Fluvial Geomorphology Variety and Applications

A selection of fact sheets and maps compiled for the Australian and New Zealand Geomorphology Group Inc. pre-conference tour, 13-15 February 2004

Edited by David Outhet
ANZGG Pre-Conference Tour Itinerary
"Fluvial Geomorphology Variety and Applications"
Times Approximate
Local Guides Shown in Bold

Friday 13 Feb., 2004

7:45-8:00 Meet and load passengers Sydney Airport Qantas Domestic terminal 3 arrival level Budget desk
8:00-11:00 travel airport to Manar Crk via Goulburn, meet Peter McAdam and John Field’s group at junction Kings Hwy/Manar Rd
11:00-2:15 field: channelised fill and palaeodrainage, Shoalhaven R bedrock nick point, picnic lunch, Araluen area valley fill preserved by Rivercare works
2:15-5:00 travel Araluen to Bega, meet Don McPhee at Bega Cheese Factory at roundabout N side of Bega.
5:00-6:30 field: Bega R sand slug and willows, avulsion control

Overnight Bega Central Hotel/Motel (02 6492 1263) and Bega Caravan Park (02 6492 2303)

Saturday 14 Feb. (Valentines Day)
7:30 pick up packed lunch Central Motel
8:00 Depart Bega, guided by Andrew Brooks
8:00-2:00 field: Genoa R, Thurra R, lunch, Cann R comparisons intact vs degraded, palaeochannel dating
2:00-4:00 travel Cann R mid-catch to Snowy R at Dalgety, meet Teresa Rose at bridge
4:00-5:00 field: Snowy channel contraction, flow releases needed, monitoring project, response to willow clearing
5:00-6:30 travel Dalgety to Adaminaby, buy fuel before 7:30

Overnight Adaminaby Snow Goose Motel (02 6454 2202) and Alpine Tourist Park (02 6454 2438)

Sunday 15 Feb

7:30-8:30 travel Adaminaby to Murrumbidgee R Long Plain reference site for alpine bedrock controlled Style
8:40-9:30 travel upper Murrumbidgee to Shelleys Crk at Snowy Mtns Hwy bridge where meet Glenn Ferguson
9:30-11:00 field: Tumut R regulated release erosion and control story, comparison with Tumut palaeochannel on Shelleys Crk
11:00-12:00 travel Tumut R to Tarcutta Crk, meet Tim Smith at Sport and Rec camp on Sturt Hwy
12:00-1:30 field: lunch, Tarcutta Crk story: management of slug vs expansion reaches
1:30-3:30 travel Tarcutta to Albury, meet Tony Crawford at boat ramp
3:30-5:30 field: Murray R boat tour ('Firefly'), dam causing sed starved reach, erosion control, willow control and native plant revegetation
5:30-7:30 travel Albury to Mt Buffalo
7:30 'til late? BBQ at Chalet

Overnight Mt Buffalo
Day 2 - Geomorphic Impacts of European disturbance on Rivers in South-East Australia - and implications for management (Dr Andrew Brooks, Griffith University, Centre for Riverine Landscapes)
Overview of Geomorphic Changes to Rivers in SE NSW and East Gippsland

The sand bed rivers in East Gippsland and southern NSW, are some of the most profoundly altered rivers in Australia (see Erskine, 1993; 1999; Erskine & White, 1996; Brooks & Brierley, 1997; Brierley & Murn, 1997; Brooks 1999a,b, Brooks and Brierley, 2000; Brooks et al, 2003). For river management to be effective, it is critical that realistic objectives are formulated for river management that are, mindful of the profound geomorphic, hydrologic and hydraulic changes that have occurred in most rivers in this region.

The magnitude and permanence of river changes and the implications for ‘recovery potential’ are best illustrated using the example of the Cann River, as outlined by Erskine and White (1996), Erskine (1999) and Brooks (1999a,b); Brooks et al., (2003), Brooks and Brierley (in press). The floodplain reach of the Cann River has experienced dramatic channel incision and expansion since European settlement associated with desnagging and extensive clearance of riparian vegetation. The Cann River channel expanded from a cross-sectional area of around 35 m² to approximate dimensions today of around 250 m² (Erskine and White (1996), Erskine (1999)). The primary control on the pre-European condition of the Cann River was the dense riparian vegetation and the extensive volumes of woody debris within the channel bed (Erskine and White (1996), Erskine (1999) and Brooks, (1999a, b) Brooks et al., (2003). Without the control of the riparian vegetation and the woody debris in the bed of the channel or management intervention, it is not possible for this sand bed channel to aggrade and remain stable in the medium to long term. It was also shown in Brooks (1999a,b) that the channel erosion over the last 100 years had removed the equivalent of 1500 years of floodplain aggradation, and that the channel had incised into sediments deposited more than 10000 years ago.

Even if it was possible to induce deposition and sustained aggradation within this now entrenched channel, having reintroduced the same vegetative controls on the channel, the timeframe for this recovery would not simply be the same as the time taken to deposit the sediment originally lost (ie. 1500 years). Brooks and Brierley (in press) estimated it would require at least 31000 years to infill the incised channel trench, and this was predicated on the riparian vegetation and wood loading being able to return to something like its original condition. The reason for this being that the energy conditions with the channel trench are fundamentally altered and that a number of key thresholds have been crossed. It has been estimated that the peak instantaneous sediment transport capacity in the contemporary Cann River channel is 3 orders of magnitude greater (ie. 1000 times) than that of the pre-disturbance channel. This has resulted in bed degradation and can only be reversed if in-channel roughness is substantially increased and/or depth and slope are greatly reduced (Erskine and ID&A, 1997). In-channel roughness can be increased through the reintroduction of Large Woody Debris. However, as the channel width (at around 65m) is now greater than the length of any logs that might find their way into the channel, it is unlikely that cross spanning logs or log jams can form as is. Without cross spanning logs, sustained bed aggradation cannot occur in this sand-bed stream if catchment-derived sediment supply is limited. Other thresholds crossed, include:

- bank height, which has now increased to the point where it is subject to mass failure;
- bank stratification, which is now an important control on bank stability.

The purpose of outlining this example is do demonstrate the point that channel recovery is often complex and re-establishing the former channel condition is often not an option. Under these circumstances a new recovery target condition is required, and achieving it may involve a significant degree of interventionist management. Disturbed sand-bed rivers have generally experienced the greatest changes. In sand-bed rivers, in particular,
the role of vegetation and woody debris is often critical to channel ‘stability’ and long
term evolution given the erodibility of the sand bed material. An example of the way that
recovery principles are being considered is evident in recent investigations undertaken in
the Cann River.

*The Cann River in the floodplain reach has altered significantly since European
settlement. Despite the dramatic channel changes as outlined above, local residents do
not want the channel to revert to its original dimensions (even if this were possible) due
to the increased frequency of overbank flows and subsequent negative impacts on
farming. A new target condition has therefore been established for the floodplain reach of
the Cann River. To prevent the ongoing degradation and erosion of the river, additional
measures must be introduced to increase the resistance of the banks and bed to erosion.
This can be achieved by introducing various engineered structures into the bed of the
river (both rock and vegetative based) and creating a dense riparian vegetation
community along the river banks and on bars within the channel. (Erskine and ID&A,
1997).*

**Stop 1**
**Lower Genoa River - Channel and Riparian rehabilitation using assisted natural
regeneration.**

Geomorphic impacts of disturbance on the lower Genoa River (1986)
ASSISTED NATURAL RECOVERY (Brooks et al., 2001)

Alluvial rivers that have been subjected to major geomorphic changes can recover of their own accord given sufficient time provided they retain, or can recover, all of the elements necessary for 'natural' channel and floodplain evolution and functioning. However, given the magnitude of historical disturbance to most rivers and the associated changes to channel morphology and dynamics, 'sufficient time' will often be in the order of hundreds to thousands of years. Such timeframes are generally beyond that which is acceptable for management purposes. Furthermore, due to the effective permanent loss of some of the key controls on channel conditions and the fact that fundamental thresholds have often been crossed that are not easily reversed, unassisted recovery is often not possible.

In situations where some degree of recovery is possible, the recovery process can be accelerated through the utilization of appropriate interventionist management strategies that work with the river dynamics. This can only occur through the development of a sound understanding of the disturbance processes within a catchment context. In river management, it is important to realise that the rate of recovery can be accelerated by management intervention. However there is a risk that channel conditions altered by a large flood are likely to result in subsequent floods having a greater disturbance effect. Implications are that managers and community need to be aware of the risk of management intervention not being initially successful because the success of
management intervention is dependent on subsequent flood conditions. The following are some general principles that need to be adhered to when attempting to undertake enhanced recovery:

a) Understanding your catchment, its disturbance history and its evolutionary pathway
1) Through evaluation of the pre-disturbance river conditions and evolutionary history, develop models of the channel and floodplain evolution for key parts of the catchment concerned. This will include an assessment of the key controls on channel and floodplain dynamics in different parts of the catchment prior to disturbance.
2) Develop an understanding of catchment processes and linkages (e.g. Through something like the River Styles framework - Brierley, 1999)
3) Reconstruct the river and catchment disturbance history
4) Assess the disturbance state of channel reaches within a catchment context. This will include the identification of minimally disturbed parts of the catchment, and critical parts yet to be fundamentally altered. These areas should be the highest priority for interventionist management aimed at preventing degradation. Position in the catchment is critical for understanding the potential for on-going elevated sediment supply, the potential for bed degradation due to sediment exhaustion, the availability of sediment for inducing channel contraction etc. The construction of a sediment budget will be an important tool in this component of the assessment procedure.

b) Having undertaken (a), assess recovery potential for various river reaches. Factors influencing recovery potential, include:
1) The magnitude of change within the reach - which is partly a function of the river style. Different reaches or river styles have different capacities for adjustment in terms of threshold changes, catchment hydrology, sediment supply conditions, reach hydraulics (including, roughness characteristics and the connectedness of the channel to the floodplain).
2) Upstream conditions (hydrologic changes, sediment supply conditions, vegetation conditions – i.e. the potential for native plant propagule supply and LWD supply)
3) Downstream conditions. (e.g. upstream migrating nickpoints)

c) Enhanced Recovery Utilising native vegetation
As a general rule, vegetation provides the key to enhanced river channel recovery. The more vegetation that can be encouraged to establish within a channel, on the banks, and on floodplains, the better the results that will be achieved in terms of enhanced river recovery. Vegetation within channels performs multiple functions:
- inducing roughness within the channel, and thereby lowering available energy, and hence work performed on the channel boundary.

- Increased boundary roughness is the primary mechanism for inducing sediment deposition within the channel (particularly enlarged channels) and thereby increasing the residence time of the sediment within the catchment
- Increases bank strength, thereby stabilising banks and reducing sediment supply
- Providing a source of woody debris (woody debris performs the role of inducing roughness within channels, providing armour on mobile beds, inducing form roughness, physically reinforcing beds)

It is generally better to utilise the remaining native vegetation within channels, assuming some still remains either locally or upstream, and encouraging the regeneration of these species. This will generally involve the suppression of weeds that tend to have a competitive advantage over native species (Newsome & Noble, 1986; Hobbs, 1989).
In situations where a sufficient seed source for native species still exists, and where suppression of weed is logistically possible, the optimum situation is to encourage natural regeneration. Obviously this will only apply in moderately disturbed landscapes, probably with intact portions of the catchment upstream. Natural regeneration will tend to have more chance of success than planted tubestock or direct seeding. In situations where there are remnants of the pre-existing vegetation, planting of tubestock and/or direct seeding will be required. In both cases, weed management will be critical to success. There will be some cases where it is not necessarily ideal to only have the remnant native species. In this situation, further investigations are recommended to ascertain the original vegetation. There are a number of situations where this may be necessary:

- Where the remnant community is incapable of self-regeneration;
- Where channel conditions are altered so much that the pre-existing riparian species no longer occur locally.

Furthermore, given that river management needs to take a long-term view, there is increasing recognition of the effect that global climate change is going to have on natural ecosystems. Current global climate change models predict that ecological boundaries will shift at the continental scale as a result of climate warming. Hence, if a tree species is currently at its southern limit, it may be unwise to use such a species as part of a long-term recovery scheme.
Stop 2 Thurra River (The Fluvial TARDIS)

Mediated Equilibrium – LWD and Vegetation as a long term control on channel morphology and floodplain evolution.

The forested Thurra River catchment adjacent to the Cann River catchment showing the contrasting cleared floodplain.

Thurra rainforest study reach (Stop 2) – showing the high LWD load.
Stop 3 Cann River Floodplain

Channel metamorphosis following LWD removal and riparian vegetation clearance.
Key parameters characterising the channels in the study reaches of the Thurra and Cann Rivers.

<table>
<thead>
<tr>
<th>Characteristic symbol and units</th>
<th>Thurra River</th>
<th>Cann River</th>
</tr>
</thead>
<tbody>
<tr>
<td>Width, $W$ (m)</td>
<td>13.2</td>
<td>13.2</td>
</tr>
<tr>
<td>Av. Depth, $T$ (m)</td>
<td>3.4</td>
<td>3.0</td>
</tr>
<tr>
<td>XS area, $A$ (m$^2$)</td>
<td>18.7</td>
<td>6.8</td>
</tr>
<tr>
<td>Hydraulic radius, $R_h$ (m)</td>
<td>1.14</td>
<td>0.95</td>
</tr>
</tbody>
</table>

**Methods**
- Mean of a number of surveyed cross sections determined at morphological basefall.
- (n=8) 0.0017 0.0023 0.0007 0.0018

| Bed slope $S$ (m)               | Regression fitted to detailed bed and water surface slope survey (see Fig. 8) |

<table>
<thead>
<tr>
<th>Valley slope $SY$ (m)</th>
<th>0.0027</th>
<th>0.0022</th>
<th>0.002</th>
<th>0.0022</th>
</tr>
</thead>
</table>

**Methods**
- Measured sinuosity of study reach
- Mean sinuosity of CRPC channels + additional 4.5 km paleochannels as shown in Fig. 2
- Measured sinuosity of study reach

| Sinuosity $P$                  | 1.6           | 2.3         | 2.6          | 1.1         |

| Bed material $D_{mm}$ (mm)     | 0.83          | 0.68        | 0.59         | 0.77        |

**Methods**
- Mean value from bulk sample analysis
- (n=9) 0.83 0.68 0.59 0.77

| Unit wt of bank material $\gamma$ (KN/m$^3$) | 16.4         | 15.1        | 15.9         | 18.3        |

**Methods**
- Mean value from bulk sample analysis
- (n=54) 16.4 15.1 15.9 18.3

| Saturated bank material cohesion $c_s$ (KN/m$^3$) | 20.2         | 18.2        | 20.2         | 25.2        |

**Methods**
- Measured in situ with a shear vane at bank base (i.e., saturated zone)
- Assumed value from ThFR
- Assumed value from ThFR

| Factor of safety as a function of Critical bank height $H/H_{crit}$ | 0.29          | 0.27        | 0.42         | 0.9         |

**Methods**
- See Millar and Quick (1998)

| Woody debris load (tonnes/m$^2$) | 0.052 (n=36), 0.144 (n=40) | 0.327 (n=38), 0.009 (n=50) |

**Methods**
- Census method + volume of wood-water surface areas at best fall

| Channel migration rates (mm/yr) | 25.3          | 7.7         | 29.5         | 4500        |

**Methods**
- Dated transect
- Dated transect
- Dated transect
- Air photo interp
Bed longitudinal profile changes following LWD removal and channel enlargement

Sedimentology and chronology of Cann River Floodplain at stop 3
Stop 4 Cann River at West Cann Bridge - Channel incision and works to control channel incision

Cann River at West Cann Bridge 1998 (cf today)

Bibliography
Cohen, T.J. and Brierley, G.J. (2000), Channel instability in a forested catchment: a case study from Jones Creek, East Gippsland, Australia. Geomorphology, 32: 109-128


The Mowamba River was released back into the Snowy River on the 28th of August 2002 by the Premiers of NSW and Victoria, having been diverted into Snowy Dam for 35 years. As a result, the Snowy River is now running at approximately 80% of its natural volume before being dammed for the Snowy Mountains Hydro-electric Scheme.

The NSW and Victorian Governments are investing $300 million to have the Snowy River flowing at 25% of its original volume over 10 years. Further investment is planned to take this up to 29%.

These proposals increase the river's minimum flow and survive natural seasonal peaks that occurred in the Snowy River before damming.

Much work is still to be done to ensure the river is best able to respond to the increased flows.
**There are major challenges...**

Following years of low water flow and few significant flood events, the Snowy River catchment channel has dramatically reduced in size. Large quantities of silt, sand, and organic matter have accumulated along a number of river sections.

Extensive populations of willow and blueberry have established within the river channel. These weeds will continue to be targeted for control under the Snowy River Rehabilitation Project as they have significant impacts on river ecology.

**Revegetation and channel forming...**

One of the major aims of the river rehabilitation project is to stabilise sediment deposits by revegetation using native plants.

Revegetated channels along the river's edge will direct high flows back into the main river channel, so as to scour and deepen it. This is essential for recreating a deeper, faster flowing and more natural river, which will provide a wider range of aquatic habitat.

The revegetation is being done using native trees, shrubs, and grasses propagated by local nurseries. Species will vary according to the location of the sites as plantings will be similar to the natural vegetation of each area.

**How will the recovery process benefit us?**

Recovering the ecology of the Snowy River will ultimately lead to a much healthier river system with many real benefits to the wider community.

- Recreation and tourism, including fishing, canoeing and eco-tourism opportunities will develop as the river recovers.
- Ongoing rehabilitation works provide continuing local and regional employment opportunities for many people.
- Increasing opportunities in river management are being realised for Aboriginal people who have historical links to the Snowy River.
- Higher flows will lead to a much lower risk of water quality problems like algal blooms.
- The Snowy will become a more productive river as it regains the typical characteristics of a river of this size.

As the river deepens and high water periods become more frequent, caution will be needed when traversing crossing points in use for the past 30 years, as their condition may change significantly.

Pumps and other structures placed on or near the river since the river's diversion may now need to be relocated as higher water levels become more common.
River Rehabilitation and Channel Forming

Through weed and stock control and revegetation

Representation of the degraded condition of much of the Snowy River.

Degradation influences include:
- Extensive unconsolidated sediment deposits
- Willows and other woody encroaching on the river channel
- Controlled minimum flow resulting in shallow water with wide temperature variation and poor habitat value.

Rehabilitation works typically include:
- Willow and blackberry control
- Revegetation of strategic areas
- Stock control

Revegetation aims to stabilise eroding edges of river, act as a filter to trap sediments mobilised by the increased flows, and encourage the river channel to widen and deepen, especially under more frequent flood conditions.

After 25 to 50 years...

River deepened through scouring and held within stable banks

Large woody debris and exposed river bed provide important habitat

Over a period of perhaps 25 to 50 years we expect to see a much healthier river, flowing in a deeper, colder and more dynamic channel.

River and riparian habitat is expected to improve greatly, as are recreational and aesthetic values.
HOW LONG WILL THE RIVER'S REHABILITATION TAKE?

- A scientific monitoring program has been collecting river data since 1999. This will allow the changes that occur to the river to be accurately measured and reported.
- Changes in the river are already indicated after only a few months of natural flow variation following the Mowamba River release.
- It has taken many years for the river to degrade to its current state, and it will take many more to recover. Marked improvements, however, are expected within 5 to 10 years.

THE DEAD WILLOWS...

Dead willow trees left in the river channel should break down within 3 to 6 years. As this happens the timber is expected to become useful fish habitat and a food source for insects living in the river.

Where the dead trees are considered a hazard they have been removed from the river channel and burned. The remaining trees will be prone to falling and should be treated with caution.

... AND THE REEDS?

- The apparent increase in the population of Flag Reed and Cumbungi may be partly attributed to willow removal and increased water flows
- Reeds have always been in the river but are now much more visible because of willow and blackberry control.

These plants would not normally thrive in an active river channel. It is therefore expected that with increased flows and regular flood events the reeds will tend to only grow at the pool edges where they play an essential role in stabilising sediments.

WILL THE FISH RETURN?

The establishment of fish populations in the Snowy River is dependent on water quality and habitat improving to a point where they can survive and breed. This will happen, given time and increased water flow.

Work will need to be done in the future to encourage and promote the return of native fish species and improve trout populations. The Snowy River Rehabilitation Project team is keen to hear of changes to fish populations in the Snowy River and its tributaries.

WHAT WILL THE 'NEW' RIVER LOOK LIKE?

- The rehabilitated Snowy River will occupy a smaller channel within the old riverbed
- Flow should vary widely between summer lows and spring snowmelt 'floods', whether simulated or natural
- River systems are difficult to predict, but we know that the river will alter in its appearance and dynamic state over time as it responds to rehabilitation and increased flows.

- The riverside vegetation will be dominated by native vegetation from the area, rather than exotic species.

With commitment, care and time the Snowy River will become a healthy and wonderfully diverse river, similar in many ways to the 'Snowy' many knew years ago.
Figure 2. Snowy test, reference and control river sites (Webb and Erskine, 2000).
Snowy River long section: vertical fall and how that affects the rehabilitation project.

Dalgety Uplands:
Why it needs a lot of rehabilitation work....

This section of the river is broader as well as flatter, only falling 50 meters in 40 km, which means the planned flow releases will have less stream power to re-define the river channel and clean out sediment and weeds.

Broad scale revegetation is being undertaken in numerous areas to help slow water flow in the shallower margins, which will in turn increase the rivers power in the main channel. This is expected to lead to sediment being reworked, reeds flushed out and a deeper, healthier channel being formed.

In the Beloko and Bungarby reaches, the planned flows will do most of the work....

These are steep, narrow bedrock confined river channels.

Planned flow releases should have enough energy to re-define the river channel, clear sediments and algae from the river cobble, and remove seedling weeds like willow and blackberry over time.
Department of Infrastructure, Planning and Natural Resources

SNOWY RIVER WILLOW CONTROL PROGRAM

Scale 1:350 000

Selective willow control has occurred in all areas since 1997.

Study area
1999
2000
2001
2002
2003

Jindabyne
Berridale
Dalgety
Melra

Snowy River Restoration Project, Snowy Willow Control. DJPNR, Cooma PO Box 26, Cooma NSW 2630, ph 02 6452 1455
3.5 The enterprise will be funded as follows:
   - New South Wales Government: $150 million;
   - Victorian Government: $150 million;
   - Commonwealth Government: $75 million.

These are the total financial contributions which will be made by the Governments towards achieving the target levels of water flows specified in Clause 1.2. All financial contributions will be provided in the first ten years. The Commonwealth financial contribution will be provided, in particular, to secure environmental releases to the River Murray.

Commitment of funds and the allocation of water savings for environmental purposes can only be varied by agreement between the three Governments.

3.6 The enterprise will be non-profit. It will have a defined annual cash flow and a limited capacity to carry out short-term investment, carry over of funds between financial years, and borrowing. The annual business plan of the enterprise including the proposed savings projects or package of projects will require the approval of the three Governments.

3.7 The parties recognise that NSW and Victoria are moving to establish fully functioning water markets consistent with COAG principles and MDBC resolutions and the parties also note that NSW is currently in a program of active water policy reform and that these initiatives will underpin the operation of the enterprise.

3.8 Pending the establishment of fully operating water markets, the State Governments will take all reasonable steps to promote access by the enterprise to water entitlement and water rights holders (including individuals) in both States for the acquisition of water for the purposes of this agreement.

4. STAGES FOR INCREASED FLOWS

4.1 First Stage (Initial release)

4.1.1 An initial increased release of water to the Snowy River below Jindabyne will be made from the Mowamba River and Cobbon Creek aqueducts at a time agreed by all three Governments following the proclamation of the Snowy corporatisation legislation.

4.1.2 Water to offset the increased flows in the Snowy River resulting from releases from the Mowamba River and Cobbon Creek aqueducts will be sourced for up to the first three years from Snowy Scheme storages. These borrowings will be paid back over a time scale which does not affect water allocations for irrigation farming. The repayment schedule will be part of the agreed annual business plan of the joint government enterprise. Within three years, inflows to the Snowy River from the Mowamba River and Cobbon Creek will be offset by verified water savings from the enterprise. Reductions in assured releases to the west made by Snowy Hydro Limited equal to these verified water savings will be implemented when this offsetting commences.
4.2 Second Stage (2 to 7 years)

4.2.1 Water releases from the Snowy Scheme to the Snowy River below Jindabyne will be progressively increased in tandem with increases in the verified volume of water acquired by the joint government enterprise. For this stage, the target flow in the Snowy River below Jindabyne is 15% ANF. To enable these releases to be made, within three years of corporatisation Snowy Hydro Ltd will build an outlet at Jindabyne Dam to enable a flow in the Snowy River of at least 28% ANF.

4.2.2 Dedicated environmental flows allocated to the River Murray of up to 70 gigalitres per annum will be progressively implemented in tandem with increases in the verified volume of water acquired by the joint government enterprise. The River Murray flows will be matched to the allocation to the Snowy River on the basis of one gigalitre allocated to the River Murray per two gigalitres allocated to the Snowy River over the Second Stage (2 to 7 years).

4.2.3 The MDBC will be responsible for managing a variable inflow regime, including above-target water from the Snowy Scheme to provide dedicated environmental flows to the River Murray downstream from the Hume Dam.

4.2.4 NSW will develop schedules for increased water releases to the Snowy montane rivers, including the upper Murrumbidgee River, of a total volume of water equivalent to foregone Snowy electricity generation of 100 gigawatt-hours per annum. If necessary to enable releases to the upper Murrumbidgee River, within three years of corporatisation Snowy Hydro Ltd will build an outlet at Tantangara Dam.

4.2.5 Water releases to the Snowy River below Jindabyne and to the Snowy montane rivers will mimic natural flows under prevailing climatic conditions to the extent possible, depending on the availability and reliability of offset water and the capacity of constructed outlet works at Jindabyne and Tantangara Dams.

4.3 Third Stage (8 to 10 years)

4.3.1 Water releases from the Snowy Scheme to the Snowy River below Jindabyne will be progressively increased in tandem with increases in the verified volume of water acquired by the joint government enterprise. For this stage, the target flow in the Snowy River below Jindabyne is 21% ANF.

4.3.2 In this stage, the security of the further offset water required to achieve a 21% ANF flow in the Snowy River will be at the level of reliability measured at the point of acquisition or purchase, not at the reliability level for annual inflows to the Snowy River.

4.3.3 Water allocated from the Snowy Scheme to the River Murray for dedicated environmental flows will continue to be matched to the allocation to the Snowy River on the basis of one gigalitre allocated to the River Murray per two gigalitres allocated to the Snowy River up to a maximum allocation of 70 gigalitres per annum to the River Murray within 10 years.

4.3.4 Water releases from the Snowy Scheme to the Snowy montane rivers will be increased to a total volume of water equivalent to 150 gigawatt-hours per annum of foregone electricity generation.
4.3.5 The target is to complete this stage in 10 years.

4.4 Fourth Stage (beyond 10 years)

4.4.1 The additional 7% of further flows in the Snowy River up to a total of 28% ANF may be achieved following the implementation of an additional major capital works program to achieve water savings in the southern Murray-Darling Basin beyond those required to offset the 21% ANF flows in the Snowy River. This program will be undertaken through public private partnerships in which the water saved is shared between the governments and private sector partners. Water savings allocated to the governments will be used to offset increased flows in the Snowy River and to provide further dedicated environmental flows in the River Murray.

5. COMPENSATION PAYABLE TO SNOWY HYDRO LTD

5.1 The three Governments agree that compensation for all net foregone revenue resulting from reduced availability of water flows will be paid to Snowy Hydro Ltd, by arrangement between NSW and Victoria, for any flows in the Snowy River above 21% ANF.

5.2 No flows in excess of 21% ANF will be implemented before arrangements for sharing the cost of the compensation are agreed between the NSW and Victorian Governments.

6. WATER ACCOUNTING ARRANGEMENTS

6.1 The measuring point for all Snowy River flows will be immediately below the confluence between the Snowy and Mowamba rivers.

6.2 The three Governments will present each water savings project or package of projects proposed by the joint government enterprise or by the Governments themselves to the Murray Darling Basin Commission for comment under clause 46 of the Murray Darling Basin Agreement.

6.3 A methodology for verifying the water savings actually acquired through each project for the purposes of offsetting increased flows to the Snowy River below Jindabyne and dedicated environmental flows to the River Murray will be developed for comment by the MDBC and approval by the three Governments.

6.4 An auditor appointed by the three Governments in consultation with the MDBC will review the calculation of prospective water savings from each project, certify that the calculations are reasonable and verify the actual water savings achieved by each project.

6.5 Victoria and NSW will create specific environmental water entitlements for the Snowy and Murray Rivers. The water contained in these entitlements will represent the water savings and purchases made by the joint government enterprise.

6.6 The allocation of water to the Snowy Scheme for increased flows in the Snowy River below Jindabyne and for dedicated environmental flows in the River Murray will be made when the offsetting water savings actually acquired have been verified by the auditor. However, the initial release of water from the
River to rivulet and back: Rehabilitating the Snowy River.

Born and bred in Canberra and a very keen fisher from an early age, I spent a lot of time fishing the rivers of the Southern Tablelands and the Monaro. Whilst at the Australian National University, I spent the summer vacations (1960-1963) as a technician with the Alpine Ecology Unit of the CSIRO Division of Plant Industry working with Alec Costin and Dane Wimbush. Initially, we were based at Island Bend and then at Waste Point. From this experience, I got to know the moods of the Snowy River very well and was acutely aware of the essential integrity of the unregulated Snowy compared with the degraded state of the Eucumbene as it joined the Snowy between Waste Point and the original Jindabyne. Thus, one can say that I’m very aware of what was lost in the damming the Snowy reducing it from being a surging river to a degraded rivulet below Jindabyne.

The Snowy Scheme is a massive scheme; rated by American Society of Civil Engineers as one of the seven civil engineering wonders of the world in the 20th century. It is a massive scheme encompassing 16 major dams with total capacity of 7,000Gt or 13 Sydney harbours, 145 km of interconnected inter-mountain tunnels, 80 km of aqueducts and 7 major power stations with generating capacity of 3,756 megawatts from 31 turbines. The scheme is a stark case of concretophilic developmentalism with scant environmental concerns for the rivers and for the overall environmental values of the Kosciusko National Park. The Scheme has dammed 7 major rivers, diverted flow from 5 of these (Snowy, Murrumbidgee, Geehi, Tooma, Eucumbene), supplemented greatly flow of two (Swampy Plains and Tumut), diverted water by aqueducts into the scheme from 4 major waterways (Goodradigbee, Mowamba or Moonbah, Bogong Creek, Gungarlin River). Now within the Snowy Mountains and the Kosciusko National Park, there are now only three fairly natural rivers, the Crackenback, the upper Murray and the Yarrangobilly. From the aquatic ecology point of view, the Kosciusko National Park is a badly degraded national park, with all but three of its rivers badly damaged.

The scheme was primarily built to generate electricity and not to supply irrigation water. To quote the draft EIS for the Corporisation of the Snowy Mountains Hydro-Electric Authority (2000) “ unlike electricity, there are no specific entitlements to
water from the scheme under the current legislation, apart from during specified
drought situations”. There was no recognition of the need for environmental flows in
the enabling acts, the Snowy Mountains Hydro-Electric Power Act 1949 and the
Snowy Mountains Hydro-Electric Agreement 1957. The once free-flowing rivers had
their flows greatly reduced to the very low levels of “riparian releases”. These water
releases have been set by the Snowy Mountains Council (with no freshwater ecologist)
that is also supposed to be responsible for the environmental implications of the
Scheme’s activities from the point of the rivers’ ecological condition. Thus, the
minute riparian releases are supposed to supply riparian demands, but have lead to
major disruption of the riparian zones, and may meet no more riparian demands than
those of blackberries, gorse, rabbits and sheep.

In the early 90’s, the need for rehabilitating dammed rivers by implementing
environmental flows started to arise. For example, the commissioning of the Thomson
River Dam lead to the setting of an environmental flow—originally quite substantial but
with further committees, it has been steadily whittled down. In NSW, under the leadership
of John Harris (then of NSW State Fisheries), an Expert Panel approach for developing
recommendations for flow management to rehabilitate regulated rivers was developed. I
was a member of a small team that trialled the Expert Panel approach in severely regulated
rivers in NSW (e.g., Tumut, Macquarie, Namoi). This trial was followed by the invitation
from Snowy Genoa Catchment Management Committee to devise an environmental flow
regime for the Snowy below Jindabyne. So we studied the river from Jindabyne to Orbost
seeking to identify the environmental parameters that currently influence the ecological
functioning (or non-functioning) of the Snowy River, to identify critical environmental
thresholds within the flow regime that may amplify the ecological functioning of the
Snowy River, to develop a set of recommendations for flow management to maximize
ecological benefit and to recommend a strategic environmental flow research program.
The results of the Panel were published in a precise multi-authored report in February
1996.

The release of the report triggered trenchant criticism of the expert panel approach
by other experts and consultants—especially the Centre for Water Policy Research (1996).
It is very apparent that there is a critical schism between two approaches in methods for
setting environmental flows. First, there is what may be called the Hydrol-Ecological,
such as Expert Panel Assessment Method (EPAM), Instream Flow Incremental
Methodology (IFIM) and PHABSIM. Hydrol-ecological methods are concerned with the river and its biota and have outcomes pitched in hydrological, geomorphological and ecological terms, and recognizes thresholds, both for habitat maintenance once it has been recreated, and for large hydro-geomorphological thresholds that mould and generate habitat. The second approach can be called the Enviro-socio-economic. This approach uses hydrological and ecological expertise, but also includes an assortment of interests of users and stakeholders, the very interests that have used and may have damaged the river. Thus, in the very devising of the flows, the incorporation of the socio-economic exploitative interests may compromise the ecological, so that the environmental flow may be set at a compromised mean value, below critical thresholds. For example, the Snowy Water Inquiry (1998) had to be consistent with a much wider brief that requires the Inquiry to assess economic and social trade-offs associated with re-diversions back to the east. In the usual case with this approach, environmental flows are set at low levels (10% or so) that may not achieve any improvement any ecological improvement and which, even if there is ecological monitoring, are unlikely to produce detectable ecological effects.

Perhaps the most galling attack on the Expert Panel Approach has been the claim that it is not science. To me, this criticism suggests a poor misunderstanding of what science is about. Setting an environmental flow is initially an educated guess or hypothesis, and the value of the hypothesis lies in setting up the project as an experiment—an experiment in adaptive management. In the best case, we're looking at a before-after (BACI) study. Sadly, in most cases of environmental flow setting to date, before- and after monitoring is either non-existent or perfunctory, and the monitoring is of such poor design or quality that to pick any effect would be well-nigh impossible. This is the challenge, the necessity for sound reliable monitoring in a statistically and logically rigorous design so that you can test the validity of the hypothesis that the set environmental flow is having (or not having) ecological effects.

The monitoring, which is rarely properly implemented, can be linked with an adaptive management framework. This framework means that you learn from the monitoring data how the river and its biota are reacting to the flows in relation to the hypothesized responses. Dependent on assessing these responses after an adequate time period, it may be necessary to set a new flow regime that is again monitored. The procedure allows one to learn by doing. It has been successfully used, for example, in such environmental flow work as the release of floods from the Glen Canyon Dam down the
Colorado River to improve habitat for native biota. One would like to see the Snowy River Benchmarking Project as a well-funded, long-term ecological experiment embracing adaptive management. Given the costs in the whole exercise, hopefully Federal and State Governments will be eager to have an adequately funded monitoring and adaptive management program for environmental flows down the Snowy River.

In the Jindabyne Gorge and Dalgety Uplands Reaches, the Snowy River is a travesty. From the dam, a trickle of water flows to be joined by the treated sewage of Cobben Creek. The channel has shrunk greatly and has been invaded by invasive and native riparian vegetation. Indeed, a common feature of shrunklen channels is that riparian areas, permanently exposed by low flow, are colonized predominantly by exotic invaders (willows, gorse, blackberries, Californian poppies etc). Still pools are joined by small trickling drifiles (derived from dribbles flowing through would-be ripples). These drifiles are most unusual in that they are not lined with stones and cobbles but consist of unconsolidated sand, silt and gravel. You can push a sampling net handle up to a metre or two into the drifile bed. Dwelling in the pools is a fauna resembling that of farm dams, whereas in the drifiles, there dwells a most strange fauna dominated by oligochaete worms, chironomid fly larvae and sphaeriid bivalve molluscs.

Restoring adequate flow is the major goal, but one should also recognize other issues besides those of the river channel also need urgent attention, such as spoil dumps, the lamentable catchment condition, and the degraded riparian zone. We must recognize that "the natural flow regime plays a critical role in sustaining native biodiversity and ecosystem integrity in rivers." Clearly, the river in this whole upland reach needs three things, more water to cover the channel, flow variability on a seasonal basis, and a mimicked spring flood to reshape the channel and provide new habitats.

The Expert Panel built a flow pattern by examining the river and its biota, and what we conservatively thought then would substantially return the ecological integrity of the river and return important functions such as habitat replenishment and maintenance, connectivity, and seasonal and short-term variability.

If full flow restoration is impossible, mimicking certain geomorphic processes can provide critical ecological benefits by identifying flow thresholds for effective river ecological functioning. Our recommendations were based on depths that were then converted to flows. Three flow types were set in the overall flow regime:
Absolute minimal flow. From the Dam the flow is now a constant 50ML/d. The Panel recommended a minimal flow immediately below Jindabyne dam of 200 ML/d; this approximates to 95th percentile exceedence for the driest month.

Minimum habitat flow utilization flow regime. This is a minimal seasonal flow regime that allows aquatic biota to use a reasonable amount of resources and to have a diversity of habitat for survival and life cycle completion, and to allow in-stream transport and nutrient processing to operate. This entails not only habitat inundation, but also flow variability and requires enough water to maintain moderate water quality parameters, such as temperature and oxygen availability. Thus, the Panel used the natural 95th percentile exceedence flow by month.

Channel Maintenance Flow: This was regarded as flows of sufficient strength to reconfigure the river channel and substrate and riparian zones, thus regenerating much of the structural habitat. Thus, as in other upland streams, such flows (floods) reconfigure pools, riffles and runs, flood out barriers, move large debris, and remove sand and silt and reinvigorate and reshape the riparian zones. In addition, in the Jindabyne-Dalgety Reaches the flow could remove macrophytes (eg., Phragmites, Typha) and invading riparian plants, and re-invigorate the riffles- blowing away the sand, gravel and fines- that now comprise the driftles. This means that to re-mould riffles/runs, to reshape pools, to rebuild and replenish habitat and to maintain the river in a good functional condition, it is necessary to implement large and extended channel maintenance flows as near as possible to the natural high flow condition. If these high spring flows are restored, then channel reshaping will occur and an array of riffles, pools and runs will return and the emergent macrophytes will be greatly reduced. Such high flows could also augment longitudinal connectivity by flooding out barriers to migration eg., Snowy Falls for fish. We recommended a flood flow event of 3-5 days between May-October each year, with a minimum peak of 12,000 ML/d below Jindabyne and at least 20,000 ML/d at Dalgety.

Finally, to introduce some natural variability into the flow and to provide some longitudinal connectivity for the Jindabyne-Dalgety section, we recommended the decommissioning of the aqueducts of Cobbin Creek and of the Mowamba River and the breaching of the barriers. At present, it is very evident below the dam that the water coming from the dam does not favour a normal stream fauna. It encourages algal growth, especially attached blue-greens, and filter-feeding invertebrates. Thus, the
recommendation to remove the aqueducts was made so that the river may gain an
upstream source of colonists, but may also gain allochthonous energy (detritus), sediments
and nutrients.

In building the scheme there seems to have been a strong determination to extract every
drop of water from streams. Thus, there are 80 kilometres of aqueducts extracting flows
from streams and delivering their flows into dams. Such aqueducts exacerbate the lack of
water in rivers downstream of dams, have greatly reduced the extent of middle order
streams in the National Park, and have isolated completely upland streams from their
natural downstream reaches. Thus, cut-off streams may contain isolated populations, cut
off ecologically and genetically, from other populations. In short, in the Kosciusko
National Park, connectivity involving middle order streams has been very severely
disrupted. Rivers naturally have connectivity that is critical to a river’s functioning and to
the river’s role in the surrounding landscape. Hitherto, the issue of river connectivity has
been neglected in landscape planning in general, and much more sadly in the planning and
management of conservation reserves and national parks. Thus, in the Kosciusko Park
serious thought should be given to the elimination of some aqueducts e.g., Gungarlin,
Burringubugge.

In terms of the biological responses to the flow, the most immediate ones are going
to happen in the upland reaches, and I gather that some reshaping of habitat, especially in
the drifflies has already occurred. Currently, these drifflies are very abnormal and need
reworking by some high flow events to blow out all the fine sediments. With that process
occurring, I predict that it won’t take long for the normally expected riffle fauna, of such
groups as Ephemeroptera and Trichoptera, to recolonize. I expect with increased flows,
especially the high flows, that large amounts of bamboo grass and cumbungi will be
removed—and become detritus for stream invertebrates. The killing of willows and the
donation of dead willows to the rivers I can only see as beneficial. Willow wood rots
quickly and is a food resource for a guild of wood borers and gougers in the stream. I
hope that steadily in the upland reaches with the very dilapidated riparian zones and with
the removal of such exotics as willows, gorse etc., that native vegetation (tea-trees,
acacias etc), is encouraged to replace them. Such plants are hubs of aquatic and terrestrial
insects and spiders that provide food for fish, as opposed to willows etc., that are bereft of
much macroinvertebrate life. With more flow and an improvement in water quality and an
increase in stream insect/crustacean abundance, I expect an increase in trout biomass.
With increased flows increasing longitudinal connectivity in the river, there may be some movement up into the upland reaches of eels, galaxiids, tupong, possibly even bass. With releases from Jindabyne Dam, I expect that the upland reaches will become a somewhat smaller version of the original upland river—not the original size but similar in biota and ecological functioning.

The timing of recovery is largely driven by the provision of the required flows. With suitable flows, connectivity will be restored and good habitat, in form, amount and variety, will be created. The recovery will also depend on which part of the river one is concerned about, as the more downstream one goes the more diluted will be the effects of the flows from Jindabyne Dam. In the uplands reaches, I expect water quality to be improved first, followed by the steady development of patches of habitat. With new habitat, one would expect short-lived and mobile macroinvertebrates—especially insects—to increase in variety and abundance. Fish may then start to increase in abundance and finally, and dependent on both flows and active bankside rehabilitation, the riparian zone may return as an intact system dominated by native plants.

In Australian and international spheres, we must recognize that the environmental flow project of the Snowy River is extremely important. First, it is the iconic Snowy River known to most people through poetry, films and television. Second, it is one of the few rivers to get an environmental flow that may be of an ecologically appropriate magnitude. Environmental flows have been set for some rivers, but they tend to be no more than tokenistic (e.g., 10%), or agreed upon but never implemented (Campaspe River below Eppalock). Third, the Snowy is valuable as the effects of the flow are being monitored to see if the flow works. The monitoring program is rigorously set out as a before-after (BACI) design (with 3 years of before data), and with 26 control, reference and treatment sites. The team from DLWC is monitoring hydrology, water quality, channel morphology, riparian, littoral and submerged vegetation, macroinvertebrates and fish. Then, following the adaptive management procedure, if the flow is inadequate after 28%, the monitoring results may be used to increase the flows. Finally, it could be a very encouraging example of how community, scientific, political and management interests can work together to resolve a difficult and large scale environmental problem. This is very important as it demonstrates that good progress resolving environmental problems can be made without endless prevarication, delays and broken promises. It also vividly illustrates that resolving a difficult environmental problem can bring together a community made up of many
different interests and that this community willingly accepts that solving the problem is a long-term venture.

From: Professor Sam Lake
Snowy River Benchmarking and Environmental Flow Response Monitoring Project

Background

Flows in the Snowy River below Jindabyne Dam have been reduced to 1% of mean annual natural flow since 1987.

Community concern about the degraded Snowy River led to a rapid Expert Panel Assessment in 1996 of the impacts of Jindabyne Dam on the river's ecology. The panel recommended a minimum release of 28% of mean annual natural flow.

To measure the effectiveness of flow releases, the Snowy River Benchmarking and Environmental Flow Response Monitoring Project began in 1997.

Objectives

1. Assess the condition of the Snowy River before the release of environmental flows.
2. Assess the condition of the Snowy River after the environmental flow releases.

Note: The comparisons will be made against other rivers with and without dams.

The Snowy River at Dalgety in 1997, showing the extent of vegetation encroachment into the channel as a result of reduced flows from Jindabyne Dam (26ML/d).

The Snowy River at Dalgety during a 781ML/d flow event. An environmental flow release of this size would likely result in an improvement of in-stream habitat.
The results to date indicate:

- Greatly reduced channel size.
- Pools infilling with sand.
- Loss of habitat diversity.
- Greater abundance of in-stream vegetation.
- Greater abundance of macro-algae.
- Invertebrate fauna is typical of silt, slow flowing conditions.
- Reduced abundance of native fish.
- In general, the condition of the Snowy River is poorer than nearby rivers without the impact of dams.

These results and continued monitoring will be used to:

- Report on how the environmental flows have changed the condition of the Snowy River.
- Provide data to the Snowy Scientific Committee (to be formed under the Snowy Hydro Corporatisation Act 1997) so it can advise on the pattern of environmental flow releases and their adequacy for ecological benefits.

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A Report Card on the recovery of the Snowy River

Presented to:

NSW Treasury, November 2003

The Snowy River Recovery program has a single and overriding ecological purpose, to recover the health of the Snowy River in NSW by the introduction of environmental flows and by rehabilitation of the river channel. It also has a broader aim, which is to maximise the economic and social benefits accruing from the regeneration of the river. This is in accordance with the expectations of river communities and the Government’s principles of achieving sustainability in management of natural resources.

Active intervention to rehabilitate the choked Snowy River channel is being carried out, and a pilot program is running to develop and demonstrate community and economic benefits arising from increased environmental flows. This program is being delivered to generate positive outcomes for the communities living on, or living with links to, the river. This includes the Aboriginal communities of the south-east, who have rich cultural ties to the Snowy River.

Teresa Rose
A Report Card on the recovery of the Snowy River

**Recovery Objective:** A healthy Snowy River

<table>
<thead>
<tr>
<th>Target</th>
<th>Current Status</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Environmental Flows</strong></td>
<td>- 3% flows released 28 August 2002, and the NSW-VIC Joint Government Enterprise has been established (Dec ’03), to make water savings in inland irrigation areas.</td>
</tr>
<tr>
<td>• 3% additional flow to be delivered from</td>
<td>- There is an accumulated ‘Mowamba Borrowings Debt’ of about 37GL (to Jan ’04).</td>
</tr>
<tr>
<td>Mowamba River (up to 38GL/a), balanced by</td>
<td>- Goodradigbee flow delivery arrangements have been agreed with Snowy Hydro.</td>
</tr>
<tr>
<td>38GL water efficiency savings in inland</td>
<td></td>
</tr>
<tr>
<td>irrigation areas by 2005.</td>
<td></td>
</tr>
<tr>
<td>• 7GL montane area releases to be made to</td>
<td></td>
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<tr>
<td>the Goodradigbee River, when the first flow</td>
<td></td>
</tr>
<tr>
<td>allocations (post-Mowamba) are made to the</td>
<td></td>
</tr>
<tr>
<td>Snowy River.</td>
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</table>

**Willow removal/Vegetation management**

- All willows clogging the Snowy River to be removed in NSW and Victoria (except for selected amenity trees, eg. around Dalgety township) by 2007.
- Blackberry masses to be removed from badly infested margins of the river by 2007.
- 70km of Snowy River margins needing treatment to be revegetated by 2007.

- Willows have now been killed in a 100km section of the Snowy River below Jindabyne (60km completed, 40km initial treatment - 3 treatments required to complete).
- Blackberry removed from 25km of river in NSW (additional blackberry was removed by summer fires, but requires spring herbicide follow-up).
- 3 km of river now revegetated with native riparian vegetation in NSW.

**Dalgety Township environs**

- Township river environs to be fully rehabilitated by 2004:
  - All problem Willows killed and removed,
  - All blackberry masses removed,
  - 100,000 native trees & shrubs established.

- Willow treatment and removal complete.
- 80% blackberry masses removed.
- 50,000 native riparian trees and shrubs planted.

**Native Fish Populations**

- Australian Bass to be re-established in lower 90km of river by 2007
- River Blackfish to be re-introduced to selected habitat locations in the middle reaches of the Snowy River by 2010

- Workshops with Fish Ecologists and Native Fish Australia have been held to inform and support the program.
- Snowy Fish Recovery Strategy in Preparation.
- Objective agreed with SE Aboriginal communities.

**Ecological Health of the River**

- Decline in ecological condition of the Snowy River to be halted by 2003.
- Measurable signs of ecological response to environmental flows to be evident by 2005.
- Flow Response monitoring to inform government and communities on the return to health of the Snowy River.

- River condition is benchmarked, with 3Yrs pre-flow and over 1Yr post-flow monitoring showing that:
  - Mowamba flows have already stripped algae and expanded the flow channel in the upper reaches.
  - Natural regeneration on mobile sand-banks has commenced.
  - Storm run-off after the summer bushfires has caused a significant decline in river health.

**Summary:** By 2007, the Snowy River will have been physically rehabilitated to a level that provides for maximum benefit to be achieved from the increased environmental flow allocations. River rehabilitation works are currently occurring ahead of schedule, however the ‘JGE’ arrangements to deliver the environmental releases are behind schedule. A critical point will be reached in Sept 2006 when the Jindabyne Dam outlet is completed and the community will expect to see increased releases.
A Report Card on the recovery of the Snowy River

**Recovery Objective: Stronger Snowy River communities**

<table>
<thead>
<tr>
<th>Target</th>
<th>Current Status</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Listening to river communities</strong></td>
<td>• Major consultation with South East Aboriginal communities held. [] • ANU study of community perceptions undertaken for 3 river towns in NSW as part of a Masters Degree research. [] • Inaugural NSW-Victoria ‘Snowy River Journey’ event undertaken, linking Snowy River communities from Charlotte’s Pass (NSW) to Marlo (Vic). ‘Spirited of the Snowy’ booklet and video produced, and ABC broadcast of stories from the Snowy River Journey (Nov. 2002). [] • An ABC Book project is under way.</td>
</tr>
<tr>
<td><strong>Communities are part of decision making</strong></td>
<td>• Snowy River Rehabilitation Plan committee in place, meets locally every 2-3 months. There is a high level of confidence in NSW Agencies to deliver river recovery.</td>
</tr>
<tr>
<td><strong>Building River Networks</strong></td>
<td>• A River Recovery Forum was undertaken in May 2003 at Dalgety, and a second at Orbost in August. [] • A NSW-Victorian exchange program has been initiated with a Visit to Orbost in October 2003, and a return visit planned for April ’04.</td>
</tr>
<tr>
<td><strong>Social Capacity – leadership and learning</strong></td>
<td>• Government Agencies have recognised the role of community leaders in Snowy River recovery. [] • Local school students have been involved in Snowy River recovery events and activities, and an education program is currently being expanded from Victoria. [] • A ‘Snowy River Institute’ concept paper is in circulation.</td>
</tr>
</tbody>
</table>

| **Recovery Objective: Increased local/regional economic activity**      |                                                                                                                                                                                                     |
| **Target**                                                             | Current Status                                                                                                                                                                                                 |
| • Snowy River recovery acts as a catalyst to local and regional economic activity. | • On-ground training and support has been provided for local people to gain river work. \[\] • An Aboriginal group has been trained and supported to engage in rehabilitation works generating ongoing employment for 6 people. \[\] • $600,000 investment in willow control and riparian revegetation has been directed to a growing number of local contractors and suppliers. |
A Report Card on the recovery of the Snowy River

<table>
<thead>
<tr>
<th>Increased Regional Tourism</th>
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<tbody>
<tr>
<td>• New/increased river recreation opportunities are identified</td>
<td>• Informal consultation has been carried out with</td>
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<tr>
<td>arising from Snowy flows.</td>
<td>recreation operators e.g. canoeing, rafting and</td>
</tr>
<tr>
<td>• New river-based local and regional tourism opportunities are</td>
<td>fishing.</td>
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<tr>
<td>identified.</td>
<td>• Informal consultation with tourism bodies and</td>
</tr>
<tr>
<td>• Tourism organisations participate in development of Snowy</td>
<td>operators is in progress.</td>
</tr>
<tr>
<td>River tourism product.</td>
<td>• Premier's Dept. is working with Tourism</td>
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<td></td>
<td>operators in the Snowy Mountains to develop</td>
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<td></td>
<td>Snowy River concepts and capacity for regional</td>
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<td></td>
<td>tourism.</td>
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</table>

Summary: There is a dialogue between river communities and the Government, jobs are being created, the capacity of communities to take advantage of increased Snowy flows is being developed, and people are celebrating their identity and spirit around the central thread of the Snowy River.

"Recovery of The Snowy River is one of the most ambitious river restorations in the World today" (Melbourne Age, May 2003)
Murrumbidgee River at Long Plain
Reference Reach for Geomorphic Condition Assessment

bedrock controlled, gravel bed (alpine/treeless) type

A reach 200m downstream of the Port Philip Fire Trail bridge (away from fisherman’s access tracks) is being used as a ‘natural condition’ reference reach because it has no detectable disturbance and fulfills vegetation cover, mainly due to its location in a National Park. The site is 15 km from the source of the Murrumbidgee. It exhibits the main characteristics of the bedrock controlled geomorphic type:

- a sinuous valley with bedrock spurs on the inside bends, forcing the river to follow the planform of the valley
- up to 90% of the outside bends are against the valley margin (so laterally stable)
- narrow multi-level floodplain segments on inside bends with a flood runner and backswamp
- boulder/cobble/gravel/sand bed between bedrock steps
- compound point bars/benches with chute channels where the channel can expand in major floods

The lack of trees means that this sub-type naturally has no large woody debris. The attached data for the reach are used by people comparing their test reach parameters to this reference reach to determine the relative condition of the test reach. An internal DIPNR course is provided for staff doing this work. Further details on the course and the reference reach project can be obtained from Carolyn Young, DIPNR, Queanbeyan.

(carolyn.young@dpi.nsw.gov.au)

David Oatfield
| River Name | Channel Code | Location | Survey Date 1 | Survey Date 2 | Site Location | Landowner | Landowner Address | Landowner Phone | Survey Method | Site Type | Site No. | U.S.GS | Number Code | Scale | Year | Run No. |
|------------|--------------|----------|---------------|---------------|---------------|------------|-----------------|----------------|---------------|-------------|---------|--------|--------|--------|-------|------|--------|
| Mumpfield Creek | 1 | May 2002 | April 2003 | DD, CT, TS | HPS | 6447 7005 | Turned | RR (clay) (dry season) | No (dry need for dry season) | Russ Pike | 8295 50.5 | 125000 | 102900 | 32 | 1.0000 | 1994 | 6 |

**Channel Attributes**

- **Bank Material:** | **Consequences:**
- **Land Cover:** | **Runoff:**
- **In-channel Activities:**
- **Flow Characteristics:**
- **Hydrography:**

---

**RIVER PLANFORM**

- **Number of Shelves/shoreline:**
- **Sinuosity:**

---

**Surface Character**

- **Geomorphology:**
- **Surface Material:**
- **Characteristics:**
- **Valley Geomorphology:**

---

**Geospatial Data**

- **Datum:**
- **Projection:**
- **Coordinate System:**

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**Channel Activities**

- **Incision:**
- **Accretion:**
- **Erosion:**

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**Shoreline**

- **Shoreline Type:**
- **Shoreline Stability:**

---

**Flow Characteristics**

- **Flow Regime:**
- **Flow Velocity:**

---

**Hydrography**

- **Hydrologic Data:**
- **Hydrologic Conditions:**

---

**Surface Hydrology**

- **Surface Water:**
- **Groundwater:**

---

**Sedimentology**

- **Sediment Type:**
- **Sediment Grain Size:**

---

**Geospatial Data**

- **Datum:**
- **Projection:**
- **Coordinate System:**
Tumut River
Summary of River Management Issues

Background

The Tumut River is the primary conduit for the supply of water from the Snowy Scheme via Blowering Dam to the Murrumbidgee River System water users. Additional water, as required, is supplemented from Burra Dam via the Murrumbidgee River upstream of the junction with the Tumut River.

The length of the Tumut River from Blowering Dam to the Murrumbidgee River just above Gundagai is approximately 75 km.

Managed flows in the river during the irrigation season are restricted to a maximum of 9,000 ML/Day from Blowering and 9,300 ML/Day through the Tumut township. Higher flows, whether they be operational (man made) or rainfall events, cause flooding problems at various points along the river. The minimum winter environmental flow is 560 ML/Day.

There is a perception that problems in the river started after Blowering was constructed in 1969. History shows that the first complaints (mainly about bank erosion) were registered with the NSW government in 1928, and continue through Ministerials to this present day.

History also shows that the first of the major remedial works were carried out in the 1940s and continued until just before the final construction of Blowering dam in 1969.

It was recognised in 1945 that “... this river and the Peel are the two streams in this State which call for urgent attention ...”.

In August 1949 the Tumut River Improvement District (TRID) was gazetted as a result of representation to Government by the landholders to assist in addressing the problems in the river. When they realised there would be an impact ($) on them they petitioned the Premier of the day and TRID was not enacted. The grounds for objection are given in Attachment A. The Land Owners maintain the same views today.

The land owners’ perceived problems are:
- loss of land due to erosion caused by snags and willow growth in the river,
- high flows (including flooding), and
- water logging of adjoining lands.

Environmental degradation is one of the current issues.

After the commissioning of Blowering, works of a limited nature were carried out until about 1985, when, as a result of further complaints by the landholders to Government, action was again implemented to rectify the problems in the river.

Current Situation

Each year an inspection of the river is carried out by boat to identify the problems along the river. This information is collated and forms part of the annual works program. As can be seen from the attached cross sections, the channel has been expanding laterally on both banks on straight reaches and on the outside bank on bends. Some bed erosion is occurring but it is limited by the large size of bed particles (cobbles) and the armouring effect. Some bend cutoffs have occurred.

The 1995 boat inspection was the basis for the development of the Tumut River Management Strategy 2000 (TRMS) document. This document was the first major public document presented for the purpose of presenting a Management Strategy to address ongoing erosion and channel capacity problems in the Tumut River. A Value Management Study (VMS), involving many interested parties, was conducted in 1996 and endorsed a number of recommendations in the TRMS.
Rock protection works are a major component of the current Tumut River Annual Works Program. The other major components are snag alignment rather than removal, as was the situation up to 1985, and willow control. There are other small programs e.g. revegetation along the riparian zone forms part of the annual works.

One of the recommendations was that the annual budget should be $1m for 5 years to be used for the backlog of works and address recurrent problems. Thereafter the annual budget should be $0.5m for maintenance purposes. The recommended split for cost apportionment being 20% State Government, 40%, Snowy Hydro and 40% irrigators.

The annual budget was negotiated down to $850,000 with the cost sharing arrangement being State 20% (unchanged), 24% Snowy Hydro and 56% State Water.

Another recommendation of the VMS was to form the Tumut River Advisory Committee (TRAC). TRAC is the Community Consultative process that endorses and or modifies the annual works program prepared by the Department.

The TRMS commenced 1997/98 and officially ceased in June 2003. The TRMS has been extended for 1 year with the same agreed funding arrangements while the new Management Plan is being prepared.

The new Plan will cover a 10-year period with other issues to be considered in the ongoing 5 years.

Summary of Major River Management Issues

The major issues for the river are:

- With the average of $850,000 per year for the last 5 years, the rate of bank protection has not matched the rate of erosion. When the TRMS was developed in 1995 it was recognised that there was a backlog of 5.5 km of rockwork to be completed with a recurrent rate 1.2 km (total 11.5 km for the 5 years). Since the report was prepared a total of 26.8 km of rockwork has been completed to June 2003. It is now estimated that approximately 23.4 km of erosion control works need to be carried out. We have gone backwards.
- There are currently 6 claims for compensation from landholders totalling upwards of $2.4m. The claims are predominantly based on impacts of managed high flows by the Department since the completion of Blowing, causing erosion, loss of production, and waterlogging. The claims have been assessed and the assessor is currently dealing with the claimants on behalf of the Department.
- The landholders have been pushing for some time for a reduction of high flows in the river during summer and complemented with increased winter flows.
- The recent Scoping Study for the reduction of high flows addressed a number of options. The best case scenario cost wise of diverting water through Tantangara was in the order of $250m.
- The landholders support erosion control through increased funding above the current annual $850,000 budget for rock protection works, and continuing that funding beyond June 2004. If an undertaking was given that this would occur, one of the claimants has indicated that his claim may be dropped.

Prepared by:-

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Murray – Murrumbidgee Region, DIPNR
October 2003.
Attachment A

Grounds for Objection to the Tumut River Improvement District

1. Part of the Snowy River Scheme provides for the diversion of a considerable volume of water into the Tumut River for Hydro-electricity development and irrigation.

2. To carry this extra water it is imperative that the Tumut River be snagged and cleared of all impediment and other necessary improvement work be carried out to provide for this extra water, the Tumut alluvial lands would be subject to frequent flooding and consequent erosion of valuable soil.

3. As water for irrigation is of a greater importance to the farmers of the Murrumbidgee Irrigation Area, than the farmers of the Tumut Flats, to ask the Tumut farmers to bear any cost is unreasonable.

4. That the advantages to the farmers on the Tumut flats would be problematical.

5. In the Tumut River Improvement District, as set out by the Water Conservation and Irrigation Commission, the area proposed to be rated includes many acres not affected by past floods.

6. Therefore, all things taken into account, this national work becomes a Government responsibility; and your petitioners therefore pray that the cost, or even part of the cost should not be borne by the landowners occupying the Tumut River flats which would be unjust.

Shelleys Creek

Shelles Creek runs parallel to the Tumut River along the Tumut’s floodplain on the eastern side. Geomorphically, it is 3 things:

- a palaeochannel of the Tumut River
- a flood runner
- a small intermittent creek with a small catchment in the hills to the east

It can be easily seen on air photographs taken just after large floods that remove fine sediment and vegetation that may have accumulated between floods. These flood runner flows expose the armoured cobble bed of the Tumut River palaeochannel. The flood flows have also caused bend cutoffs so Shelleys Creek now has a lower sinuosity and a steeper slope than the Tumut.

One option investigated for reducing the expansion of the Tumut River was to put some of the irrigation releases down Shelleys Creek to take pressure off the Tumut. However, due to the discontinuous nature of the creek, a lot of earthwork would have been required. Also, the resulting steep ‘canal’ would have to be rock or concrete lined to prevent it from eroding in the same way as the Tumut. Along with the major environmental impact and purchase of valuable land, these things made the option far more expensive than the ongoing Tumut River bank erosion control program or even large pipes (also investigated).

David Outhet
THE TARCUTTA RIVERCARE PROJECT

TARCUTTA CREEK CATCHMENT COMMITTEE

Project Duration: 2.5 years (not including initial negotiations to receive money).
Total cash budget: $620,000
Total cash and in-kind budget: $1,380,000

Science behind project:
- This has (impressively) ranged from the broad to fine scales. (Even today, few catchments have such information available at variable scales).
- Within the Murray-Darling basin, the Murrumbidgee was targeted as a high priority.
- Within the Murrumbidgee the Upper and Mid Murrumbidgee were identified as areas contributing the greatest amount of sediment from in-stream (or connected) sources.
- Within the Upper & Mid catchments Tarcutta was seen to have the most informed and prepared community ready to adopt a large-scale project.
- Within the Tarcutta catchment funding was only given to stream-bank/stream-bed erosion and the erosion of connected gullies.
- Within the in-stream areas, particular reaches were targeted based upon their ecological condition (which was assessed by biota (including native and introduced plants and macroinvertebrates) and geomorphology).
- Initially invested centred around “hotspots” as these were the obvious areas to see and treat.
- Interestingly, during the project the community adopted the concept of giving higher priority to those areas that weren’t eroding, i.e. Rutherford’s stream prioritisation theory. This may be the first time ever in Australia that the theory of stream restoration has been adopted and implemented.

Note: In terms of the amount of science used at each project site, it would have to be described as “none to minimal”. Once the prioritisation information had been used and there was land-holder interest and support to conduct works at a “priority” site, there was usually no further use of science, scientific methods, any technical geomorphic surveys or even monitoring (other than photos) to quantify changes at the site post-works. So far, the experience of officers (either Rivercare, Landcare or Soilworks) is relied upon most heavily in making design decisions on-site. This is of course poor. Essentially we are using experience-based guesswork to design works or select the scale of works (i.e. percentage of willow control to be conducted annually).

Question: What can academic geomorphologists provide (e.g. decision tools) so that their wealth of detailed knowledge can guide the designs of works at specific sites? i.e. How can we improve on our “suck-it-and-see” method?

For getting information, or dropping-off ideas, please contact:
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The Tarcutta Creek Catchment Committee is nearing completion on an innovative and targeted project aimed at improving water quality in the Tarcutta catchment. The project is based on implementing the Tarcutta Rivercare Plan.

The Tarcutta Creek is a 170,000 ha catchment on the South West Slopes of NSW and is part of the Murrumbidgee Catchment.

The Tarcutta community received a major grant to undertake targeted works as both the local community and government authorities recognised that the Tarcutta Creek was a major source of nutrients and sediments within the Murrumbidgee catchment and the Murray Darling Basin.

The project is the result of 10 years of community efforts towards improving the health of the Tarcutta creek catchment. This was initiated with the preparation of the Rivercare plan, followed by intensive ecological research as well as lobbying for support funding and culminating in extensive on ground works.

The project is unique in that way in which it has struck a balance between the community’s desire to target environmental hot spots and research findings on protecting the best sections of the creek.

The project has offered landholders incentives to change their land management practices and to undertake activities that are essential in the rehabilitation of the Tarcutta Creek system. This has included fencing off creeks and gullies to control stock access, providing off creek water storage, stabilising eroding creek banks and gullies, undertaking strategic willow control and revegetating using native trees and shrubs.

Over the past 24 months the project has encouraged more than 100 landholders (approximately 40% of the total farming community) to undertake Rivercare projects on their own properties. As a result, the project has been instrumental in the protection of over 107 km of stream and flow lines in the Tarcutta catchment. This has included more than 126km of fencing and the planting of approximately 87,000 native trees and shrubs.

The project has been well received by the Tarcutta community with landholders seeing both the productivity and environmental benefits of undertaking works on their property and in working with their neighbours.

One of the major successes of the project has been the innovative means in which it has attracted the majority of landholders with creek frontage, including landholders not previously involved in Landcare, to participate in the project.

Cherie White
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