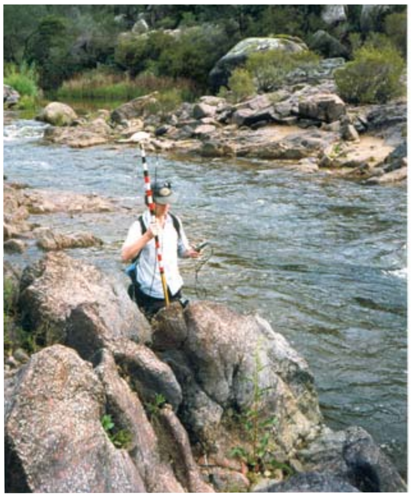
SNOWY RIVER RECOVERY

SNOWY RIVER FLOW RESPONSE MONITORING

FIELD MANUAL FOR IDENTIFYING AND MAPPING CHANNEL UNITS IN THE SNOWY RIVER



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Snowy River Recovery
Snowy River flow response monitoring:
Field manual for identifying and mapping channel units in the Snowy River

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Abstract

River discharge is a major determinate of physical habitat in streams, which in turn is a significant determinant of the composition of aquatic plants and animals. Dams and their operation have a substantial impact on the available habitat and habitat quality of rivers. In order to measure the physical and ecological changes associated with environmental water releases to the Snowy River a consistent method was needed to measure the physical changes in channel units, as these river attributes were expected to quickly respond to changes in the hydrological regime.

This manual revises the existing descriptions of site/flow conditions from the literature and applies the descriptions of channel units specifically to the Snowy River. Such information will provide the basis for:

- Quantifying the channel units within the Snowy River test and reference sites, and,
- Guiding field sampling for the biological components of the Snowy River Flow Response Monitoring.

It is expected that the data generated from this physical habitat mapping will assist in developing revised flow rules that improve the extent and condition of the riverine habitat.

1. Introduction

The ability to correctly and consistently identify channel units in rivers under varying flows is important when conducting large-scale, long-term (> 10 years) physical and biological environmental flow response monitoring programs especially when biological sampling is based on channel units. Correct field identification will allow repeated, accurate channel unit mapping and will minimise operator bias between sampling occasions by sampling the same channel units consistently.

The term channel unit is used by physical and biological scientists to describe the different types of physical habitat of riverine biota (Hawkins *et al.* 1993; Bisson and Montgomery 1996; Peterson and Rabeni 2001a and 2001b; Erskine 2005). Examples of channel units include falls, rapids, riffles, runs, pools, cascades, backwaters. Hawkins *et al*. (1993) describes the channel unit as a 'quasi-discrete area of relatively homogeneous depth and flow that is bounded by a sharp physical gradient', but it is often difficult to interpret this definition in the field in a consistent manner.

There are many channel unit definitions in the literature generally associated with classification systems and they are usually developed at low flow eg., Frissell *et al.* 1986; Kellerhals and Church 1989; Church 1992; Hawkins *et al.* 1993; Poole *et al.* 1997; Raven *et al*. 1998; Maddock 1999; Newson and Newson 2000; Erskine 2005. Definitions of channel units in these studies apply to the rivers for which they were constructed hence they will require revision when applied to other rivers (Erskine 2005). Only the study of Jowett (1993) explained how to objectively identify channel units in the field and this was limited to the identification of pools, runs and riffles. Accordingly, when studying a new river, existing channel unit definitions must be revised and methods must be developed to correctly and consistently identify channel units under varying flows in the field.

The Snowy River downstream of Jindabyne Dam has been severely degraded since the dam was completed in 1967. Until the first environmental water release in 2002 only 1% of Mean Annual Natural Flow (MANF) was measured in the Snowy River at Jindabyne and the channel pattern has become homogeneous with channel units likened to a chain of ponds system (Pendlebury *et al.* 1996). Many of the running water hydraulic habitats associated with a greater range of river discharge were minimal or absent from sections of the river.

Over ten to fifteen years from the 28 August 2002 the Snowy River will receive staged environmental flow releases of up to 28% of mean annual natural flow to rehabilitate the physical and biological values of the river (NSW Government 2002). It is hypothesised that after flow releases, the first order responses will be measured at habitats. The channel units will be drowned out, re-created or re-configured through erosion and deposition. Second order changes in biological condition are expected following an improvement in the diversity and quality of channel units.

The Snowy River Environmental Flow Response Monitoring Project was developed to detect and then measure the magnitude and direction of physical and biological change following environmental water releases. Channel units are being mapped to measure changes in the heterogeneity and area inundated and to guide field sampling location for a range of biological indicators. The latter is important because the biological sampling is based on hydraulic changes within the channel unit.

The aim of this field manual is to describe each type of channel unit that currently exists in the Snowy River catchment or may be created following flow releases. Multiple photos have been selected to show the variation within each type of channel unit.

The objectives of this field manual are to provide sufficient detail to enable repeated channel unit identification under low flow conditions in rivers of the Snowy River catchment, most specifically to:

1. Map changes in channel unit heterogeneity and area by physical monitoring scientists; and,

2. Guide the biological field sampling location at the site scale.

2. Spatial scales

Channel units form part of the nested hierarchical spatial approach to stream classification adapted from Webb and Erskine (unpublished), and the temporal sensitivity approach developed by Frissell *et al*. (1986) and Petts (1984) (Table 1). Classification is necessary so the river can be stratified to allow the estimation of variability at different spatial scales. Classification spans catchment, macro-reach, geomorphic reach, site and channel unit scales.

In this project sampling is conducted at two spatial scales: the site / reach (Figure 2 and Figure 3) and the channel unit which are sub-units of the reach. Hydrology, water quality, geomorphology (habitat quantity, diversity and quality), riparian vegetation and fish are measured at the site (reach) scale. At this scale the occurrence of biota is determined by overall features such as topography, altitude and fluvial processes (Maddock 1999). Sediment, aquatic macrophytes, macro-algae and macroinvertebrates are measured at the channel unit scale where the occurrence of biota is influenced by the type of channel unit (eg., riffles, runs, pools etc.), dominant substrate, average flow velocity and flow depth (Maddock 1999).

Table 1. Spatial and temporal organisation based on river morphology (Webb and Erskine unpublished; Frissell *et al*. 1986; Petts 1984).

Spatial classification level	Linear spatial scale (m)	Essential features	Response time	Sensitivity to change
Catchment	>10^5	Snowy River	Long	Low
Macro reach	10^4	A stretch of river between major tributaries	↓	↓
Geomorphic reach	10^4	Relatively homogeneous associations of topographic features and habitat types which distinguish them from adjoining reaches	↓	↓
Site (reach)	10^2-10^3	A stretch of river 10-15 times longer than the channel width, including two riffle pool sequences	↓	↓
Channel units	10	Areas of relatively homogeneous flow and depth eg. rapids, riffles, runs, pools	Short	High

Physical habitats are spatially organised into a hierarchical channel unit typology that differentiates channel units on the basis of fast and slow water then type, based on unique hydraulic characteristics (Figure 1; Bisson *et al*. 1996; Erskine 2005). Channel units identified in the Snowy River Flow Response Monitoring are at the coarse end of the meso-scale and are mapped in two dimensions (ie. x and y) but not a third (ie. z).

Figure 1. Hierarchical channel unit typology for the Snowy River.

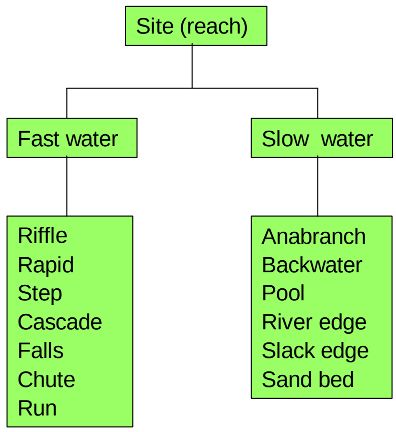


Figure 2. Site scale aerial view of the Snowy River reach downstream of Blackburn Creek.

Figure 3. Site scale (oblique view) of the Snowy River reach downstream of Blackburn Creek (looking upstream).

3. Channel unit definitions

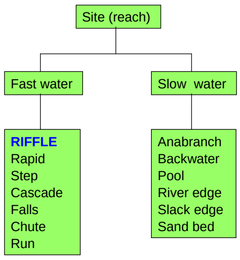
Definitions of channel unit types was initially based on the literature then adjusted to suit the local conditions of the Snowy River. Each definition is based on observations of that channel unit type across the whole Snowy River catchment. This enables standardisation of channel unit recognition between operators, and thus minimise errors associated with sampling effort. For this reason the definition of some channel unit types has been expanded to provide a clearer definition (Table 2).

Table 2. Diagnostic features of riffle, rapid, step and cascade channel units.

Channel unit type[1]	Fluvial environment	Range of hydraulic characteristics	Dominant substrate
Riffle	Shallow part of the river bed with moderately steep water surface profile	Rippled, unbroken standing waves 5-10% water surface area in supercritical flow[2] >5-10% water surface area in supercritical flow but finer substrate and more gradual slope than rapid	Gravel and cobble
Rapid	Deeper (than riffle) part of the river bed with steep or stepped water surface profile No pool formation either upstream or downstream	15-50% water surface area in supercritical flow	Cobble and boulder
Step	Point of rapid change in grade (greater than rapid) Backwater pool upstream and plunge pool downstream	>50% water surface area in supercritical flow. Vertical drops of water lower than the bankfull channel depth	Boulder or bedrock or log
Cascade	Steep channel units of closely spaced step pool sequences	>50% water surface area in supercritical flow Flow cascades	Boulder or bedrock
Fall	Flow obstruction commonly found in bedrock, cascade and step-pool river reaches	Vertical drops of water higher than the bankfull channel depth	Generally bedrock

[1] Fast water channel units listed in increasing order of longitudinal grade change, and critical flow
[2] Also termed white water

3.1 RIFFLE



A riffle is described as a large scale, shallow, fast flowing, steep water surface profiled bed-form that is floored with relatively coarse sediment (Hawkins et al. 1993). Riffles usually alternate with pools in gravel bed streams (Gordon *et al.* 2004) and are rhythmically spaced at about 5-7 channel widths (Erskine and Turner pers. comm.).

Specifically, riffles are areas of subcritical flow modified by localised free-surface instabilities and small hydraulic jumps over the river bed (ie. bed roughness elements). The water surface is typically rippled in appearance (Figure 4A), depths are shallower and velocities are greater than in pools at low flow. Typically, only 5-10% of the water surface area exhibits supercritical phenomena such as hydraulic jumps or standing waves at low flow (Figure 4B; Grant *et al*. 1990). In some cases, riffles may exhibit > 5-10% supercritical flow across the channel but unlike rapids, the change in elevation of bed morphology is more gradual (Figure 4C).

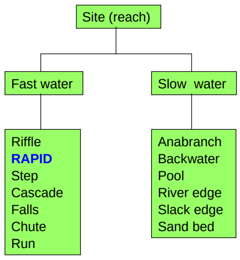
Figure 4. Riffles with (A) unbroken standing waves only (B) 5-10% and (C) >10% of the water surface area in supercritical flow (white water).

A

B

C

3.2 RAPID

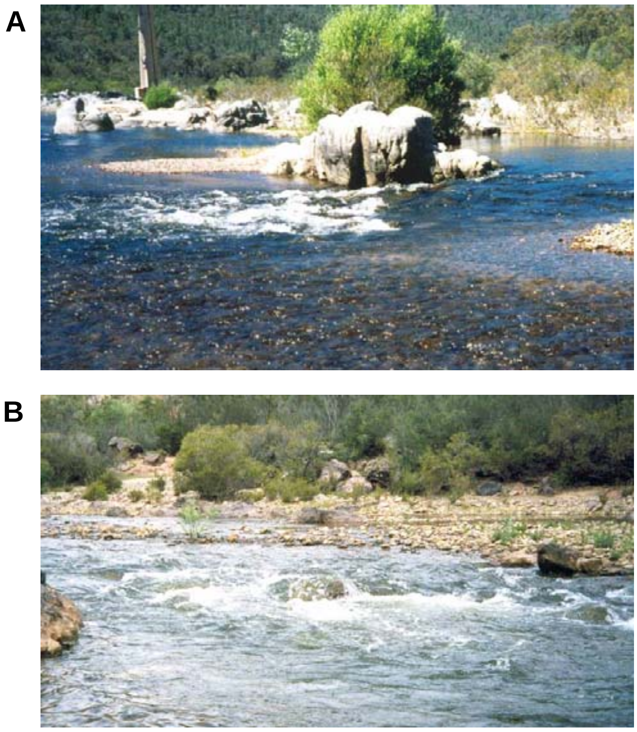


Rapids can be distinguished from riffles by a steeper bed gradient and:

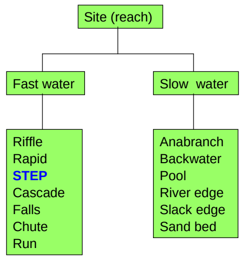
1. Greater percentage of stream area (15% to 50%) in supercritical flow over cobble or boulder substrate (Raven *et al*. 1998);
2. Organisation of boulders into irregular ribs oriented more or less perpendicular to the channel and exposed at low flow. Ribs partially or fully span the active channel width as 'steps' (Grant *et al*. 1990; Figure 5); and,
3. Generally rapids have a majority of broken standing waves (i.e., 15-50% white water) over stepped, boulder/cobble substrate.

Rapids can be distinguished from steps by absence of pool formation either upstream or downstream.

Figure 5. Rapid (A) partially and (B) fully spanning the active channel and steep change in bed morphology.



3.3 STEP



Steps are low (less than bankfull channel depth), essentially vertical drops over bedrock boulders or logs that may not span the channel (Erskine 2005). Bedrock, boulder and log steps are individual steps less than one channel width long that is sufficiently distinct from upstream and downstream units to be identified as separate features (Figure 6). Steps are perpendicular to the channel axis and separate a backwater pool upstream from a plunge pool downstream (Grant *et al.* 1990). Willow log steps may form following significant flood events.

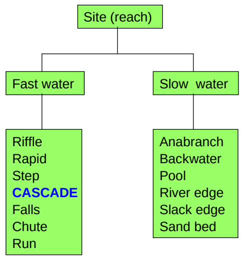
Figure 6. Examples of steps in the Snowy River (A) bedrock (B) boulder and (C) log.

A

B

C

3.4 CASCADE



Cascades are steep channel units where water flows over large boulders in a series of short, well defined steps about one particle diameter (approximately 200 mm to 1000 mm) high. These are separated by areas of more tranquil flow less than one channel width in length to create a staircase appearance; cascades have more than 50% of stream area in supercritical flow (Grant *et al.* 1990). They are a large-scale bed-form unit.

Cascades are divided into two sub types:

1. <u>Boulder cascades</u> are composed of well developed, closely spaced step-pool sequences created by boulders partially emergent at low flow (Grant *et al.* 1990; Figure 7A); and,
2. <u>Bedrock cascades</u> are where water flows directly on bedrock; individual steps in bedrock cascades are more uniform than in boulder cascades and commonly coincide with rock structure (Grant *et al*. 1990; Figure 7B).

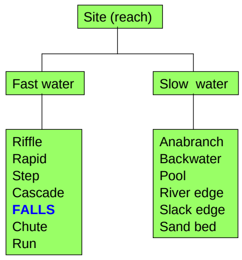
Cascades can be distinguished from a step, by a step-pool in series.

Figure 7. Types of cascades (A) boulder and (B) bedrock in the Snowy River.

A

B

3.5 FALLS



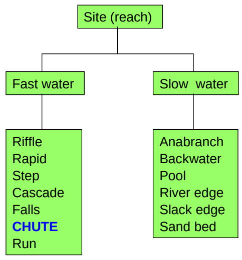
Falls are high, essentially vertical drops of water, spanning the whole channel and are commonly found in bedrock, cascade and step pool stream reaches (Bisson and Montgomery 1996; Figure 8). Falls are distinguished from bedrock or boulder log steps by height. Falls are higher than the bankfull channel depth and have scour plunge pools at their base (Erskine 2005). Falls obstruct fish passage except when drowned out or where flooded anabranches (side channels) occur.

Figure 8. Falls with a (A) small vertical drop (~2m) at Pinch Falls and (B) large vertical drop (>5m) at Snowy Falls.

A

B

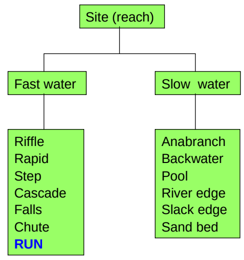
3.6 CHUTE



Chute channel units are typically narrow, steep slots in bedrock. They are common in bedrock reaches but they also occur in cascade and step-pool reaches (Bisson and Montgomery 1996). Flow around a chute typically exhibits upstream convergence and downstream divergence (Newson and Newson 2000; Figure 9).

Figure 9. Bedrock and boulder chute.

3.7 RUN



A run is a large-scale bed-form that is intermediate between pools (floored with relatively fine sand) and riffles (comprising gravels and cobbles). A run is characterised by uniform steady flow because the bed and water surface profiles are parallel (Erskine and Turner pers comm) and therefore does not exhibit supercritical flow. Runs are divided into two subtypes:

1. A fast run has similar current velocity to a riffle but is deeper than a riffle (Brooker 1981). It is shallower than a pool and can include a step run which is swiftly flowing water without surface agitation or surface waves and approximates uniform flow (Kershner and Snider 1992; Figure 10A); and,

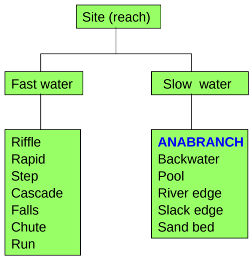
2. A slow run has reduced current velocity (Brooker 1981;Figure 10B).

Figure 10. Run types (A) fast and (B) slow.

A

B

3.8 ANABRANCH



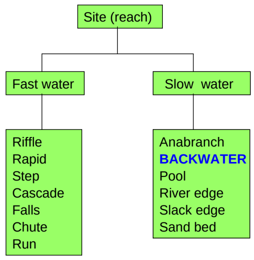
Anabranches are separate river channels that branch from and rejoin the main river channel. These habitats can be at various stages of inundation depending on the river discharge, they can be flowing (Figure 11A), or contain standing water (Figure 11B), or damp (Figure 11.).

Figure 11. Anabranch (A) flowing, (B) standing water and (C) damp.

A

B

C



3.9 BACKWATER

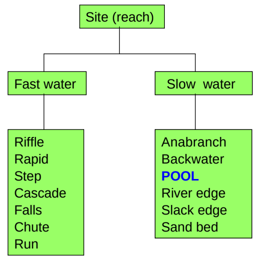
Backwaters are areas of minimal current velocity (circular in pattern, Bisson and Montgomery 1996) partially isolated from the main channel during low flow (Brooker 1981; Kershner and Snider 1992). Low flow in conjunction with gravel bars or other topographic features may cause this partial isolation. There are vegetated (Figure 12A) and non-vegetated (Figure 12B) backwaters in the Snowy River. Backwaters can be of variable depth. Backwaters >1.0 m wide are recorded in the project.

Figure 12. (A) Vegetated and (B) non vegetated backwaters

A

B

3.10 POOL



A pool is a large scale bed-form relative to other channel units. A pool is generally a deeper part of the river bed with a flat water surface profile and slow flow and floored with relatively fine sediment. Pools usually alternate with riffles in gravel bed streams and are rhythmically spaced at about 5 to 7 channel widths (Erskine and Turner pers comm.). Pools can be formed by damming (Figure 13A-B) or by scour (Figure 13C). Pools could be further subdivided into scour, step, backwater, dammed and trench if required, but that detailed classification is outside the scope of this study.

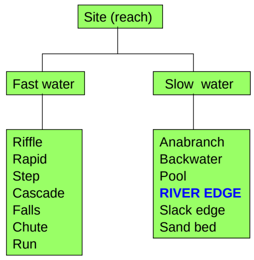
Figure 13. Pools in the Snowy River, (A-B) typical pool and (C) plunge pool.

A

B

C

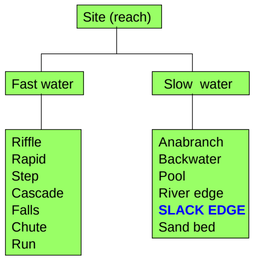
3.11 RIVER EDGE



The river edge is defined as the wetted edge of the active river channel (Figure 14). This channel unit is not strictly a bed-form. It is included as it assists in defining the area inundated at various river discharge rates. It also assists in defining the water level within the channel unit.

Figure 14. River edge.

3.12 SLACK EDGE

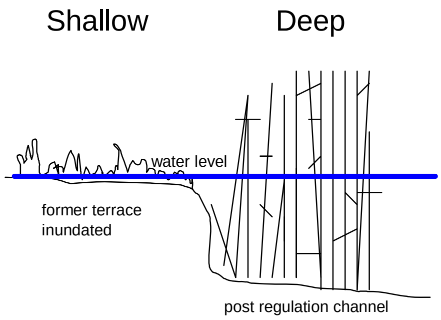


Slack edge are generally narrow areas of inundated vegetation (but >1.0 m wide) occurring along the littoral margin of pools, runs and instream bars with low-no flow velocity. Depending on the change in grade of the cross-section a slack edge can be just wet when walked in, shallow with standing water (Figure 15B), or deep (Figure 15C), or both shallow and deep (Figure A). Slack edges differ from vegetated backwaters because they are part of the main river channel, not partially isolated.

If water is visibly flowing through the habitat it is not considered a slack edge.

Figure 15. Slack edge: (A) combined slack edge , (B) shallow slack edge and (C) deep slack edge.

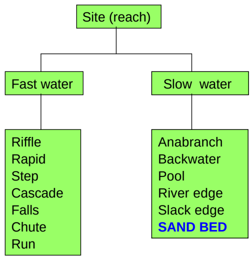
A



B

C

3.13 SAND-BED



Sand-beds are defined as wetted perimeter of a predominantly sand-bed river channel. Drifts of gravel deposited under higher flows can occur under this category (Figure 16A). Sand bars are exposed at low flow (Figure 16B).

This channel unit was developed specifically for the lower reaches of the Snowy River where the river channel is a highly mobile, homogeneous, shallow sand stretch that does not fit the definition of either pool or run. The major distinguishing feature between the sand-bed channel unit and pools and runs is the mobility of the bed.

Figure 16. Sand-Bed with (A) gravel drifts and (B) exposed bars.

A

B

4. Field identification and mapping of channel units

Physical and biological monitoring scientists must have the same understanding and interpretation of channel units so they sample in the correct location in the field. That is, physical monitoring scientists must identify channel units correctly to map changes after flow releases, while biological scientists must correctly identify channel units so they can direct sampling location for vegetation, macro-algae, macroinvertebrates and fish. The ability to differentiate one channel unit from another is therefore essential. This section looks at the field practicalities of identifying and mapping channel units in the Snowy River system.

4.1 FIELD CONDITIONS

The following conditions need to be met in order to identify channel units:

I. low-flows- the channel unit types are more apparent and the field survey is safer during low flow periods (see Appendix);

II. No wind or rain – turbulence at the water surface makes it difficult to determine flow velocity and substrate size using field observations;

III. Low turbidity / colour- visual assessments of substrate type require low turbidity/colour water; and,

IV. Warm water- the water temperature needs to be warm enough to allow river access by the survey team;

Additionally access to a powered boat is required at some sites where it is too deep to wade.

4.2 METHODS

Channel units are identified and mapped by the physical monitoring scientists by:

I. Applying the channel unit definitions used in this manual;

II. Recording the date, time, surface water level and river discharge at the gauge on the day of sampling;

III. Reviewing previous channel unit maps in relation to the gauge reading. Higher, lower or similar flow will provide a mental picture of the potential for change eg., higher flows than on the previous sampling period may drown out some channel unit types;

IV. Conducting a reconnaissance of channel unit types (fast or slow) and their boundaries within the entire site (ie., between the most upstream and downstream permanently marked cross sections). This requires walking the length of the reach along both banks and getting into the stream to feel the substrate and flow velocity. A field party consists of one scientist, one surveyor and one survey field assistant;

V. Methodically recording the boundary of each channel unit type by Differential GPS (including the water level within each feature), or laser where flow is too fast to map by foot; then,

VI. Downloading the data and creating a channel unit map after the completion of each site to ground truth the observed channel unit types and their relationship to each other.

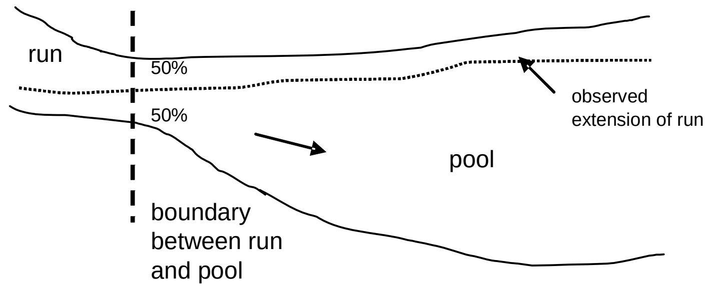
4.3 BOUNDARIES AND PRECISION

Channel units and their boundaries are stage or water level dependent. Ideally, identification and mapping of channel units is conducted under low flow conditions for each stage of the environmental water releases when a definite distinction between channel unit boundaries can be observed (see Appendix 7.1 and 7.2). The precision with which channel unit boundaries can be determined is ± 1.0m.

When water velocity and depth in the river channel is low, the extent of each channel unit can be identified and mapped by foot. If water velocity and depth prevent safe river access, then boundaries are determined from the bank by visually estimating the line where the channel unit being measured becomes <50% of the wetted channel (Figure 17A). In the case of multiple channels, <50% of individual channels combined (Figure 17B). Consistent identification of boundaries is important for mapped area comparisons (Figure 18). A channel unit mixture is distinguished as either one channel unit or another (eg. pool or run) at the 50:50 cut-off.

Figure 17. Channel unit boundary where the channel unit being measured becomes <50% of the wetted channel (A) single channel and (B) multiple channel.

A



B

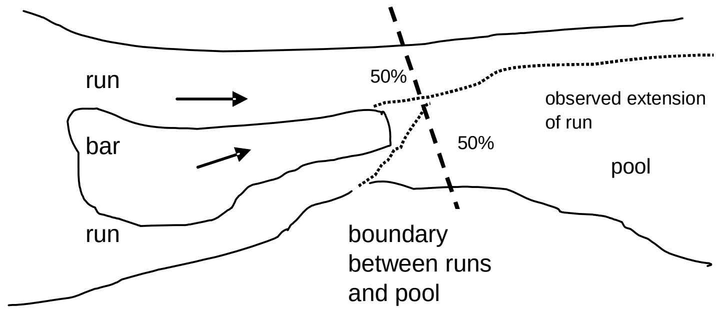
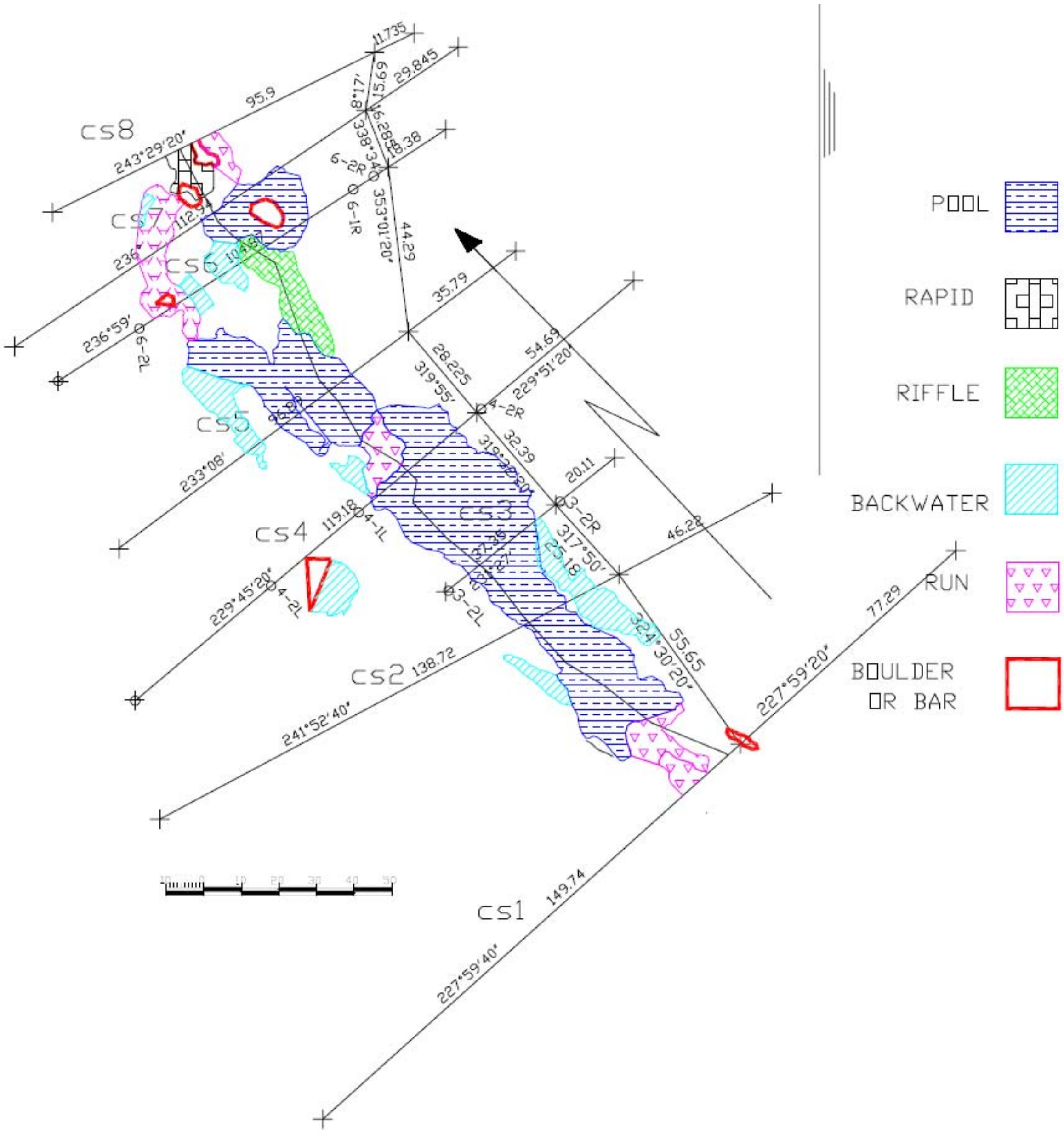


Figure 18. Example of a typical channel unit map: Snowy River at Burnt Hut Crossing (site 5).



4.4 WILLOWS

Extensive willow encroachment has occurred since flow regulation and at some sites trunks and/or branches lay parallel to the water surface. Willows cause slack edges (Figure 19A) and/or backwaters (Figure 19B) and/or small scour pool (Figure 19C) channel units to occur. These channel units are not recorded because the willows are being killed at sampling sites as part of a comprehensive Snowy River willow removal program. Any change in channel units around willows therefore, is more likely to be a response to the willow intervention and not a response to environmental flows. The purpose of the Snowy River Flow Response Monitoring Project is to measure changes resulting from increased flows. The channel unit recorded around willows then, is that of the main wetted channel. Care must be taken when identifying channel units around willows to avoid confounding channel unit area results.

Figure 19. Willow trees altering local instream hydraulics: (A) overhanging a pool creating a slack edge (record as pool channel unit) **(B) Willow gallery along the margin of a pool creating small backwaters** (record as pool channel unit) and **(C) Willow causing a scour pool in a run** (record as run channel unit).

A
B
C

5. Glossary

Bar	Deposit of sand or gravel or other material in a river eg. lobate, point, alternate, channel junction, transverse, mid channel etc. They can also be vegetated or non-vegetated.
Bed-form	A geometric configuration of bed material on the river bed surface that is more than one grain diameter high and that is formed by flow. A purely geomorphic term.
CB	Citizens Band
Channel unit	'Quasi-discrete' areas of relatively homogeneous depth and flow that are bounded by sharp physical gradients' (Hawkins et al. 1993) and 'exhibit different physical characteristics that can be associated with habitat-specific fish species assemblages (Peterson & Rabeni 2001a & 2001b).
Channel unit type	Riffle, run, rapid, cascade, step, backwater etc. used to describe different physical habitats.
DGPS	Differential Geographical Positioning System.
Fast and slow water	Relative terms used to distinguish between current velocities observed at moderate or slow flows respectively. 'Fast water' is a relative term that describes current velocities observed at low to moderate flows and distinguishes this type of channel unit from other channel units in the same river with 'slow water'. Often, but not always, 'slow water' channel units will be deeper than 'fast water' units at a given discharge (Bisson & Montgomery 1996).
Froude number (Fr)	Is the dimensionless velocity/depth ratio $Fr = Vm \div \sqrt{(gY)}$, where Vm is the mean water column velocity, Y the water depth, and g the acceleration due to gravity (9.81 ms-2). It is used to define subcritical and supercritical flows (Jowett 1993). Froude number is a good descriptor of bulk flow characteristics such as surface waves, sand bed-forms and the interaction between flow depth and velocity at a given cross section or between boulders.
Habitat	The living place of an organism or community characterised by its physico-chemical biotic properties.
Hydraulic jump	Transitional feature which is formed when the flow is converted from supercritical flow and result in much turbulence and air entrainment (Erskine pers comm)
IQQM	Integrated Quantity and Quality Model
Low flow	Flows exceeded 95% of the time (Pendlebury *et al.* 1996).

MANF	Mean Annual Natural Flow
MLd^{-1}	Megalitres per day
Physical habitat	The living place of an organism or community characterised by its physical properties.
SMS	Snowy Mountains Scheme
Standing wave	Undular standing wave (wavy surface) in which the crest faces upstream (Newson & Newson 2000).
Subcritical flow	Defines tranquil flow where Fr<1; Subcritical flow does not produce backwater effects and hence has pools (Erskine pers comm 1999).
Supercritical flow	Defines rapid flow where Fr>1; Found where water passes over and around boulders and in the spillway chutes of hydraulic structures (Gordon *et al*. 2004). Super-critical flow produces no backwater effects i.e., there are no pools when there is super-critical flow (Erskine pers comm 1999).
Turbulent	Channel units are classified as turbulent if they possess super-critical flow i.e., hydraulic jumps sufficient to entrain air bubbles and create localised patches of white water (Bisson and Montgomery 1996).

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7. Appendix

7.1 MEASURING CHANNEL UNITS UNDER DIFFERENT FLOWS

Since 17 April 1967 flow in the Snowy River downstream of Jindabyne Dam was regulated to approximately 1% of its mean annual natural flow (MANF) by three impoundments: Island Bend, Guthega Pondage and Jindabyne Dam (Rose, 1999). The flow from the Eucumbene River, Cobbin Creek and the Mowamba River was also diverted into Jindabyne Dam for hydro-electric-power. Following community and scientific concern for the river's health, an agreement was reached by the Victorian, NSW and Federal governments to release environmental flows back to the Snowy River in stages (Table 3). The first flow was released on 28 August 2002 by shutting down the diversion valve on the Mowamba River Weir.

The Snowy River Flow Response Monitoring measures hydrology and environmental indicators of water quality, geomorphology, vegetation, aquatic macroinvertebrates and fish. They will determine if the environmental flows have caused ecological changes and what the size and direction of the changes are. Results will guide the adaptive management of the flow releases to improve the ecology of the Snowy River. Measuring channel units is part of the geomorphology study and provides a way to maximise sampling effort across the environmental indicators and to measure the change in channel unit types and area following flow releases. Reducing the error in measuring the size and direction of change in channel units and planning field sampling under different flows is problematic because of:

1. The timing of the staged releases and the regime is uncertain. These decisions are political and determined by the Snowy Scientific Committee;

2. The innate natural hydrological variability in the river catchment from localised rainfall events will increase flow at some sites and not others;

3. The effectiveness of the flow release is expected to decrease with distance downstream;

4. The need to sample safely under increasing flow volumes and flow velocities; and,

5. The need to plan a full sampling program in one period ahead of time, not wait for a specific flow to eventuate at each site.

Error in measurement can be minimised and sampling conducted more safely with increased flows however, if sampling is conducted under low flow conditions after each flow period (Table 3).

Table 3. Flow periods to calculate low flows in the Snowy River.

Flow period	Dates/Timing	Flow volume MANF at Jindabyne (% and $GLyr^{-1}$)
pre-SMS	up to April 1967	100% (1,164)
post-SMS and pre-flow release	18 April 1967 – 28 August 2002	
after 1st flow release	initial	4% (47)
after 2nd flow release	2 – 7 years	15% (175)
after 3rd flow release	8 – 10 years	21% (244)
after 4th flow release	> 10 years	28% (326)

7.2 CALCULATING LOW FLOW CONDITIONS

Low flow in the Snowy River is where flow is exceeded 95% of the time (Pendlebury *et al*. 1996). Seasonal patterns of low flow conditions were modelled through IQQM under a proposed 28% MANF flow release regime (Table 4 and Figure 20) that includes:

1. 2 x 20,000 MLd^{-1} floods of 3 days duration each year; and,
2. 200 MLd^{-1} mean annual baseflow;

at four Snowy River catchment gauging stations:

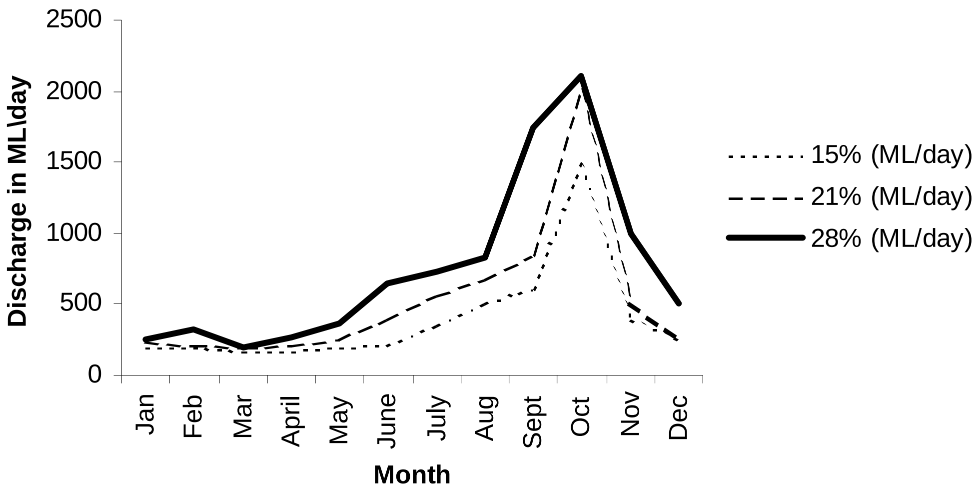
1. Jindabyne 222501 (old);
2. Dalgety 222006 (old) and 222026 (new);
3. McKillops Bridge 222209; and,
4. Jarrahamond 222200.

Table 4. Previously agreed (August 2000) daily target flows in MLd^{-1} (d/s Mowamba River) used in the model runs.

Flow release scenario %	Jan	Feb	Mar	April	May	Jun	July	Aug	Sept	Oct	Nov	Dec	Total	Legislation
4	?	?	?	?	?	?	?	?	?	?	?	?	?	1516
15	200	200	170	170	190	210	350	500	600	1480	400	250	5676	5644
21	234	206	190	216	253	394	564	680	845	2000	507	235	7975	7869
28	250	320	190	270	370	640	725	825	1742	2100	1000	500	10707	10514

Notes:
1. 4% is assumed to be just the Mowamba Weir spill (snpcal20.s63)
2. 15% has 3 day @ 12,000 MLd^{-1} channel maintenance flow in October (snocal21.s63)
3. 21% has 3 day @ 12,000 MLd^{-1} channel maintenance flow in October (snocal22.s63)
4. 28% has 3 day @ 12,000 MLd^{-1} channel maintenance flow in October (snocal23.s63)
5. Pre- development conditions (snocal17.s63)
6. Current conditions (snocal18.s63)
7. Model results from Snowy IQQM simulating period 1/1/1974 to 31/12/1995
8. Model results in directory I:\iqqm\snow\modruns\yrs7495

Figure 20. Previously agreed (August 2000) daily target flows (downstream of the Mowamba River) used in the model runs



Seasonal low flow conditions have been modelled for different flow release periods to guide the timing of channel unit identification and mapping in the field (Table 5, Table 6, Table 7, Table 8, Table 9, Table 10). Model results in MLd^{-1} are from the Snowy IQQM simulating period 1/1/1974 to 31/12/1995.

33 Lowest flow

Optimal period for field channel unit identification

Table 5. Ninety-five percentile low flows pre- SMS development conditions (file ame:sortcal17.srt)

Gauge	Jan	Feb	Mar	April	May	Jun	July	Aug	Sept	Oct	Nov	Dec
Jindabyne	0	0	0	0	0	0	0	0	0	0	0	0
Dalgety	37	38	**33**	34	54	98	80	47	93	99	98	73
McKillops Bridge	268	**133**	146	152	399	703	898	911	996	1193	928	392
Jarrahmond	350	224	**184**	221	488	972	1184	1131	1287	1680	1229	588

Table 6. Ninety-five percentile low flows for current conditions (post- SMS and pre- flow release)(file name:sortcal18.srt)

Gauge	Jan	Feb	Mar	April	May	Jun	July	Aug	Sept	Oct	Nov	Dec
Jindabyne	0	**8**	**1**	**1**	1	1	1	1	1	1	1	1
Dalgety	**11**	15	28	24	21	15	18	16	22	23	16	22
McKillops Bridge	140	105	101	**96**	152	295	404	489	520	407	290	188
Jarrahmond	183	**106**	116	126	194	410	587	676	743	592	415	221

Table 7. Ninety-five percentile low flows for 4% release conditions (file name:sortcal20.srt)

Gauge	Jan	Feb	Mar	April	May	Jun	July	Aug	Sept	Oct	Nov	Dec
Jindabyne	0	**8**	**1**	**1**	1	1	1	1	1	1	1	1
Dalgety	36	**33**	**34**	**35**	**32**	36	39	48	49	59	43	40
McKillops Bridge	146	108	103	**100**	158	305	419	524	546	434	306	196
Jarrahmond	189	**109**	119	132	201	417	597	706	765	608	428	225

Table 8. Ninety-five percentile low flows for the 15% release option (file name:sortcal21srt)

Gauge	Jan	Feb	Mar	April	May	Jun	July	Aug	Sept	Oct	Nov	Dec
Jindabyne	37	65	0	0	0	0	0	0	0	733	0	0
Dalgety	180	190	**156**	161	181	204	344	490	584	1459	384	233
McKillops Bridge	246	213	193	**191**	253	407	702	907	998	1565	563	319
Jarrahmond	289	206	**205**	215	289	509	829	1056	1170	1636	678	352

Table 9. Ninety-five percentile low flows for the 21% release option (file name:sortcal22srt)

Gauge	Jan	Feb	Mar	April	May	Jun	July	Aug	Sept	Oct	Nov	Dec
Jindabyne	71	71	**0**	0	0	0	0	150	60	1252	0	0
Dalgety	213	196	**177**	207	244	387	558	668	829	1978	488	218
McKillops Bridge	264	217	**206**	219	293	561	877	1047	1189	1878	670	309
Jarrahmond	298	**210**	214	243	326	628	987	1183	1316	1949	777	348

Table 10. Ninety-five percentile low flows for the 28% release option (file name23.srt)

Gauge	Jan	Feb	Mar	April	May	Jun	July	Aug	Sept	Oct	Nov	Dec
Jindabyne	87	185	**0**	0	28	0	0	294	957	1352	488	156
Dalgety	230	310	**177**	261	360	633	719	813	1723	2078	980	483
McKillops Bridge	277	289	**206**	252	368	786	1003	1161	1755	1965	1070	494
Jarrahmond	319	277	**226**	274	394	831	1115	1286	1730	2044	1123	509