Department of Primary Industries Water

Snowy River Recovery: Snowy Flow Response Monitoring and Modelling Program

Strategy for the Snowy River Increased Flows 2015-16

August 2015

Introduction

Environmental water is delivered everyday to the Snowy River below Jindabyne as part of the Snowy River Increased Flows (SRIF). This factsheet outlines the details of the release strategy for the Snowy River Increased Flows for 2015-16.

The water available for the Snowy River is dependent on the climatic conditions in the Western Rivers, and will vary from year to year.

The total annual target for releases from Jindabyne steadily rose from 10.5GL in 2002-03 to a maximum of 181.6 GL in 2013-14 (Figure 1).

In 2015-16, a total of 150.64 GL was initially identified for release in 2015-16. The 150.64 GL volume includes an allocation of 141.64 GL from the Snowy River Increased Flows (SRIF) plus a base passing flow of 9GL, with 0.5 and 8.5 GL from delivered from the Mowamba Weir and Jindabyne Dam respectively. An over release of 0.8GL to the Snowy River in 2014-15 will reduce this year's target by this amount.

In addition, due to a natural spill event in 2012-13 which led to 16GL of additional water being delivered to the Snowy River, 8GL is being paid back by 2GL/year for four years commencing in 2015-16.

This results in a revised operational target of 147.9 GL to be released to the Snowy River during 2015-16.

Aims

The aims of this fact sheet are to present:

1. The mean daily, peak hourly and monthly total hydrographs for the 2015-16 environmental flow regime for the Snowy River below Jindabyne Dam, and
2. The likely environmental outcomes from the 2015-16 release strategy.

The annual environmental objectives are designed to meet the long term environmental water outcomes for the Snowy River.

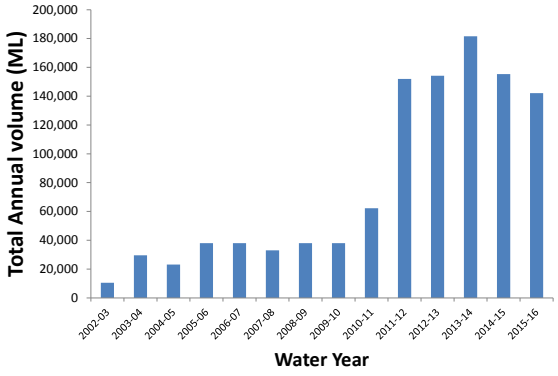

Figure 1. Total annual water targets for the Snowy River Increased Flows 2002-03 to 2015-16.

Flow management

In 2013-14 and 2014-15 the "natural flow scaling" method formed the basis of the release strategy to the Snowy River (Reinfelds *et al.* 2013; Williams and Reinfelds 2013; Williams 2014; Coleman and Williams 2014).

The premise of the flow- scaling method is to deliver environmental water to mimic the natural hydrological cues of a Snowy Montane River. The flow scaling approach is again the basis for the flow targets in 2015-16.

Environmental water can be delivered to the Snowy River via two locations within the Snowy River below Jindabyne, either via (i) the Mowamba Weir and (ii) Jindabyne Dam.

The engineering works at Jindabyne Dam provide a unique opportunity to deliver some world class outcomes for environmental water delivery to the Snowy River.

There are two key components to the engineering works that allow large flexibility in the operational delivery of environmental water, these being:

- flows up to 5,000 MLd^{-1} can be easily programmed into a daily flow sequence to introduce a high degree of natural flow variability; and
- within channel flood flows of more than 5,000 MLd^{-1} can be delivered via spillway gates, but require more careful management of lake levels (including a major shift in dam operations by Snowy Hydro Limited).

It was not until the 2013-14 water year that these infrastructure capabilities were implemented to their full potential, allowing generation of flow sequences reflecting natural patterns of daily flow variability together with peak flow rates with frequencies and durations reflective of natural flood events.

The 2015-16 release strategy will further utilise this approach to deliver more frequent small flood pulse events with flow peaks of up to 5,000 MLd^{-1} using the cone valves and one event of more than 5,000 MLd^{-1} via the spillway to better replicate natural high flow events. This spillway release is formally defined as a “Flushing Flow” and may occur in any year that the annual target exceeds 100GL.

Additionally, the 2015-16 flow strategy will also include an experimental release from the Mowamba Weir during May 2015. The Mowamba Weir actively diverts water between 3 and 523 $MLd^{-1,}$ this typically represents the 99th and 2nd flow percentiles.

The flow rates within this range are not sufficient to make physical changes to the morphology of the downstream Snowy River, but the chemical composition of the tributary water differs from that of the Lake Jindabyne, as it has higher concentrations of dissolved organic carbon and dissolved silica (Dye 2010; Coleman *et al.* 2011; Rohlfs et. al. in prep).

The experimental release will be undertaken to better understand the delivery of dissolved organic carbon to the Snowy River.

Key hydrological aspects of the 2015-16 strategy

The annual targeted volume of 147.9 GL from Jindabyne Dam is the 5th largest since the program began in 2002. The 2015-16 daily flow release strategy (Figure 2) has a number of key components and they are briefly described below.

The ‘hydrological-scaling’ approach for 2015-16 will deliver an enhanced seasonal signal in the monthly flow pattern (Figure 3) that is typical of a mixed snowmelt / rainfall river system characteristic of the Snowy Mountains, including:

- Sustained higher flow rates over winter and spring months, with six consecutive months between July and December discharging in excess of 10,000 ML per month. In September and October 2015 total discharge is greater than 20,000 ML per month. This provides a small sustained ‘press disturbance’ to the Snowy River and its estuary, which is a characteristic of the pre-regulation period.
- Low flow periods in late summer and autumn, with a minimum release rate of 71 ML/day that are punctuated by frequent small flow pulses reflective of natural summertime rain storms.
- Median daily flows for the year are 309 ML/day.
- An annual flood with a primary 8 hour peak of 93.871 m^3 per second (i.e. equivalent to 8,110 ML/day), and a total daily target volume of 5,335 ML to be delivered via the Jindabyne Dam spillway.
- Four additional smaller flood pulse releases (1,2,3 and 5), with an hourly release strategy to specifically increase the peak flow rate over an eight hour period. These four events will have peak flow rates sustained over eight hour durations ranging 22.554 – 40.090 $m^{3/}$second (equivalent to 1,949 – 3,464 ML/day). These releases will require a higher level of active management by Snowy Hydro Limited to generate the eight hour peaks and to obtain the overall daily target.
- Substantially increased flow variability between days, i.e. the river discharge is different from one day to the next.
- Complex multi-peak hydrographs that are typical of rivers in the Snowy Mountain.
- The flow sequence differs from the previous years and introduces variability between years, especially around the timing and magnitude of flood events. The key difference to 2012-13 and 2013-14 is that there are two winter high flow events during August 2015.

- An experimental environmental flow release from the Mowamba Weir will occur during May 2015. This release pattern will typically reflect the catchment inflows to the Mowamba Weir. Accordingly, the catchment inflows will require the daily flow targets to be reviewed at the end of this experimental release to ensure that the desired annual target volume is still delivered to the Snowy River.
- During the experimental release from the Mowamba Weir, an additional minimal base flow of 40ML/day will be released for the Jindabyne Dam.

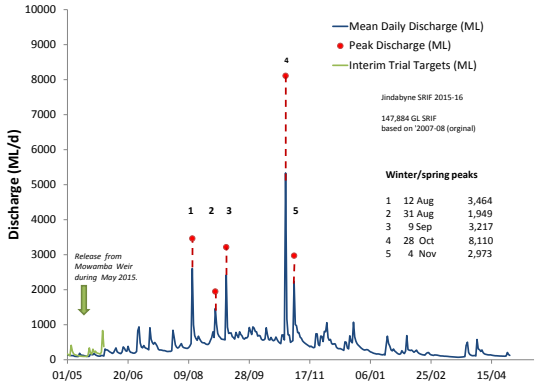

Figure 2. Snowy River below Jindabyne mean daily discharge pattern for 2015-16 (blue), with one primary (4) and four secondary (1,2,3,5) 8-hourly flow peaks (red dotted lines).

Note: daily flow targets have been revised between July-April to account for adjustments following experimental flow release in May 2015.

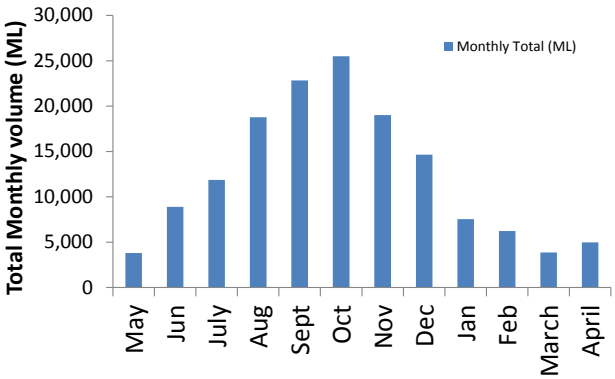

Figure 3. The proposed Snowy River below Jindabyne Dam total monthly discharge pattern for 2015-16.

Key environmental objectives for the 2015-16 SRIF strategy

The Snowy Water Inquiry sets out five key objectives for the Snowy River. These five objectives being:

(1) improving the temperature regime of river water;

(2) achieving channel maintenance and flushing flows within rivers;

(3) restoring connectivity within rivers for migratory species and for dispersion;

(4) improving triggers for fish spawning; and

(5) improving the aesthetics of currently degraded riverine environments.

These original objectives have been further developed in-order to incorporate new information and to better define the aspects of riverine health that are key to the recovery of the Snowy River.

Objective 1- Overall long term rehabilitation

Issue:

The fundamental question in relation to environmental water release strategies is:

"How do you make the most of the available water when significant flow alteration still occurs?" (Figure 4).

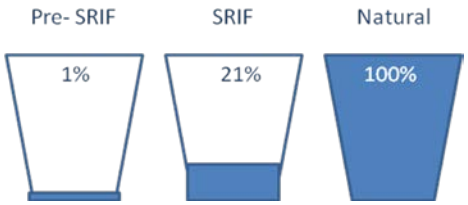

Figure 4. How do you make the most of the available water? Pre SRIF, SRIF and Natural mean annual discharge targets.

The long-term objective for an environmental flow regime based on 21% of MANF and natural daily and hourly flow sequences based on the flow regime of the Thredbo River is 'to facilitate the rehabilitation and evolution of the Snowy River below Jindabyne Dam into a smaller but healthy river.'

Over decadal to century long time scales, environmental water releases that mimic the flows of a smaller un-regulated snow-melt river will allow the Snowy River to slowly develop a size, shape and condition, similar to that of an unregulated Snowy montane river.

This over-all long-term objective implicitly recognises that:

- It is not possible to meet historical hydrological metrics for the Snowy River with one fifth of its former flow volume.
- It is not possible to restore or maintain the Snowy River to its former size with one fifth of its former flow volume.
- The in-stream and riparian habitat needs to be substantially improved in-order for major secondary and tertiary ecological responses to be observed, and habitat improvement forms the primary focus of the strategy in the early stages of the river recovery.
- A focus on understanding and repairing riverine and estuarine processes, where possible, is fundamental to ensuring long term ecological outcomes.

Long term expected outcomes:

- To facilitate the rehabilitation and evolution of the Snowy River below Jindabyne Dam into a smaller but healthy river.
- To mimic the natural hydrological characteristics of a smaller but unregulated Snowy montane river using the available water to:
    - re-introduce a higher degree of daily flow variability
    - re-introduce a montane seasonal flow pattern
    - re-introduce a high flow regime into the Snowy River (Figure 5)

Figure 5. Introducing a high flow regime in the Snowy River below Jindabyne is critical to improving habitat condition and the in-stream ecology (source: S. Williams).

Objective 2- Morphological change

Issue:

The Snowy River catchment has highly erodible granitic soils. The flow regulation of the Snowy River, coupled with land degradation, drought and bush fires, has resulted in the in-stream habitat becoming in filled by catchment generated fine sediment (i.e. clay, silt, and sand), and with the channel being less well defined.

This poor in-stream riverine habitat condition has been identified as a key constraint to river recovery including future improvement in the status of aquatic biota.

Long term expected outcomes:

- To develop a more defined river channel morphology within the former river channel (Figures 6 and 7).

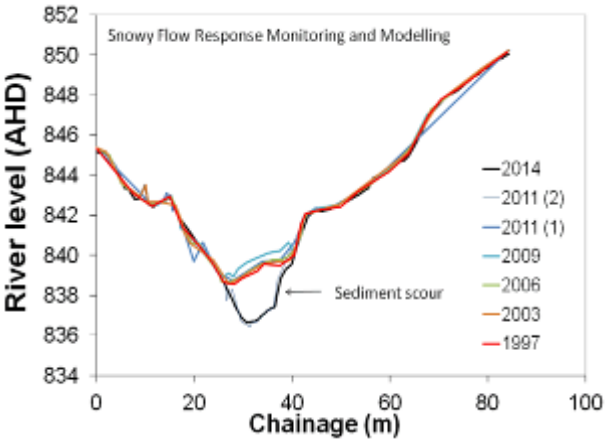

Figure 6. Localised change in channel morphology in the Snowy River downstream of the Mowamba River (Site 1- cross section 6) following the introduction of high flows in 2011 (source: S. Williams).

Figure 7. Changes in channel morphology in the Snowy River downstream of the Blackburn Creek (Site 4-Dalgety Uplands) following the introduction of high flows in 2011 (source: T: Rose and S. Williams).

Objective 3- River bed maintenance

Issue:

The bed of the Snowy River has been impacted by (i) the infilling of fine sediment and (ii) the increase in the abundance of periphytic algae. These responses are primarily attributable to limited high flow events and constant low flow rates (i.e. 25MLd^{-1}) following the development of the Scheme.

The reduction in riverbed quality limits the in-stream functions (i.e. such as primary production) and the ability to provide a suitable habitat for benthic bacteria, diatoms (Biggs 1996), aquatic macro-invertebrates, fish and Platypus.

Long Term Expected outcomes:

To change the composition and structure of the river bed from (i) a bed smothered in clay, silt and sand with limited interstitial spaces to a substrate with visually obvious cobbles, and with gravels, sands and obvious interstitial spaces (Figure 8).

To change the riverbed substrate from one with high abundance of (i) chlorophyll-a, and (ii) filamentous green algae to a substrate with low abundance of chlorophyll-a and primarily comprised of diatoms.

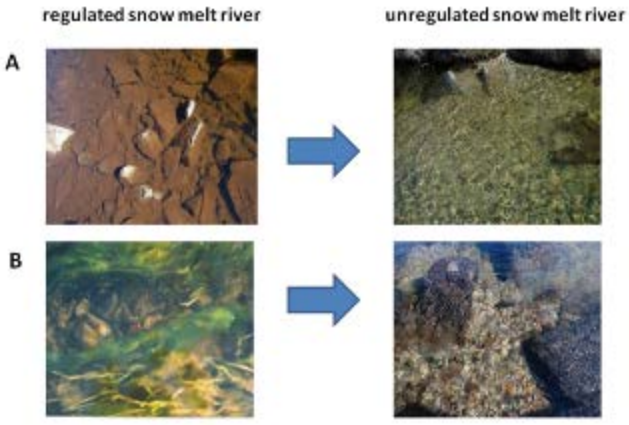

Figure 8. Visual comparison of the expected changes in the substrate condition of (A) pools and (B) Riffles in the Snowy River (source: S. Williams).

Objective 4- Primary productivity

Issue:

Carbon is a basic and important component of the aquatic food web. Carbon occurs in many forms in waterways, such as dissolved, fine and coarse particulate matter, and large woody debris. The delivery of carbon can stimulate the available food resources for bacteria, attached algae, plankton, water bugs, fish and higher trophic levels.

Prior to river regulation, carbon was delivered via (i) catchment generated runoff/inflow (Figure 9) or via (ii) the inundation of in-channel features, such as lower in-channel benches and riparian zone during higher flow events.

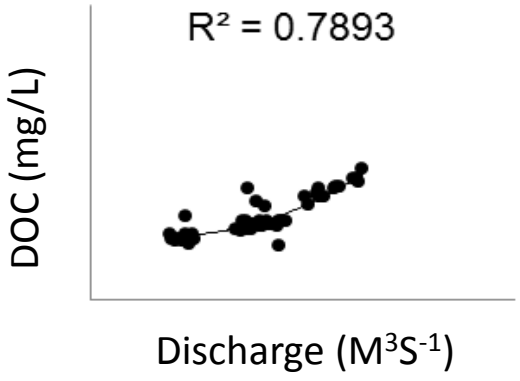

Figure 9. Significant relationship between river discharge and Dissolved Organic Carbon (DOC) concentration generated in the unregulated reaches of the Mowamba River during spring 2013 (source: Coleman *et al.* in prep.)

Jindabyne Dam now limits the quality and amount of catchment generated carbon delivered to the Snowy River (Rolfs et *al*. 2015; Rolfs *et al*. in prep; Coleman *et al.* in prep).

Dams often release lower concentrations of highly processed carbon that have "lower nutritional value" than the often complex carbon molecules generated from catchment runoff in undisturbed river systems.

Additionally, Jindabyne Dam also captures many of the higher flow events which influence the delivery of in-channel/riparian generated carbon. Many of the lower benches in the upper reaches are inundated at flow rates of about 1,500 MLd^{-1}.

The loss of multiple small to moderate peaks has potentially limited the delivery of carbon from these lower benches/riparian zone to the river. The likely reduction in primary productivity is likely to have reduced feeding opportunities to higher trophic levels in the aquatic food chain.

Simply, the high flow disturbance improves the habitat (i.e. the quality of the house) and the provision of carbon via (i) tributaries, (ii) catchment generated runoff or (iii) managed events that inundate lower in-channel benches provides the food resource (i.e. the refrigerator/pantry) for the aquatic ecosystem to recover.

It is anticipated that delivery via tributaries, catchment generated and managed high flow events will generate a higher quantum of DOC.

Long term expected outcomes:

To increase the delivery of higher concentrations of complex Dissolved Organic Carbon (DOC) to the Snowy River.

To increase the frequency of events that inundate the lower in-channel river benches, and/or the riparian zone.

To deliver higher DOC concentrations via environmental water from regulated downstream tributaries such as the Mowamba River.

To increase proportion of time heterotrophic primary productivity is greater than autotrophic productivity in the Snowy River.

Objective 5- Riverine and aquatic vegetation

Issue:
The regulation of the Snowy River had resulted in changes to the vegetation in the former river channel and the riparian zones:

- In habitats that infrequently became inundated, the ingress of terrestrial plants (i.e. *Leptospermum lanigerum*) into the former river channel has occurred (Figure 10).

- In lower elevation habitats that remained wet, but received few high flow hydrological disturbances, an increase in the abundance of aquatic plants (i.e. *Phragmites*, *Tyha*, *Carex* spp.) and weeds (i.e. Willows) occurred, effectively reducing the open water and running water habitat. The river effectively behaved like an upland wetland rather than a montane river.

Figure 10. **Ingress of *Leptospermum lanigerum* in the upstream riffle of the Snowy River downstream of the Mowamba River (Site 1-Jindabyne Gorge), October 2007, and the reduction in plant abundance following high flows, May 2015** (source: S. Williams).

Long term expected outcomes:

To limit the ingress of terrestrial plants into the former river channel of the Snowy River and to re-establish native aquatic and riparian vegetation communities (Figure 10).

The following subset of vegetation objectives are set for each meso-habitat.

Riverbed - To reduce the abundance of attached submerged macrophytes (i.e. *Vallisneria* and *Myriophyllum* spp.).

Open water - To increase the area of open water in the active channel, including greater riffle area.

Littoral edge -To establish a defined but narrow littoral margin of standing water aquatic plants (i.e. *Phragmites*, and *Schenoplectus* sp).

Lower bench -To increase the area of aquatic macrophyte cover of amphibious fluctuation tolerators (i.e. *Carex*, *Persicaria*, *Eleocharis* spp.) on the lower bench of the river channel.

Higher bench -To establish a diverse aquatic plant flora on the higher river channel (i.e. *Juncus* spp.).

River bank -To promote a diverse native plant assemblage of canopy (i.e. *Eucalyptus* spp.), shrub layers (i.e. *Leptospermum*, *Banksia*,

Hakea, *Grevillea*), and ground cover (i.e. *Poa and Lomandra* spp.) in the high elevation river bank meso-habitat.

In channel - To increase the amount of Large Woody Debris (LWD) within the river channel resulting from improved riparian vegetation condition via the re-introduction of mature native trees.

Objective 6- Thermal regime

Issue:

The management of thermal regimes of water in rivers can be categorized by either: (i) reduced water mixing opportunities attributable to a lack of higher magnitude events accounting for localised habitat temperature differences or (ii) the thermal properties of the water released differs substantially from the surrounding locality/ rivers (i.e. either too cold or warm). In the Snowy River, both of these issues are partly relevant to the thermal properties of river water.

Warm water releases

All releases from Lake Jindabyne to the Snowy River occur through infrastructure designed to draw water from the near surface of the lake (i.e. upper 5m of the water profile), meaning that the Snowy River is not affected by cold water pollution. However, at times of the year (i.e. autumn and winter) the water can be 4-8^{o}C warmer than the surrounding rivers in the Snowy Mountains.

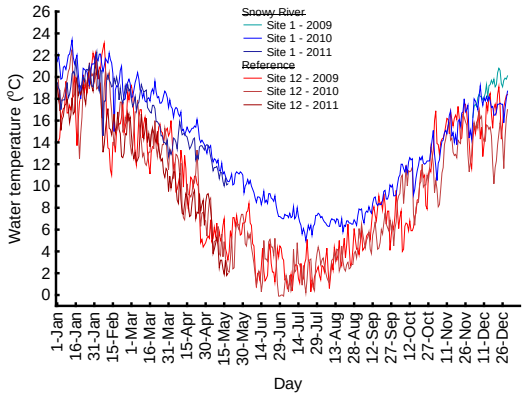

Figure 11. **Comparison of mean daily water temperature between the Snowy River in the Jindabyne Gorge (Site 1) and the Mowamba River (Site 12), 2009-2011.**

The warmer water could potentially disrupt ecological cues for aquatic biota, but the specific impacts have not been fully defined. However, the warmer water issue cannot be addressed with the current Jindabyne dam infrastructure.

Reduced water mixing

The impacts of reduced water mixing attributable to the loss of high flow events can be categorised into its effects on (i) deep water habitats and (ii) shallow water habitats.

In deeper river pool habitats there is a possibility of thermal stratification and low dissolved oxygen levels occurring in summer.

Previous experimental high flow summer releases to the Snowy River have demonstrated that: (i) mixing of the pool water can be achieved via relatively minor high flow events, (ii) mixing via high flows was transitory and (iii) thermal stratification of the river pools did not present a significant risk of anoxia in the deep pools of the Snowy River below Jindabyne.

Shallow water habitats can be exposed to extreme water temperature variability. However, the higher and variable base flows punctuated by regular events may limit: (i) the excessive heating of some of the shallow water habitats during summer and potentially limiting lethal water temperatures to aquatic biota and (ii) the freezing of shallow littoral habitats in winter.

Long term expected outcomes:

To provide a thermal regime that has similar characteristics of an unregulated Snowy Montane River.

The following sub-set of thermal objectives are set for each meso-habitat.

River pools - To provide high flow events to allow sufficient mixing of the water column in pools.

Shallow standing water - To provide sufficient daily flow variability to allow sufficient mixing of the water column.

Riffles - To provide a base flow during summer that limits the exposure of riffle habitats to extreme air temperature.

Objective 7- Aquatic Macro-invertebrates

Issue:

The regulation of the Snowy River had resulted in a change in the composition and abundance of the aquatic macroinvertebrate fauna, from one dominated by Caddiesflies, Stoneflies and Mayflies, to one dominated by sediment tolerant taxa such as worms and non-biting midges (i.e. Chironomids) (Russell *et al.* 2010).

The former aquatic macro-invertebrate fauna of Caddiesflies, Stoneflies and Mayflies were supported by free flowing high energy riverine

environments with clean substrates. Aquatic worms, Chironomids and Caenids are favoured by low energy habitats with silty substrates. These sediment tolerant taxa became abundant following river regulation (Russell *et al.* 2010).

Long term expected outcomes:

To increase the abundance of aquatic invertebrate fauna (i.e. Stoneflies, Caddisflies and Mayflies and Beetles) commonly found in unregulated Snowy Montane Rivers with gravel and cobble substrate.

The following sub-set of aquatic macro-invertebrate objectives is set for each meso-habitat.

In riffles – To increase the abundance of Caddiesflies (i.e. Conoesucidae, Glossosomatidae) Mayflies (i.e. Leptophlebiidae, Colobruscoidae (Figure 12)) and Riffle Beetles (i.e. Elmidae) in the Snowy River.

In river pools - To increase the abundance of Mayflies (i.e. Baetidae, and Oniscigastridae) and Stoneflies (i.e. Gripopterygidae) in the Snowy River.

In pools and riffles – To reduce the abundance of aquatic worms, midges and Caenids.

Figure 12. **Invertebrates like the Mayfly Colobruscoidae are expected to increase in abundance in the riffles of the Snowy River.**

Objective 8a- Fish assemblages- upper Snowy River

Issue:

The freshwater fish assemblages in the upper Snowy River (i.e. above Snowy Falls) are highly altered (Gilligan and Williams 2010). Typically the native fish in these reaches comprise four species Long finned and Short finned Eels, the Mountain Galaxid complex (*G. olidus, G. Teranoa*, and *G.ornatus)* (Raadik 2014) and the River Blackfish.

All of these taxa have been previously recorded in low abundances across the upper Snowy River catchment.

River Blackfish are confined to the left bank lower gradient tributaries of the Delegate, Little, and Bombala rivers, but were historically observed in the Snowy River in the Dalgety Uplands. Ecological modelling by Gilligan (unpublished), indicates that the Dalgety Uplands should support River Blackfish populations.

However, no River Blackfish have been recorded in the main stem of the Snowy River between 2000 and 2015 (Gilligan and Williams in prep).

Figure 13. **(A) River Blackfish (*Gadopsis marmoratus*) a once common species in the Snowy River, now has a very restricted distribution and (B) Electro-fishing for River Blackfish in the Delegate River 2015.**

The absence of River Blackfish in the main stem and the fact they have a very small home range (i.e. <50m), and may not easily disperse indicates that recovery of River Blackfish will be slow or not occur at all.

The freshwater eels contribute the largest fish biomass in the upper Snowy River. Other than the two freshwater eels, it is highly unlikely that any other catadromous fish (i.e. Australian Bass) would have naturally occurred in these upper reaches of the Snowy, as they typically occur below 200m elevation in other catchments.

Exotic fish such as Red fin, Mosquito Fish and Trout occur in these upper reaches.

Long term expected outcomes:

To reflect the more diverse native fish community composition of the unregulated tributaries in the main channel of the upper Snowy River.

The following sub-set of native fish flow objectives are set for each meso-habitat.

- In riffles – To increase Long-Finned Eel abundance and biomass.
- In pools – To increase the abundance and biomass of Mountain Galaxid, short finned eel and possibly River Blackfish.
- To reduced the abundance of the exotic fish taxa such as Red Fin and Mosquito fish.

Objective 8b- Fish assemblages- lower river

Issue:

The freshwater fish assemblages of the lower Snowy River are highly altered, but differ from the Upper Snowy River. A longitudinal ecological pattern of greater fish diversity is measured in the lower altitude reaches. This longitudinal pattern is exhibited in lower altitude rivers world-wide.

Long term expected outcomes:

To reflect the native fish community composition of the unregulated tributaries in the main channel of the lower Snowy River.

The following sub-set of native fish flow objectives are set for each meso-habitat.

- In riffles - To increase Long-Finned Eel abundance and biomass.
- In pools – To increase in the abundance and biomass of Mountain Galaxid, short finned eel and possibly Australian Grayling.
- In the Estuary – To sustain a viable population of Australian Bass and Estuary Perch occurs.

Objective 9- Large scale fish passage

Issue:

At this stage in the rehabilitation program, large scale fish passage is not seen as a high priority objective.

Large scale fish migration is a lower priority as:

- The migratory freshwater fish species (i.e. Eels) are currently able to move through to the upper system, albeit that they may utilise more energy to traverse the river under lower flow rates.
- The other freshwater species, Mountain Galaxid complex and River Blackfish in the upper Snowy River have small home ranges, and will not make large scale movements.
- The catadromous fish species (i.e. Australian Bass, Australian Grayling) in the system are naturally limited to lower elevations waters (i.e. typically below 250mADH) in coastal catchments and are unlikely to move to the colder higher altitudes. The thermal regime, estuarine salinity dynamics and events via tributaries appear to be the key driver for large scale movement in the lower reaches.
- The catadromous fish may not be able to traverse the large natural barriers, including Snowy Falls, at the flows available for release. It's possible that large natural floods, beyond those considered 'safe' for a regulated release, would be required to achieve large scale fish passage along the Snowy River. However, these high flows during natural events and the high flow releases will provide opportunities for local scale movement.

Long term expected outcomes:

To increase the magnitude and variability of high flow events to facilitate fish movement in the Snowy River.

- To improve the condition (i.e. ↑weight/ ↓lesions) of migratory fish species in the Snowy River as large scale movement will require less energy attributable to drowning out minor hydraulic features.
- To increased opportunities for localised movement of freshwater fish in the upper and lower Snowy River.

Objective 10- Platypus

Issue:

Platypus are a cold water species and are commonly found throughout the waterways of the Snowy Mountains region, particularly where the habitat condition of the river/ stream is still intact.

The condition of the (i) habitat and the (ii) availability of aquatic macro-invertebrate resources are a key determinate of the presence of Platypus (Scott and Grant 1997).

The Snowy Mountains Scheme has had an impact on the local Platypus community by substantially reducing quality of the habitat and the availability food resources.

Platypus typically feed in water between 1-3m deep (Grant, 1982), typically in reaches with riffle pool sequences. In these types of riffle meso-habitats the quality of habitat and the quantum of habitat have significantly declined since the development of the Snowy Mountains Scheme.

Platypus typically feed in slow to moderate hydraulic meso-habitats, with clean substrate. Daily and seasonal flow patterns need to be able to complement local scale movement, foraging, and breeding activities.

Expected outcomes:

To increase the abundance of Platypus in the Snowy River following the re-introduction of a high flow and more variable daily flow regime.

- To increase opportunities for localised Platypus movement in the Snowy River by the provision of more variable flow regimes.
- To increase opportunities for feeding within riffles/runs following the expansion of running water habitat.
- To increase opportunities for breeding by providing higher and variable seasonal flows for lactating females during December-January.
- To limit predation of Platypus by foxes/dogs by the improved riparian vegetation habitat generated from a more variable flow regime.

Objective 11- Estuary health / Salinity dynamics

Issue:

The Snowy River estuary is highly complex, but has significantly changed since the construction of the Snowy Mountains Scheme. Mean Annual Natural Inflows to the lower Snowy River have declined to 65% of MANF (Morton *et. al* 2010).

The reduction of inflow to the estuary has significantly altered the salinity dynamics (McLean and Hinwood 2013; McLean and Hinwood 2015), entrance condition and local inundation patterns of the surrounding wetlands/riparian zones.

Under low flow conditions the Snowy River, above its confluence with the Brodribb River, is strongly stratified with saline waters (McLean and Hinwood 2013). The strong salinity gradient in the estuary appears to be unsuitable for Australian Bass recruitment, with limited areas of between 10-12ppt salinity available.

It is estimated that the Snowy River estuary entrance closed twice in over 200 years pre-SMS, with 12 closures occurring in the 47 years post the Scheme, and with 8 closures during the 2000-10 drought (McLean and Hinwood unpublished).

Long term expected outcomes:

Given that the Snowy River estuary is a very complex system, with varying mixing rates between the river stem, lakes and wetlands, a press disturbance will be delivered to the Snowy River estuary during winter and spring. The objectives are:

- To allow for a greater period of freshwater mixing in these estuarine habitats.
    - To create a less severe salinity gradient in the upper reaches of the Snowy River Estuary, if possible.
    - To provide a defined salinity gradient of between 10-12 ppt in the estuary to facilitate Australian Bass reproduction.
- To assist with the maintenance of the estuary entrance condition over winter-spring.
- To assist in the inundation of very low lying riparian / estuarine wetland vegetation.

Objective 12- Aesthetics

Issue

Aesthetic assessments of rivers at a landscape scale are at an early developmental stage, but typically consider channel morphology, riparian vegetation, flow regime and visual clarity. Empirical relationships between river flow and scenic beauty scores suggest that river discharge strongly influences river aesthetics quality (Pfluger *et al*. 2009).

Perceptions of river health and ‘suitability’ for human use can deviate from ecological goals.

Aesthetic impacts typically include; high turbidity, water colour, increased aquatic weeds and algae, or the loss of ecosystem attributes that people identify with including flow habitats, geomorphic features, and iconic river species.

Aesthetic impacts are much more difficult to quantify than ecological variables, and as such

studies have not been carried out in the Snowy Mountains.

High turbidity in regulated rivers is often a consequence of increased fine sediment inputs and low export rates (Petts 1984). Although increased flows will inevitably mobilise fine sediment and temporarily increase turbidity (e.g. Williams and Coleman in prep), as fine sediment is reduced under a high flow regime, so will turbidity levels. However, it may be considerable time before flushing flows improve water clarity.

Long term expected outcomes:

To improve the aesthetic value of the riverine habitat of the Snowy River.

- To ensure high water clarity.
- To ensure a clean substrate, low in silt and benthic algae.
- To ensure a defined river channel, that is inclusive of open water and high hydraulic diversity.
- To ensure a complex native riparian vegetation composition.

Objective 13- Cultural recognition

Issue

Five aboriginal communities have a strong connection to the Snowy River and the waterways of the Snowy Mountains (Connolly and Williams 2014a).. These communities are:

- Maneroo-Ngarigo people
- Bidwell Maap people
- Southern Monero people (Monero Ngarigo / Yuin / Bolga)
- Wongalu people
- Wiradjuri people

These five traditional groups are not permanent residents of the upper Snowy, but are located throughout South-Eastern NSW and Eastern Victoria. Traditionally, these five communities would access the Snowy mountains waterways for various purposes.

The health of the Snowy River is a major concern of the Aboriginal people of this region.

Long term expected outcomes:

The interim cultural water objectives (Connolly and Williams 2014b) for the Snowy River act as a starting point for the further development of long term cultural water objectives. The overarching cultural objectives include:

To inform Aboriginal stakeholders of the Snowy River Increased Flows and the Snowy Montane River Increased Flows program.

To provide greater cultural recognition, including the recognition of the Snowy Rivers Traditional Nations values and practises for the preservation of cultural water dependants values and sites, where possible within the existing legal framework

To link relevant cultural and environmental water objectives, where appropriate.

To provide greater cultural representation, and,

To gain a longer-term understanding of the waterways in the Snowy Mountains by integrating traditional knowledge with contemporary science.

More detailed cultural objectives are provided by Connolly and Williams (2014b), but the broader objectives are essential in order to develop a holistic and integrated release strategy in the Snowy River.

In recognition of the five traditional Aboriginal groups associated with the Snowy Mountains Rivers, the five 2015-16 winter-spring high flow releases have been called:

1. Djuran (running water)
2. Waawii (Water Spirit)
3. Billa Bidgee Kaap (Big Water Season)
4. Wai – Garl (River Black Fish)
5. Bundrea Nooruun Bundbararn (Waterhole

Big Lizard)

Conclusion

The 2015-16 SRIF strategy attempts to document the hydrological characteristics of the releases and the anticipated ecological responses to the environmental water.

The use of the hydrological-scaling approach for the 2015-16 water year will allow for: (i) the introduction of a flow regime that is similar to a snow melt river, within the available annual allocation, (ii) partly address the key long-term ecological objectives, (iii) allow the engineering capabilities at Jindabyne Dam to be fully tested, and (iv) incorporate an adaptive management approach via the trial of tributary releases to supplement the outcomes of the high flow regime delivered via the dam.

Significant improvements in the condition of the Snowy River have occurred particularly since the introduction of the high-flow regime in 2011, but overall, the environmental water releases to the

Snowy River will need to continue over many decades in-order to meet the various longer term environmental objectives.

Finally, the annual SRIF strategy recognises that a smaller but healthier river is the target condition. This improved condition will be delivered by providing a new hydrological regime that repairs related river processes.

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More information

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