Strategy for the Snowy River Increased Flows 2017-18

Introduction

The Snowy Water Initiative (SWI) is an agreement for water recovery and environmental flows between the NSW, Victorian and Australian governments, and Snowy Hydro Limited (SHL) which is set out in the Snowy Water Inquiry Outcomes Implementation Deed 2002 (SWIOID 2002). The SWI provides three main environmental water programs as part of rebalancing the impacts of the Snowy Hydro-electric Scheme on montane rivers. These three programs are increased flows for: (i) Snowy River, (ii) River Murray, and (iii) Snowy Montane Rivers. The NSW Government is responsible for the implementation of the SWI.

In order to improve the health of the Snowy River in south eastern Australia, environmental water is delivered everyday below Jindabyne as part of the Snowy River Increased Flows (SRIF) program (Figure 1).

This document outlines the details of the environmental water release strategy for the Snowy River, 2017-18. This annual SRIF strategy forms part of the commitment of the NSW Government to implement the SWI during 2017-18.

Aims

The aim of the document is to:
1. State the set of ecological principles for flow based river rehabilitation upon which the strategy is based,
2. Define the ecological objectives and the likely environmental outcomes from the annual release strategy,
3. Briefly describe the temporal changes to SRIF hydrological targets since the program was implemented in 2002, and
4. Define the annual release strategy for the environmental flow regime for the Snowy River below Jindabyne Dam.
Ecological process: the basis for flow based river rehabilitation.

Aquatic biota have adapted life history strategies to local climatic and hydrological conditions (Bunn and Arthington 2002; Baumgartner et al. 2015). Mimicking the varied characteristics of the local hydrology is a key driver to river recovery from flow regulation.

Understanding the flow related river processes that support: (i) habitats, (ii) resource availability and productivity (iii) reproduction and recruitment and, (iv) biotic dispersal form the ecological basis of the strategy and guides the setting of rehabilitation objectives for the Snowy River (Figure 2).

The key riverine processes considered important are stated as a set of overarching ecological principles. These over-arching ecological principles for environmental water management include:

- River dynamics including high daily flow variability and hydraulic diversity are required to meet a wide range of ecological water requirements including aquatic biota and their various life stages.
- River discharge is managed to repair flow related river processes and applied at a whole ecosystem scale rather than for individual species.
- Hydrological disturbance and the repair of instream habitat (Coleman and Williams 2016) provide a template for recovery of aquatic biota and needs to be implemented early in the recovery process in order for complementary measures (i.e. provision of basal resources via tributary releases) to be successful.
- The repair of instream habitat is important to provide instream nutrient translocation sites to support benthic biofilms (Baldwin et al. 2014) and provide a more efficient flow of energy to higher trophic levels and support third order ecological responses, i.e. recruitment.
- The focus on the type of nutrient translocation site may differ based on the river type, but should focus on dominate hard surface area i.e. montane reaches—cobble substrate, and lowland reaches—large woody debris (LWD).
- The provision of basal resources, such as dissolved organic carbon (DOC) and dissolved silica (DSi) are required to stimulate the food web to maintain viable populations. These types of basal resources are unlikely to be made available via managed dam releases, but rather sourced from unregulated tributaries (Rohlfs et al. 2015; Rohlfs et al. 2016; Williams et al. in prep) or floodplain contributions (Figure 3).
- The landscape is not uniform, and understanding the bio-geochemical processes such as the source and uptake of basal resources (i.e. “hot spots” or “hot moments” (Figure 3)) provides an opportunity to improve productivity and target rehabilitation (McClain et al. 2003; Rohlfs et al. in prep).
- Understanding river productivity is a major consideration for system wide success using environmental water.
- Consideration of flow related reproduction cues should be considered in conjunction with recruitment requirements and success, when allocating water across a year. Potentially, substantial energy may be consumed by aquatic biota for reproduction, but recruitment may not be successful unless basal resources are available post reproduction.
- Provision of increased recruitment opportunities are required to maintain viable populations, but require the provision of basal resources (i.e. DOC and DSi) to maintain the new recruits.
- Consideration of the organisation of populations across multiple spatial scales is required, including functional sites, landscapes and networks (Poiani et al. 2000). Some specific areas of the riverine landscape may be more...
significant in supporting viable populations (Kiffney et al. 2006).

- Dispersal mechanisms need to be considered if the taxa of interest are absent or in low abundance in the regulated river. Particularly, if the ecological end points require the dispersal of aquatic biota from unregulated tributaries to a regulated river. This requires the:
  - active management of tributaries, and the junction of tributaries with regulated rivers.
  - consideration and management of hydraulically induced barriers.
  - consideration of active re-location of target taxa to the significantly improved habitat condition of the regulated river. This active management should only be considered late in the rehabilitation process, once it’s clear that taxa are unlikely to disperse from tributaries.

- Flow may not always be the primary driver for improvement in ecological function or status. Other factors, such as water temperature, are significant drivers of ecological processes, i.e. decomposition, respiration, production reproduction and movement (Bothwell 1998; Carr et al. 1997; Caissie 2006).

- The management of rare taxa per se does not provide the primary driver for flow strategies, but will be achieved by addressing the above river rehabilitation principles (i.e. river processes rather than the management of a series of rare taxa). The management of rare taxa will be achieved by adopting functional variable flow regime, i.e. akin to functional landscapes/networks described by Poiani et al. (2000).

- A greater understanding of life histories is required than currently available. The limited life-history knowledge provides great uncertainty in the setting of ecological targets, particularly where large investment occurs on limited understanding of basic ecology.

- The sequencing of priorities will be important to implement a long term flow regime and will change as the primary objectives are achieved. Initially, a higher priority will be given to flow objectives that relate to habitat maintenance or improvement. Flow objectives relating to connectivity and productivity are only likely to be achievable/ maximised once in-stream habitat is considerably improved.

- Ecological rehabilitation takes time (i.e. decades). Use the time to experiment with releases and build the scientific evidence that allows future adaption.

- There is a need to focus on holistic river management rather than just water allocation targets and environmental water. The prerequisite conditions (i.e. habitat suitability), need to be in-place for significant environmental water achievements.

<table>
<thead>
<tr>
<th>Order</th>
<th>Response Type</th>
<th>Management Priority</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>River hydrology</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>River hydraulics and physical processes</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Bio-geochemical processes</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Biological responses</td>
<td></td>
</tr>
</tbody>
</table>

Figure 2. Ecological rehabilitation theory and river processes forms the basis of the Snowy River program. The early stages of the program focus on improving hydrology, hydraulics, habitat and biochemical processes rather than expecting immediate biological responses in higher trophic levels (i.e. 1 through 4, rather than 1 and 4).
Understanding the flow related river processes that support (i) habitats, (ii) resource availability and productivity (iii) reproduction and recruitment and, (iv) biotic dispersal forms the basis of the strategy and the setting of rehabilitation objectives for the Snowy River. Over the long term, the sequencing of objectives and emphasis will generally follow the above order for implementation.

Key environmental water objectives for the SRIF strategy

The Snowy Water Inquiry Implementation Outcomes Deed 2002 sets out five key environmental objectives for the Snowy River:

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 although important in their own right, do not provide a comprehensive rehabilitation framework. These original SWIOID 2002 objectives have been further developed in-order to incorporate new information and rehabilitation ecology theory to better define the aspects of riverine health that are key to the recovery of the geomorphologically confined Snowy River. In developing a more comprehensive set of ecological objectives, the focus of the strategy is to repair the flow related river processes that support:

- habitats (i.e. hydraulic diversity, water mixing, substrate condition, channel morphology, thermal regime, LWD availability, and entrance condition)
- resource availability (i.e. DOC, DSI) and productivity
- reproduction and recruitment, and,
- biotic dispersal.

Issues relating to aquatic biodiversity outcomes associated with hydrological alteration will be achieved via re-instating these key riverine flow based processes (Williams 2016).

For the Snowy River, it is envisaged that the following ecological benefits will be realised by the release of environmental water:

- To mimic the hydrological characteristics of a smaller montane river.
  - To re-introduce a higher degree of daily flow variability.
  - To re-introduce a montane seasonal flow pattern.
  - To re-introduce a high flow regime.

Habitat

- To provide a physical in-stream habitat that reflects the hydraulic characteristics of a smaller montane river.
  - To increase the wetted area within the river channel.
  - To increase the open water habitat within the river channel.
  - To increase the hydraulic diversity within the river channel.
  - To develop a more defined river channel morphology within the former river channel. The new channel
strategy reflects the long term volume of water released.
  - To increase the depth to wide ratio of pools.
- To provide greater frequency of water mixing within in-channel habitats.
  - To mix the water column in the larger pools in the upper reaches.
  - To allow for a greater period of freshwater mixing in 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 assist with the maintenance of the estuary entrance condition over winter-spring by the provision of a press flow disturbance.
- To provide a thermal regime that has similar characteristics of an unregulated Snowy Montane River. The following sub-set of thermal objectives is set for each mesohabitat.
  - River pools- To provide high flow events to allow sufficient mixing of the water column of deeper pools (i.e. >4m).
  - Shallow standing water- To provide sufficient daily flow variability to allow sufficient mixing of shallow water habitats to limit freezing in winter.
  - Riffles- To provide a base flow during summer that limits the exposure of riffle habitats to extreme air temperature.
- To actively manage a-seasonal warm water regime in the Snowy River by releasing colder tributary water. A release in autumn is expected to reduce water temperature by 2-4°C and provide similar thermal properties of an unregulated Snowy Montane River.

**Resource availability and productivity**

- To provide regular scour of the river substrate 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.
  - To increase the grain size of the river substrate.
  - 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.
- To promote energy transfer from biofilms to higher trophic levels via the creation of biochemical hot moments by:
  - increasing biofilm respiration rates, and
  - shifting bacterial enzyme profiles

This will be undertaken by (i) managed high flow pulse disturbances and (ii) tributary press disturbances.

**Connectivity and biotic dispersal**

- To improve hydrological and ecological connectivity along the water source.
  - To increase the hydraulic connectivity between
    - headwater tributaries and the regulated lower altitude river reaches
    - pools within the regulated river, and
    - instream habitats and the riparian zone.
  - Downstream provision of dissolved organic carbon, and dissolved silica to provide bio-chemical responses.
  - Downstream provision of river bed sediment.
  - Downstream provision of plant prologues.
• Downstream drift of aquatic macroinvertebrates and fish.

• To provide increased opportunities for flow related for biotic dispersal.
  o To increase the frequency, magnitude and variability of high flow events to facilitate biotic movement in the Snowy River.
  o To increased opportunities for localised movement of freshwater taxa in the upper and lower Snowy River.
  o To improve the condition (i.e. ↑weight/ ↓lesions) of migratory species in the Snowy River as large scale movement will require less energy attributable to drowning out minor hydraulic features.

Reproduction and recruitment

• To establish ecological communities (i.e. biofilms, vegetation, bugs, and fish) reflecting those of a reference Snowy montane river.
• To provide flow related opportunities for reproduction and recruitment.

Aquatic vegetation

• To establish a clear aquatic and riparian vegetation community within the channel of the former river based on the new hydraulic gradient. The following subset of vegetation objectives are set for each meso-habitat.
  o Riverbed- To reduce the abundance of attached submerged macrophytes (i.e. Vallisneria sp. and Myriophyllum spp.).
  o Open water- To increase the area of open water in the active channel, including greater riffle area.
  o Littoral edge- To establish a defined but narrow littoral margin of standing water aquatic plants (i.e. Phragmites sp., and Schoenoplectus sp.).
  o 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 former river channel.
  o Higher bench- To establish a diverse aquatic plant flora on the higher river channel that is periodically wetted (i.e. Juncus spp.).
  o 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.
  o In channel- To increase the amount of native Large Woody Debris (LWD) within the river channel resulting from improved riparian vegetation condition via the re-introduction of mature native trees.

Aquatic macroinvertebrates

• 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.
  o In riffles, to increase in the abundance of Caddiesflies (i.e. Conoesucidae, Glossosomatidae), Mayflies (i.e. Leptophlebiidae), and Riffle Beetles (i.e. Elmidae) in the Snowy River.
  o In river pools, to increase in the abundance of Mayflies (i.e. Baetidae, and Oniscigastridae), and Stoneflies (i.e. Gripopterygidae) in the Snowy River.
  o In pools and riffles, to reduce the abundance of aquatic worms, non-biting midges (i.e. Chironiomidae) and sediment tolerant Mayflies (i.e. Caenids).

Fish

• 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 (*Anguilla reinhardtii*) abundance and biomass.
- In pools, to increase in the abundance and biomass of Mountain Galaxid, short finned eel and possibly River Blackfish (*Gadopsis marmoratus*).
- To reduce the abundance of the exotic fish taxa such as Red Fin and Mosquito fish.

- 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 (i.e. *Prototroctes maraena*).
  - In the Estuary, a viable population of Estuary Perch is established.

**Platypus**

- 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.

**Social, cultural and economic consideration: the critical success factor for flow based river rehabilitation.**

The considerations of social, cultural and economic factors are greatly understated in river rehabilitation programs. Greater consideration of social, cultural and economic factors provides an increased adoption of rehabilitation programs and acceptance of the stated ecological objectives by the broader community. Social, cultural and economic factors are considered important and are stated as a set of overarching social/cultural/economic principles. These over-arching principles have been incorporated into the implementation of the SWI and include:

**Social**

- Ecological rehabilitation takes time (i.e. decades). Use the time to
  - build local relationships and develop collective partnerships. This is by far, the single most important principle.
  - Experiment to fill knowledge gaps, and generate an improved scientific understanding.
- Acknowledge ecological uncertainties with stakeholders, but identify the likely recovery pathway(s) and options to resolve these ecological uncertainties.
- Demonstrate ecological change with the available water, rather than focus on larger future targets. This allows greater stakeholder discussion and input throughout the program. This builds capacity and allows for socially acceptable incremental water management change.
- Identify key decision points for stakeholder input, as it allows for a more constructive feedback.
- Improving the aesthetic value of the riverine habitat of the regulated river will occur by changing habitat condition.
Cultural

• Greater linkages between Aboriginal communities, waterways and water management are required. Cultural linkages to water can be increased by:
  o improving "Recognition" of cultural linkages to water by documenting Aboriginal water culture
  o providing opportunities for "Representation" by changing legislation to ensure aboriginal representation, and
  o providing opportunities for greater "Responsibility" in the management of environmental water management.

• Existing water managers act as facilitators, and assist the Aboriginal community to improve the cultural and water management linkages.

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

• Work constructively with the Aboriginal communities that have a strong connection to the waterways of the Snowy Mountains (Connolly and Williams 2014a). These communities are:
  o Maneroo-Ngarigo people
  o Bidwell Maap people
  o Southern Monero people
    (Monero Ngarigo / Yuin / Bolga)
  o Wongalu people
  o Wiradjuri people

The health of the Snowy River is a major concern of the Aboriginal people of this region. Detailed cultural water objectives are provided by Connolly and Williams (2014b).

In recognition of the five traditional Aboriginal groups associated with the Snowy Mountains Rivers, the five 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)

Economic

• Consider the financial implications of environmental water management decisions. These financial implications need to consider:
  o operational limitations and costs of water delivery to the infrastructure operator.
  o a long term perspective, and allow flexibility in water delivery, particularly if short term operational constraints (i.e. infrastructure failure) are difficult to manage, and
  o third party impacts to downstream stakeholders.

• Leverage the public investment in environmental water management to seek economic outcomes for the local community where possible.
Snowy River and flow based river rehabilitation, 1967-2018

The construction of the Snowy Hydro-electric Scheme and the significant water diversion resulted in a release of 1% of the Mean Annual Natural Flow (MANF) being delivered to the Snowy River below Jindabyne between 1967 and 2002. The small and constant Base Passing Flow (BPF) of 24MLd⁻¹, resulted in a significant deterioration in the health of the Snowy River during this period (Gilligan and Williams 2010; Russell et al. 2010; Honeysett 2015).

Since 2002, four key components of environmental flow management needed to occur in order to release environmental water to the Snowy River. These components being:

(i) securing water entitlements in the western valleys,
(ii) capital infrastructure upgrades at Jindabyne Dam,
(iii) the development and implementation of release strategies to the Snowy River, and
(iv) the measurement and reporting of the ecological outcomes.

Securing water entitlements

Securing water entitlements in the Southern Connected Murray-Darling Basin occurred between 2003 and 2015. In 2015, the 212GL target (i.e. 21% of MANF) of securing water entitlements was achieved.

While the water entitlements were being secured, the total annual allocations to the Snowy River showed a stepped increase from 10.5GL in 2002-03 to a maximum of 212 GL in 2017-18 (Figure 4). The stepped increase reflects the combination of the gradual attainment of water savings entitlements and the variation in precipitation in the southern connected Murray-Darling Basin.

The allocation of water to an entitlement for the Snowy River is dependent on the climatic conditions and the water allocation processes in the Southern Connected Murray-Darling Basin. Hence the annual volume availability for the Snowy River will vary from year to year.

Capital Infrastructure upgrades

Between 2002 and 2011, Jindabyne Dam infrastructure was upgraded to provide a unique opportunity to deliver some world class outcomes for environmental water delivery to the Snowy River. This involved the construction of (i) a multi-level off take, and (ii) upgrade of release structures, including the cone valves and spillway upgrade.

The infrastructure upgrades have allowed greater flexibility in the operational delivery of environmental water, including that:

(i) 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
(ii) 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).

These new infrastructure capabilities allow flow sequences reflecting natural patterns of daily
flow variability together with peak flow rates with frequencies and durations reflective of natural flood events in montane rivers.

**SRIF release strategies**

Since 2002, release strategies have delivered environmental water to the Snowy River via two locations, either via (i) a montane tributary and/or (ii) Jindabyne Dam.

To-date, four key strategies have been used to deliver environmental water to the Snowy River. These four flow management stages included:

(i) **Stage 1**: a small montane river “Tributary Release” (TR) reflecting local catchment hydrology,

(ii) **Stage 2**: a “Default Monthly Setting” (DMS) based on monthly average targets,

(iii) **Stage 3**: a “Building Blocks Method” (BBM) based on perceived ecological water requirements, and

(iv) **Stage 4**: a strategy based on the hydrology of an unregulated “Reference River” (RR), the Thredbo River.

Complementary flow management to the reference river method has also been implemented during stage 4. In order to provide increased basal resources (i.e. Dissolved Organic Carbon (DOC), dissolved silica (Dsi) and macro nutrients) to the Snowy River, a tributary release occurs during autumn. This complementary measure has been undertaken by agreement with SHL on an annual basis as it’s varies from the terms of the SWOID 2002.

The application of these four flow management approaches has resulted in four distinctive hydrological signals being displayed (Figure 5 and Figure 6) in the daily SRIF targets below Jindabyne.

Since the SRIF was introduced to the Snowy River in 2002-03, the yearly mean daily discharge targets have steadily increased from below 100 ML/day to over 599 ML/day in 2017-18 (Figure 6).

**Figure 5.** Mean daily discharge (A) targets (ML) and (B) probability of exceedance at Jindabyne, for the four SRIF release strategies, 1998-99 to 2017-18.

**Figure 6.** Mean (95% CL) daily discharge targets (ML) per year at Jindabyne for (A) base passing Flow- 1999-2002, and (B) SRIF 2002-03 to 2017-18.

A high flow regime has been gradually introduced in to the Snowy River since 2010-11 (Figure 7), with a peak instantaneous discharge event of 3,080 ML. However, since 2011-12 peak instantaneous discharge SRIF targets have ranged between 8,109 and 13,000 ML. Since 2013-14 there has also been a step increase in the magnitude of the secondary high flow events (Figure 7).
Flow management 2017-2018

The SRIF strategy again utilises the infrastructure upgrades and represents part of the fourth stage of environmental water delivery to the Snowy River.

In 2017-18, a total of 221 GL was initially identified for release (Table 1). The 221 GL includes an allocation of 212 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. However, 2GL is being deducted from the annual total, due to a natural spill event in 2012-13 which led to 16GL of additional water being unintentionally delivered to the Snowy River. The SWI partners have agreed to pay back 8GL to SHL over four years commencing in 2015-16. The current strategy marks the third year of water pay back. This results in a revised operational target of 218.5 GL to be released to the Snowy River during 2017-18 from Jindabyne Dam.

Table 1. Summary of annual water allocation to the Snowy River.

<table>
<thead>
<tr>
<th>Water account</th>
<th>Annual volume (GL)</th>
</tr>
</thead>
<tbody>
<tr>
<td>SRIF</td>
<td>212</td>
</tr>
<tr>
<td>BPF- Jindabyne</td>
<td>8.5</td>
</tr>
<tr>
<td>BPF- Mowamba</td>
<td>0.5</td>
</tr>
<tr>
<td>sub-total</td>
<td>221</td>
</tr>
<tr>
<td>Debit - 2012-13</td>
<td>-2</td>
</tr>
<tr>
<td>Total</td>
<td>219</td>
</tr>
</tbody>
</table>

*volume is amended following the review of target achievement of previous water year.

The 2017-18 SRIF strategy marks the five year of using a reference montane river to develop the release strategy to the Snowy River (Williams and Reinfelds 2013; Williams 2014; Williams 2015; Williams 2016b).

The premise of the reference river method is to deliver environmental water to mimic the natural hydrological cues of a Snowy Montane River.

The 2017-18 release strategy will further utilise this approach to deliver more frequent smaller secondary 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 2017-18 flow strategy will also include an experimental release from the Mowamba Weir during May 2017.

Key hydrological aspects of the 2017-18 strategy

The annual targeted volume of 218,500 ML from Jindabyne Dam is the largest since the program began in 2002. The 2017-18 daily flow release strategy (Figure 8) has a number of key components and they are briefly described below.

The ‘reference river’ approach will deliver an enhanced seasonal signal in the monthly flow pattern (Figure 9) that is typical of a mixed snowmelt / rainfall river system characteristic of the Snowy Mountains, including:

- Sustained higher flow rates over winter, spring and early summer, with eight months between June and January discharging in excess of 10,000 ML per month. During this period five months exceed a total discharge of greater than 20,000 ML per month. This higher monthly discharge provides a sustained ‘press disturbance’ to the Snowy River and its estuary, which is a characteristic of the pre-regulation period. Additionally, a more pronounced secondary seasonal peak has been re-introduced into the flow regime, reflecting the winter rainfall patterns.

- Low flow periods in summer and autumn, with a minimum release rate of 60 ML/day in late...
autumn which reflects the natural low flow period.

- Median daily flows for the year are 439 ML/day. Mean daily flow is 599 ML/day.
- An annual flood with a primary 8 hour peak of 150.46 m³ per second (i.e. equivalent to 13,000 ML/day), and a total daily target volume of 8,100 ML to be delivered for the day. During this high flow period, the daily flow rate will exceed 1,000 ML/d for 30 days.
- Four additional smaller secondary 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 38.47 – 52.68 m³/second (equivalent to 3,324 – 4,552 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 other stage 4 high release strategies is that there are three winter high flow events during June and July 2017, which reflect winter rainfall and provide a seasonal secondary peak for the first time.
- An experimental environmental flow release from the Mowamba Weir will occur during May 2017. 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.
- It is anticipated that substantial natural tributary inflows will occur below the junction with the Delegate River, and contribute greatly to the flow regime in the lower reaches and processes in the Snowy River estuary.
High flow events for 2017

One primary high flow event and four secondary high flow events will be delivered to the Snowy River during winter to spring 2016 (Figure 10 and Figure 11).

These five events will deliver 85,687 ML to the Snowy River (Figure 10), over 74 days. The duration of each event ranges from seven to 28 days. Each high flow event is characteristically different from one another, and represents a variable high flow regime, typical of high flow events in the Snowy Mountains.

Figure 10. Total discharge and duration for each planned high flow releases to the Snowy River 2017.

Figure 11. The five planned high flow releases to the Snowy River 2017.
Complementary tributary releases to the Snowy River

The 2017-18 flow strategy includes an experimental release from the Mowamba Weir during May 2017. 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; Rohlf et al. 2015, Rohlf et al. 2016; Williams et al. in prep).

In regulated confined montane rivers, the delivery of basal resources is severed by two processes: (i) the limited hydraulic connectivity to local stores of basal resources in the headwaters (Perry and Sheldon 1986, Ward and Stanford 1995, Stanford et al. 1996), and (ii) the altered composition of the stored water released from the reservoir (Cole et al. 2007, Larson et al. 2007) to the receiving river. The extended residence time of stored water within reservoirs results in the consumption, photo-degradation and benthic sequestration of key resources such as DOC and dissolved silica (DSi), reducing concentrations in outflowing reservoir water (Cole et al. 2007, Larson et al. 2007). The chemical composition of DOC in the stored water may also change from slowly metabolised aromatic species, to rapidly metabolised aliphatic DOC (Del Giorgio and Davis 2003). The hydrological and hydraulic simplification of rivers by impoundment and substantial water diversions via inter-basin transfers results in a more homogenous supply of fine organic matter and dissolved nutrients rather than the complex and heterogeneous pulse in unregulated rivers (Stanford and Ward 1986, Shannon et al. 1994). Reduced organic matter supply from headwaters and the severe reduction in high discharge magnitude events starve rivers of more complex nutrient compounds and disrupt the pathways for energy transfer in aquatic ecosystems (Mitrovic and Baldwin 2016).

Historical practices of environmental water delivery have focused predominantly on providing large volumes of water onto the floodplain landscape to deliver DOC and expect third order trophic level responses of charismatic taxa.

In an upland system with limited water availability, and a limited floodplain, the key management question is how do we get more carbon into the river to “feed” our upland rivers in the intervening periods between providing winter and spring high flows?

The current strategy for the Snowy River is to provide tributary releases, which provides a higher concentration of complex carbon compounds (Figure 12). For the sixth year running (2012-2017), tributary releases are occurring during May. The tributary releases objectives are to:

- Increase basal resources in the Snowy River (i.e. DOC and DSi).
- Reduce a-seasonal warm water by 2-4 °C.
- Provide downstream movement of seed propagules and invertebrates.

Ultimately this tributary environmental water approach is doing more with less water. “The high flows over winter-spring improve the habitat “house”, and provide the nutrient translocation sites, but the autumn tributary flows provide the “fridge” to support benthic biofilms and the aquatic food chain.”

Figure 12. Comparison of complementary tributary releases and dam releases to the Snowy River.

NSW DPI Water, May 2017
Ecological constraints to recovery and SRIF

In order to meet the defined environmental water objectives greater consideration of ecological factors that may limit the achievement of the new desired state is required. The following factors have been identified as potential ecological constraints to ecological recovery in the Snowy River and need to be considered if flow based rehabilitation is to be successful. These ecological constraints include:

1. Habitat
   - Limited wetted habitat.
   - Limited hydraulic diversity.
   - Poor substrate condition (i.e. abundant fine sediment and filamentous green algae).
   - Thermal regime (i.e. warm water in autumn and winter).
   - The re-establishment of woody environmental weeds such as Willows (*Salix fragilis*), and Blackberry (*Rubus fruticosus* agg.) into the former river channel. The ingress of other environmental woody weeds such as Hemlock (*Conium maculatum*) and Box Elder (*Acer negundo*) requires management.
   - Poor riparian zone condition and grazing pressures.
   - Salinity regime of the Snowy River estuary is not conducive for reproduction and recruitment of Australian Bass (*Macquaria novemaculeata*).
   - Climate change and rising sea-levels will result in further adverse changes in the salinity dynamics of the Snowy River estuary.

2. Resource availability and production
   - Insufficient basal resources (i.e. DOC, DSI).
   - Insufficient nutrient translocation sites (i.e. cobbles/ large woody debris).
   - Limited opportunities for heterotrophic production.
   - Limited instream LWD with hallows for usage by demersal fish species.

3. Reproduction and recruitment
   - Insufficient habitat (see above).
   - Insufficient resources and resource competition.
   - Insufficient abundance / densities within system.
   - Low fecundity of target taxa or host taxa.

4. Biotic dispersal
   - Limited ability of target taxa to disperse.
   - Limited connectivity to remnant populations of target taxa.
   - Limited numbers and patch size of remnant populations.
   - Significant hydraulically induced barriers (natural/ built).

Complementary measures

Complementary resource management activities are required to support the delivery of environmental water and the flow based river rehabilitation objectives. These complementary activities potentially include:

- Management of catchment sources of fine sediment.
- Management of exotic weeds such as willows/blackberry, to allow channel change with the available water. If not addressed in the next two years (2017-18) then greater volumes of water will be required to undertake the desired physical reworking of the river channel.
- Management of large bodied exotic animals to protect in-channel habitats,
riparian zones, and headwater streams/swamps.

- The use of tributary releases during autumn.
- Consider translocation of River Blackfish from the low gradient tributaries to the low gradient reaches of the regulated river after 2025.

**Conclusion**

The annual strategy attempts to document the hydrological characteristics of the releases and the anticipated ecological responses to the flow based river rehabilitation.

The use of the reference river approach for the current 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 utilised, 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 (pers. obs Williams 2017), 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 water objectives.

Finally, the annual SRIF strategy recognises that a “smaller but healthier montane river” is the target condition. This improved condition will be delivered by attempting to re-create components of the previously disturbed hydrologically related river processes (Williams in prep ).

**References**


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