work will permit use of the data for more than the basic purpose of description of the reach characteristics. Where use of the IFG method is intended, it may in fact be worthwhile modifying the procedure for selecting representative examples of the sub-environments so that they can be used in the IFG method, that is by ensuring that at least two each of riffles, pools, and runs are contiguous.

In rivers with multiple channels, this possibility is less likely to occur, and a reach will have to be selected specifically for application of the IFG method. The key requirement is that the reach contains the same proportions of the various sub-environments and has the same frequency distributions of depth, velocity and sediment character as the river section as a whole; completion of the remainder of the survey may be necessary before the shorter reach can be selected. The number of transects required depends on the variability of channel form and the size of the river. However, as a rule of thumb, a minimum of two cycles of riffle-pool-run should be included, each with a minimum of 7–8 transects, depending on length and constancy of width. Each cycle should have a transect at its downstream end which is on the head of a riffle, to act as a downstream control (Jowett and Wing 1980).

Because space does not allow this report to also be a manual for the application of the IFG incremental method, the reader is referred to the user manual for the MWD RIVERS computer package (MWD 1978), and to the reports by Jowett and Wing (1980) and Jowett (1980) which present results from the only applications so far made in this country.

Discussion

The data obtained if this survey procedure is followed will provide a detailed description of the river, and will provide a basis for evaluating likely impacts of a proposed water resource development; they must be interpreted and analysed by specialists in disciplines such as biology. For example, a number of procedures for assessing a river's suitability as fish habitat have been developed and are referred to above. The data do not in themselves specify fish habitat quality, but may readily be used in one (or any) of the established procedures in order to do so. Where data are collected at several discharges, habitat quality may be estimated for each, and the regression method of incremental analysis used to make an informed decision as to the likely change in quality resulting from an induced change in hydrologic regime. If the survey procedure is modified or extended, application of the IFG (computer-based) method of incremental analysis may be used instead, although great caution must be exercised in applying it to rivers that violate the assumptions that underly the method. Procedures for using the survey data for such purposes are currently under consideration.

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Appendix 1
Survey Procedure Checklist

Pre-field Work

i Decide on the purpose of the survey, and consult other organisations that are involved or can provide assistance or advice.
ii Obtain aerial photographs and maps; select representative reaches.
iii Position cross-sections and aerial photographs.
iv Collate hydrologic (streamflow and water quality) data.

Field Work

i Topographical survey.
  (a) Locate and mark cross-section end points and survey in relative elevations and positions.
  (b) Carry out topographic survey along at least five cross-sections and the longitudinal profile down the thalweg. Collect data on sediment character and the proportions of the water surface in each aquatic sub-environment along each cross-section.
  (c) Draw sketch map and take photographs.
ii Survey of water condition along cross-sections.
  (a) Measure water depth, velocity (at 0.6 depth and/or 20 cm above the bed), water surface character and bed sediment character across all water bodies intersected by cross-section lines.
  (b) Measure discharge.
iii Aquatic sub-environment survey.
  (a) Count total number of each type in the reach, and select the sample to be examined in detail.
  (b) For each, estimate number of transects required and mark on the ground with "Dazzle".
  (c) Measure water depth, velocity, water surface character and bed sediment character across the transects, to give a total of about 50 measurements.
  (d) Measure slope.
  (e) Carry out "Wolman" sampling of bed sediment.
iv Survey the streambanks and vegetation along the banks (see Appendix 3), and any instream debris in the reach.
v Survey riparian vegetation (see Appendix 5).
vi Identify emergent sub-environments, carry out "Wolman" sampling of the bed sediment, and take photographs.
vii Complete sketch map of the reach, and (as far as possible) the reach environment and setting questionnaire (see Appendix 2).

Post-field Work

i Collate data on geographic location data and prepare a location map.
ii Complete the reach environment and setting questionnaire (see Appendix 2) and assemble sketch map, vertical aerial photograph, and ground photographs of the reach.
iii Draft cross-sections and longitudinal profile.
iv Calculate and tabulate low flow and bankfull flow variables (including discharge) for each cross-section, and compute means and standard deviations.
v Tabulate frequency distributions of depth-velocity classes, and prepare graphical frequency distributions of depth and velocity separately, for the whole water surface intersected by the cross-sections. Tabulate data on bed sediment character, water surface character, and proportions of aquatic sub-environments along the cross-sections.

vi Tabulate the physical characteristics of the aquatic sub-environments, as discussed under "Hydraulic Geometry"; prepare graphs of the frequency distributions of water depth, water velocity and bed sediment, and tabulate the proportions of each water surface type. Data for the surveyed examples of each aquatic sub-environment should be presented in combination.

vii Process data on stream bank vegetation, and bed sediment characteristics (see Appendix 3).

(a) Compute total length of banks, total eroding length, total length with water at base, and total length overhanging water.

(b) Calculate area per km of channel of water overhung by banks, and prepare frequency distribution graph of width of overhang.

(c) Calculate area per km of channel of water overhung by vegetation (for each vegetation type separately).

(d) Calculate area of instream debris.

(e) Tabulate data from vegetation survey (see Appendix 5).

(f) Prepare frequency distributions of the bed sediment in emergent sub-environments.

Field Equipment Needed

The following items have been found to be necessary or useful:

Surveying: level, theodolite or tacheometer; staff; 30 m tape; compass; clinometer; survey forms; aerial photographs; stakes.

Velocity measurement: current meters; wading rods; headphones or counter; tag line; data forms; stopwatch; thigh or body waders; weighted ping-pong ball float on 3 m cord.

Sediment measurement: sediment gauge plate; data forms.

Miscellaneous: camera(s); film; small blackboard and chalk; 'Dazzle' spray paint; clipboards; spare pencils and erasers; thermometer; suntan cream; pocket stereoscope; mallet; red marking tape.

Appendix 2
River Environment Survey Questionnaire

RIVER ENVIRONMENT SURVEY

ENV. HYD. G.P.: CARD 4

River name: ________________ at: ________________ (grid ref: ______________) River Reach Code ____________

Date: ________________ Observer: ________________ Refer to Reach Sketch attached.

Note: Complete codes by circling number(s).

A. SURVEY REACH SETTING

General description of the landscape in the vicinity of the survey reach

Terrain type		Vegetation/land use	Lithology (specify rock type)
1 mountainous	1 1 1	Bare ground	
2 foothills	2 2 2	Native grassland	
3 uplands (plateaux)	3 3 3	Shrub/scrubland	________________
4 hills	4 4 4	0-25% forest (native)	
5 lowlands or plain	5 5 5	25-75% forest (native)	
	6 6 6	75-100% forest (native)	
	7 7 7	Developed pasture	
	8 8 8	Arable	________________
	9 9 9	Exotic forest plantations	
	0 0 0	Urban	

Comments: ____

____

B. SCENIC QUALITY

Diversity of flora along banks	Condition of flora along banks	Litter on bank (paper, cans, etc.)
1 Great	1 Excellent	1 < 2 per 30 m
2	2	2 2-5 per 30 m
3	3	3 5-10 per 30 m
4	4	4 10-50 per 30 m
5 Limited	5 Poor	5 > 50 per 30 m

Diversity of local scene	Confinement of scene	Presence of vistas
1 Great	1 Open	1 Far vistas
2	2	2
3	3	3
4	4	4
5 Limited	5 Confined	5 No vistas

Accessibility/level of use
1 Wilderness
2
3
4
5 Paved access/mass use

Comments: ____

____

____

C. GEOMORPHOLOGY

Valley Characteristics in the vicinity of the survey reach (Do not include artificial changes such as stopbanks; refer to diagram sheet.)

Valley type	If no valley:-	Valley measurements
0 Not applicable	0 Not applicable	Depth from surrounding hills ____m
1 Stream cut valley	1 Alluvian fan	Top width ____m
2 Glacial trough	2 Alluvial or outwash plain	Bottom width ____m
3 Rock gorge	3 Delta	
4 Wide lowland valley	4 ________________ (specify)	
5 ________________ (specify)		

Terraces
0 None
1 Indefinite
2 Fragmentary
3 Continuous

Number of terrace levels: ______

Active undercutting of valley walls by stream (sites of sediment input to stream)
0 No undercutting
1 Occasional minor undercutting
2 Occasional major undercutting
3 Frequent major undercutting

Length of valley wall undercut by stream on left bank ______%
right bank ______%

Lithology of valley sides (specify rock type)

____

Land capability class of valley sides (specify)

____________ ____________

Valley flat/floodplain in the vicinity of the survey reach: Refer to diagram sheet

Presence
0 Absent
1 Indefinite
2 Fragmentary
3 Continuous

Extent: incl. floodplain outside stopbanks
0 Absent
1 Narrow (<1 active channel width)
2 Moderate (1-5 active chl.widths)
3 Wide (>5 active chl.widths)

Average active channel width ____m
Average distance between stopbanks (if present) ____m

Channel constriction by valley walls or terraces
0 No constriction
1 Occasional constriction
2 Frequent constriction
3 Confined
4 Entrenched

Valley flat/floodplain measurements (if confined by terraces or valley sides)
Mean width ____ m
Maximum width ____ m
Length of channel with floodplain on left bank ____ %
right bank ____ %

D. VEGETATION SURVEYS

Vegetation/land use of valley sides
1 1 1 Bare ground
2 2 2 Native grassland
3 3 3 Shrub/scrubland
4 4 4 0-25% native forest
5 5 5 25-75% native forest
6 6 6 75-100% native forest
7 7 7 Developed pasture
8 8 8 Arable
9 9 9 Exotic forest plantations
0 0 0 Urban

Floodplain vegetation/land use
1 1 1 Bare ground
2 2 2 Native grassland
3 3 3 Shrub-scrubland
4 4 4 0-25% native forest
5 5 5 25-75% native forest
6 6 6 75-100% native forest
7 7 7 Developed pasture or parkland
8 8 8 Arable
9 9 9 Exotic forest plantation
0 0 0 Urban
* * * Marsh

Bank vegetation type (Species)
00 None
11 Grass, weeds ____________
22 Bushes (incl. gorse and broom) ____________
33 Trees - scattered ____________
44 Trees - dense ____________
55 Vegetative protection work: dense, layered ____________

E. CHANNEL PATTERN FOR SURVEY REACH (at low flow unless otherwise specified).

Bankfull	Low Flow	CHL Pattern
1	1	Straight
2	2	Sinuous
3	3	Irregular
4	4	Regular meanders
5	5	Irregular meanders
6	6	Tortuous meanders
7	7	Braided

Islands
0 None
1 Occasional
2 Frequent
3 Braided

Bar types
0 None
1 Alternate bars
2 Meander point bars
3 Mid-channel bars
4 Diagonal bars ("riffles, boulder banks")
5 Sand waves or large dunes

Reach parameters
Sinuosity: ______________ Meander wavelength: ______ m
Floodplain slope: ______________
Bed slope (along main stream at time of survey): ______________
Braiding index (bankfull): ________ Mean number of branch channels per cross-section (bankfull): ________
Braiding index (low flow): ________ Mean number of branch channels per cross-section (low flow): ________

Number of branch channel bifurcations per km of channel (bankfull): ________
Number of branch channel bifurcations per km of channel (low flow): ________
Number of diagonal bars/riffles/boulder banks per km of channel, (low flow): ________

Comments: ____
____

F. CHANNEL BOUNDARY CONDITIONS AND MATERIALS

Obstructions in channel
0 0 None
1 1 Logs, debris, stumps in mid-channel
2 2 Growing vegetation in mid-channel (specify ______________)
3 3 Boulders in mid-channel
4 4 Overhanging trees at edge of channel
5 5 Slumped banks
6 6 Artificial constriction (specify ______________)

Degree of obstruction of channel
0 None
1 Occasional minor
2 Occasional major
3 Frequent minor
4 Frequent major

Channel bed material
1 1 Sand-silt
2 2 Sand-gravel (<64 mm)
3 3 Gravel
4 4 Cobbles
5 5 Boulders
6 6 Bedrock

Bedrock in channel
0 None
1 One occurrence
2 Two occurrences
- ___ occurrences per ____ m length of reach

Bedrock lithology (specify)
____

percent of channel bed composed of bedrock ______ %

Channel bank material: alluvial
0 0 0 No alluvial banks
1 1 1 Clay and silt (cohesive)
2 2 2 Silt and sand (non-cohesive)
3 3 3 Sand and gravel (<64 mm)
4 4 4 Sand to cobbles
5 5 5 Sand overlain by silts
6 6 6 Gravel overlain by silt
7 7 7 Cobbles overlain by silt
8 8 8 Boulders

Channel bank material: non alluvial
0 0 0 All alluvial bank material
1 1 1 Glacial deposits
2 2 2 Bedrock (specify lithology ______________)
3 3 3 Protection work (specify ______________)

Percentage of bank in alluvium on:
left bank ____ %
right bank ____ %

Percentage of bank being actively eroded on
left bank ____ %
right bank ____ %

Floodplain surficial material
0 0 No floodplain
1 1 Silt/clay
2 2 Sand/silt
3 3 Gravel (<64 mm)
4 4 Cobbles

Floodplain land capability class
(specify class outside and inside stopbanks, if applicable)
____
____

Comments: ______________________________

G. WATER QUALITY

Water Colour
1 Colourless
2 Pale green
3 Green
4 Light brown
5 Brown

Turbidity - degree
1 Clear
2
3
4
5 Very turbid
Depth at which bottom visible: ____m

Turbidity - cause
1 Algae
2 Dissolved (brown humic) matter
3 Rock (glacial) flour
4 Other sediment load
5 (Specify) ____________

Evidence of pollution (specify)
1 None
2 ____________
3 ____________
4 ____________
5 Severe ____________

River fauna (specify species)
1 Large variety ____________
2 ____________
3 ____________
4 ____________
5 None

Attached/weed growth (% cover)
1 0-20%
2 20-40%
3 40-60%
4 60-80%
5 80-100%

Slimes/algal growth (% cover)
1 0-20%
2 20-40%
3 40-60%
4 60-80%
5 80-100%

Comments: ______________________________

SKETCH of SURVEY REACH

Location ____________

Reach Code ____________

Date ____________

Include: flow direction, branch channels, active channel zone, floodplain boundaries (terraces, valley sides, stopbanks), swamps, vegetation zones, stable and eroding banks, cross section locations, aerial photography markers, reach boundaries. If vegetation survey has been carried out, mark line transect locations.

Sketch Typical Cross-Section thru' Survey Reach

Include approx location of branch channels, active channel zone, berms, stopbanks, islands terraces, valley sides, vegetation, true left and true right banks

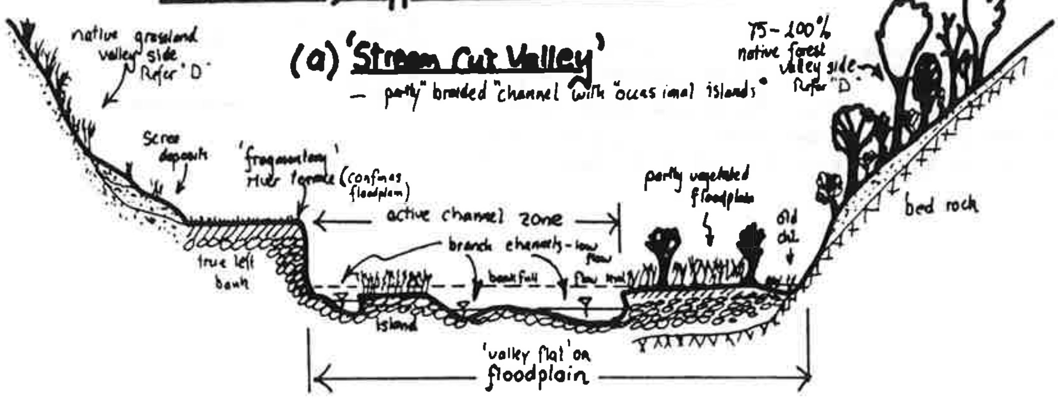
Reach Code ____

Survey Date ____

Sketches of Typical Cross-Sections

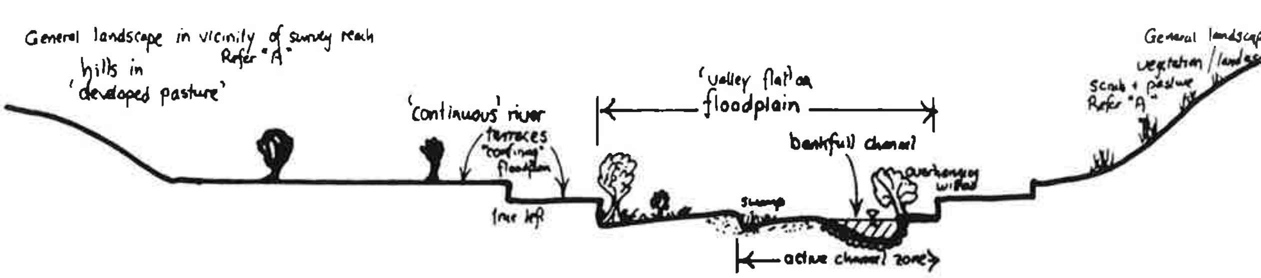
(a) 'Stream Cut Valley'

– partly braided channel with occasional islands



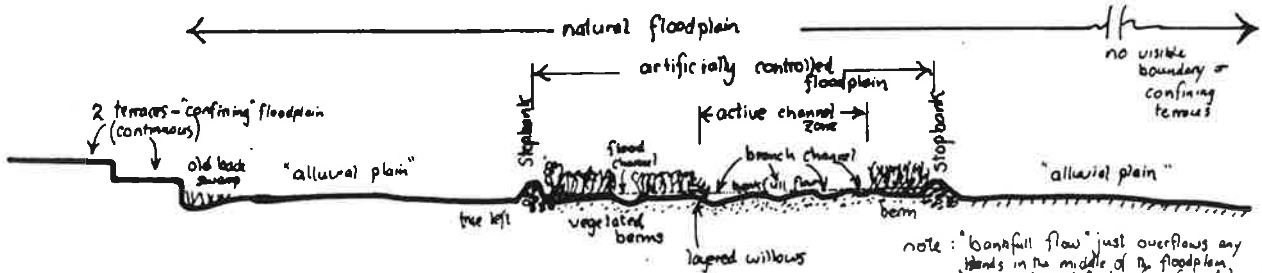
(b) 'Wide Lowland Valley'

– single thread channel with 'regular meanders'



(C) Alluvial or Outwash Plain

– artificially controlled floodplain
– braided channel with vegetated berms



Notes for Use of River Environment Survey Questionnaire

General Numbers should be circled in order of dominance.

A Survey reach setting

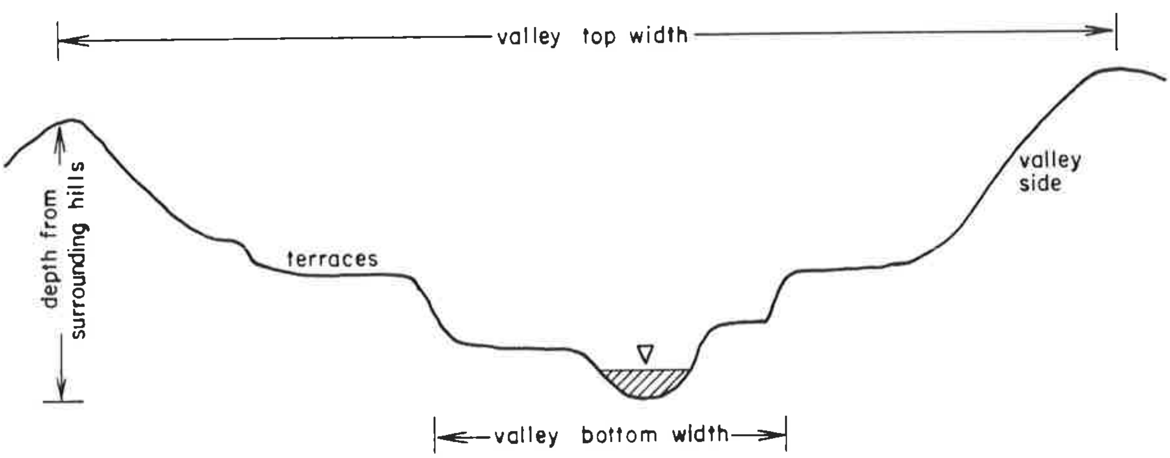
This refers to the landscape away from the immediate valley sides sloping down to the river or the land adjoining the floodplain.

B Scenic quality

'Flora' refers to any plants, ranging from grasses to trees.

C Geomorphology (refer to page 4 of questionnaire)

'Valley measurements' refers to the general valley rather than to a locally entrenched feature.



'Valley flat or floodplain' refers to the section of the floodplain or valley flat as shown on page 4 of the questionnaire, inclusive of the active channel width. It is land which is flooded in events with a return period of <5 years (or which would be if stopbanks were not present). The N.Z. Land Resource Inventory Worksheets provide a good indication of floodplain extent.

'Active channel width' refers to the active channel zone on the diagrams and includes all channels and river beds which are regularly swept clean of vegetation by freshes and floods; it excludes vegetated islands within the active channel zone.

D Vegetation surveys

'Valley sides' refers to the valley in the immediate vicinity of the floodplain, i.e., visible from the river bed.

E Channel pattern for survey reach (refer Fig. A.2.1, A.2.2)

Define channel pattern (Fig. A.2.1) for both bankfull and low flow (at time of survey) by circling one (or more, if necessary) numbers in columns 1 and 2.

'Islands' refers to any land in the active channel zone that is surrounded by water at bankfull flow.

'Bar types'—refer to Fig. A.2.2.

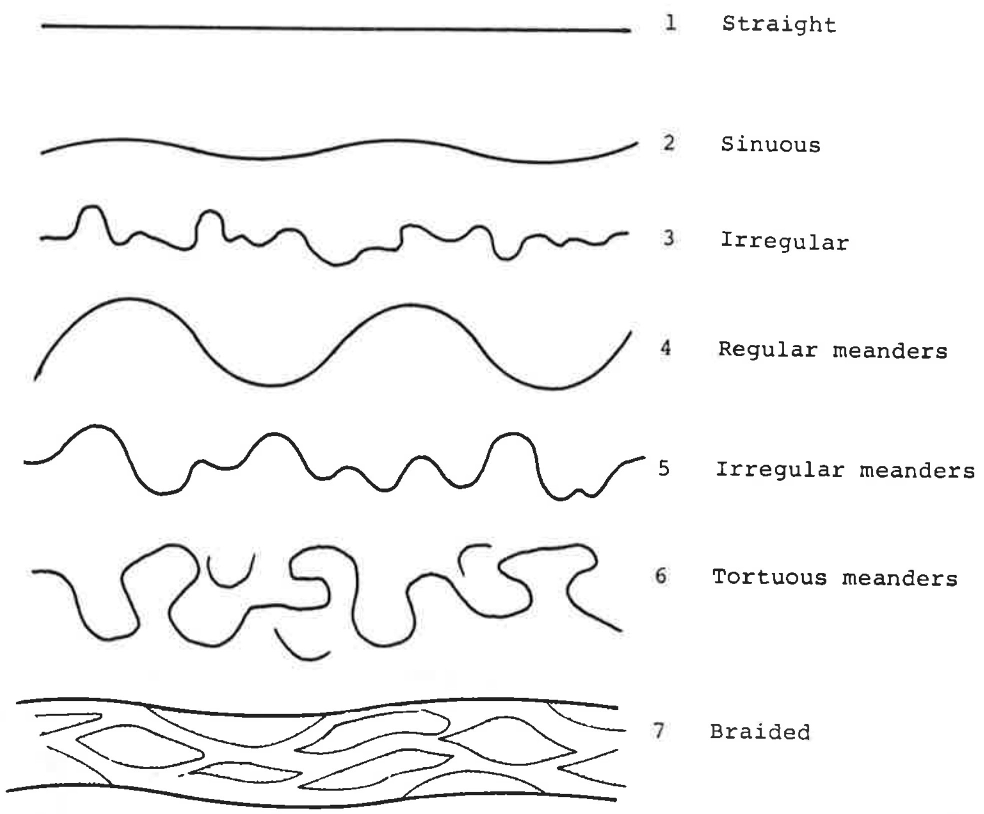


Figure A.2.1 Definition of channel pattern types.

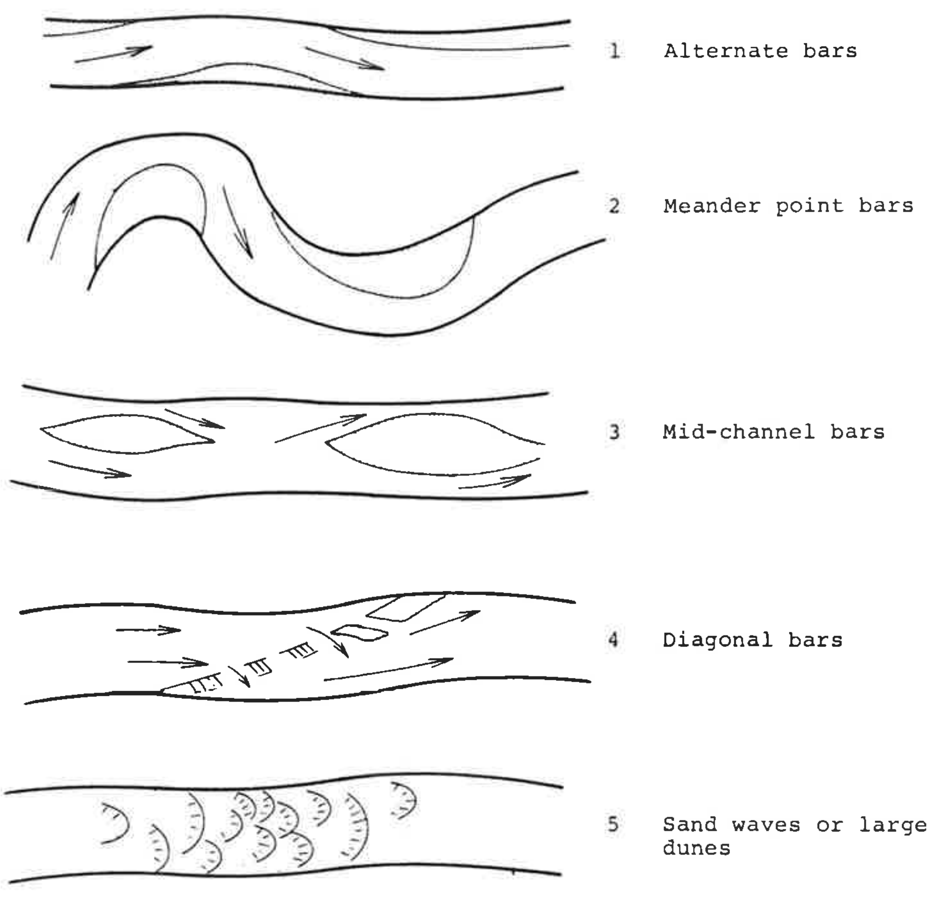


Figure A.2.2 Definition of bar types.

'Reach parameters' are obtained from aerial photograph interpretation, field inspection, and survey of the cross-sections and longitudinal profile in the reach. Refer to Fig. A.2.3 for definitions. A 'bifurcation' is a point where flow divides into two channels.

F Channel boundary conditions

Sediment size classes:

Silt-clay	<0.062 mm
Sand	0.062–2 mm
Gravel	2–64 mm
Small cobbles	64–128 mm
Large cobbles	128–256 mm
Boulders	>256 mm

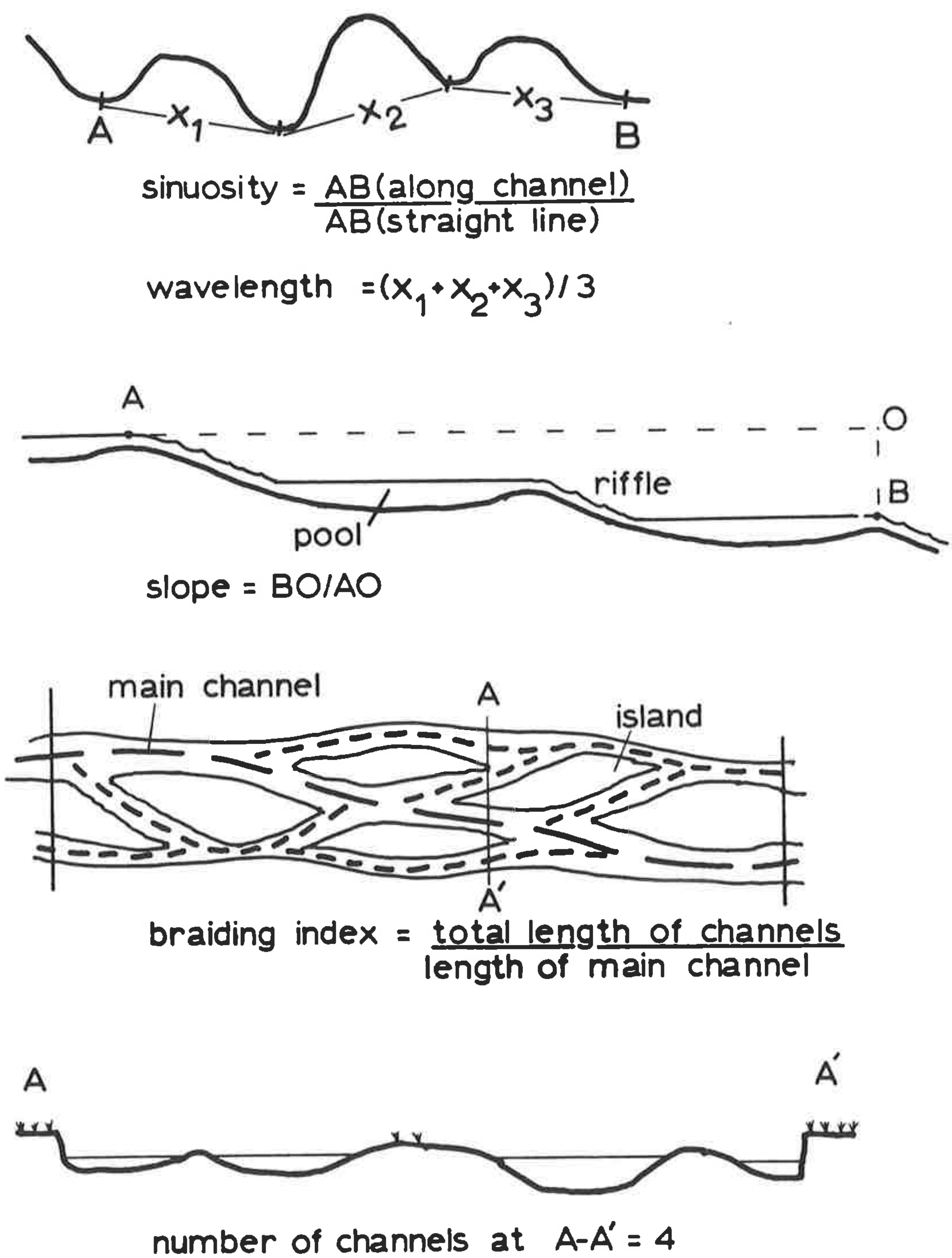


Figure A.2.3 Definition sketches of reach parameters.

Appendix 3
River Environment Survey: Bank and Vegetation Cover, Data Collection Card

RIVER ENVIRONMENT SURVEY : BANK and VEGETATION COVER: CARD 6

RIVER ______________ LOCATION ______________ REACH CODE ____

RIVER No. ______________ Surveyor's Initials ______________ DATE of SURVEY ______________

Survey Reach 1. Length ____ metres

Survey Reach BANKS 2. Total Length (incl. veget.^{d} islands) ____ metres

3 Total Eroding Length ____ metres

4. Total Length with water at base ____ metres ie. low flow chl, backwater, pool.

5. Total length overhanging water ____ metres: Total Area of Water Overhung ____ M^2

Survey Reach Overhanging vegetation,

6 Total length over water ____ metres: Total Area of Water overhung ____ M^2

(Note: see other side of card for examples)

DISTANCE along BANK	BANK ASPECT	ERODING BANK LENGTH (M.)	ERODING BANK AVERAGE HEIGHT above water (M)	BANK LENGTH in contact with water (M)	OVER HANGING BANKS Length over water (M)	OVER HANGING BANKS Width over water (M)	OVER HANGING BANKS Area over water M^2	UNDER CUT BANKS Length below water (M)	UNDER CUT BANKS Width below water (M)	UNDER CUT BANKS Area below water surf. (M^2)	OVERHANGING VEGETATION Length over water (M)	OVERHANGING VEGETATION Width over water (M)	VEG. TYPE	OVERHANGING VEGETATION Area overhung (m^2)
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TOTALS														

continued over side

River Environment Survey : Bank and Vegetation Cover : Continued

Card 6

DISTANCE along BANK (metres)	BANK ASPECT	ERODING BANK LENGTH (m)	ERODING BANK AVERAGE HEIGHT above water (m)	BANK LENGTH in contact with water (m)	OVER HANGING BANKS Length over water (m)	OVER HANGING BANKS Width over water (m)	OVER HANGING BANKS Area over water (m²)	UNDER CUT BANKS Length below water (m)	UNDER CUT BANKS Width below water (m)	UNDER CUT BANKS Area below water surf (m²)	OVER HANGING VEGETATION Length over water (m)	OVER HANGING VEGETATION Width over water (m)	OVER HANGING VEGETATION VEG.N TYPE	OVER HANGING VEGETATION Area overhung (m²)
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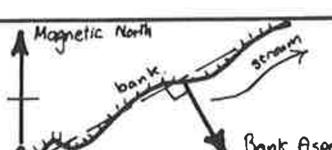
TOTALS

COMMENTS

EXAMPLES

1: Bank Aspect

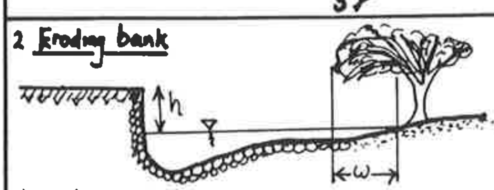


Codes
N North
NW North-west
E east
etc.

VEGETATION TYPE CODE

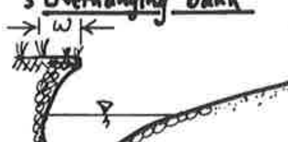
- **T** = Trees > 3·0 m ht
- **B** = Bushes 1·0 → 3·0 m ht
- **G** = Grasses < 1·0 m ht
- **W** = weeds in water

2 Eroding bank



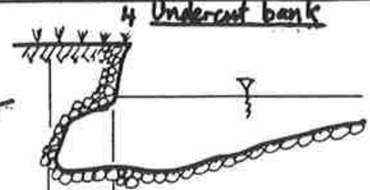
h = height of eroding bank
ω = width of overhanging vegetation

3 Overhanging bank



ω = width over water

4 Undercut bank



ω = width below water

Appendix 4
Sediment Sampling

A Field Data Form for Coarse Sediment Sampling (Wolman Method)

COARSE SEDIMENT ANALYSIS

SITE: MEAN DIAMETER:

DATE:

COMMENTS:

Size class (mm)	Count in class	Total in class	Cumul. Total	Cumul. %
less than 8				
8-11.3				
11.3-16				
16-22.6				
22.5-32				
32-45.3				
45.3-64				
64-90.5				
90.5-128				
128-181				
181-256				
greater than 256				
	Total:			

Observer: ______________

B Field Data Form for Bed Character Sampling

STREAM BED CHARACTER

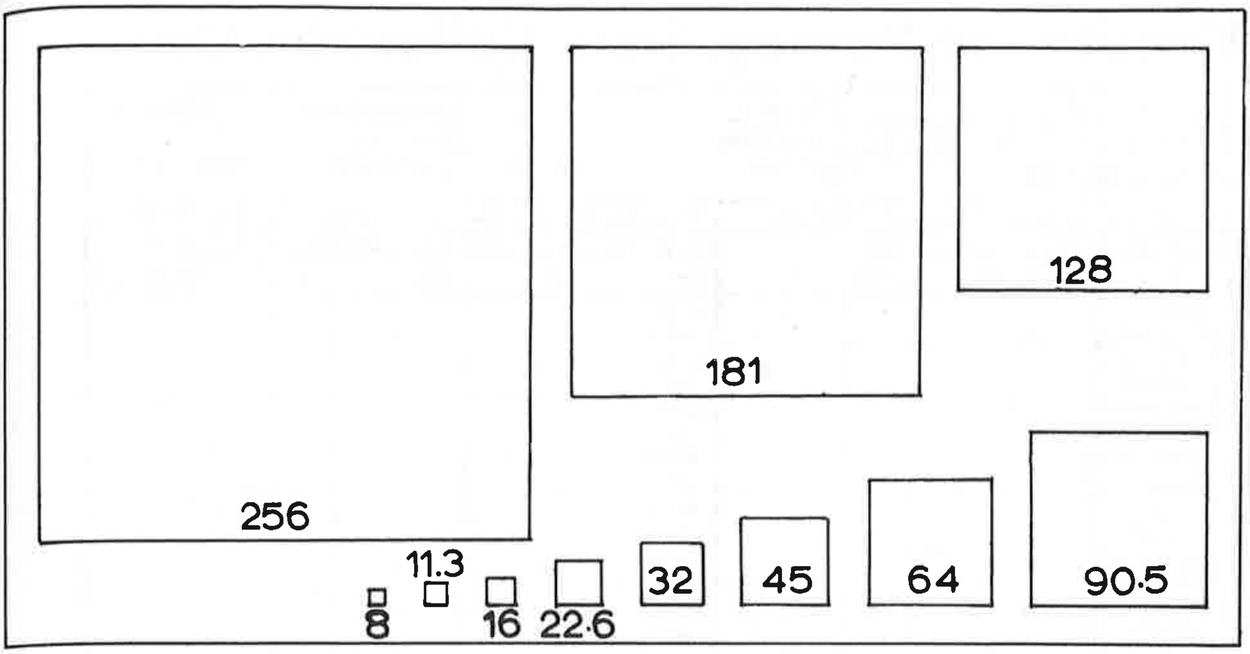
SITE:

DATE:

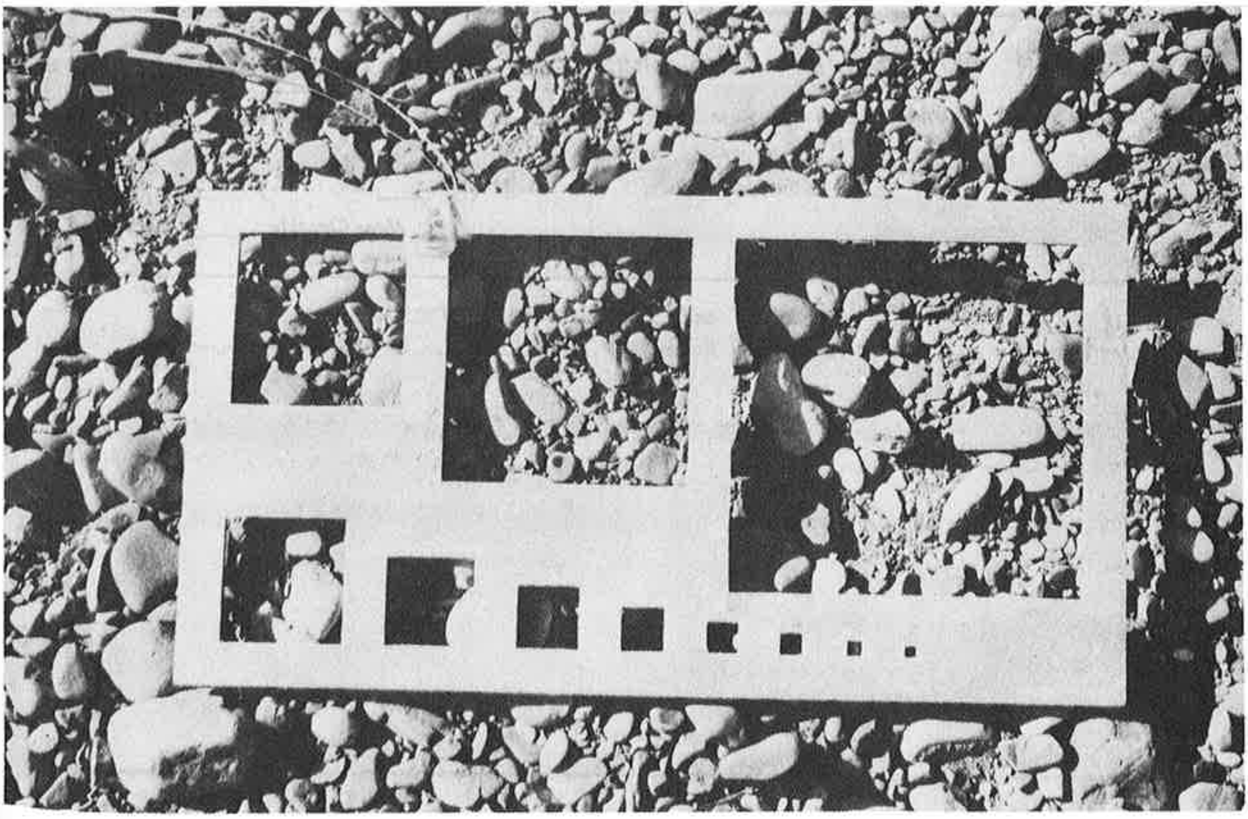
COMMENTS:

Bed Type	Code	Count in Class	Total in Class	% of Overall Total
Clay-silt (<0.062 mm)	CS			
Sand (0.062-2mm)	S			
Gravel (2-64mm)	G			
Small cobbles (64-128mm)	SC			
Large cobbles (128-256mm)	LC			
Boulders (>256mm)	B			
Bedrock	R			
Plant material	P			
Other	O			
		Total		100.0

C Design of Sediment Gauge Plate



Materials: 650 mm × 330 mm sheet of 6 mm thick aluminium or plywood. Square holes with the dimensions shown above cut into the sheet {sizes of holes are equivalent to sieve sizes used by geologists between 8 and 256 mm (−3 to −8 phi, in 0.5 phi increments)}.



Appendix 5
Vegetation Survey, Data Collection Card

VEGETATION SURVEY RIVER ______ Surveyors Initials ____ CARD 5
LOCATION ______ REACH CODE ____ DATE ______
FLOOD PLAIN FEATURE ______ VEG.ⁿ TYPE ______ LINE No. __ LINE LENGTH ___ m SAMPLE SPACE __ m

Veget.ⁿ type at sample pt. along transect line

	HEIGHT RANGE (m)		VEGETATION TYPE	COUNT IN VEG.ⁿ TYPE	TOTAL in Type		
	0·0		Bare Ground				
0·0	0·0 m →	grassland	Grass + weeds				
	0·3	grassland	Low gorse/broom < 0·3 m				
0·3	0·3 m →	shrubs and	gorse/broom (thorney bushes)				
	→	shrubs and	other Shrubs				
	1·0	shrubs and	swamp vegⁿ rushes, tall grasses				
1·0	1·0 m →	tall bushes	tall gorse/broom (thorney bushes)				
	→	tall bushes	native bush and shrubs				
	3·0 m	tall bushes	other bushes incl. willow				
3·0		trees	willow				
	>	trees	poplar				
	3·0 m	trees	exotic sps. unpruned				
		trees	exotic sps. pruned				
		trees	native trees				
			TOTAL				

Stem diam (Ø) at 1·0 m above ground level

ENV. HYD. GP.

Stem Ø Class	COUNT in Diam. Class	TOTAL Class	CUMUL TOTAL	CUMUL %	Comments (dominant species)
0–2 cm					
2–4 cm					
4–8 cm					
8–16 cm					
16–32 cm					
32–64 cm					
64–128 cm					
>128 cm					
	TOTAL				

Instructions: refer to notes on 'survey method'

1. Select typical area of a floodplain feature ie island, bank, floodplain or berm
2. Lay out tape across representative area along selected line.
3. Sample vegetation at selected intervals as above and record on card
4. Aim for 75 sample pts covering range of vegetation types in representative area.
5. If necessary, slash line thru' scrub and sample exposed face of vegetationⁿ; assume undisturbed condition.
6. Carry out stem count at 3 sites along line ie 12, 35 and 62 m for 75 m transect
7. Record unusual features, mark vegetation boundaries and mark locations on aerial photographs.

STEM COUNT at 1·0 m above ground at 3 sites (1/6, 1/2, 5/6 dist.ᶜᵉ along transect line)

TOTAL No. of STEMS counted along 10·0 m line Sample 1 ______ Density 1 _____ stms/M
(note: count stem if obviously disturbed by slashing of line or tramping) 2 ______ 2 _____ Stems/M
3 ______ 3 _____ stems/M
Mean Density _____ stems/M

SKETCH of LINE TRANSECT LOCATION and VEGETATION PATTERN
incl. comments on dominant species. Tie in transects to features which can be identified on recent aerial photographs.

CONTINUE ON OTHER SIDE IF NECESSARY

Notes for Use of Vegetation Survey Data Collection Card

i Using recent stereo aerial photography of the selected reach, delimit approximate boundaries of vegetation zones within the floodplain (area flooded by events with a recurrence interval less than 5 years).

ii Verify vegetation zones and boundaries in the field, and select straight line transects across an area representative of each vegetation zone. Transects should be selected objectively; e.g., one end is selected by throwing a cobble in the air, standing in the centre of the area, and the direction is chosen with eyes closed.

iii Lay out a tape along the transect; it may be necessary to slash through the vegetation to keep to the pre-selected transect line. The length of transect should be chosen such that it does not extend beyond the limits of the vegetation zone.

iv Sample vegetation at a spacing appropriate to give 75 points; record dominant vegetation type (largest percentage of biomass) at each sample point in the appropriate class, in the 'count in vegetation type' column.

v At each point, if the height of the vegetation is >1.0 m, record the largest stem diameter of that bush or tree in the "count in diam. class" column, in the appropriate class.

vi To give an estimate of vegetation density on the transect, carry out a stem count along three 10 m long lines perpendicular to the transect at 1/6, 1/2, 5/6 distance along the transect. Lay out a tape, and count all stems at 1 m above ground immediately above the tape. For dense scrub, record the stem count along an exposed face cut with slashers, if necessary.

vii Prepare a sketch map and photograph vegetation zone sampled.

Appendix 6
Example of Geomorphic/Hydrologic Data Collection and Presentation

Ashley River Near Bullock Creek Confluence: Physical Character

Introduction

This characterisation of the Ashley River was carried out to test and refine a data collection methodology that is intended to provide the information needed for a detailed analysis of the environmental impacts of flow manipulation. Full hydrological data are not included, as they are not necessary for this specific purpose. Because it is the first application of the method it may be deficient, and critical comments are welcomed.

Choice of reach

The reach was selected on the basis of aerial photograph interpretation. The lower Ashley River (below the Gorge) has three distinctive sections which extend from the Gorge to the mouth of the Okuku, from the Okuku to a point 4 km below the Ashley railway bridge, and from there to the sea. The study reach selected is representative of the first reach; it was specifically chosen because, (1) it has easy access, and (2) complementary data on fish populations were to be collected by Fisheries Research Division staff.

Procedure

A transect (cross-section) was established at the point of access, and surveyed. This provided a measure of bankfull channel width (360 m); nine other transects were then established at a spacing of 180 m up and downstream from the surveyed transect, each perpendicular to the bankfull channel. Alternate transects were surveyed in detail, and all ten were tied in by a level traverse. During the detailed survey, bed sediment character was classified at each staff setup point, and a sketch map of the reach and cross-sections was then prepared.

Water depth and velocity and stream bed sediment size were measured at intervals across all watercourses (including backwaters and disconnected pools) intersected by all ten transects, to provide an estimate of the frequency distributions of these variables for the whole reach. Each water course was simultaneously classified as a pool, riffle, run, backwater or isolated pond. A discharge measurement was finally carried out using standard gauging techniques. Velocities along the transects were measured by current meter at 0.6 depth or by float movement in shallow (<10 cm) water.

Five examples of each of the aquatic sub-environments listed above were randomly selected (by taking those intersected by a transect, starting with transect 5 and working outwards). Data were collected as stipulated in the main report, but included geometric factors and sediment size distributions. Surface sediment size distributions were also determined for a number of emergent environments, using the Wolman sampling method, and information on riparian vegetation, streambank character, instream cover, and general reach environment obtained.

Geographic Location

The following data define the geographic location of the study reach at a national/regional scale.

River: Ashley River.

Location of study reach: Extending 1100 m upstream and 540 m downstream from the confluence of Bullock Creek (Fig. A.6.1).

Reach representative of: Ashley River from Gorge to Okuku River confluence.

NZMS map reference: S67:836904. Lat. 43° 15′ 10″ S, Long. 172° 26′ 40″ E.

Catchment area: 680 km^2.

Elevation: 97 m a.s.l.
Maximum catchment elevation: 1934 m.
Distance from sea: 25 km.
Distance from head of catchment: 65 km.

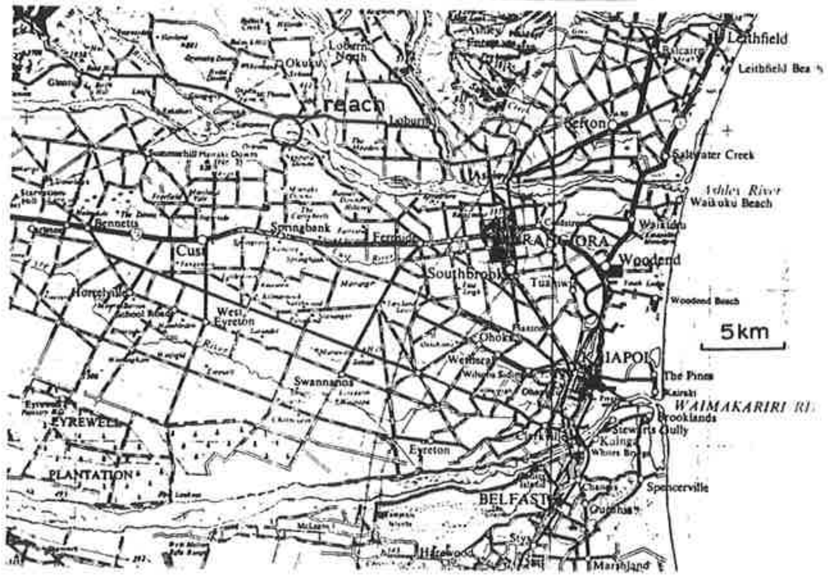


Figure A.6.1 Location of study reach, Ashley River.

Reach Environment and Setting

The check list in Appendix A provides information on the general setting and appearance of the study reach. Figure A.6.2 shows a sketch map, and Fig. A.6.3 includes ground level views of the reach. No vertical aerial photographs show the reach with its present form.

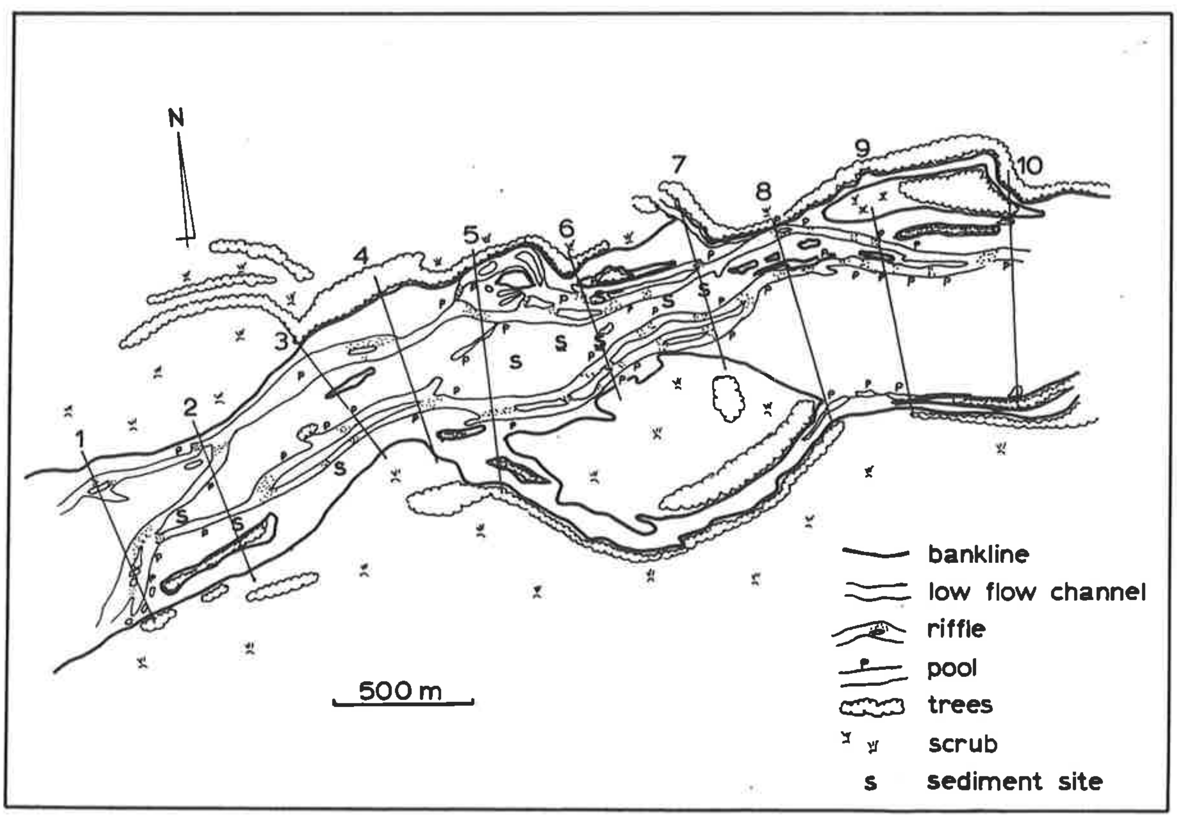
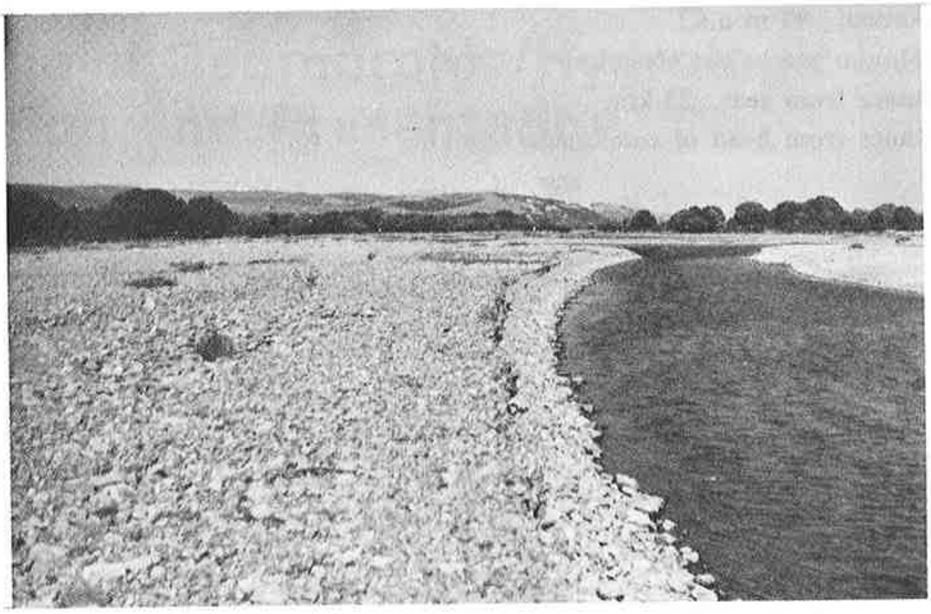


Figure A.6.2 Sketch map of Ashley River at Bullock Creek, showing cross-sections.



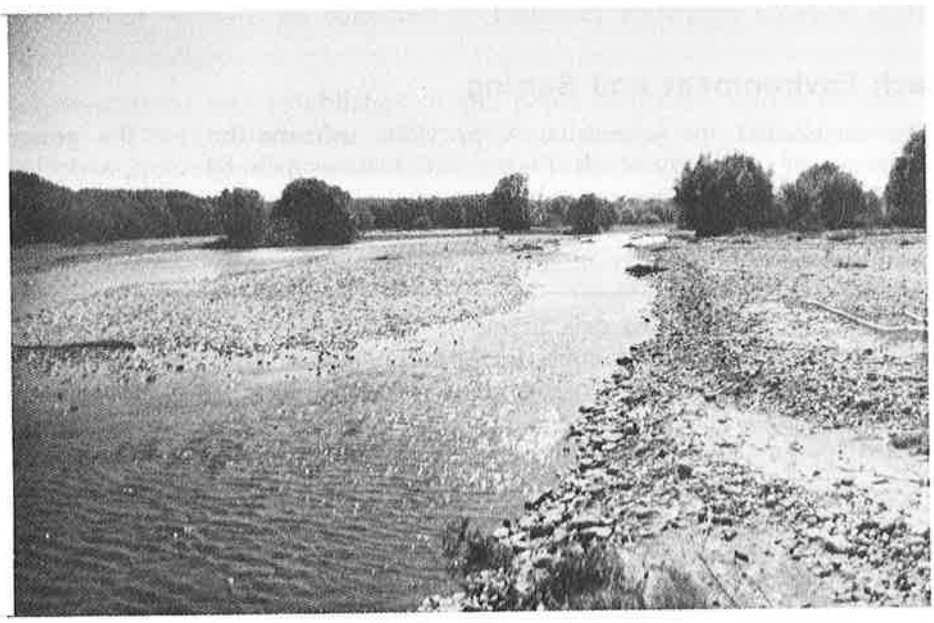


Figure A.6.3 Ground level views of the study reach looking upstream (top) and downstream (bottom).

Hydraulic Geometry

The five surveyed cross-sections are shown in Appendix B; their locations are marked on Fig. A.6.2. Summary data to describe hydraulic geometry at low flow and at bankfull flow are listed in tables A.6.1 and A.6.2. Bankfull discharge was estimated using the equation given by Mosley (1979); low flow is taken as that at the time of the survey, that is, 2.25 m^3s^{-1}. Ideally, hydraulic geometry data would be gathered at two or three other discharges, e.g., 5 m^3s^{-1} and 10 m^3s^{-1}.

Figures A.6.4 and A.6.5 show the cumulative frequency distributions of water depth and velocity in the reach, on the assumption that depths and velocities measured along the cross-sections are a random sample of those in the reach as a whole. Since the spacing of the measurements was not constant, each measurement was weighted according to the water surface width that it represented. Table A.6.3 is a cross-tabulation of water depth and velocity at the time of the survey (discharge = 2.25 m^3s^{-1}).

A representative sample of aquatic sub-environments (riffle, pool, etc.) was selected as described above; Tables A.6.4 to A.6.8 present data to define their physical characteristics. Measurement procedures were as described in the text of the main report. The proportion of the total water surface area in the reach that is in each sub-environment was obtained by classifying each watercourse crossed by a transect, summing the total width in each class, and dividing by the total water surface width crossed by all transects. The total water surface area in the reach was estimated by multiplying reach length (1640 m) by mean water surface width along the transects (47.5 m) to give a total of 77 900 m^2,or 47 500 m^2 per km of channel.

Because pools and riffles are of particular interest for their recreational and fishery importance, cumulative frequency distributions of depth in these two sub-environments are included on Fig. A.6.4. Cumulative frequency distributions of water depth and velocity are also presented for selected riffles, pools and runs in Fig. A.6.6.

Appendix C presents an example of a field data form for collection of depth and velocity information completed for transect 1.

Table A.6.1 Hydraulic geometry for cross-sections in the Ashley River, at Bullock Creek, at low flow (discharge = 2.25 m^3s^{-1}).

XS no.	XS area (m^2)	Water surface width (m)	Mean depth (m)	Max depth (m)	Mean velocity (m/s)	Discharge (m^3/s)
1	7.60	55.9	0.14	0.40	0.21	1.57
2	7.06	52.0	0.14	0.36	0.25	1.74
3	9.67	49.5	0.20	0.75	0.24	2.36
4	6.17	43.2	0.14	0.21	0.34	2.08
5	10.85	58.5	0.19	0.47	0.22	2.34
6	8.04	53.6	0.15	0.45	0.21	1.66
7	5.31	54.9	0.10	0.25	0.32	1.68
8	6.50	51.0	0.13	0.79	0.24	1.59
9	11.04	31.9	0.35	0.83	0.15	1.61
10	6.29	24.4	0.26	0.61	0.13	0.81
Mean	7.85	47.5	0.18	0.51	0.23	1.74
s.d.	2.02	11.1	0.07	0.22	0.07	0.45

Table A.6.2 Hydraulic geometry for cross-sections in the Ashley River study reach at bankfull stage (mean estimated bankfull discharge = 306 m^3s^{-1}).

XS no.	XS area (m^2)	Water surface width (m)	Mean depth (m)	Max depth (m)	Mean velocity (m/s)	Estimated discharge (m^3/s)
1	223	311	0.72	1.73	1.43	318
3	179	221	0.81	2.30	1.52	272
5	167	298	0.56	1.72	1.25	208
7	275	352	0.78	2.14	1.49	410
9	220	293	0.75	2.35	1.46	321
Mean	213	295	0.72	2.05	1.43	306
s.d.	42.6	47.4	0.10	0.30	0.11	74

Note: Only alternate cross-sections were surveyed.

Table A.6.3 Ashley River at Bullock Creek. Velocity and depth cross-tabulation. Values are water surface widths in metres (widths are not necessarily contiguous).

Velocity ($m\,s^{-1}$).

Depth (m)	≤−0.1	≤0	≤0.1	≤0.2	≤0.3	≤0.4	≤0.5	≤0.6	≤0.7	≤0.8	≤0.9	≤1.0	≤1.1	≤1.2	≤1.3	≤1.4	≤1.5	≤1.6	
0		3.3																	3.3
≤0.1		10.6	48.4	54.6	46.8	15.5	15.4	4.4	2.0	1.0									198.7
≤0.2		6.3	10.9	18.3	25.9	13.8	26.9	11.3	10.0	5.9	3.9	3.9	1.4				1.0		139.5
≤0.3		9.5	3.0	21.7	1.0	17.4	12.3	6.0	9.2										80.1
≤0.4			6.3	2.6		4.9	1.5	5.7	1.7										22.7
≤0.5		1.8	2.6	2.6				4.1	2.4	1.7									15.2
≤0.6	1.2	0.3			0.6	2.5													4.6
≤0.7				2.5	1.8		1.2												5.5
≤0.8				0.6		2.5		1.2											4.3
	1.2	31.8	71.2	102.9	76.1	56.6	57.3	32.7	25.3	8.6	3.9	3.9	1.4				1.0		473.9 [b]

Note: a Depth and velocity measurements are weighted for water surface width.
b total water surface width along ten cross-sections = 473.9 m.

Table A.6.4 Physical characteristics of selected riffles, Ashley River at Bullock Creek (discharge = 2.25 m^3s^{-1})

Location	Length (m)	Mean width (m)	Water surface area (m^2)	Median depth (m)	Maximum depth (m)	Median velocity (ms^{-1})	Maximum velocity (ms^{-1})	Slope	Measurements at head of riffle: Width (m)	Maximum depth (m)	Width with depth exceeding 0.1 m	0.2 m	0.3 m
XS5 channel 2	85	7.9	670	0.099	0.20	0.26	0.67	0.01	13.4	0.13	4.7	0	0
XS5 channel 4	45	15.3	688	0.045	0.26	0.35	1.16	0.03	10.0	0.18	3.0	0	0
XS7 channel 4	23	5.8	133	0.11	0.22	0.41	0.89	0.01	8.0	0.17	3.0	0	0
XS7 channel 3	40	11.5	461	0.092	0.29	0.47	1.25	0.03	15.5	0.19	10.0	0	0
XS6 channel 5	12	15.8	189	0.052	0.13	0.35	1.32	0.04	15.4	0.11	1.0	0	0

Location	Percentage bed sediment in: Clay-silt	Sand	Gravel	Small Cobbles	Large Cobbles	Percentage water surface: Still	Wavy	Broken	Turbulent	Rock
XS5 channel 2	2	3	42	44	9	19	55	19	2	5
XS5 channel 4	0	1	77	20	2	9	50	30	4	7
XS7 channel 4	0	2	54	35	9	23	58	12	4	4
XS7 channel 3	0	2	55	32	11	9	46	31	13	0
XS6 channel 5	0	0	83	13	4	13	41	28	11	7

Additional data: 1 Percentage of total water surface area in riffles = 30% (14 250 m^2 km^{-1} of channel).
2 Number of riffles = 30 per km of channel.

Table A.6.5 Physical characteristics of selected pools, Ashley River at Bullock Creek (discharge = 2.25 m^3s^{-1}).

Location	Length (m)	Mean width (m)	Water surface area (m^2)	Median depth (m)	Maximum depth (m)	Median velocity (ms^{-1})	Maximum velocity (ms^{-1})
XS8 channel 1	17	3.8	643	0.24	0.89	0.15	0.43
XS5 channel 1	25	4.6	115	0.32	0.95	0.02	0.10
XS9 channel 2	45	12.6	567	0.38	1.07	0.28	0.50
XS1 channel 3	38	5.6	211	0.31	0.57	0.11	0.54
XS9 channel 1	25	9.2	230	0.38	1.20	0.08	0.50

Location	Percentage bed sediment in: Sand	Gravel	Small cobbles	Large cobbles	Percentage water surface: Still	Wavy	Broken
XS8 channel 1	50	46	3	1	36	61	3
XS5 channel 1	22	52	8	1	79	21	0
XS9 channel 2	9	71	15	5	55	45	0
XS1 channel 3	21	61	18	0	71	29	0
XS9 channel 1	34	36	18	12	80	20	0

Additional data:1 Percentage of total water surface area in pools = 10.4% (4940 m^2 km^{-1} of river).
2 Number of pools = 8 per km of river.

Table A.6.6 Physical characteristics of selected runs, Ashley River at Bullock Creek (discharge = 2.25 m^3s^{-1}).

Location	Length (m)	Mean width (m)	Water surface area (m^2)	Median depth (m)	Maximum depth (m)	Median velocity (ms^{-1})	Maximum velocity (ms^{-1})
XS5 channel 2	57	2.8	159	0.025	0.08	0.03	0.27
XS5 channel 3	120	17.1	2046	0.20	0.43	0.34	0.54
XS6 channel 3	12	3.2	38	0.07	0.14	0.19	0.69
XS6 channel 5	93	12.0	1116	0.13	0.32	0.39	0.88

Location	Percentage bed sediment in						Percentage water surface			
	Clay-silt	Sand	Gravel	Small cobbles	Large cobbles	Boulders	Still	Wavy	Broken	Rock
XS5 channel 2	0	14	59	21	6	0	78	18	0	4
XS5 channel 3	0	3	83	14	0	0	6	94	0	0
XS6 channel 3	5	6	71	16	2	0	18	60	18	5
XS6 channel 5	0	4	56	28	7	5	7	86	4	3

Additional data: 1 Percentage of total water surface area in runs = 57% (27 075 m^2 km^{-1} of river)

Table A.6.7 Physical characteristics of selected isolated ponds, Ashley River at Bullock Creek (discharge = 2.25 m^3s^{-1}).

Location	Length (m)	Mean width (m)	Surface area (m^2)	Mean depth (m)	Max depth (m)	Overhanging cover (%)
XS 1 Channel 4†	7.5	1.64	12.3	0.24	0.51	0
XS 1 Channel 4†$_{II}$	15.0	2.76	41.4	0.41	1.00	0
XS 1 Channel 4	6.5	1.74	11.3	0.22	0.42	0
XS 2 Channel 1–2	20.5	1.96	40.3	0.08	0.19	0
XS 5 Channel 1–2	10	2.16	21.6	0.24	0.62	13.0
Mean	11.9	2.05	25.4	0.24	0.55	2.6
s.d.	5.2	0.40	13.1	0.10	0.27	5.2

Note: 4† refers to beyond channel 4.
Additional data: 1 No. of isolated ponds per kilometre of river = 4.
2 Percent of total water surface in isolated ponds = 1% (475 m^2 km^{-1} of channel).

Table A.6.8 Physical characteristics of selected backwaters, Ashley River at Bullock Creek (discharge = 2.25 m^3s^{-1}).

Location	Length (m)	Mean width (m)	Surface area (m^2)	Mean depth(m)	Max depth A (m)	Max depth B (m)	Overhanging cover (%)
XS 1 Channel 4	46	3.4	156	0.14	0.32	0.25	0
XS 1–2	33	4.4	145	0.07	0.15	0.13	0
XS 3 Channel 2	11	2.5	27	0.35	0.76	0.07	15
XS 5 Channel 4	17	2.1	36	0.15	0.47	0.04	0
XS 6 Channel 1	5	1.7	8	0.19	0.41	0.18	100
Mean	22.4	2.8	74.4	0.18	0.42	0.13	23.0
s.d.	15.0	1.0	62.9	0.09	0.20	0.08	38.9

Note: a Max depth$_A$ = Max water depth in backwater.
b Max depth$_B$ = Max water depth in the shallowest cross-section where backwater connects to the main channel.
Additional data: 1 Number of backwater per kilometre of river = 4.
2 Percentage of total water surface in backwater = 1.6% (760 m^2 km^{-1} of channel).

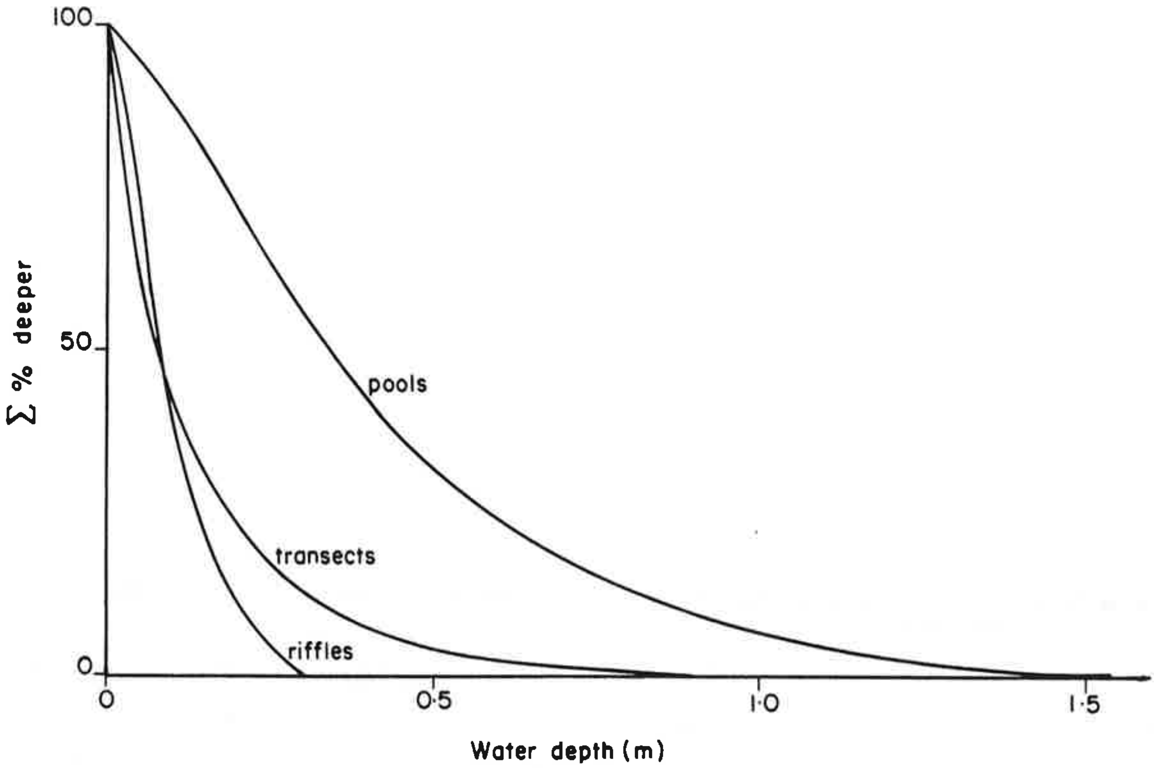


Figure A.6.4 Frequency distribution of water depths in riffles, pools, and along all transects (cross-sections combined) in the Ashley River at Bullock Creek (discharge = 2.25 m^3s^{-1}).

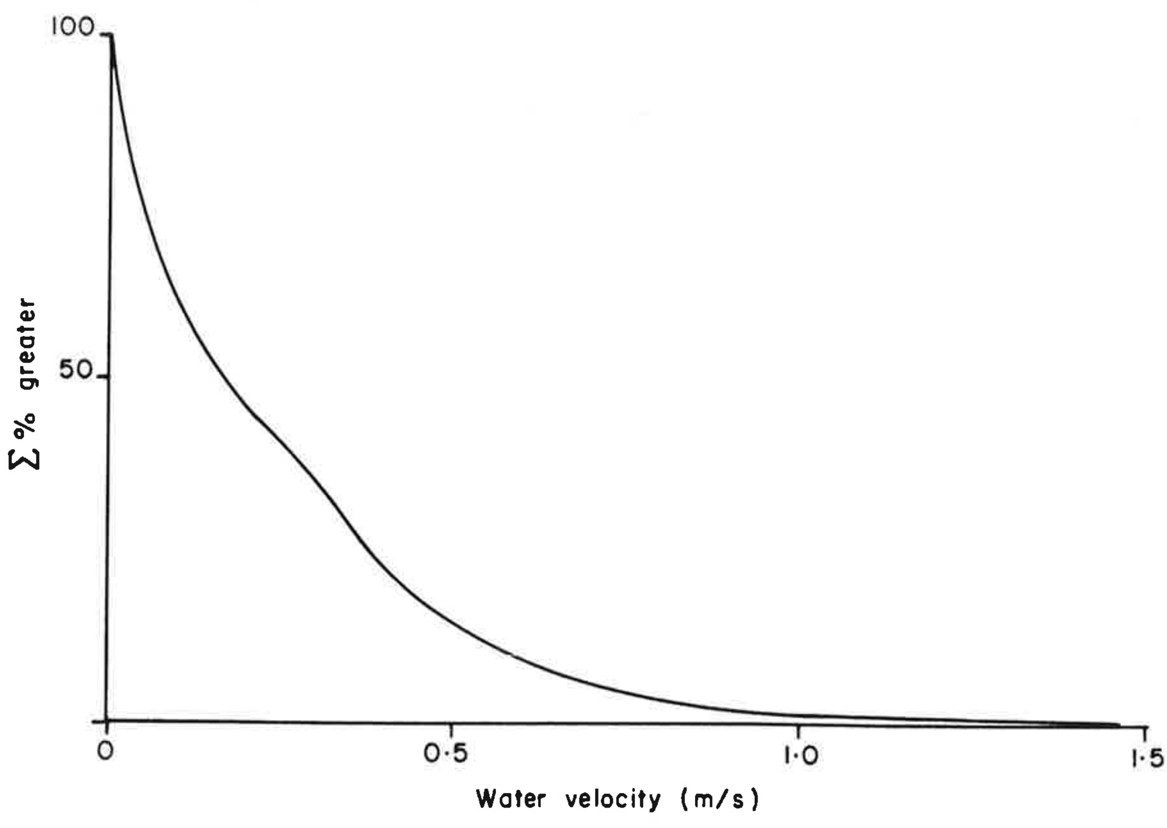


Figure A.6.5 Frequency distribution of water velocities along all cross-sections combined, in the Ashley River at Bullock Creek (discharge = 2.25 m^3s^{-1}).

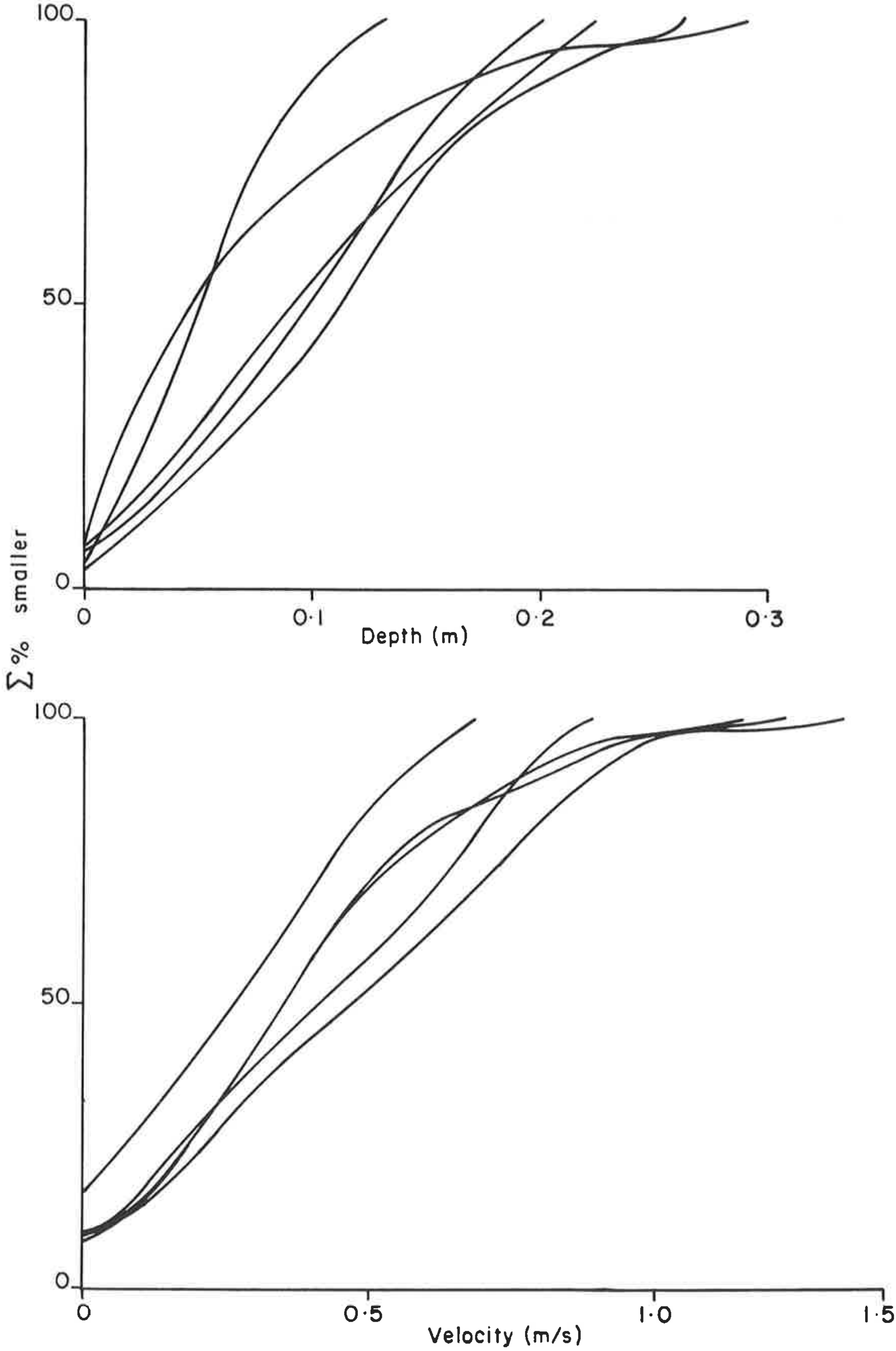


Figure A.6.6 Frequency distributions of water depth and velocity in selected riffles, Ashley River at Bullock Creek.

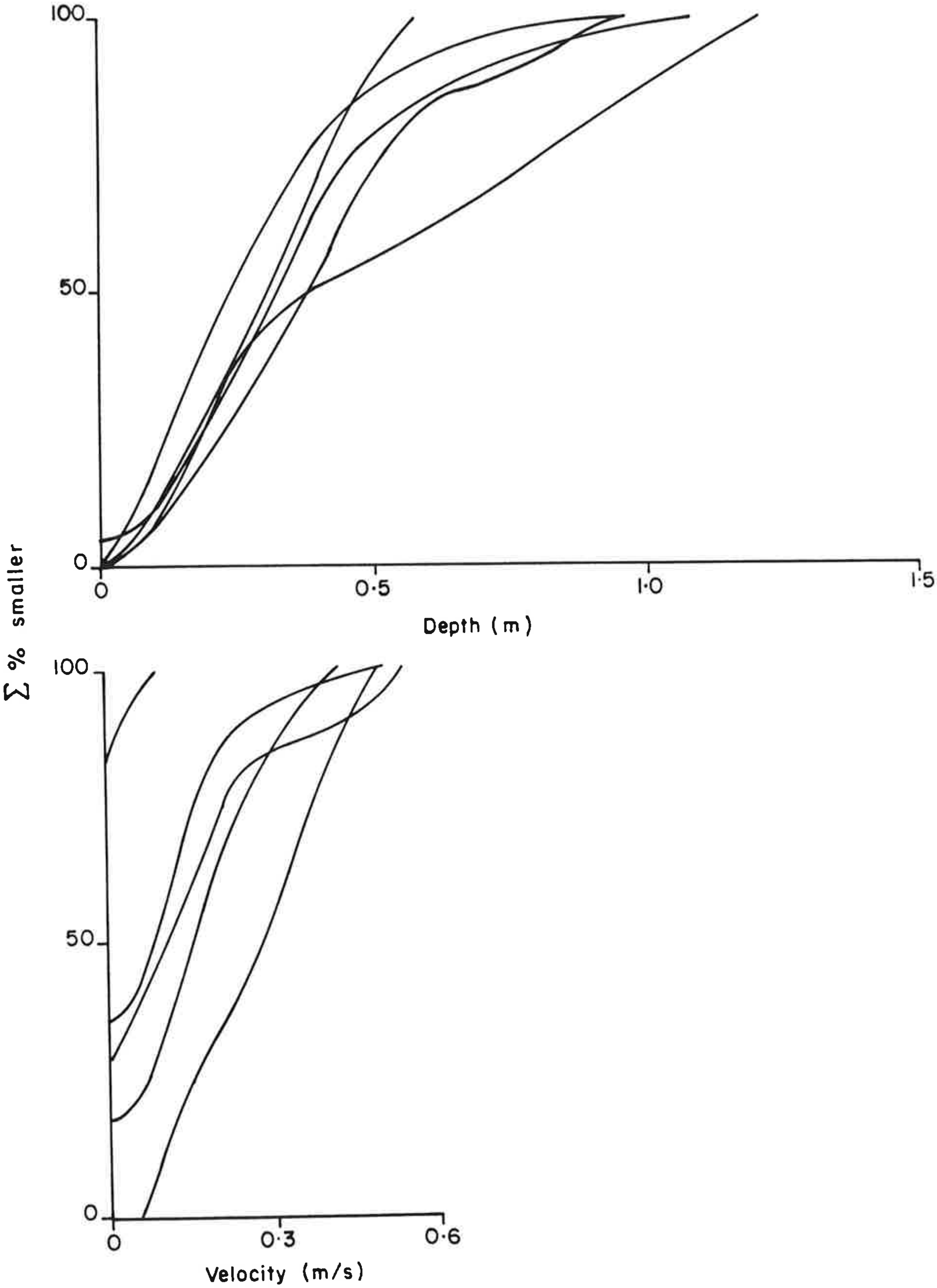


Figure A.6.6 *(continued)* Frequency distributions of water depth and velocity in selected pools, Ashley River at Bullock Creek.

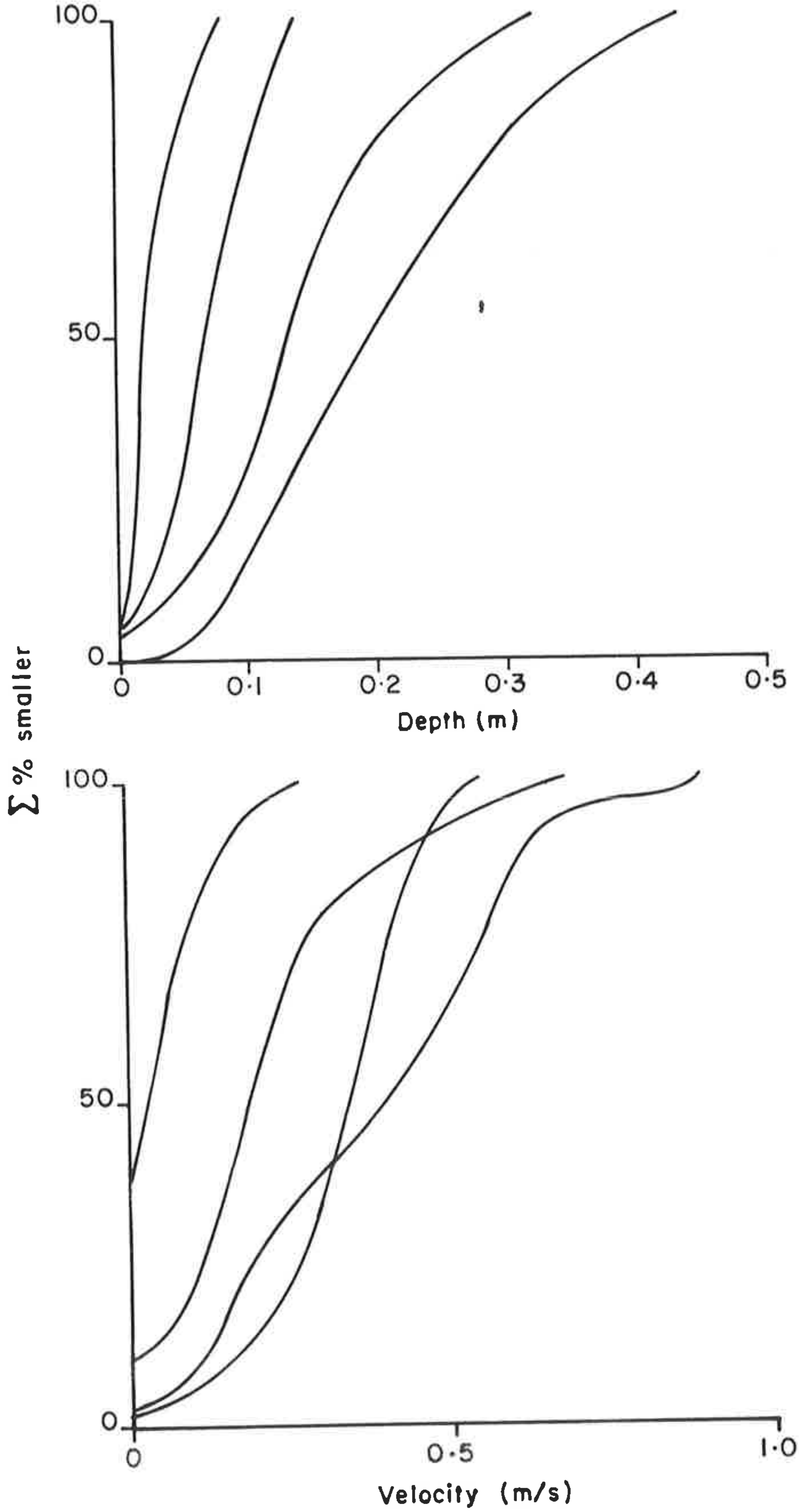


Figure A.6.6 *(continued)* Frequency distributions of water depth and velocity in selected runs, Ashley River at Bullock Creek.

Sediment character

The overall character of the stream bed in the reach, using data obtained during the transect surveys, is indicated in Table A.6.9, which shows the proportion of the whole stream bed, and the stream bed submerged during the survey, in each of nine classes (six sediment size classes, bedrock, plant material, and 'other').

More detailed analyses of sediment size distribution in each aquatic sub-environment and several emergent sub-environments (that is, several levels of gravel bars) were made, and their results are presented in Fig. A.6.7. Sampling sites are marked on Fig. A.6.2, and Fig. A.6.3 shows typical examples of the surface of the stream bed.

Appendix D includes examples of the completed field data forms for the two methods of bed character and coarse sediment sampling.

Table A.6.9 Streambed character, Ashley River at Bullock Creek.

Bed type class	Whole stream bed: Total observations in class	Whole stream bed: % of total	Bed submerged at low flow (discharge = 2.25 m^3s^{-1}): Total observations[1] in class	Bed submerged at low flow: % of total
Clay/silt (<0.062 mm)	9	2.1	4.2	0.9
Sand (.062–2 mm)	127	29.1	15.3	3.2
Gravel (2–64 mm)	202	46.2	283.6	59.7
Small cobbles (64–128 mm)	66	15.1	151.3	31.9
Large cobbles (128–256 mm)	6	1.4	20.5	4.3
Boulders (>256 mm)	0	0	0	0
Bedrock	0	0	0	0
Plant material	27	6.2	0	0
Other	0	0	0	0

Note: [1]Observations were weighted according to their spacing along the transects.

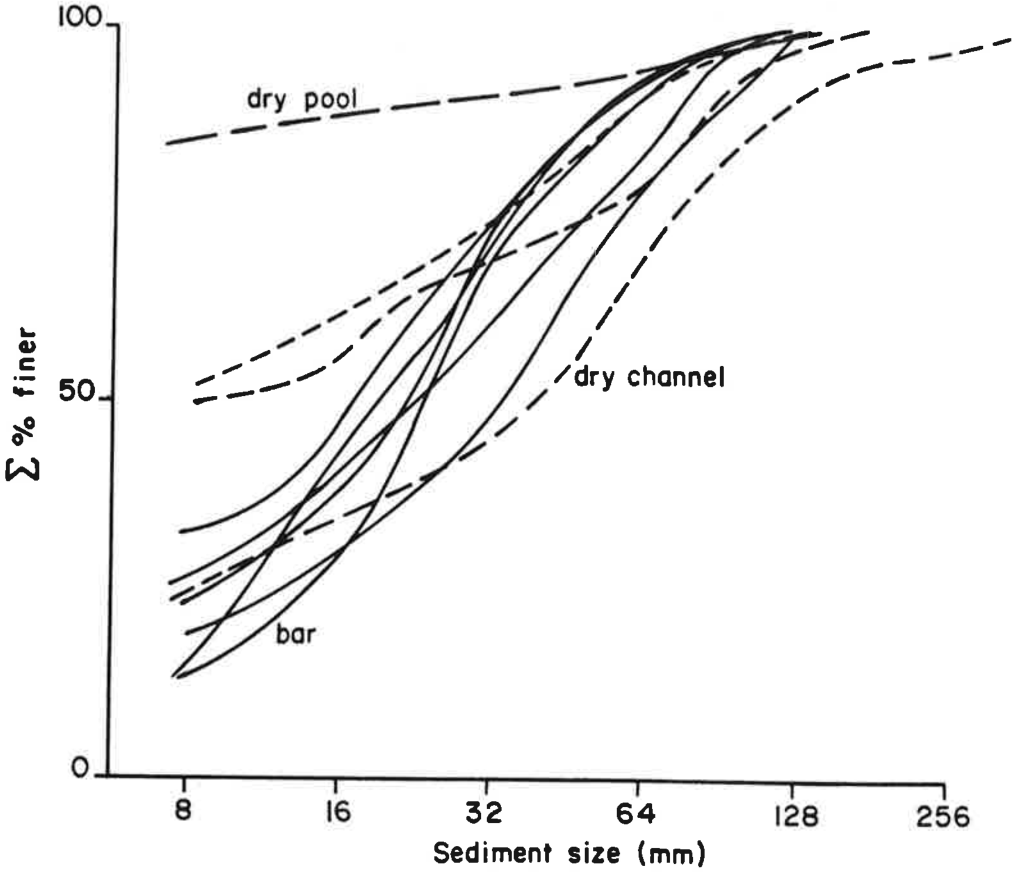


Figure A.6.7 Sediment size frequency distributions in emergent environments: dry channels (short dashed lines), bars and flood overflow surfaces (continuous lines) and a dry pool (long dashed line).

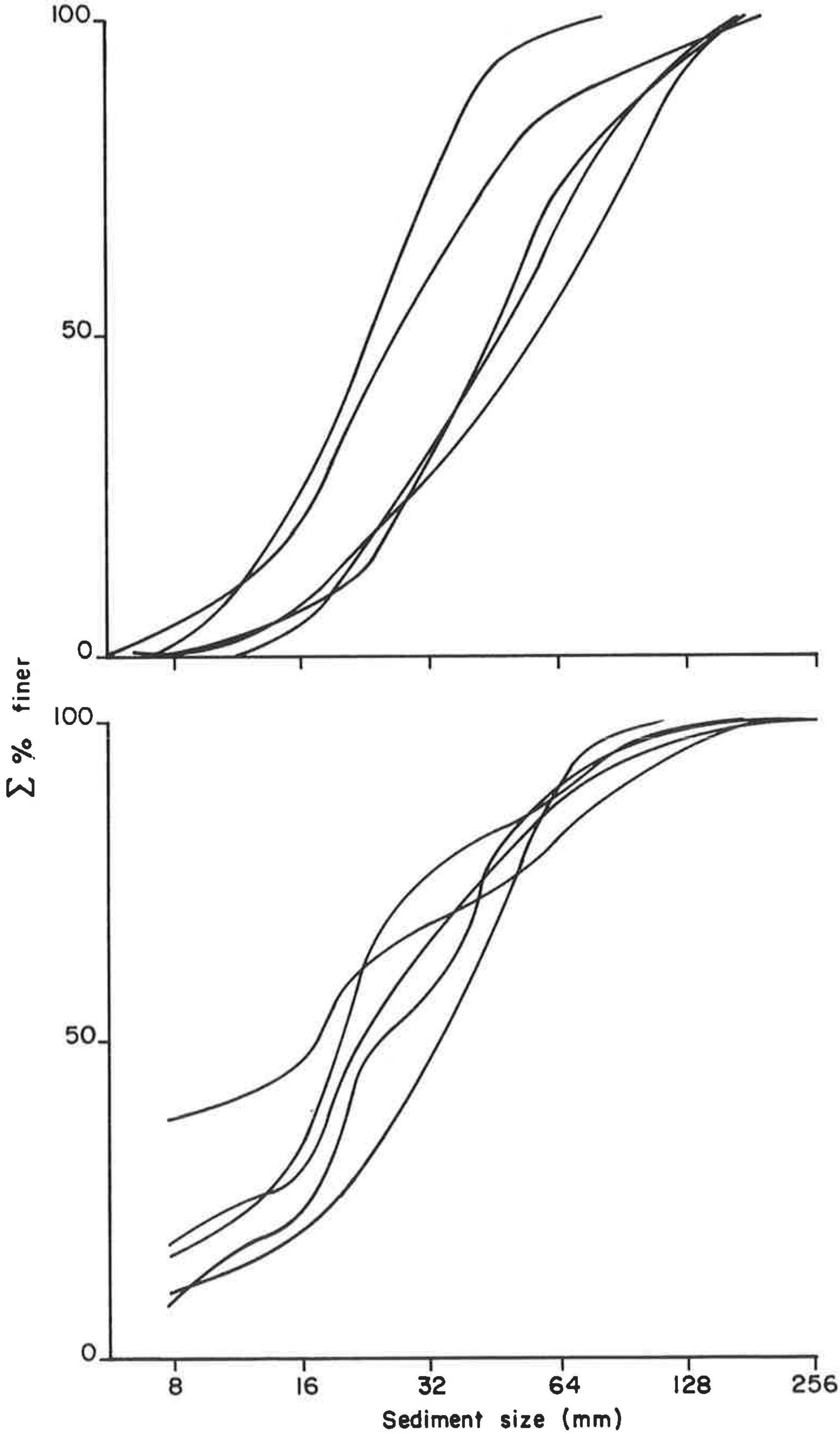


Figure A.6.7 *(continued)* Sediment size frequency distributions in (top) riffles and (bottom) pools, Ashley River at Bullock Creek at low flow.

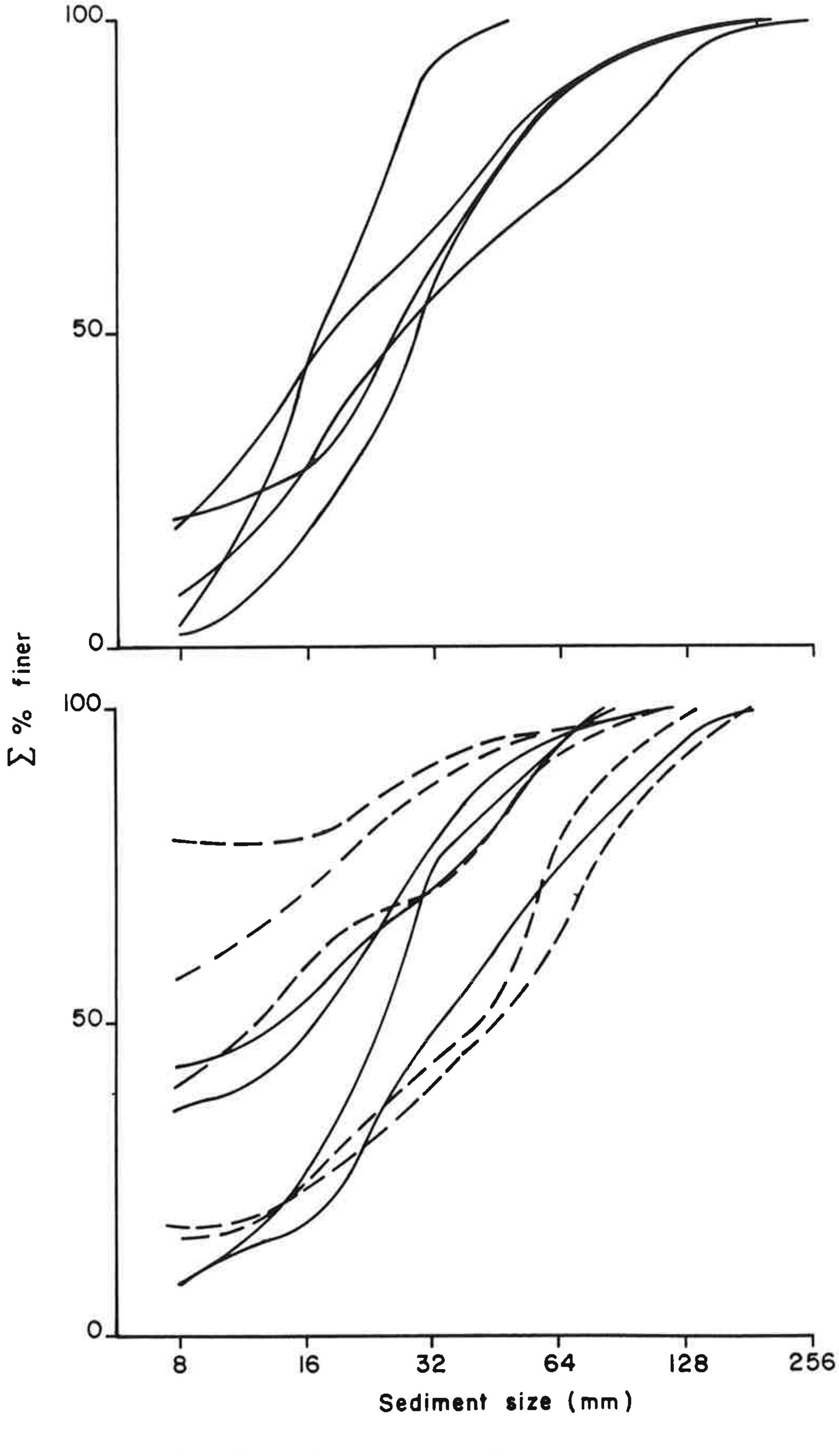


Figure A.6.7 *(continued)* Sediment size frequency distributions in (top) runs and (bottom) backwater (solid lines) and isolated ponds (dashed lines), Ashley River at Bullock Creek at low flow.

Cover

Cover for fish includes a number of elements, particularly water depth, sediment character, the presence of turbulent water, overhanging banks and vegetation, and instream cover provided by dead snags, logs, etc.

Water Depth

The frequency distributions of depths in the reach (riffles, pools and overall) are shown in Fig. A.6.4. It indicates, for example, that 7% of the total water surface area of pools is deeper than 1 m (1017 m^2 per km of river).

Bed sediment size

Sediment size distributions in the low flow channel sub-environments are indicated in Fig. A.6.7. The median grain size on riffles ranges between 20 mm and 60 mm and on pools between 18 mm and 35 mm.

Aerated water that would constitute good cover for fish was measured along the ten transects. It amounted to 0.4% of the total water surface crossed by the transects, or 190 m^2 per km of river.

Overhanging banks

Length of surveyed reach = 1640 m.

Total length of bank = 5030 m.

Total length of bank, at the foot of which there is water = 820 m (16.3% of total bank length).

Total area water surface overhung by bank = 3.4 m^2.

Overhanging vegetation

Total water surface area of reach = 77 900 m^2.

Water surface area overhung by:

- tall cover (tall trees, etc.) = 4098 m^2 (5.26%)
- medium cover (low trees/shrubs) = 573 m^2 (0.74%)
- low cover (shrubs/grasses, etc.) = 58 m^2 (0.07%)

Hydrologic Regime

The nearest site for which a discharge record is available is the Ashley River Gorge (catchment area = 521 km^2). The North Canterbury Catchment Board has supplied summary data for this site which provide some indication of the overall flow regime of the river at the Bullock Creek site (Table A.6.10). Discharges are not necessarily greater than those at the Gorge by a constant proportional to drainage area, because the character of the catchment is markedly different above and below the Gorge.

Table A.6.10 Summary hydrologic data for Ashley River at Gorge (catchment area = 521 km^2).

	J	F	M	A	M m^3s^{-1}	J	J	A	S	O	N	D
Mean minimum daily flow 1973–7	3.3	3.1	3.3	3.3	5.0	6.0	7.7	7.9	10.9	10.2	7.0	4.0
Minimum daily flow 1973–7	1.9	1.6	1.4	1.4	2.4	3.3	3.5	5.4	8.1	5.6	4.9	2.2
Mean monthly flow 1973–7	9.5	8.5	8.8	11.0	11.3	11.3	16.7	20.9	28.2	20.2	12.9	8.6
Mean maximum daily flow 1973–7	31.2	26.1	57.6	80.1	60.3	53.5	75.4	107.6	94.9	57.6	35.0	35.5
Maximum daily flow 1973–7	102.7	58.2	236.8	271.6	130.5	99.4	103.2	328.1	216.5	97.7	53.9	89.3

Year	Maximum instantaneous discharge (m^3s^{-1})
1973	139
1974	309
1975	312
1976	217
1977	205
1978	322

Mean annual flood = 250 m^3s^{-1}

Standard deviation of mean annual flood = 75 m^3s^{-1}

Mean discharge = 14.4 m^3s^{-1}

Minimum recorded daily flow = 1.4 m^3s^{-1}

Maximum recorded instantaneous discharge = 322 m^3s^{-1}

The river below the railway bridge may become dry in summer; the study reach therefore is not connected to the sea at all times.

No data are available for water quality parameters.

Commentary

The Ashley River at Bullock Creek is a wide, braided, gravel-bedded river with a substantial growth of vegetation (willows, broom, gorse) both along the banks and within the bankfull channel limits. Discharges vary widely, but during the summer months discharge tends to stabilise at 1.5–2 cumecs, flowing in one main channel and 1–3 smaller side channels. Riffles and pools are common and provide habitat for small fish, particularly native species, although water temperatures have been observed to reach at least 22°C in the reach. Some pools also provide good, though small, swimming holes, and the reach therefore receives significant recreational use, both on a day visit and overnight basis. There are numerous signs also of stock use of the river bed, but limited evidence of the presence of wildlife, possible because the wide gravel bed is exposed to sun and the north-west winds and also provides little in the way of shelter or a food supply. Algal growth in the low flow channel is extensive during the summer, and large areas of the stream bed, particularly in the slower moving runs and pools but also in the riffles, are covered with filamentous green algae and with an algal coating on the stones themselves.

Appendix A

Example of River Environment Survey

Ashley River near Bullock Ck

RIVER ENVIRONMENT SURVEY

ENV. HYD. G.P.: CARD 4

River name: Ashley at: Bullock Creek (grid ref: S67:836904) River Reach Code ASY/1

Date: 2.2.81 Observer: DST/DT Refer to Reach Sketch attached.

Note: Complete codes by circling number(s).

A. SURVEY REACH SETTING

General description of the landscape in the vicinity of the survey reach

Terrain type
1 mountainous
2 foothills
3 uplands (plateaux)
4 hills
5 lowlands or plain

Vegetation/land use
1 1 1 Bare ground
2 2 2 Native grassland
3 3 3 Shrub/scrubland
4 4 4 0-25% forest (native)
5 5 5 25-75% forest (native)
6 6 6 75-100% forest (native)
7 7 7 Developed pasture
8 8 8 Arable
9 9 9 Exotic forest plantations
0 0 0 Urban

Lithology (specify rock type)
1. Holocene River gravel, sand/silt, swamp deposits (Hawera series)
2. Greywacke/Argillite (Torlesse Group)

Comments: Difficult to define valley limits. On true right beyond low ridge is predominantly developed pasture underlain by Hawera series. On true left is a lowland plain (developed pasture/Hawera series) extending to Mt Thomas S.F. (exotic forest and scrub/ Torlesse greywacke-argillite).

B. SCENIC QUALITY

Diversity of flora along banks
1 Great
2
3
4
5 Limited

Condition of flora along banks
1 Excellent
2
3
4
5 Poor

Litter on bank (paper, cans, etc.)
1 < 2 per 30 m
2 2-5 per 30 m
3 5-10 per 30 m
4 10-50 per 30 m
5 >50 per 30 m

Diversity of local scene
1 Great
2
3
4
5 Limited

Confinement of scene
1 Open
2
3
4
5 Confined

Presence of vistas
1 Far vistas
2
3
4
5 No vistas

Accessibility/level of use
1 Wilderness
2
3
4
5 Paved access/mass use

Comments: Meandering river bed with willows along banks, on islands and scattered over the bed restricting sighting distance to <1 km. Isolated views of foothills through trees. Vegetation restricted to willows, scrub and some grassy areas. Good shade and picnic spots, & access track. Area receives significant use in summer for recreation.

C. GEOMORPHOLOGY

Valley Characteristics in the vicinity of the survey reach (Do not include artificial changes such as stopbanks; refer to diagram sheet.)

Valley type
0 Not applicable
1 Stream cut valley
2 Glacial trough
3 Rock gorge
4 Wide lowland valley
5 ______ (specify)

If no valley:-
0 Not applicable
1 Alluvial fan
2 Alluvial or outwash plain
3 Delta
4 ______ (specify)

Valley measurements
Depth from surrounding hills - m
Top width - m
Bottom width - m
width plain: >8 km true right
≃2 km true left

Terraces
0 None
1 Indefinite
2 Fragmentary
3 Continuous

Number of terrace levels: 2

Active undercutting of valley walls by stream (sites of sediment input to stream)
0 No undercutting
1 Occasional minor undercutting
2 Occasional major undercutting
3 Frequent major undercutting

Length of valley wall undercut by stream on left bank - %
right bank - %

Lithology of valley sides
(specify rock type)
true right : Kowai gravels
true left : Torlesse greywacke/ argillite

Land capability class of valley sides (specify)
True right Al-gK-C III e 4 sh - Pl
True left (Al/Gw)-4la-F VII e3 2Shs J1G-N4

Valley flat/floodplain in the vicinity of the survey reach: Refer to diagram sheet

Presence
0 Absent
1 Indefinite
2 Fragmentary
3 Continuous

Extent: incl. floodplain outside stopbanks
0 Absent
1 Narrow (<1 active channel width)
2 Moderate (1-5 active chl.widths)
3 Wide (>5 active chl.widths)

Average active channel width 590 m
Average distance between stopbanks (if present) - m

Channel constriction by valley walls or terraces
0 No constriction
1 Occasional constriction
2 Frequent constriction
3 Confined
4 Entrenched

Valley flat/floodplain measurements (if confined by terraces or valley sides)
Mean width 146 m
Maximum width 290 m
Length of channel with floodplain on left bank 100 %
right bank 100 %

D. VEGETATION SURVEYS

Vegetation/land use of valley sides
1 1 1 Bare ground
2 2 2 Native grassland
3 3 3 Shrub/scrubland (true left)
4 4 4 0-25% native forest
5 5 5 25-75% native forest (T.L.)
6 6 6 75-100% native forest
7 7 7 Developed pasture (true right)
8 8 8 Arable
9 9 9 Exotic forest plantations (true left)
0 0 0 Urban

Floodplain vegetation/land use
1 1 1 Bare ground
2 2 2 Native grassland
3 3 3 Shrub-scrubland
4 4 4 0-25% native forest
5 5 5 25-75% native forest
6 6 6 75-100% native forest
7 7 7 Developed pasture or parkland
8 8 8 Arable
9 9 9 Exotic forest plantation
0 0 0 Urban
* * * Marsh

Bank vegetation type (Species)
00 None
11 Grass, weeds grass
22 Bushes (incl. gorse and broom) both
33 Trees - scattered
44 Trees - dense willows
55 Vegetative protection work: dense, layered willows

E. CHANNEL PATTERN FOR SURVEY REACH (at low flow unless otherwise specified).

Bankfull	Low Flow	CHL Pattern
1	1	Straight
2	2	Sinuous
3	3	Irregular
4	4	Regular meanders
5	5	Irregular meanders
6	6	Tortuous meanders
7	7	Braided

Islands
0 None
1 Occasional
2 Frequent
3 Braided

Bar types
0 None
1 Alternate bars
2 Meander point bars
3 Mid-channel bars
4 Diagonal bars ("riffles, boulder banks")
5 Sand waves or large dunes

Reach parameters
Sinuosity: 1.13 Meander wavelength: - m
Floodplain slope: 0.005
Bed slope (along main stream at time of survey): 0.006
Braiding index (bankfull): 3.9 Mean number of branch channels per cross-section (bankfull): 2.2
Braiding index (low flow): 4.2 Mean number of branch channels per cross-section (low flow): 3.1

Number of branch channel bifurcations per km of channel (bankfull): 4
Number of branch channel bifurcations per km of channel (low flow): 9
Number of diagonal bars/riffles/boulder banks per km of channel, (low flow): 65

Comments:

F. CHANNEL BOUNDARY CONDITIONS AND MATERIALS

Obstructions in channel
0 0 None
1 1 Logs, debris, stumps in mid-channel
2 2 Growing vegetation in mid-channel (specify Willows)
3 3 Boulders in mid-channel
4 4 Overhanging trees at edge of channel
5 5 Slumped banks
6 6 Artificial constriction (specify)

Degree of obstruction of channel
0 None
1 Occasional minor
2 Occasional major
3 Frequent minor
4 Frequent major

Channel bed material
1 1 Sand-silt
2 2 Sand-gravel (<64 mm)
3 3 Gravel
4 4 Cobbles
5 5 Boulders
6 6 Bedrock

Bedrock in channel
0 None
1 One occurrence
2 Two occurrences
- ___ occurrences
per ___ m length of reach

Bedrock lithology (specify)
-
percent of channel bed composed of bedrock 0 %

Channel bank material: alluvial
0 0 0 No alluvial banks
1 1 1 Clay and silt (cohesive)
2 2 2 Silt and sand (non-cohesive)
3 3 3 Sand and gravel (<64 mm)
4 4 4 Sand to cobbles
5 5 5 Sand overlain by silts
6 6 6 Gravel overlain by silt
7 7 7 Cobbles overlain by silt
8 8 8 Boulders

Channel bank material: non alluvial
0 0 0 All alluvial bank material
1 1 1 Glacial deposits
2 2 2 Bedrock (specify lithology)
3 3 3 Protection work (specify wire ropes/concrete blocks)

Percentage of bank in alluvium on:
left bank 100%
right bank 100%

Percentage of bank being actively eroded on:
left bank 46%
right bank 50%

Floodplain surficial material
0 0 No floodplain
1 1 Silt/clay
2 2 Sand/silt
3 3 Gravel (<64 mm)
4 4 Cobbles

Floodplain land capability class
(specify class outside and inside stopbanks, if applicable)
True left : III S 9 $\frac{\text{A1-40a*-A}}{\text{SB-PIM7}}$
True right : III S 9 $\frac{\text{A1-40d*-A}}{\text{TW-P1}}$

Comments: ______________________________

G. WATER QUALITY

Water Colour
1 Colourless
2 Pale green
3 Green
4 Light brown
5 Brown

Turbidity - degree
1 Clear
2
3
4
5 Very turbid
Depth at which bottom visible: ____ m

Turbidity - cause
1 Algae
2 Dissolved (brown humic) matter
3 Rock (glacial) flour
4 Other sediment load
5 (Specify) ______

Evidence of pollution (specify)
1 None
2 ______
3 ______
4 ______
5 Severe ______

River fauna (specify species)
1 Large variety Trout
2 Eel
3 Torrent fish
4 Bullies
5 None

Attached/weed growth (% cover)
1 0-20%
2 20-40%
3 40-60%
4 60-80%
5 80-100%

Slimes/algal growth (% cover)
1 0-20%
2 20-40%
3 40-60%
4 60-80%
5 80-100%

Comments: Filamentous green algae common in backwaters, ponds and low velocity sections of runs. Algal growth on cobble bed on low velocity sections of channel.

SKETCH of SURVEY REACH

Location Bullock Creek

Reach Code A.S.Y.1

Date 2.2.81

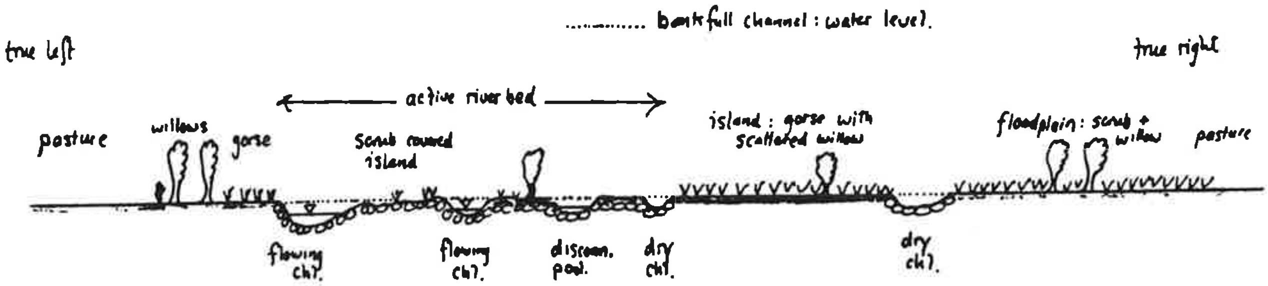
Include: flow direction, branch channels, active channel zone, floodplain boundaries (terraces, valley sides, stopbanks), swamps, vegetation zones, stable and eroding banks, cross section locations, aerial photography markers, reach boundaries. If vegetation survey has been carried out, mark line transect locations.

See Figure A·6·2

Sketch Typical Cross-Section thru' Survey Reach

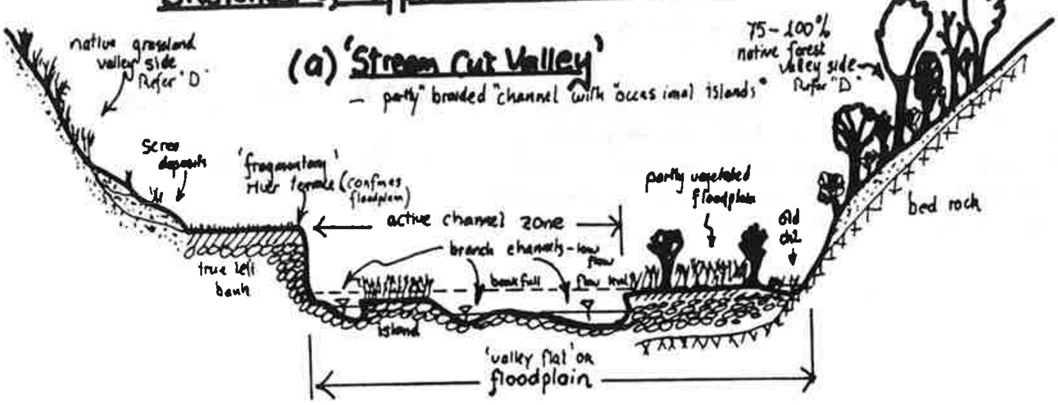
Include approx location of branch channels, active channel zone, berms, stopbanks, islands terraces, valley sides, vegetation, true left and true right banks

Reach Code A.S.Y.1.
Survey Date 2.2.81.

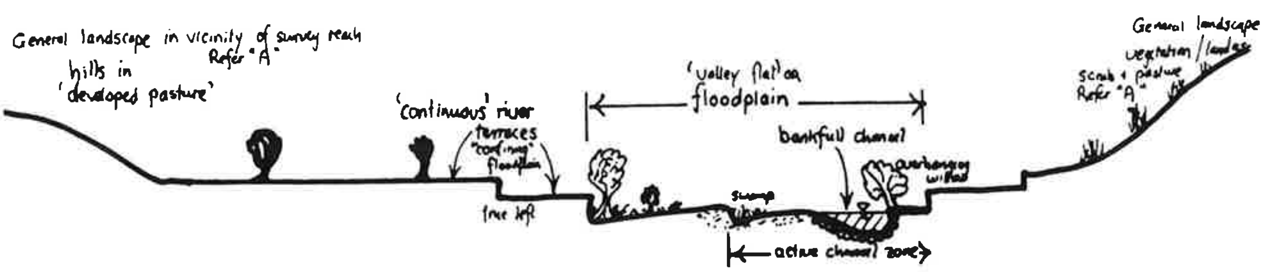


Sketches of Typical Cross-Sections

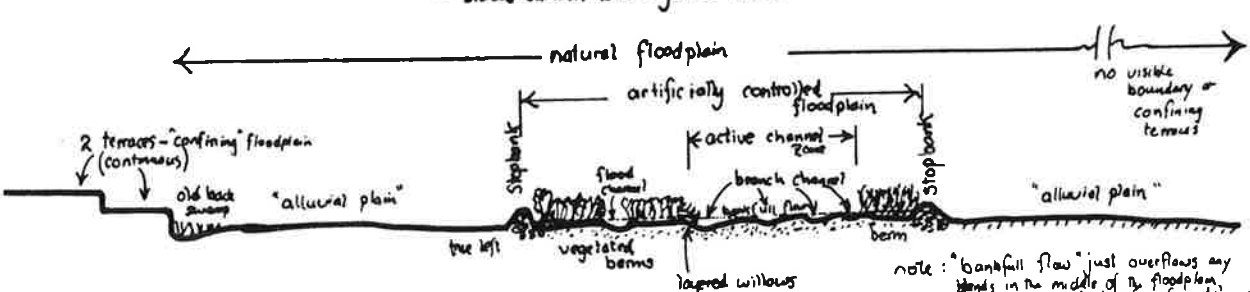
(a) 'Stream Cut Valley'
– partly braided channel with occasional islands



(b) 'Wide Lowland Valley'
– single thread channel with 'regular meanders'

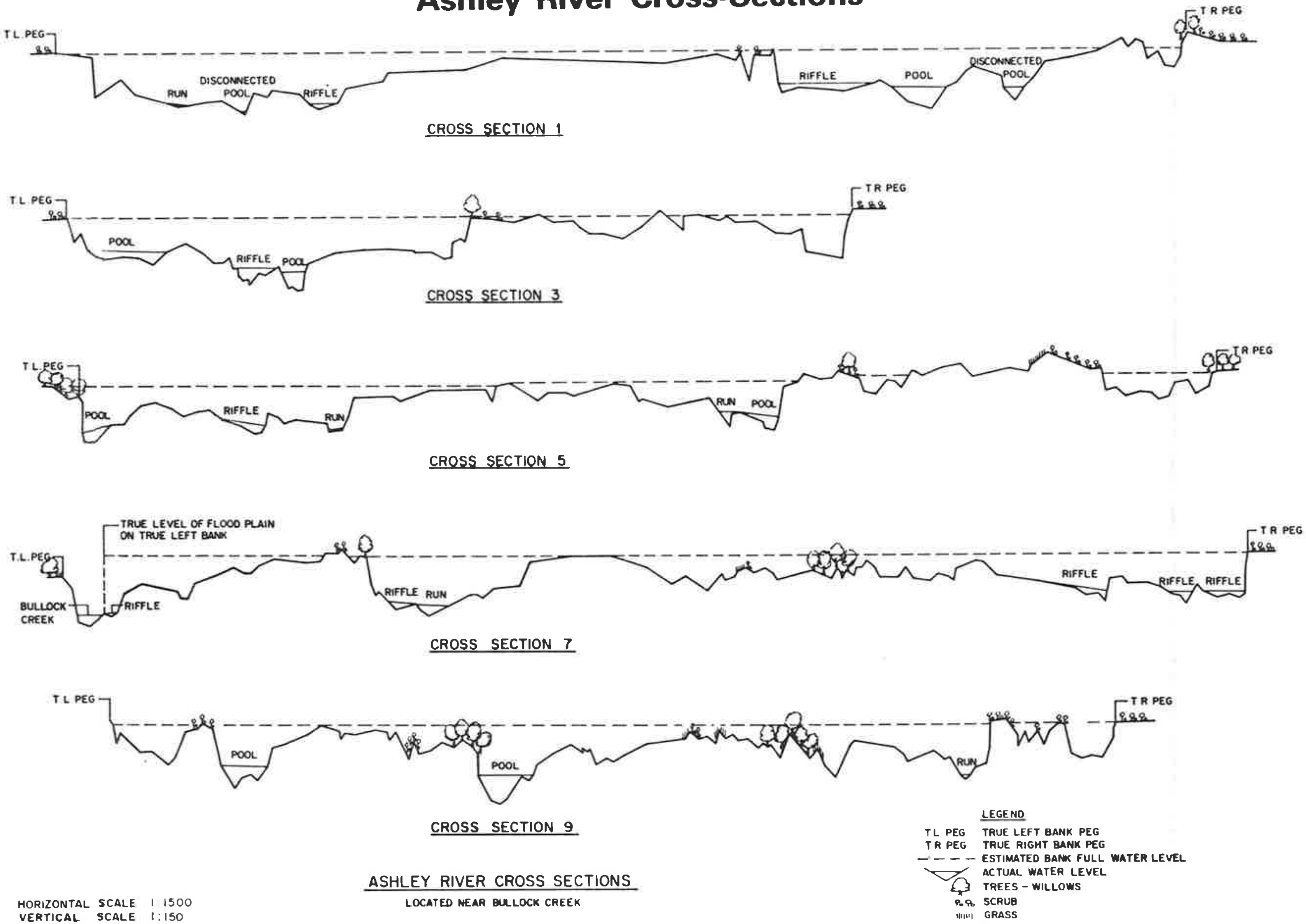


(c) Alluvial or Outwash Plain
– artificially controlled floodplain
– braided channel with vegetated berms



Appendix B

Ashley River Cross-Sections



Appendix C

Field Data for Cross-section 1; Ashley River Hydraulic Geometry

CARD (1)

	LOCATION: Trans. No.	Sub chl. code	Dist. from Init. Pt.	VELOCITY: Obs. Depth	Method	Angle Coeff.	Revol-utions	Time (in sec)	CHL. BOUNDARIES: Silt	Algae	Chl. Morph	Water Surf.	VELOCITY: Computed m/s	SED. CHARACTER: C.S.	S.	G	S.C	L.C	B.	R.	O.	E.
TLWE	01	A	0.0	.0					0	2	RU		.0				✓					
			2.0	.01					0	2	RU		.0				✓					
			4.0	.09	F	1.00	0.9m	3.9s	0	2	RU	SM	0.24			✓						
			6.0	.09	F	1.00	0.9m	5.9s	0	2	RU	WA	0.16			✓						
			8.0	.07	F	1.00	1.0m	7.9s	0	2	RU	WA	0.13			✓						
			10.0	.02	E	1.00			0	2	RU	SM	0.06			✓						
TRWE			12.0	.0					0	2	RU	SM				✓						
TLWE	C2	A	0.0	.0					0	2	RI	SM	.0				✓					
			1.0	.03	E	0.97			0	2	RI	WA	.30				✓					
			2.0	.07	F	0.97	1.0m in 1.8s		0	2	RI	WA	.56			✓						
			3.0	.04	E	0.97			0	2	RI	SM	.36					✓				
			4.0	.07	F	0.97	0.5m in 3.2s		0	2	RI	SM	.16			✓						
			5.0	.09	F	0.97	1.0m in 5.7s		0	2	RI	SM	.18			✓						
			6.0	.06	F	0.97	0.5m in 2.2s		0	2	RI	SM	.23				✓					
			7.0	.06	F	0.97	0.5m in 3.2s		0	2	RI	WA	.16				✓					
TRWE			7.9	.0					0	2	RI	SM	.0				✓					

BRANCH CHL. No. ___

M.W.D.: ENV HYD GP CHL. DEPTH: VEL. DATA

HYDRAULIC GEOM. OF BRAIDED RIVERS C1

Observer's Name DST RIVER NAME ASHLEY

DATE 28 01 81 RIVER NO. 662000

REACH: BRANCH CODE ASY1

FLOW THRU REACH M³/SEC 2.25

BRANCH CHANNEL LENGTH ___ M

NO. OF SECTIONS ___

MEAN SECTION SPACING ___ M

TIME (HRS) START 0915 FIN ___

BOAT ___ METER TYPE ___ NO. ___

RATING NO. ___ DATE ___

WADING ___ METER TYPE GUR NO. GN997

RATING NO. 1 DATE ___

SPIN TEST: BEFORE ___ AFTER ___ SECS

METER ___ MM ABOVE BOTTOM OF ___ KG WT

WATER TEMP ___ °C

REMARKS (SKETCH OF BRANCH CHANNEL)

BRANCH CHL. WATER DEPTH MAX. ___

MAX. DEPTH/SHALLOWEST SECT. ___

see sketch map, figure A-6-2

BRANCH CHL. No. ___

Card 1 Observer's Names DST BRANCH CHL. No. ____

	LOCATION			VELOCITY					CHL. BOUNDARIES					VELOCITY	SED. CHARACTER								
	Trans. No.	Sub-CHL. code	DIST from INIT PT.	OBS. DEPTH	METHOD	ANGLE COEFF.	REVOLUTIONS	TIME (in sec)	Silt	algae	CHL morph	water surf.	Loose rocks	Computed m/s	C.S clay/silt	S sand	G gravel	S.C small cobbles	L.C large cobbles	B. boulder	R. bed rock	O	E
	1 2	3 4	5 6 7 8	9 10 11	12 13	14 15 16	17 18 19	20 21 22	24	25	26 27	28 29	30 31	34 35 36 37	38	39	40	41	42	43	44	45	46
TLWE	03	A	0	.0					0	1	PO	SM		.0					✓				
			3.0	.27	W6	0.99	11	22.7	0	1	PO	WA		.33			✓						
			6.0	.23	W6	0.99	11	20.8	0	1	PO	WA		.37				✓					
			9.0	.27	W6	0.99	19	20.4	0	1	PO	WA		.63				✓					
			12.0	.29	W6	0.99	20	20.0	0	1	PO	WA		.67				✓					
			15.0	.29	W6	0.99	20	21.4	0	1	PO	WA		.63				✓					
			18.0	.17	W6	0.99	12	20.4	0	1	RI	WA		.40				✓					
			21.0	.07	F	0.99	1.0m in	2.45	0	1	RI	WA		.42			✓						
TRWE			23.5	.0					0	1	RI	SM		.0			✓						
TLWE	04	A	0	.0					0	2	PO	SM		.0			✓						
			2.6	.40	W6	0.97	7	22.2	0	2	PO	WA		.22			✓						
			5.2	.31	E	0.97			0	2	PO	SM		.11			✓						
			7.8	.14	E	0.97			0	2	PO	SM		.11			✓						
			10.4	.06	E				0	2	PO	SM		.0				✓					
TRWE			13.0	.0					0	2	PO	SM		.0				✓					

NOTES:

Trans. No. Branch channel code number (braided river only).
Method: W6 - wading/current meter at 0.6 depth
F - float
E - estimated
B - boating
Chl morph: Channel morphology - RI is riffle, PO is pool, RU is run, BW is backwater, DP is disconnected pool, TO is torrent
algae: algal cover on stones - 0 is none, 1 is <50% cover, 2 is >50% cover
silt: silt cover on stones - 0 is none, 1 is slight (<2 mm deep), 2 is thick (>2 mm deep).
sed. character: size ranges as per appendix 4B.
Tick indicates dominant size. Alternatively, percentages may be entered.

This form is a special-purpose modification of the standard gauging card (WS form 4).

Appendix D

Field data form for 'Wolman' sediment sample, riffle at cross-section 5, channel 2.

COARSE SEDIMENT ANALYSIS

SITE: ASHLEY @ BULLOCK CK MEAN DIAMETER:

DATE: 14-1-81

COMMENTS: RIFFLE @ XS5, CHANNEL 2.

Size class (mm)	Count in class	Total in class	Cumul. Total	Cumul. %
less than 8	I	1	1	1.5
8-11.3	-	.	1	1.5
11.3-16	IIII	4	5	7.6
16-22.6	卌 III	8	13	19.7
22.5-32	卌	5	18	27.3
32-45.3	卌 IIII	9	27	40.9
45.3-64	卌 卌	10	37	56.1
64-90.5	卌 卌	10	47	71.2
90.5-128	卌 卌 卌	15	62	93.9
128-181	IIII	4	66	100.0
181-256	.			
greater than 256	.			
	Total:	66		

Observer: DST

Field data form for bed character sampling at cross-section 1 (Transect method).

STREAM BED CHARACTER

SITE: ASHLEY RIVER AT BULLOCK CREEK

DATE: 15-1-81

COMMENTS: AT XS 1.

Bed Type	Code	Count in Class	Total in Class	% of Overall Total
Clay-silt (<0.062 mm)	CS		0	
Sand (0.062-2mm)	S	卌 IIII	9	15.5
Gravel (2-64mm)	G	卌 卌 卌 卌 卌 卌 卌 IIII	39	67.2
Small cobbles (64-128mm)	SC	卌 II	7	12.1
Large cobbles (128-256mm)	LC	I	1	1.7
Boulders (>256mm)	B		0	
Bedrock	R		0	
Plant material	P	II	2	3.4
Other	O		0	
		Total	58	100.0

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WATER AND SOIL MISCELLANEOUS PUBLICATIONS

(see also back cover)

WATER AND SOIL MISCELLANEOUS PUBLICATIONS (cont'd)

30. Future Groundwater Research and Survey in New Zealand. $3.00 — 1982

31. Land and water resource surveys of NZ: map coverage and reference lists. C L Clark. $8.00 — 1982

32. A procedure for characterising river channels. M P Mosely. $8.00 — 1982

33. The United States Environmental Protection Agency's 1980 ambient water quality criteria: a compilation for use in NZ. D G Smith. $5.00 — 1982

34 Water Quality Research in NZ, 1981. J S Gifford. $5.00 — 1982

35 Liquid and waterborne wastes research in NZ, 1981. J S Gifford. $3.00 — 1982