Environmental Flow Study Review for the Yarra River

Melbourne Water

Final Report

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Environmental Flow Study Review for the Yarra River

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Contents

1. Environmental Flow Study Review

1.1 Introduction

This report documents a review and update of specific flow recommendations for the Yarra River, undertaken by an Environmental Flow Technical Panel (EFTP) and Melbourne Water. Melbourne Water identified a number of aspects to be considered within this environmental flow study review, and include:

1) New findings in past 5 years that provides grounds for revising flow recommendations and new studies that support or increase confidence around existing and revised flow recommendations.
2) Reach 2 Winter low flow recommendations under a changing climate outlook.
3) New flow recommendations for Platypus.
4) Any new knowledge on the relationship between amenity / social / cultural values and environmental flows.
5) Guidance on the inter-annual Environmental Water priority watering actions in a changing climate and climate change impacts raised in the Yarra River Environmental Water Management Plan (Jacobs 2017f).

This FLOWS review and update is limited to Reaches 1-6 (Table 1.1, Figure 1.1). Reach 7 (Estuary), Reach 8 (Watts River) and Reach 9 (Plenty River) are excluded from the review and update.

Table 1.1 : Yarra FLOWS Reaches considered in this review and update.

Reach		Site no.	Site location	Gauge
1	Upper Yarra Reservoir to Armstrong Creek junction	1	Downstream of Upper Yarra Reservoir, Reefton	Doctors Creek
2	Armstrong Creek to Millgrove	2a	Warburton East (downstream of major tributary harvesting operations)	Millgrove
		2b	Millgrove gauge	Millgrove
3	Millgrove to Watts River junction	3a	Immediately upstream of Healesville-Woori Yallock Rd	Yarra Grange
		3b	Everard Park, upstream of Maroondah Highway.	Yarra Grange
4	Watts River to top of Yering Gorge	4	Tarrawarra Abbey, Yarra Glen.	Yarra Glen
5	Top of Yering Gorge to Mullum Mullum Creek	5a	Immediately downstream of Yering Gorge pumping station.	Warrandyte
		5b	Everard Drive, Warrandyte	
6	Mullum Mullum Creek to Dights Falls	6a	Finns Reserve	Chandler Hwy
		6b	Banyule Flats, downstream of Plenty River	

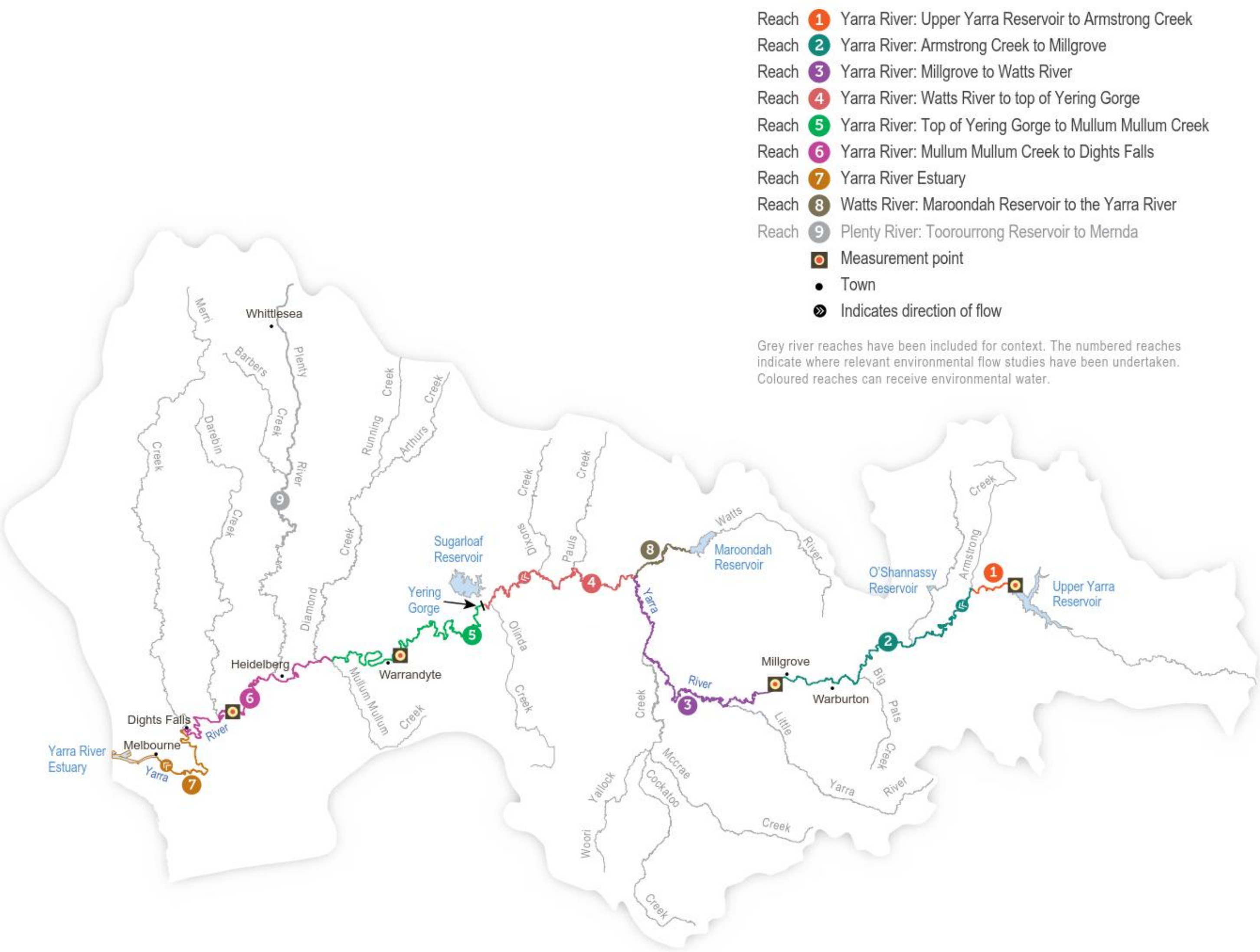

Figure 1.1 : Yarra River reaches for environmental water management. Source: VEWH (2016).

1.2 Review and update of flow recommendations

1.2.1 Technical review of ecological objectives and flow recommendations

Each member of the EFTP completed a technical review of ecological objectives and flow recommendations as documented in the 2012 FLOWS Study (SKM 2012). Particular aspects that this review included:

- The development of new flow recommendations and objectives for Platypus, drawing upon insights from platypus surveys and conceptual models of platypus flow requirements (Jacobs et al. 2016).
- More explicit consideration of birds and frogs in flow recommendations, drawing upon information documented in Jacobs (2017f) and with consideration to the new Health Waterway Strategy.
- Response of fish monitoring conducted by ARI for the purposes of understanding the response of native fish to environmental flows, notably Australian Grayling and Macquarie Perch (Tonkin et al. 2017). This information has been used to revise current flow recommendations, especially those related to migration and spawning triggers.
- Analysis of new water quality data collected from the Dights Falls weir pool to understand and confirm / refine flow recommendations to prevent (or mitigate) low dissolved oxygen conditions. Pool water quality data for the Yarra River is currently limited to Dights Falls weir pool and this pool currently serves as an indicator of water quality for pools in other reaches (i.e, if conditions are suitable in Dights Falls weir pool, other pools are also likely to be suitable). It is acknowledged that there are also some pools downstream of Yering Gorge that have experienced elevated salinity at very low flows (<200 ML/d and see Ewert & Pettigrove 2003), but current minimum flow recommendations are considered sufficient to maintain water quality in those pools (SKM 2005, 2012).
- Refinement of acceptable release limits from the Upper Yarra Reservoir with reference to recent monitoring of flow releases downstream of the reservoir (GHD 2016).
- Recent hydraulic modelling (completed by Jacobs) associated with billabong investigations that can help to clarify bank full and overbank flow magnitudes at various locations (Yarra Bridge – Reach 3, Spadonis Reserve and Yering Backswamp – Reach 4), Banyule Flats and Bollin Bollin – Reach 6). More explicit guidance on the level of flow/rather than the discharge needed for water to fill these billabongs.
- New insights of the effects of urban runoff on flows, in particular the frequency of high intensity disturbance events and the impacts these have on channel form (Jacobs 2017b).
- Consideration of the social and amenity values of water and linkages with water-dependent indigenous cultural values. The recent Yarra River EWMP (Jacobs 2017f) provides a brief description of social and amenity values and linkages with water-dependent indigenous cultural values, however this is an area of ongoing work, and as such, is not available in a form that can be readily incorporated into this Flow Review.

1.2.2 Changes to ecological objectives

A summary of changes to ecological objectives is presented in Table 1.2. Revised ecological objective tables and a more detailed description of changes is presented in Appendix A. Following is a brief summary of changes made:

- Minor changes to 'Function', 'Expected response' and 'Timing' components of Geomorphology and Macroinvertebrate objectives. For geomorphology, changes made highlight potential influence of urban runoff on channel dimensions and form in Reaches 4, 5 and 6. For macroinvertebrates, changes made capture assumed seasonal changes in low flows on macroinvertebrate biomass.
- Fish objectives have been revised so that the 'Functions' are more species specific, the 'Timing' of flow components refined and more measurable 'Expected responses' provided, where new supporting evidence exists, particularly for Australian grayling, tupong, eels, lamprey and Macquarie perch.
- Vegetation objectives have been restructured to reflect different vegetation habitats (in-stream, riparian, billabong/floodplain and terrestrial). 'Functions' and 'Expected responses' of flow components have been revised to make them accord better with revised objectives.

- Objectives that are not linked to a specific flow component but are contingent on complementary management actions have been removed from the ecological objectives tables and are now summarised in a separate table (refer to Table B.1 in Appendix B). This has meant that water quality objectives have now been removed from ecological objectives tables for Reaches 1-4.
- New ecological objectives have been developed for platypus. Generic ecological objectives have also been included for Birds, Frogs and Amenity.

Table 1.2 : Summary of changes to ecological objectives.

Asset / Description of changes
Geomorphology
No changes made to geomorphology objectives in Reaches 1, 2 and 3. Minor changes to 'Functions' and 'Expected response' components of geomorphology objectives for Reaches 4, 5 and 6 with reference to new insights of the effects of urban runoff on flows, in particular the frequency of high intensity disturbance events and the impacts these have on channel form (Jacobs 2017b). In particular, the intent should be to limit the frequency and duration of flows above scouring thresholds.
Macroinvertebrates
Modified low flow objective and related 'Functions' so as to capture assumed changes in Summer / Autumn and Winter / Spring macroinvertebrate biomass production linked to inundation of habitat areas. Evidence suggests that winter biomass production is low compared with summer production due to cooler temperature conditions. To compensate for this a larger area of wetted habitat is required to maintain both primary (algal) and secondary (macroinvertebrate) production over the winter period. This is particularly important in streams supporting platypus because they have a high food demand, especially during winter and spring when females are gestating and lactating. Hence, winter requires higher base flows than summer in order to provide access to additional habitat. The 'Timing' of flow components has also been refined.
Fish
The 'Functions' associated with fish objectives have been made more species-specific. New species-specific 'Functions' have been developed, the associated 'Timing' of flow components refined, and more measurable 'Expected responses' provided, where new supporting evidence exists, particularly for Australian grayling, tupong, eels, lamprey, and Macquarie perch.
Vegetation
Restructured objectives according to (a) in-stream, (b) riparian, (c) billabong/floodplain, and (d) terrestrial habitats. In Reaches 1 and 2, the maintenance of in-stream microbial biofilms is explicitly stated as objectives. Where possible, objectives were rationalised by collapsing multiple objectives into a smaller set of more coherent objectives that addressed a number of desired ecological outcomes; this resulted in a reduction of the number of individual objectives for Reaches 3−6. The 'Functions' of various flow components were revised for each reach to make them accord better with the revised objectives and to be more transparent (e.g. the ecological functions of low-flows in the Summer/Autumn and Winter/Spring periods are now separated, whereas they were considered together in the original report). In some cases (e.g. Reach 3) freshes were divided into small and large events, the former targeted mostly at fish (but with some benefits expected for vegetation) and the latter targeted mostly at vegetation. A Winter/Autumn High Flow was also included in addition to the freshes for some reaches. Note that a single flow component provides for multiple ecological functions. 'Expected responses' by vegetation were revised to make them accord better with the revised ecological 'Functions' of each flow component. 'Functions' and 'Expected responses' are now more clearly related to individual objectives for each flow components, across all the reaches.
Water quality
Water quality objectives that are not linked to a specific flow component but are contingent on complementary management actions have been removed from the ecological objectives tables and summarised in a separate

Asset / Description of changes
table with other complementary objectives. As a result of these changes, water quality objectives are now only included in ecological objectives tables for Reach 5 and 6.
Platypus
New ecological objectives have been developed drawing upon insights from platypus surveys and conceptual models of platypus flow requirements (Jacobs et al. 2016). A summary of habitat/flow requirements for platypuses is included in the boxed section below.
Birds, Frogs and Amenity
Generic ecological objectives have been added for Birds, Frogs and Amenity as documented in the Yarra River EWMP (Jacobs 2017f)

Habitat/flow requirements of platypuses

Platypuses are adaptable to a range of environmental conditions as demonstrated by the wide range of aquatic habitats and climatic zones they inhabit across their range (Grant 1992, Grant & Temple-Smith 1998). However, in broad terms, there are three key components required: permanent water, abundant macroinvertebrates, and stable earthen banks to construct burrows. Importantly, platypuses are highly mobile with individual home ranges and daily movements typically encompassing several kilometers (Griffiths et al. 2014, Gust & Handasyde 1995, Kelly et al. 2012, Otley et al. 2000, Serena et al. 1998a) and densities estimated at 1-2/km in a small creek around Melbourne (Serena 1994). Therefore, large contiguous areas of suitable habitat are required to support a self-sustaining platypus population. Population viability analysis (PVA) models have been used to estimate a minimum population size of 30 individuals is required for a platypus population to have a high probability of persisting for 50-100 years with moderate environmental stochasticity (Serena & Williams 1999), although a much larger population is required to avoid genetic problems in the longer term (Frankham et al. 2014, Soule 1980). Using 30 platypuses as a minimum population size and estimates of typical densities above, we estimate a stretch of at least 15-30 km of suitable contiguous habitat is required. The presence of off-stream (but connected) wetlands can increase the carrying capacity of an area (Serena 1994).

Critically, platypuses require adequate surface water and flow regimes to support a reliable supply of macroinvertebrate prey. Platypuses are adapted to feed exclusively in water where they forage for a range of benthic macroinvertebrates with adults consuming about 15-30% of their bodyweight daily (Holland & Jackson 2002, Krueger et al. 1992). Therefore, many habitat variables associated with platypus presence abundance are those favourable for macroinvertebrates. Platypuses are known to preferentially forage in areas of coarse benthic substrates (i.e. cobbles, rocks, pebbles) and large woody debris (Grant 2004, Serena et al. 2001). Other variables known to be important for platypuses include large riparian trees, overhanging vegetation, pools 1-3 m deep, and near vertical or undercut banks at least 0.5 m above the water (Bethge et al. 2003, Ellem et al. 1998, Grant 2004, Serena et al. 1998a, Serena et al. 1998b, Serena et al. 2001, Worley & Serena 2000). Conversely, platypuses are known to avoid areas of fine substrates (silt or clay) and dense willows (Serena et al. 2001).

The importance of suitable flow regimes for platypus is increasingly understood. Platypus distribution throughout Melbourne is known to be limited by catchment imperviousness (Martin et al. 2013, Serena & Pettigrove 2005) indicating that platypuses are sensitive to direct and indirect impacts of altered flow regimes of urban streams. Urban streams typically suffer from high flow variability with increased magnitude and frequency or high flows and reduced and extended baseflows. Generally, this leads to depauperate macroinvertebrate assemblages, increased erosion and sedimentation, and facilitates input of litter and pollutants from the surrounding catchment. High flow events may also increase foraging energetics for platypuses (Griffiths et al. 2014, Gust & Handasyde 1995). Reproduction in platypus has been linked with rainfall (and presumably reliable flows) in the months preceding breeding (March-July; Serena & Grant 2017, Serena et al. 2014), while late spring/summer floods may compromise juvenile recruitment (Bino et al. 2015, Serena et al. 2014).

Therefore, an ideal flow regime for platypuses would include (Jacobs 2017c):

1) maintaining minimum baseflow to maintain habitat for macroinvertebrates and longitudinal connectivity along stream for safe platypus movement;

2) moderate variability to support diverse macroinvertebrate community;

3) reliable surface water from March-July;

4) avoidance of bankfull or overbank flows during summer.

1.2.3 Changes to flow recommendations

A summary of revised flow recommendations for the six reaches is presented in Table 1.3. Tabulated summaries of the revised flow recommendations for each of the reaches are also included in Appendix C.

A summary of changes to flow recommendations is documented in Table 1.4. Revised flow recommendations tables and a more detailed description of changes are presented in Appendix D.

Following is a brief summary of changes made:

- Colour coding of flow components to highlight flows those that are managed (blue) from those that are expected naturally and hence do not require active delivery (green)
- Revised objectives to include explicit reference to native fish species in each reach and specific reference to role of flows (i.e. Summer/Autumn freshes cue downstream migration of eels and may facilitate juvenile platypus dispersal).
- Review and update of flow recommendations (volume, frequency and when, duration and rise/fall) for wet/average and dry years.
- Rates of rise and fall have been reviewed for all reaches. The rate of rise has been increased to 2.0; as it sits between 50-80th percentile for all reaches, this value is still conservative. In terms of rate of fall, we want this to remain slow to prevent ecological impacts (e.g. bank slumping and stranding of biota). Hydrological analysis indicates that for all reaches 0.8 would be sufficient. For natural flow events, rates of rise/fall have been changed to N/A (not applicable) as there is no control over this.
- Recommended change in flow regime for Reach 1 with more frequent managed releases of Winter/Spring High and Bankfull flows. These changes in the recommended flow regime should be monitored to assess the cumulative impact of high flow releases on the channel and rate of recovery between events.
- Recommended transitioning in low flows from Summer/Autumn to Winter /Spring in Reach 2 and 3.
- Recommendations for the duration of freshes were also re-examined, and in some cases shortened. Changes to the volume, timing and duration of Winter / Spring fresh recommendation in Reaches 2-6. This results in a lower/longer duration fresh in June or July to facilitate fish migration and a higher/shorter duration fresh between June and September to maintain flood-tolerant vegetation higher on banks.
- Recommended changes in the timing of Winter/Spring high flow from October-November to September-October (prior to Macquarie Perch spawning) for Reaches 3-6.
- A literature review was undertaken to inform the length of inundation to drown-out terrestrial vegetation; this review supported, in general, the previous 14-day recommended duration of Winter/Spring high flow to drown out terrestrial vegetation.
- Magnitude of overbank flows has been revised for Reaches 3, 4 and 6 following a review of results from recent hydraulic modelling associated with billabong investigations.

Table 1.3 : Summary of revised flow recommendations. Flow components have been colour coded to highlight those that are managed (blue) from those that are natural (green). For further information on ecological objectives and expected ecological response to flow components refer to tables in Appendixes.

Season	Flow	Wet/Avg/ Dry	Reach					
			1	2	3	4	5	6
Summer / Autumn (Dec-May)	Low flow	Wet/Avg	10 ML/day	80 ML/day	Min 120 ML/day at Woori Yallock and 150 ML/day at Everard Park	Min 200 ML/day	Min 200 ML/day	Min 300 – 450 ML/day
		Dry						
	Fresh	Wet/Avg	60 ML/day (4/yr, min 1 day at peak)	350 ML/day (3/yr, min 2 days at peak)	350 ML/day at Woori Yallock and 450 ML/day at Everard Park (3/yr, min 2 days at peak)	Min 450 ML/day (3/yr, min 2 days at peak)	Min 750 ML/day (3/yr, min 2 days at peak)	Min 750 ML/day (3/yr, min 2 days at peak)
		Dry						
	High	Wet/Avg	Not recommended	560 ML/day (1/yr in Apr/May, must occur 2 in 3 yrs, min 7 day duration)	900-1100 ML/day to ensure minimum flow of 1300 ML/day at Chandler Hwy (1/yr in Apr/May, must occur 2 in 3 yrs, min 7 days at peak, Event 14 days duration)	900-1100 ML/day to ensure minimum flow of 1300 ML/day at Chandler Hwy (1/yr in Apr/May, must occur 2 in 3 yrs, min 7 days at peak, Event 14 days duration)	1300 ML/day (1/yr in Apr/May, must occur 2 in 3 yrs, min 7 days at peak)	1300 ML/day (1/yr in Apr/May, must occur 2 in 3 yrs, min 7 days at peak)
		Dry						
Winter / Spring (Jun-Nov)	Low flow	Wet/Avg	10 ML/day	Min 200-350 ML/day (200 ML/day Jun, 350 ML/day Jul-Nov)	Min 200-350 ML/day (200 ML/day Jun, 350 ML/day Jul-Nov)	Min 350 ML/day	Median 750 ML/day with a min 350 ML/day	Median 750 ML/day with a min 350 ML/day
		Dry		Min 80-350 ML/day (80 ML/day Jun/Jul, 200 ML/day Jul, 350 ML/day Aug-Oct, 200 ML/day Nov)	Min 80-350 ML/day (80 ML/day Jun/Jul, 200 ML/day Jul, 350 ML/day Aug-Oct, 200 ML/day Nov)	Min 350 ML/day, but may not reach this magnitude until late June or mid July	Median 600 ML/day with a min 350 ML/day	Median 600 ML/day with a min 350 ML/day
	Fresh	Wet/Avg	100 ML/day (3/yr, min 2 day at peak)	700 ML/day (2/yr Jun-Aug, 3 days at peak)	1100 ML/day (Min 700 ML/day) (1/yr in Jun/Jul, min 7 days at peak)	1100 ML/day (1/yr in Jun/Jul, min 7 days at peak)	1300 ML/day (1/yr in Jun/Jul, min 7 days at peak)	1300 ML/day (1/yr in Jun/Jul, min 7 days at peak)
					1800 ML/day (1/yr in Jun-Sep, min 2 days at peak)	2000 ML/day (1/yr in Jun-Sep, min 2 days at peak)	2500 ML/day (1/yr in Jun-Sep, min 2 days at peak)	2500 ML/day (1/yr in Jun-Sep, min 2 days at peak)
		Dry						
	High	Wet/Avg	300 ML/day (1/yr or min 1 in 2 yrs, 3 days at peak)	700 ML/day (1/yr in Sep, 14 days duration)	1800 ML/day (1/yr in Sep/Oct, 14 days duration)	2000 ML/day (1/yr in Sep/Oct, 14 days duration)	2500 ML/day (1/yr in Sep/Oct, 14 days duration)	2500 ML/day (1/yr in Sep/Oct, 14 days duration)
		Dry		Not necessary to deliver but allow to occur naturally				
	Bankfull	Wet/Avg	600 ML/day (1 in 2-5 yrs in June-Sept, 3 days)	2700 ML/day (1 in 2 yrs, 2 days at peak)	4000 ML/day (1/yr, 2 days duration)	5000 ML/day (1/yr, 2 days duration)	5000 ML/day (1/yr, 2 days duration)	11,000 ML/day (1/yr, 2 days duration)
		Dry		Not expected, but let it occur naturally.				
	Bankfull / Overbank	Wet/Avg	Not recommended	2700 ML/day (1 in 2 yrs, 2 days at peak)	4000-6000 ML/day (1 in 1-2 yrs, 1-2 days duration)	8000-10,000 ML/day (1 in 1-2 yrs, 1-2 days duration)	5000-14,000 ML/day (1/yr, 1-2 days duration)	11,000-16,000 ML/day (1/yr, 1-2 days duration)
		Dry		Not expected, but let it occur naturally.				

Table 1.4 : Summary of changes to flow recommendations.

Reach / Description of changes	
1	**Upper Yarra Reservoir to Armstrong Creek junction**
	· Acceptable release limits from the Upper Yarra Reservoir have been refined with reference to recent monitoring of flow releases downstream of the reservoir (GHD 2016). · Recommended change in flow regime, with more frequent managed releases of Winter/Spring High and Bankfull flows. The volume of the recommended bankfull flow has also changed from 1100 ML/day to 600 ML/day. · These changes in the recommended flow regime should be monitored to assess the cumulative impact of high flow releases on the channel and rate of recovery between events.
2	**Armstrong Creek to Millgrove**
	· Recommend transition in low flows from Summer/Autumn to Winter /Spring. In Wet/Average years recommend a lower minimum flow in June (200 ML/day) transitioning to 350 ML/day in July. In Dry years, the following low flow transitions are recommended; 80 ML/day June, 200 ML/Day July, 350 ML/day August – October and 200 ML/day in November. · Changes to the timing and duration of Winter / Spring freshes so that these are consistent with revisions to flow recommendations in downstream Reaches 3-6. Change in recommended timing of Winter / Spring freshes from between June and September to between June and August and shortened recommended duration from 7 days to 3 days at peak (since this shorter duration is likely to be sufficient to meet the vegetation and fish objectives). · A literature review was undertaken to inform the length of inundation required to drown out terrestrial vegetation. This generally supported the 14-day duration of the Winter/Spring high flow recommendation for this reach and reaches downstream.
3	**Millgrove to Watts River junction**
	· Similar to Reach 2, recommend transition in low flows from Summer/Autumn to Winter /Spring. In Wet/Average years recommend a lower minimum flow in June (200 ML/day) transitioning to 350 ML/day in July. In Dry years, the following low flow transitions are recommended; 80 ML/day June, 200 ML/Day July, 350 ML/day August – October and 200 ML/day in November. Allow incoming tributaries to provide additional flow and variation in average and wet years. · Revised volume, timing and duration of Winter / Spring fresh recommendation. Changed from 2 Freshes of 1800 ML/Day for seven days at peak to: a 1100 ML/day fresh, in June or July to facilitate migration of fish, min 7 days at peak (Minimum of 700 ML/day is that which comes out of Reach 2, acknowledging that tributary inflows provide additional water); and a 1800 ML/day fresh between June and September, min 2 days at peak – higher but shorter duration fresh to maintain flood-tolerant vegetation higher on banks. · Changed timing of Winter/Spring high flow from October-November to September-October (prior to Macquarie Perch spawning). As noted for Reach 2, we reviewed and retained the recommended 14-day duration of the Winter/Spring high flow to drown out terrestrial vegetation. · Changed recommended volume of overbank flow from 9000 ML/day to 4000-6000 ML/day as a result of more recent investigations into the water regime of Yarra Bridge Billabong.
4	**Watts River to top of Yering Gorge**
	· Revised volume, timing and duration of Winter / Spring fresh recommendation. Changed from 2 Freshes of 2000 ML/day for seven days at peak to: a 1100 ML/day fresh, in June or July to facilitate migration of fish, min 7 days at peak; and a 2000 ML/day fresh between June and September (assuming additional volume is provided by Watts River and other tributaries), min 2 days at peak – higher but shorter duration fresh to maintain flood-tolerant vegetation higher on banks. · Changed timing of Winter/Spring high flow from October-November to September-October (prior to Macquarie Perch spawning). As noted for Reach 2, we reviewed and retained the recommended 14-day duration of Winter/Spring high flow to drown out terrestrial vegetation.

Reach / Description of changes	
·	Revised recommended frequency of bankfull flow to 1 per year, consistent with upstream reach.
·	Changed recommended volume of overbank flow from 10,000 ML/day to 8,000-10,000 ML/day as a result of more recent investigations into the water regime of Yering Swamp and Spadoni's Billabong.
5	**Top of Yering Gorge to Mullum Mullum Creek**
·	Revised volume, timing and duration of Winter / Spring fresh recommendation. Changed from 2 Freshes of 2500 ML/day for seven days at peak to: a 1300 ML/day fresh, in June or July to facilitate migration of fish, min 7 days at peak (Minimum of 700 ML/day is that which comes out of Reach 2, acknowledging that tributary inflows provide additional water); and a 2500 ML/day fresh between June and September, min 2 days at peak – higher but shorter duration fresh to maintain flood-tolerant vegetation higher on banks.
·	Changed timing of Winter/Spring high flow from October-November to September-October (prior to Macquarie Perch spawning). As noted for Reach 2, we reviewed and retained the recommended 14-day duration of Winter/Spring high flow to drown out terrestrial vegetation.
·	Combined 'Small Bankfull' and 'Large Bankfull' to create new recommendation for 'Bankfull/Overbank' events. Revised frequency to 1 per year, consistent with upstream reach.
6	**Mullum Mullum Creek to Dights Falls**
·	Revised volume, timing and duration of Winter / Spring fresh recommendation. Changed from 2 Freshes of 2500 M/Day for seven days at peak to: a 1300 ML/day fresh, in June or July to facilitate migration of fish, min 7 days at peak (Minimum of 700 ML/day is that which comes out of Reach 2, acknowledging that tributary inflows provide additional water); and a 2500 ML/day fresh between June and September, min 2 days at peak – higher but shorter duration fresh to maintain flood-tolerant vegetation higher on banks.
·	Changed timing of Winter/Spring high flow from October-November to September-October (prior to Macquarie Perch spawning). As noted for Reach 2, we reviewed and retained the recommended 14-day duration of Winter/Spring high flow to drown out terrestrial vegetation.
·	Combined 'Small Bankfull' and 'Large Bankfull' to create new recommendation for 'Bankfull/Overbank' events. Changed volume from 13,000-21,500 to 11,000-16,000 ML/day as a result of more recent investigations at Bolin Bolin and Bunyule Billabong. Revised frequency to 1 per year, consistent with upstream reach.

Reach 2 Winter/Spring low flow recommendations have been in revised for wet/average and dry years. The current Winter low flow recommendation of 350 ML/d in average and wet years, and 200 ML/d in dry years is almost never met in June, and release from the environmental entitlement is required to deliver this flow, despite flows of 80 ML/d being released for operational requirements during June. Winter low flows in this reach are aimed to maintain access to habitat for bugs and fish. To meet these objectives, riffle habitat needs to be accessed and stream vegetation should be maintained and/or rehabilitated (microbial as well as macrophytic).

Two important revisions were made to the original recommendations. First, the objectives, in accord with the hydrology and hydraulic models, were reviewed to determine whether they could be achieved with less water. If so, water from the environmental entitlement could be reserved for other flow releases. Second, we assessed whether a shoulder or transition recommendation could be made that enabled a smoother transition to the Winter low flow. The outcomes of this review is that it is recommended that there should be a transition in low flows from Summer/Autumn to Winter /Spring. In wet/average years a minimum low flow of 200 ML/day is recommended in June transitioning to 350 ML/day in July. In dry years, a minimum of low flow of 80 ML/day is recommended in June, transitioning to 200 ML/Day in July, 350 ML/day from August to October and then dropping down to 200 ML/day in November. These revised recommendations are illustrated in Figure 1.2.

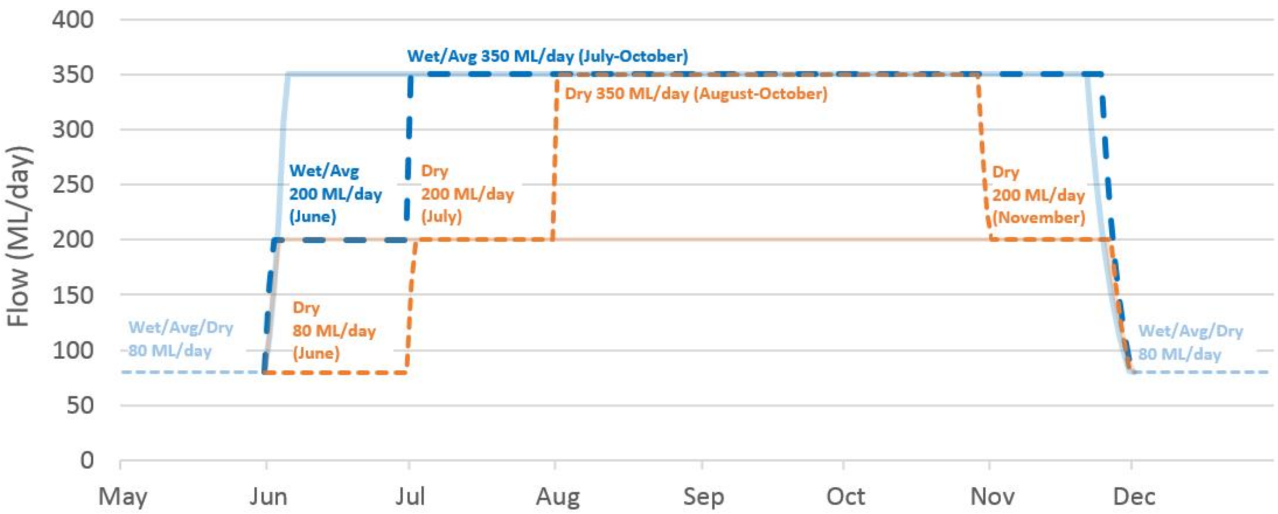

Figure 1.2 : Plot showing the new recommended transition in low flows from Summer/Autumn (Dec-May) to Winter/Spring (Jun-Nov) in Reach 2 for Wet/Average (blue dotted lines) and Dry years (orange dotted lines). Existing flow recommendations are shown in the background (solid lines - Wet/Avg 350 ML/day and Dry 200 ML/day Jun-Nov).

The volume, timing and duration of Winter/Spring freshes and High flow have also been revised. An illustration of updated flow recommendation is presented in Figure 1.3 for Reach 2.

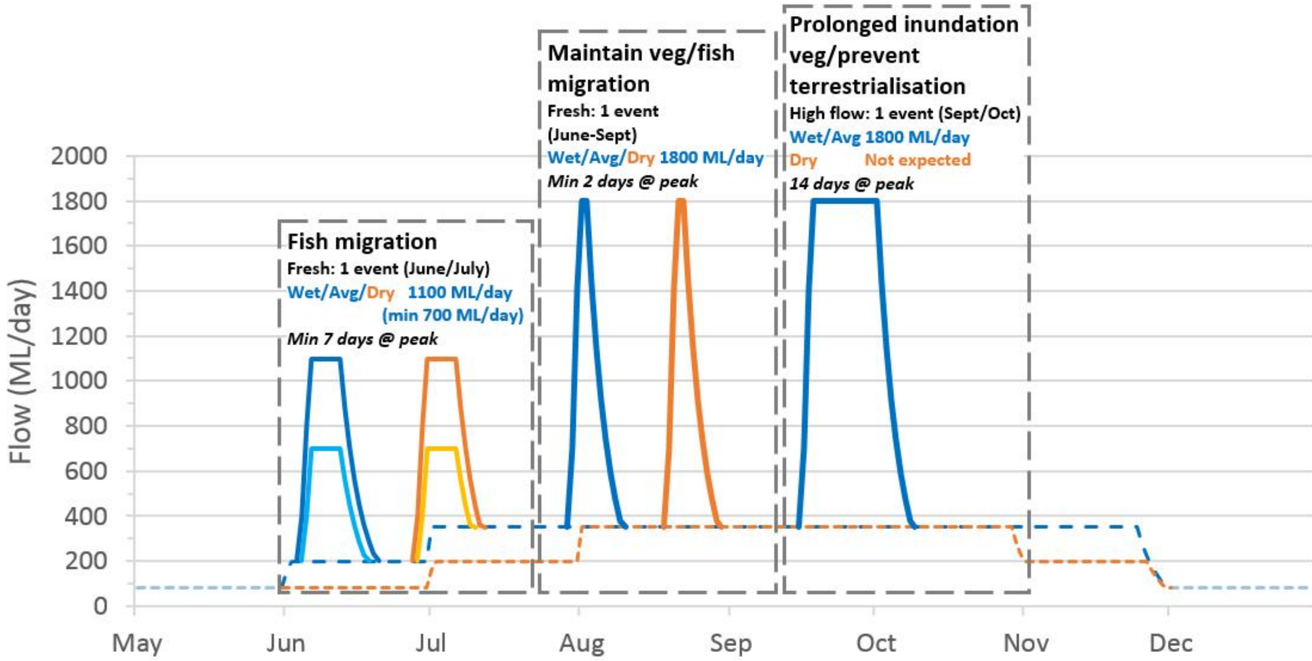

Figure 1.3 : Plot highlighting recommended Winter / Spring Freshes and alternative scenarios for delivering these events to achieve a similar outcome (example provided for Reach 2). Changes in low flow recommendation are documented in Figure 1.2.

The recommendation for Freshes has changed from two freshes of 1800 M/Day for seven days at peak to two peaks of different magnitude:

- 1100 ML/day fresh, in June or July to facilitate migration of fish, min 7 days at peak (Minimum of 700 ML/day is that which comes out of Reach 2, acknowledging that tributary inflows provide additional water); and
- 1800 ML/day fresh between June and September, min 2 days at peak – higher but shorter duration fresh to maintain flood-tolerant vegetation higher on banks.

The timing of the Winter/Spring high flow has also changed from October-November to September-October (prior to Macquarie Perch spawning). The basis for the 14-day duration of the high flow to drown out terrestrial vegetation has also been reviewed by checking the available literature on the topic, and the original recommendation upheld.

1.3 Climate change impacts on Yarra River flows

1.3.1 Outlook

Victoria's climate is changing. Greenhouse gas concentrations and surface air temperatures have increased, and are now influencing the climate. Global average combined land and ocean surface temperature show a warming of 0.85 [0.65 to 1.06]°C over the period 1880 to 2012 (IPCC 2014). Local temperature trends in Victoria over a similar period show similar trends (Grose et al. 2015, Timbal et al. 2016).

Scientists globally, and in Victoria, have observed that climate change can occur as both gradual and step changes. In Victoria it appears that there may have been changes in climate that occurred in the mid 1970's and again post 1997. These changes have resulted in a reduction in cool season (April to October) rainfall over recent decades, and were particularly evident during the Millennium Drought, but have continued in many parts of Victoria since the end of the drought (Timbal et al. 2016).

Changes in rainfall are amplified when translated into changes in catchment runoff. Historical reductions in the runoff in Victorian streams, particularly over the Millennium Drought, have been well documented. They have been presented in each year's Victorian Water Accounts (e.g. DELWP 2015), with the statistical significance of a step change in streamflow being identified in several studies, including the CSIRO Murray-Darling Basin Sustainable Yields project (CSIRO 2008), and by the Bureau of Meteorology at its hydrologic reference stations across Victoria (Bureau of Meteorology 2016).

With increased greenhouse gas concentrations, most of Victoria is expected to become hotter and drier. The medium and high climate change scenarios show a decrease in rainfall and runoff across all of Victoria by 2040, with the greatest impacts seen in western Victoria. The low climate change scenario projects a small increase in rainfall and runoff across Victoria in 2040 and 2065. Table 1.5 shows the predicted changes in annual runoff under a range of climate chance scenarios for the Yarra River basin. It should be noted that the seasonal factors given in Potter et al. (2016) were also investigated however the change in compliance compared to the annual factors was minimal.

Table 1.5 : Projected changes in average annual runoff relative to the current climate baseline across all seasons for the Yarra Basin (Source: DELWP 2016)

Average annual runoff (mm) (1975-2014)	Change relative to current climate baseline (%)					
	Year 2040			Year 2065		
Historic	10th percentile (Low)	50th percentile (Medium)	90th percentile (High)	10th percentile (Low)	50th percentile (Medium)	90th percentile (High)
227 mm	+10.0 %	-11.0 %	-29.2 %	+0.8 %	-16.4 %	-44.3 %

The impact of climate change on Yarra Flows and compliance with flow recommendation was assessed using the Victoria Climate Change Guidelines (DELWP 2016) as well as a stochastically generated climate change projections developed by the University of Melbourne. Details surrounding each method are presented as well as the results in the following sections.

1.3.2 Assessment using the Victoria Climate Change Guidelines

Compliance Assessment

Modelling of climate change impacts on Yarra River flows (Environmental Flow Reaches 2 and 5) was undertaken by taking the historical flow regime (i.e. gauged data) and applying a flow reduction consistent with the predicted runoff reductions in Table 1.5. The climate change flow scenarios were then assessed to see how well the flow regimes complied with updated environmental flow recommendations using the compliance assessment process described in the Yarra Environmental FLOWS Study Review (SKM 2012). It should be noted that classification of wet, average, dry years was undertaken using rainfall and dividing equally into three parts, while shortfalls were calculated as the volume required to meet environmental flow volume requirements. Rainfall was chosen in order to be consistent with the approach used in SKM (2012), also, rainfall provides a better representation of actual climate conditions because unlike streamflow, rainfall is not impacted by or regulation / extraction.

Table 1.6 : Compliance with environmental flow recommendations under unimpacted (natural), historical (gauged) and climate change scenarios and for wet, average and dry climate type years for the Yarra River environmental flow Reach 2 noting that environmental flow recommendations differ between wet, average and dry climate years.

		Unimpacted							Historical							CC 2040 Medium (-11.0 %)							CC 2065 Medium (-16.4%)						
Climate Type	Year	Summer / Autumn Low Flow	Summer / Autumn Fresh	Autumn High	Winter / Spring Low Flow	Winter / Spring Fresh	Spring High	Winter / Spring Bankfull / Overbank	Summer / Autumn Low Flow	Summer / Autumn Fresh	Autumn High	Winter / Spring Low Flow	Winter / Spring Fresh	Spring High	Winter / Spring Bankfull / Overbank	Summer / Autumn Low Flow	Summer / Autumn Fresh	Autumn High	Winter / Spring Low Flow	Winter / Spring Fresh	Spring High	Winter / Spring Bankfull / Overbank	Summer / Autumn Low Flow	Summer / Autumn Fresh	Autumn High	Winter / Spring Low Flow	Winter / Spring Fresh	Spring High	Winter / Spring Bankfull / Overbank
W	1964	0	0	3,360	0	1,275	0	0	0	540	3,360	752	1,275	0	0	0	1,080	3,360	1,176	1,275	0	0	0	1,620	3,360	1,463	1,275	0	0
A	1965	0	0	0	0	1,275	0	4,850	0	540	3,360	4,451	0	5,950	4,850	0	540	3,360	6,580	0	5,950	4,850	0	540	3,360	7,793	0	5,950	4,850
W	1966	0	0	0	0	1,275	0	0	0	0	3,360	161	0	5,950	4,850	12	540	3,360	810	0	5,950	4,850	45	540	3,360	1,420	0	5,950	4,850
D	1967	0	0	3,360	446	1,478	NA	4,985	0	1,080	3,360	11,423	2,955	NA	4,985	7	540	3,360	13,849	2,955	NA	4,985	31	540	3,360	15,084	2,955	NA	4,985
W	1968	94	0	0	0	1,275	0	0	2,709	1,080	3,360	0	0	5,950	0	3,382	1,080	3,360	120	0	5,950	0	3,759	1,080	3,360	373	0	5,950	0
A	1969	0	0	0	0	1,275	0	0	2	0	3,360	2,037	0	0	4,850	25	0	3,360	3,279	0	0	4,850	53	0	3,360	4,080	0	0	4,850
W	1970	0	540	0	0	1,275	0	0	0	0	0	39	1,275	0	0	0	0	0	256	1,275	0	0	0	0	0	467	1,275	0	0
W	1971	0	0	0	0	1,275	0	0	0	0	0	2,147	0	5,950	0	0	0	3,360	3,548	0	5,950	0	0	0	3,360	4,342	0	5,950	0
D	1972	0	0	3,360	0	1,478	NA	4,985	0	0	3,360	14,147	2,955	NA	4,985	0	0	3,360	16,598	2,955	NA	4,985	0	0	3,360	17,904	2,955	NA	4,985
W	1973	0	0	0	0	1,275	0	0	878	0	3,360	4,016	1,275	0	4,850	1,293	0	3,360	6,004	1,275	0	4,850	1,579	0	3,360	7,249	1,275	0	4,850
W	1974	0	540	0	0	0	0	0	233	0	3,360	1,665	0	0	0	583	540	3,360	2,287	0	0	0	821	540	3,360	2,597	1,275	0	0
W	1975	0	0	0	0	0	0	0	0	540	3,360	1,526	1,275	0	0	0	540	3,360	2,524	1,275	0	0	0	540	3,360	3,198	1,275	0	0
D	1976	0	540	3,360	0	1,478	NA	0	0	1,080	3,360	5,703	1,478	NA	4,985	6	1,080	3,360	7,609	1,478	NA	4,985	25	1,620	3,360	8,711	1,478	NA	4,985
W	1977	0	0	0	0	1,275	0	0	0	0	3,360	11,810	0	5,950	0	0	540	3,360	13,612	0	5,950	0	0	540	3,360	14,562	0	5,950	0
W	1978	0	0	3,360	0	1,275	0	0	0	1,620	3,360	4,390	1,275	0	4,850	0	1,620	3,360	6,193	1,275	0	4,850	13	1,620	3,360	7,290	1,275	5,950	4,850
D	1979	0	0	3,360	0	0	NA	4,985	0	1,080	3,360	9,673	2,955	NA	4,985	0	1,080	3,360	12,349	2,955	NA	4,985	1	1,080	3,360	13,740	2,955	NA	4,985
A	1980	0	0	3,360	0	1,275	0	0	222	1,620	3,360	10,255	1,275	5,950	0	668	1,620	3,360	12,844	1,275	5,950	4,850	988	1,620	3,360	14,246	1,275	5,950	4,850
A	1981	0	0	3,360	0	0	0	0	20	1,080	3,360	12,122	1,275	5,950	0	122	1,080	3,360	14,444	1,275	5,950	0	229	1,080	3,360	15,724	1,275	5,950	4,850
D	1982	0	0	3,360	0	0	NA	4,985	6	1,080	3,360	24,136	2,955	NA	4,985	152	1,620	3,360	26,320	2,955	NA	4,985	331	1,620	3,360	27,417	2,955	NA	4,985
A	1983	68	0	3,360	0	0	0	0	3,308	1,620	3,360	10,611	2,550	5,950	4,850	4,134	1,620	3,360	13,179	2,550	5,950	4,850	4,581	1,620	3,360	14,625	2,550	5,950	4,850
A	1984	0	0	3,360	0	1,275	0	0	2	540	3,360	6,498	0	5,950	4,850	53	540	3,360	8,638	0	5,950	4,850	173	1,080	3,360	9,849	0	5,950	4,850
A	1985	0	0	3,360	0	0	0	0	0	1,620	3,360	11,269	0	5,950	0	9	1,620	3,360	13,852	0	5,950	0	65	1,620	3,360	15,202	0	5,950	0
W	1986	0	540	0	0	1,275	0	0	0	0	3,360	5,413	1,275	5,950	4,850	0	0	3,360	7,851	1,275	5,950	4,850	0	0	3,360	9,302	1,275	5,950	4,850
A	1987	0	0	0	0	1,275	0	4,850	0	1,080	3,360	13,978	2,550	5,950	4,850	0	1,080	3,360	16,909	2,550	5,950	4,850	3	1,080	3,360	18,473	2,550	5,950	4,850
A	1988	0	0	3,360	0	0	0	4,850	326	1,620	3,360	15,034	1,275	5,950	4,850	867	1,620	3,360	18,316	2,550	5,950	4,850	1,243	1,620	3,360	20,100	2,550	5,950	4,850
W	1989	0	0	3,360	0	1,275	0	0	58	1,620	3,360	1,435	1,275	5,950	0	210	1,620	3,360	2,489	1,275	5,950	4,850	384	1,620	3,360	3,292	1,275	5,950	4,850
W	1990	0	0	0	0	0	0	0	9	1,080	3,360	4,754	0	0	4,850	140	1,080	3,360	6,535	0	0	4,850	274	1,080	3,360	7,554	0	0	4,850
A	1991	0	1,080	3,360	0	0	0	0	0	1,080	3,360	4,933	0	0	0	0	1,080	3,360	6,191	0	0	0	0	1,080	3,360	6,943	1,275	0	0
W	1992	0	0	3,360	0	1,275	0	0	0	0	3,360	188	0	0	0	0	540	3,360	358	0	0	0	0	540	3,360	473	0	0	0
W	1993	0	1,080	0	0	1,275	0	0	0	1,080	0	201	1,275	0	0	0	1,080	3,360	544	1,275	0	0	0	1,080	3,360	768	1,275	0	0
A	1994	0	1,080	0	0	0	0	4,850	0	0	3,360	4,032	1,275	5,950	4,850	0	0	3,360	6,534	1,275	5,950	4,850	0	0	3,360	8,196	1,275	5,950	4,850
W	1995	0	540	0	0	1,275	0	0	0	0	3,360	2,650	0	5,950	0	0	540	3,360	4,443	0	5,950	0	0	1,080	3,360	5,576	0	5,950	0
W	1996	0	1,080	0	0	0	0	0	0	0	0	130	0	0	0	0	0	3,360	404	0	0	0	0	0	3,360	629	0	0	0
D	1997	0	0	3,360	384	0	NA	4,985	0	1,620	3,360	14,705	2,955	NA	4,985	0	1,620	3,360	17,424	2,955	NA	4,985	0	1,620	3,360	18,837	2,955	NA	4,985
D	1998	0	0	3,360	0	0	NA	0	0	1,620	3,360	8,246	2,955	NA	4,985	2	1,620	3,360	10,367	2,955	NA	4,985	18	1,620	3,360	11,601	2,955	NA	4,985
D	1999	19	0	3,360	0	0	NA	4,985	0	540	3,360	9,538	2,955	NA	4,985	0	540	3,360	12,329	2,955	NA	4,985	0	540	3,360	13,795	2,955	NA	4,985
A	2000	0	0	3,360	0	1,275	0	0	0	540	3,360	945	0	0	0	0	1,080	3,360	1,769	1,275	0	0	12	1,080	3,360	2,462	1,275	0	4,850
D	2001	0	0	3,360	0	0	NA	0	0	1,080	3,360	6,088	1,478	NA	4,985	0	1,620	3,360	7,938	1,478	NA	4,985	0	1,620	3,360	8,937	1,478	NA	4,985
D	2002	0	0	3,360	0	0	NA	4,985	0	1,080	3,360	13,875	1,478	NA	4,985	0	1,080	3,360	16,149	1,478	NA	4,985	3	1,080	3,360	17,314	2,955	NA	4,985
D	2003	0	0	3,360	0	0	NA	0	15	1,620	3,360	1,689	0	NA	4,985	269	1,620	3,360	2,003	0	NA	4,985	528	1,620	3,360	2,236	0	NA	4,985
A	2004	0	0	3,360	17	1,275	0	0	0	1,620	3,360	1,607	0	0	4,850	0	1,620	3,360	2,289	0	0	4,850	0	1,620	3,360	2,731	0	5,950	4,850
A	2005	0	0	3,360	617	0	0	0	0	540	3,360	9,203	2,550	5,950	4,850	0	540	3,360	11,913	2,550	5,950	4,850	0	540	3,360	13,327	2,550	5,950	4,850
D	2006	0	540	3,360	8,962	2,955	NA	4,985	5	1,080	3,360	21,189	2,955	NA	4,985	13	1,620	3,360	23,621	2,955	NA	4,985	17	1,620	3,360	24,862	2,955	NA	4,985
D	2007	862	0	3,360	68	1,478	NA	0	17	1,620	3,360	13,346	2,955	NA	4,985	80	1,620	3,360	15,882	2,955	NA	4,985	182	1,620	3,360	17,203	2,955	NA	4,985
D	2008	81	0	3,360	1,661	0	NA	4,985	12	1,620	3,360	10,398	1,478	NA	4,985	287	1,620	3,360	12,757	2,955	NA	4,985	619	1,620	3,360	14,054	2,955	NA	4,985
D	2009	55	0	3,360	0	0	NA	0	269	1,620	3,360	7,414	2,955	NA	0	636	1,620	3,360	9,139	2,955	NA	4,985	885	1,620	3,360	10,098	2,955	NA	4,985
A	2010	0	0	3,360	0	0	0	0	90	1,080	3,360	987	0	0	0	324	1,620	3,360	1,825	1,275	0	0	526	1,620	3,360	2,490	1,275	0	0
W	2011	0	1,080	0	0	1,275	0	0	0	0	0	320	1,275	5,950	4,850	0	0	0	1,187	1,275	5,950	4,850	0	0	0	1,920	1,275	5,950	4,850
A	2012	0	1,080	0	0	1,275	0	0	0	0	3,360	492	0	0	0	0	0	3,360	1,516	0	0	4,850	0	0	3,360	2,078	0	0	4,850
D	2013	0	0	3,360	0	0	NA	0	0	540	3,360	488	0	NA	4,985	0	540	3,360	1,032	0	NA	4,985	3	540	3,360	1,428	0	NA	4,985
D	2014	0	0	3,360	0	1,478	NA	0	0	0	3,360	2,040	1,478	NA	4,985	1	0	3,360	3,733	1,478	NA	4,985	22	0	3,360	4,859	0	NA	4,985
D	2015	0	0	0	37	1,478	NA	4,985	0	540	0	4,230	1,478	NA	4,985	0	540	0	6,511	2,955	NA	4,985	0	540	0	7,805	2,955	NA	4,985
A	2016	22	0	3,360	0	0	0	0	0	540	3,360	531	0	5,950	4,850	28	540	3,360	1,416	0	5,950	4,850	141	540	3,360	2,100	0	5,950	4,850

Mostly complies		Less than	95%		of maximum possible shortfalls / year
Frequently complies		Between	75% &	95%	of maximum possible shortfalls / year
Often complies		Between	50% &	75%	of maximum possible shortfalls / year
Occasionally complies		Between	25% &	50%	of maximum possible shortfalls / year
Rarely complies		Between	5% &	25%	of maximum possible shortfalls / year
Never complies		Between	0% &	5%	of maximum possible shortfalls / year

As seen in Table 1.6 under historical and short term climate change outlooks (i.e. CC 2040 Medium scenario), compliance with flow recommendations remains relatively good in wet and average climate years with compliance remaining relatively similar. Shortfall volumes were slightly greater in the 2040 scenario. However, there is a decrease in compliance in dry climate years. Under the longer term climate change scenario (i.e. CC

2065 Medium), there is a significant decrease in compliance with flow recommendations, including in wet climate years. Although not presented, there was even greater decreases in compliance for all of the flow recommendations for the 2065 high climate change outlook. In terms of Reach 5 shown in Table 1.7, a similar trend is exhibited as in Reach 2, however overall compliance is predicted to be better, despite overall shortfall volumes being greater, which is caused by the large spring high shortfall volume. This suggests that Reach 5 is less vulnerable then Reach 2, as downstream flows and tributary inflows are large enough to improve compliance with the majority of the recommendations.

Table 1.7 : Compliance with environmental flow recommendations under unimpacted (natural), historical (gauged) and climate change scenarios and for wet, average and dry climate type years for the Yarra River environmental flow Reach 5 noting that environmental flow recommendations differ between wet, average and dry climate years.

		Unimpacted							Historical						
Climate Type	Year	Summer / Autumn Low Flow	Summer / Autumn Fresh	Autumn High	Winter / Spring Low Flow	Winter / Spring Fresh	Spring High	Winter / Spring Bankfull / Overbank	Summer / Autumn Low Flow	Summer / Autumn Fresh	Autumn High	Winter / Spring Low Flow	Winter / Spring Fresh	Spring High	Winter / Spring Bankfull / Overbank
W	1964	0	0	7,700	0	0	0	0	0	2,200	7,700	0	0	0	0
A	1965	0	0	7,700	0	0	0	0	0	0	7,700	0	0	30,100	0
W	1966	0	0	7,700	0	0	0	0	182	0	7,700	0	0	30,100	0
D	1967	0	0	7,700	0	6,650	NA	NA	191	2,200	7,700	3,872	6,650	NA	NA
W	1968	3,138	1,100	0	0	0	0	0	13,854	2,200	7,700	0	0	30,100	0
A	1969	0	0	0	0	0	0	0	212	0	7,700	0	0	0	0
W	1970	0	0	0	0	0	0	0	145	0	0	0	0	0	0
W	1971	0	0	0	0	0	0	0	0	0	0	0	0	0	0
D	1972	0	0	7,700	0	0	NA	NA	0	0	7,700	0	6,650	NA	NA
W	1973	0	0	0	0	0	0	0	2,726	0	0	0	0	0	0
W	1974	0	1,100	0	0	0	0	0	107	0	0	0	0	0	0
W	1975	0	0	0	0	0	0	0	0	0	7,700	0	6,650	0	0
D	1976	0	0	7,700	0	6,650	NA	NA	0	1,100	7,700	22	6,650	NA	NA
W	1977	0	0	0	0	0	30,100	0	0	0	7,700	0	0	30,100	0
W	1978	0	0	7,700	0	0	0	0	0	2,200	7,700	0	0	0	0
D	1979	0	0	7,700	0	6,650	NA	NA	0	0	7,700	0	6,650	NA	NA
A	1980	0	0	7,700	0	0	0	0	2,885	3,300	7,700	3,049	0	30,100	0
A	1981	0	0	7,700	0	0	0	0	919	1,100	7,700	2,408	0	30,100	0
D	1982	0	0	7,700	0	0	NA	NA	780	2,200	7,700	8,760	6,650	NA	NA
A	1983	470	0	7,700	0	0	0	0	9,150	3,300	7,700	11,306	6,650	30,100	0
A	1984	0	0	7,700	0	0	0	0	68	1,100	7,700	488	6,650	0	0
A	1985	0	0	7,700	0	0	0	0	0	1,100	7,700	801	0	30,100	0
W	1986	0	1,100	0	0	0	0	0	0	0	7,700	0	0	30,100	0
A	1987	0	1,100	0	0	0	0	0	0	0	7,700	0	0	30,100	0
A	1988	0	0	7,700	0	0	30,100	0	6	1,100	7,700	59	6,650	30,100	4,650
W	1989	0	0	7,700	0	0	0	0	0	0	7,700	0	0	30,100	0
W	1990	0	0	0	0	0	0	0	0	0	7,700	0	0	30,100	0
A	1991	0	0	7,700	0	0	0	0	0	2,200	7,700	106	0	0	0
W	1992	0	0	7,700	0	0	0	0	0	0	7,700	0	0	0	0
W	1993	0	2,200	0	0	0	0	0	0	2,200	7,700	0	0	0	0
A	1994	0	2,200	0	0	0	0	0	0	1,100	7,700	0	0	30,100	4,650
W	1995	0	0	0	0	0	30,100	0	0	0	0	83	0	30,100	0
W	1996	0	2,200	0	0	0	0	0	0	2,200	0	0	0	0	0
D	1997	0	0	7,700	0	6,650	NA	NA	0	0	7,700	3,004	6,650	NA	NA
D	1998	0	0	7,700	0	0	NA	NA	0	2,200	7,700	2,136	6,650	NA	NA
D	1999	0	0	7,700	0	0	NA	NA	0	0	7,700	2,076	6,650	NA	NA
A	2000	0	0	7,700	0	0	0	0	36	0	7,700	181	0	30,100	0
D	2001	0	0	7,700	0	0	NA	NA	19	0	7,700	3,121	6,650	NA	NA
D	2002	0	0	7,700	0	0	NA	NA	0	1,100	7,700	6,123	6,650	NA	NA
D	2003	0	0	7,700	0	0	NA	NA	994	3,300	7,700	1,329	6,650	NA	NA
A	2004	0	0	7,700	0	0	0	0	85	2,200	7,700	13	0	30,100	0
A	2005	0	0	7,700	23	6,650	0	0	0	0	7,700	388	6,650	30,100	4,650
D	2006	0	0	7,700	10	6,650	NA	NA	120	1,100	7,700	6,100	6,650	NA	NA
D	2007	688	0	7,700	53	0	NA	NA	2,650	3,300	7,700	9,521	6,650	NA	NA
D	2008	577	0	7,700	741	6,650	NA	NA	2,659	3,300	7,700	17,568	6,650	NA	NA
D	2009	50	1,100	7,700	0	0	NA	NA	3,916	3,300	7,700	12,823	6,650	NA	NA
A	2010	0	0	7,700	0	0	0	0	192	3,300	7,700	3,867	6,650	30,100	0
W	2011	0	2,200	0	0	0	0	0	0	0	0	0	0	30,100	0
A	2012	0	2,200	0	0	0	0	0	0	0	7,700	0	0	0	0
D	2013	0	0	7,700	0	0	NA	NA	0	1,100	7,700	0	6,650	NA	NA
D	2014	0	0	0	0	0	NA	NA	0	0	7,700	9	0	NA	NA
D	2015	0	0	0	0	0	NA	NA	2	1,100	7,700	277	6,650	NA	NA
A	2016	0	0	7,700	0	0	0	0	398	0	7,700	169	6,650	30,100	4,650

		CC 2040 Medium (-11.0 %)							CC 2065 Medium (-16.4%)						
Climate Type	Year	Summer / Autumn Low Flow	Summer / Autumn Fresh	Autumn High	Winter / Spring Low Flow	Winter / Spring Fresh	Spring High	Winter / Spring Bankfull / Overbank	Summer / Autumn Low Flow	Summer / Autumn Fresh	Autumn High	Winter / Spring Low Flow	Winter / Spring Fresh	Spring High	Winter / Spring Bankfull / Overbank
W	1964	89	3,300	7,700	28	0	0	0	210	3,300	7,700	125	0	0	0
A	1965	21	0	7,700	0	0	30,100	0	61	1,100	7,700	2	0	30,100	0
W	1966	525	0	7,700	0	6,650	30,100	0	778	0	7,700	0	6,650	30,100	0
D	1967	630	1,100	7,700	6,104	6,650	NA	NA	1,066	1,100	7,700	7,550	6,650	NA	NA
W	1968	15,327	2,200	7,700	0	0	30,100	0	16,087	2,200	7,700	0	0	30,100	0
A	1969	614	0	7,700	0	0	0	0	897	0	7,700	0	0	0	0
W	1970	421	0	0	0	0	0	0	712	0	0	0	0	0	0
W	1971	0	0	0	0	0	0	0	0	0	7,700	0	0	0	0
D	1972	0	0	7,700	487	6,650	NA	NA	0	0	7,700	1,163	6,650	NA	NA
W	1973	3,540	0	7,700	0	0	30,100	0	3,988	0	7,700	0	0	30,100	0
W	1974	518	0	0	0	0	0	0	862	0	0	0	0	0	0
W	1975	0	0	7,700	0	6,650	0	0	0	1,100	7,700	0	6,650	0	0
D	1976	0	2,200	7,700	286	6,650	NA	NA	0	2,200	7,700	685	6,650	NA	NA
W	1977	0	0	7,700	0	0	30,100	0	0	0	7,700	25	0	30,100	0
W	1978	29	2,200	7,700	0	6,650	0	0	148	2,200	7,700	0	6,650	0	0
D	1979	0	1,100	7,700	0	6,650	NA	NA	0	1,100	7,700	9	6,650	NA	NA
A	1980	4,273	3,300	7,700	4,347	0	30,100	0	5,081	3,300	7,700	5,089	0	30,100	0
A	1981	1,650	1,100	7,700	4,173	0	30,100	0	2,140	1,100	7,700	5,155	0	30,100	0
D	1982	1,533	2,200	7,700	12,288	6,650	NA	NA	2,030	2,200	7,700	14,284	6,650	NA	NA
A	1983	11,086	3,300	7,700	13,534	6,650	30,100	0	12,165	3,300	7,700	14,676	6,650	30,100	0
A	1984	392	1,100	7,700	1,436	6,650	0	0	752	1,100	7,700	2,045	6,650	0	0
A	1985	44	2,200	7,700	1,476	0	30,100	0	239	2,200	7,700	1,917	0	30,100	0
W	1986	0	0	7,700	0	0	30,100	4,650	0	0	7,700	0	0	30,100	4,650
A	1987	0	0	7,700	0	0	30,100	0	0	0	7,700	0	0	30,100	0
A	1988	276	1,100	7,700	258	6,650	30,100	4,650	724	1,100	7,700	502	6,650	30,100	4,650
W	1989	0	0	7,700	0	0	30,100	0	0	0	7,700	0	0	30,100	0
W	1990	0	1,100	7,700	22	0	30,100	0	32	2,200	7,700	64	0	30,100	4,650
A	1991	0	2,200	7,700	278	0	0	0	0	3,300	7,700	409	0	0	0
W	1992	3	0	7,700	0	0	0	0	15	0	7,700	0	0	0	0
W	1993	0	2,200	7,700	0	0	0	0	0	2,200	7,700	0	6,650	0	0
A	1994	0	0	7,700	0	0	30,100	4,650	0	0	7,700	0	0	30,100	4,650
W	1995	0	1,100	0	122	0	30,100	0	0	1,100	0	157	0	30,100	0
W	1996	0	0	0	0	0	0	0	0	0	0	0	0	0	0
D	1997	0	1,100	7,700	5,368	6,650	NA	NA	0	1,100	7,700	6,854	6,650	NA	NA
D	1998	0	3,300	7,700	3,709	6,650	NA	NA	23	3,300	7,700	4,694	6,650	NA	NA
D	1999	6	0	7,700	4,012	6,650	NA	NA	18	1,100	7,700	5,190	6,650	NA	NA
A	2000	241	1,100	7,700	431	0	30,100	0	510	1,100	7,700	736	0	30,100	0
D	2001	162	2,200	7,700	5,253	6,650	NA	NA	344	2,200	7,700	6,545	6,650	NA	NA
D	2002	0	2,200	7,700	10,037	6,650	NA	NA	0	2,200	7,700	12,282	6,650	NA	NA
D	2003	2,238	3,300	7,700	3,111	6,650	NA	NA	3,057	3,300	7,700	4,309	6,650	NA	NA
A	2004	828	2,200	7,700	232	6,650	30,100	0	1,423	3,300	7,700	474	6,650	30,100	0
A	2005	0	1,100	7,700	1,458	6,650	30,100	4,650	0	1,100	7,700	2,342	6,650	30,100	4,650
D	2006	343	1,100	7,700	9,913	6,650	NA	NA	549	2,200	7,700	12,234	6,650	NA	NA
D	2007	4,939	3,300	7,700	14,135	6,650	NA	NA	6,321	3,300	7,700	16,577	6,650	NA	NA
D	2008	4,559	3,300	7,700	22,078	6,650	NA	NA	5,683	3,300	7,700	24,410	6,650	NA	NA
D	2009	5,488	3,300	7,700	16,599	6,650	NA	NA	6,753	3,300	7,700	18,542	6,650	NA	NA
A	2010	744	3,300	7,700	5,654	6,650	30,100	0	1,376	3,300	7,700	6,569	6,650	30,100	0
W	2011	0	0	0	0	0	30,100	4,650	0	0	0	0	0	30,100	4,650
A	2012	12	0	7,700	0	0	30,100	0	69	0	7,700	0	0	30,100	0
D	2013	0	1,100	7,700	21	6,650	NA	NA	0	1,100	7,700	143	6,650	NA	NA
D	2014	44	0	7,700	47	0	NA	NA	120	1,100	7,700	83	0	NA	NA
D	2015	58	2,200	7,700	1,397	6,650	NA	NA	156	2,200	7,700	2,275	6,650	NA	NA
A	2016	1,215	2,200	7,700	536	6,650	30,100	4,650	1,847	3,300	7,700	946	6,650	30,100	4,650

Mostly complies	Less than	95%		of maximum possible shortfalls / year
Frequently complies	Between	75% &	95%	of maximum possible shortfalls / year
Often complies	Between	50% &	75%	of maximum possible shortfalls / year
Occasionally complies	Between	25% &	50%	of maximum possible shortfalls / year
Rarely complies	Between	5% &	25%	of maximum possible shortfalls / year
Never complies	Between	0% &	5%	of maximum possible shortfalls / year

It should be noted that the compliance and shortfalls for the Autumn High (April/May) environmental flow recommendations in both reaches (shown in Table 1.6 and Table 1.7) suggests that the recommendation is not being achieved at all, despite historically being targeted between 2010 to 2016. This is because partial achievement of a flow recommendation for a single event is not considered compliant if the duration is not fully met (in the case of the Autumn High, 7 full days above 560 ML/day in Reach 2 and 1300 ML/day in Reach 5 is required).

This is demonstrated with reference to historical (gauged) flows in Reach 5 for the following years in the Autumn (April/May) period:

- 2011/12 – Flows above 1300 ML/day for 6 days at the end of May, event continues post May above threshold but is not included in the 7 day duration.
- 2012/13 – Flows above 1300 ML/day for 1 day.
- 2013/14 – Flows above 1300 ML/day for 6 days and 1 day below (so non-event based on how event is defined in compliance assessment – less than 7 day duration above 1300 ML/day)
- 2014/15 – Flows above 1300 ML/day for 4 days.
- 2015/16 – No event.

Partial achievement of flow recommendation and hence partial compliance for an event is not calculated, where the flow component has only 1 event (as is the case with the Autumn high flow). In a particular year, it either meets the full 7 days or not, so the shortfalls are consistently the same if it is 1 day short or 5 days short of the recommended 7 day duration. This is different to other flow components that have partial compliance because they have more than 1 event as part of their recommendations. If the tool was set up to assess partial compliance for the Autumn High flow, then the assessment of compliance would be greater and shortfall volumes lower for this recommended flow component.

Shortfall Assessment

Shortfalls were calculated as the volume required to meet environmental flow volume requirements. Compliance and shortfalls for Reach 2 and Reach 5 are presented as box-whisker plots to illustrate the distribution of event compliance and shortfalls. Figure 1.4 illustrates the components of a box-whisker plot, where the box represents the distribution of values between 25th (Q2) and 75th (Q3) percentiles, with whiskers representing the 10th and 90th percentiles as lower and upper bounds.

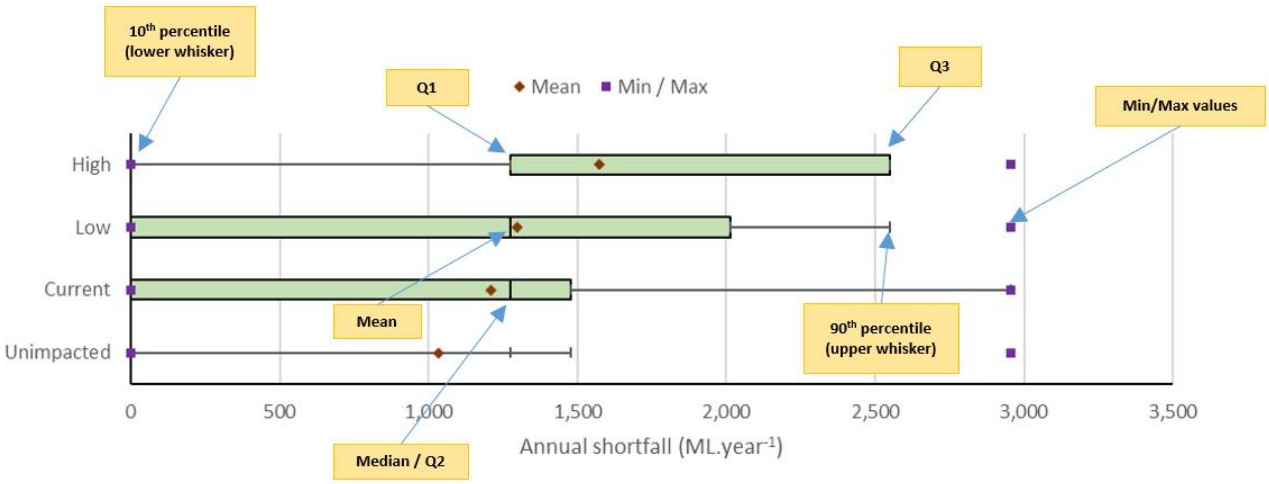

Figure 1.4 : Box-Whisker plot interpretation.

An assessment of the magnitude of the annual shortfall (the volume of water required to deliver all environmental flow recommendations assuming the river was flowing at the minimum passing flow), was also undertaken. Shortfall volumes were calculated for current conditions and climate change 2040 and 2065 scenarios for low flow recommendations, and separately for fresh and high flow recommendations for Reaches 2 (see Figure 1.5) and 5 (see Figure 1.6). Shortfall volumes were not determined for bankfull or overbank flow recommendations because the Environmental Entitlement (EE) is not used to deliver these types of flow events. The shortfalls are presented as box plots that show the percentage of time (in years) that a particular shortfall volume is required for wet, average and dry climate year under historical and various climate change scenarios.

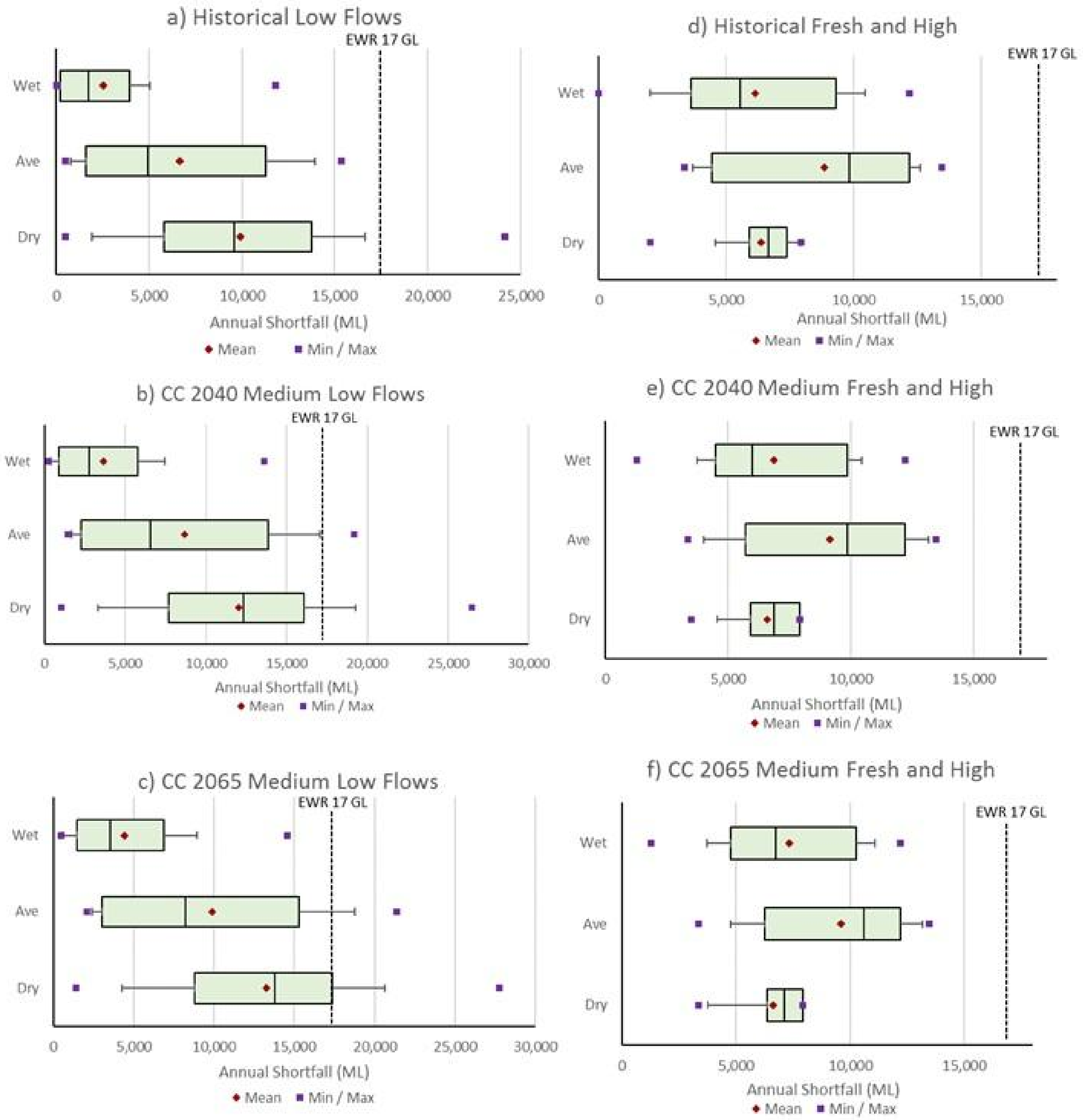

Figure 1.5 : Shortfall volumes required to achieve compliance with summer and winter low flow recommendations and fresh and high flow recommendations in the Yarra River (Reach 2) in wet, average and dry climate years under current and medium impact climate change flow scenarios. The centre of the box marks the median annual shortfall volume, margins of the box shows the 25th and 75th percentile shortfall volume ranges, the whiskers mark the 5th and 90th percentile shortfall volume ranges. The dotted line indicates the volume of the existing Environmental Entitlement (17 GL).

The analysis for Reach 2 and 5 shows that for summer and winter low flows under current conditions there is very little shortfall in delivery of low flow recommendations. This is because low flows are currently delivered as a passing flow requirement. However, during very dry years, and with climate change, there is a decrease in compliance with low flow recommendations and an increase in the volume of water that would need to be released from storages in order to meet low flow recommendations. Under the long term climate change scenario (CC Medium 2065), a significant volume of water would need to be released just to meet low flow recommendations, particularly in a dry climate year. The shortfall volume required to meet low flow recommendations would use the majority of the annual entitlement presently held in the EE (17 GL/annum) and in those years there would be not enough spare entitlement to deliver any fresh or high flows.

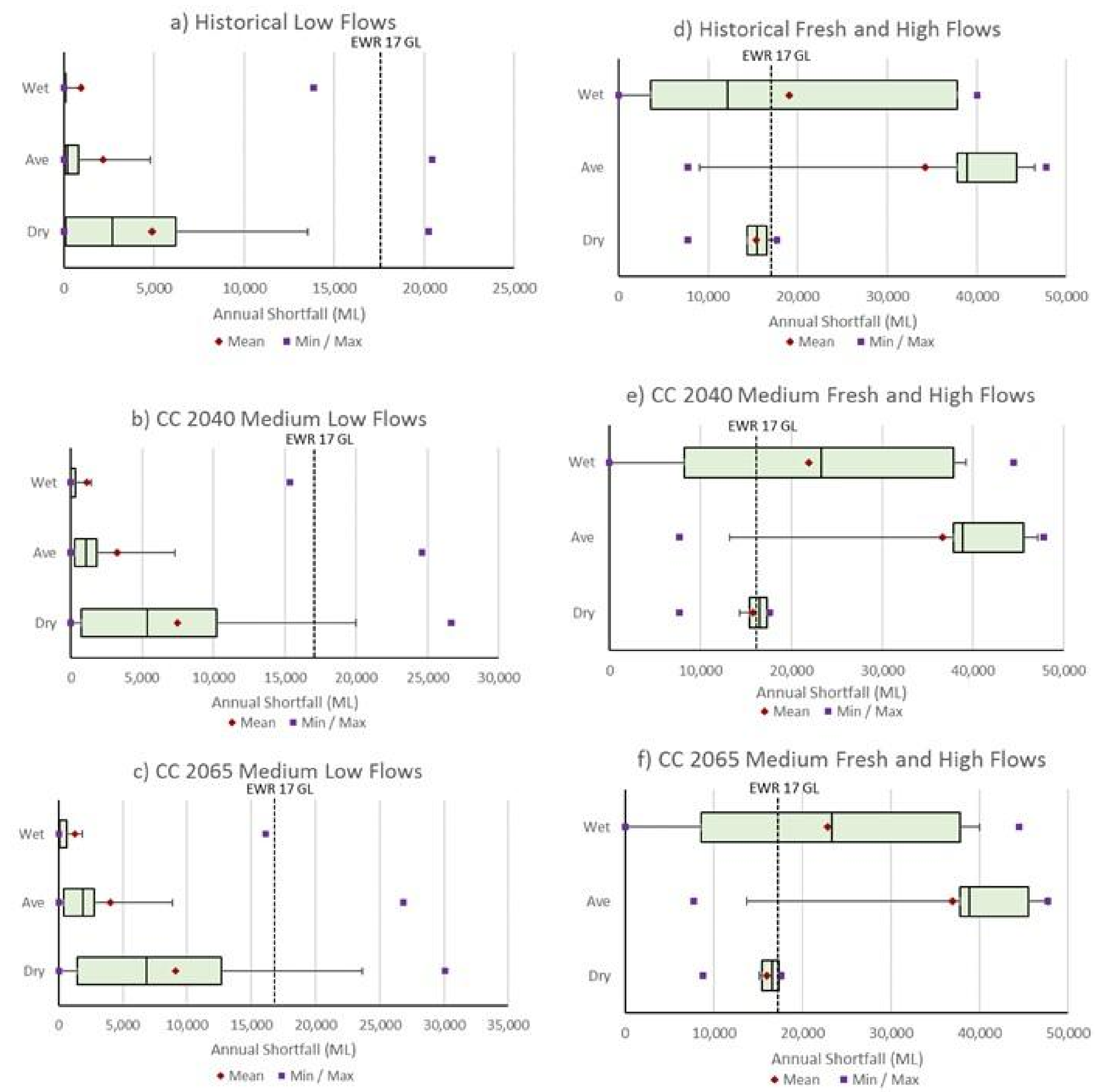

Figure 1.6 Shortfall volumes required to achieve compliance with summer and winter low flow recommendations and fresh and high flow recommendations in the Yarra River (Reach 5) in wet, average and dry climate years under current and medium impact climate change flow scenarios. The centre of the box marks the median annual shortfall volume, margins of the box shows the 25th and 75th percentile shortfall volume ranges, the whiskers mark the 5th and 90th percentile shortfall volume ranges. The dotted line indicates the volume of the existing Environmental Entitlement (17 GL).

A similar trend is found for the fresh and high flow events, with shortfall volumes increasing in average years versus wet years for Reach 2. A significant reduction in shortfalls in dry years is shown, this is due to the different recommendations for average/wet years versus dry. This analysis also shows that under all conditions, the existing EE is sufficient to deliver all fresh and high flow recommendations in all years for Reach 2. On the other hand, the assessment for Reach 5 shows that under all conditions in the majority of years there would not be enough EE to meet fresh and high flow events in wet/average years. This is because of the shortfall volumes for spring high flow events are significantly larger (i.e. 30,000 GL) than the remainder of recommendations thereby increasing the total annual shortfall volume. However, the EE would be enough to meet compliance in dry years, given the fact that the dry flow recommendations require less volume. It should be noted that the compliance and shortfall assessment in this section treats the reaches independently, that is, it does not consider the connectivity between the flow events across the reaches. This results in apparent differences in compliance and shortfall volumes when comparing reaches.

Environmental Entitlement Assessment

The average compliance and shortfall pre and post the introduction of the EE and delivery of environmental flows in 2010, in the Reaches 2 and 5 for each year type were analysed and are presented in Table 1.8. The EE under the historical scenario suggests that there has been an improvement in compliance and reductions in shortfalls in both reaches. This is particularly evident in dry and average years, where total shortfall across all recommendations reduces by 12 GL in Reach 2 with the active management of the EE. Further downstream in Reach 5, shortfalls have reduced by approximately 8.8 and 1.3 GL for dry and average years, respectively.

Table 1.8 : Average compliance with environmental flow recommendations and associated shortfall under historical (gauged) and climate change scenarios and for wet, average and dry climate type years for the Yarra River environmental flow Reach 2 and 5 noting that environmental flow recommendations differ between wet, average and dry climate years.

		Climate Type	Historical						
			Summer / Autumn Low Flow	Summer / Autumn Fresh	Autumn High	Winter / Spring Low Flow	Winter / Spring Fresh	Spring High	Winter / Spring Bankfull / Overbank
Reach 2	Pre 2010	W	229	445	2,569	2,428	600	2,450	1,426
		A	277	964	3,360	7,641	911	4,250	3,118
		D	22	1,188	3,360	11,438	2,364	NA	4,653
	Post 2010	W	0	0	0	320	1,275	5,950	4,850
		A	30	540	3,360	670	0	1,983	1,617
		D	0	360	2,240	2,253	985	NA	4,985
Reach 5	Pre 2010	W	1,001	647	4,982	5	391	12,394	0
		A	954	1,179	7,700	1,343	1,900	23,650	996
		D	755	1,540	7,700	5,097	6,650	NA	NA
	Post 2010	W	0	0	0	0	0	30,100	0
		A	197	1,100	7,700	1,345	4,433	20,067	1,550
		D	1	733	7,700	95	4,433	NA	NA

		Climate Type	CC 2040 Medium (-11.0 %)						
			Summer / Autumn Low Flow	Summer / Autumn Fresh	Autumn High	Winter / Spring Low Flow	Winter / Spring Fresh	Spring High	Winter / Spring Bankfull / Overbank
Reach 2	Pre 2010	W	331	635	3,162	3,480	600	2,450	1,712
		A	420	1,003	3,360	9,767	1,093	4,250	3,464
		D	97	1,260	3,360	13,622	2,463	NA	4,985
	Post 2010	W	0	0	0	1,187	1,275	5,950	4,850
		A	117	720	3,360	1,585	425	1,983	3,233
		D	0	360	2,240	3,759	1,478	NA	4,985
Reach 5	Pre 2010	W	1,203	712	5,435	10	1,174	14,165	274
		A	1,387	1,336	7,700	1,973	2,375	23,650	996
		D	1,327	1,980	7,700	7,559	6,650	NA	NA
	Post 2010	W	0	0	0	0	0	30,100	4,650
		A	657	1,833	7,700	2,063	4,433	30,100	1,550
		D	34	1,100	7,700	488	4,433	NA	NA

		Climate Type	CC 2065 Medium (-16.4%)						
			Summer / Autumn Low Flow	Summer / Autumn Fresh	Autumn High	Winter / Spring Low Flow	Winter / Spring Fresh	Spring High	Winter / Spring Bankfull / Overbank
Reach 2	Pre 2010	W	404	699	3,162	4,150	675	2,800	1,712
		A	525	1,041	3,360	10,982	1,184	4,675	4,157
		D	176	1,296	3,360	14,786	2,561	NA	4,985
	Post 2010	W	0	0	0	1,920	1,275	5,950	4,850
		A	222	720	3,360	2,222	425	1,983	3,233
		D	8	360	2,240	4,697	985	NA	4,985
Reach 5	Pre 2010	W	1,343	841	5,888	22	1,565	14,165	547
		A	1,714	1,571	7,700	2,382	2,375	23,650	996
		D	1,723	2,127	7,700	9,022	6,650	NA	NA
	Post 2010	W	0	0	0	0	0	30,100	4,650
		A	1,097	2,200	7,700	2,505	4,433	30,100	1,550
		D	92	1,467	7,700	834	4,433	NA	NA

Mostly complies	Less than	95%			of maximum possible shortfalls / year
Frequently complies	Between	75%	&	95%	of maximum possible shortfalls / year
Often complies	Between	50%	&	75%	of maximum possible shortfalls / year
Occasionally complies	Between	25%	&	50%	of maximum possible shortfalls / year
Rarely complies	Between	5%	&	25%	of maximum possible shortfalls / year
Never complies	Between	0%	&	5%	of maximum possible shortfalls / year

Under the short and long term climate change outlooks, there is a reduction in compliance and increased shortfalls for all years compared with Historical. As was the case for the historical scenario, shortfalls are reduced post 2010 indicating that the active management of the EE under a climate change scenario would also be of benefit in management of the river. Additionally, it can be seen that a reduced shortfall does not necessarily equate to an increased compliance. This is because of how compliance has been defined (e.g. frequently occurs ranges between 75-95%). It should be noted, the years since the EE was enacted tend to correspond to dry climate years when compliance is not as good, so the benefit of the EE is much more evident. This suggests and demonstrates that the intended use of the EE, that is, to protect flows during dry years, is being achieved.

It should be noted, compliance and shortfalls for the Autumn High environmental flow recommendations under Historical conditions with the introduction of the EE, suggests that there has been minimal improvement despite being targeted. This is because partial compliance using the compliance tool for a single event is not considered met if the duration is not entirely achieved. In reality, compliance would be greater and shortfall volumes lower for the Autumn High, further supporting the importance of the EE.

A summary table comparing the average shortfalls for dry, average and wet years to the environmental entitlement for different climate change projection is given in Table 1.9. It can be seen for Reach 2, that under the historical scenario the current EE is enough to meet all shortfalls, with 2,440 ML remaining in the EE. However, this volume begins to reduce under climate change, this is particularly noticeable for the 2065 outlook, where an additional volume of 1,232 ML is required. Reach 5 shortfall analysis, on the other hand, suggests that there is not enough EE to meet environmental flow recommendation currently, with the historical scenario needing an additional 14,627 ML. This is because the EE is not enough to meet the spring high flow event environmental flow recommendation. The net water required to meet the environmental flow recommendations increases to 19,604 ML under a longer term climate change outlook.

Table 1.9 : Comparing average shortfalls to available environmental entitlement for dry, average and wet years for each environmental flow component and climate change projection for Reach 2 and 5.

Climate Scenario	Historical Baseline	2040 Median Climate	2065 Median Climate
Reach	**Reach 2: Armstrong Creek to Millgrove**		
Summer - Autumn Low	156	253	334
Summer - Autumn High, Fresh	3,773	4,061	4,102
Winter - Spring, Low	6,210	7,885	8,856
Winter - Spring High, Fresh	4,421	4,551	4,940
Total Shortfall	-14,560	-16,750	-18,232
Environmental Water	17,000	17,000	17,000
Net Water	2,440	250	-1,232
Reach	**Reach 5: Top of Yering Gorge to Mullum Mullum Creek**		
Summer - Autumn Low	798	1,169	1,441
Summer - Autumn High, Fresh	7,762	8,154	8,485
Winter - Spring, Low	1,870	2,793	3,360
Winter - Spring High, Fresh	21,197	23,295	23,418
Total Shortfall	-31,627	-35,411	-36,704
Environmental Water	17,000	17,000	17,000
Net Water	-14,627	-18,411	-19,704

1.3.3 Assessment using stochastically generated climate change scenarios

Four climate scenarios were stochastically generated as part of the ARC Linkage Project at the University of Melbourne. Scenarios include an (i) unimpacted, (ii) current, (iii) low climate change outlook, and (iv) high climate change outlook. The four generated scenarios were derived using a stochastic data generation method in order to characterize *natural* variability in a consistent manner. Considering the spatial variation of rainfall across the catchment, a multi-site stochastic weather generator, the Multi-site weather Generator of École de Technologie Supérieure (MulGETS; Chen et al. 2014), was used to generate daily rainfall at main sub-catchments. MulGETS generates spatially coherent climate information at multiple sites by driving the individual single-site models with temporally independent but spatially correlated random numbers.

Changes in future climate was estimated by comparing the simulations of a future period 2055-2074 (centered on 2065) to a reference period 1986-2005. The emission scenario adopted is Representative Concentration Pathways 8.5, which is a climate projection with the highest greenhouse gas emission. Two GCMs have been selected, with ACCESS1.0 representing a relatively high estimate of this climate change scenario and MIROC5 representing a relatively low estimate. Climate simulations of the two GCMs are available from the Coupled Model Intercomparison Project Phase 5 (CMIP5).

Once two hundred years of daily rainfall was developed for each scenario, a rainfall runoff model, SIMHYD was used to generate two hundred years of streamflow data at Reach 2 and 5. Bias correction was then applied to remove any bias originating from the stochastic weather generator. It should be noted that for the remainder of this section, 200 years of data will be defined as 200 replicates.

Figure 1.7 and Figure 1.8 show the daily streamflows for all four scenarios, with the middle line representing the median of the 200 replicates and the shaded area represents the range between the 5^{th} and 95^{th} percentile. In both figures, it can be seen that under the low and high climate change (plots c) and d), respectively) the spread and median streamflow is reduced compared with current (plot a). Alternatively, the unimpacted scenario has larger median streamflows and a wider spread (i.e. more variation in predicted stream flow and overall higher flows).

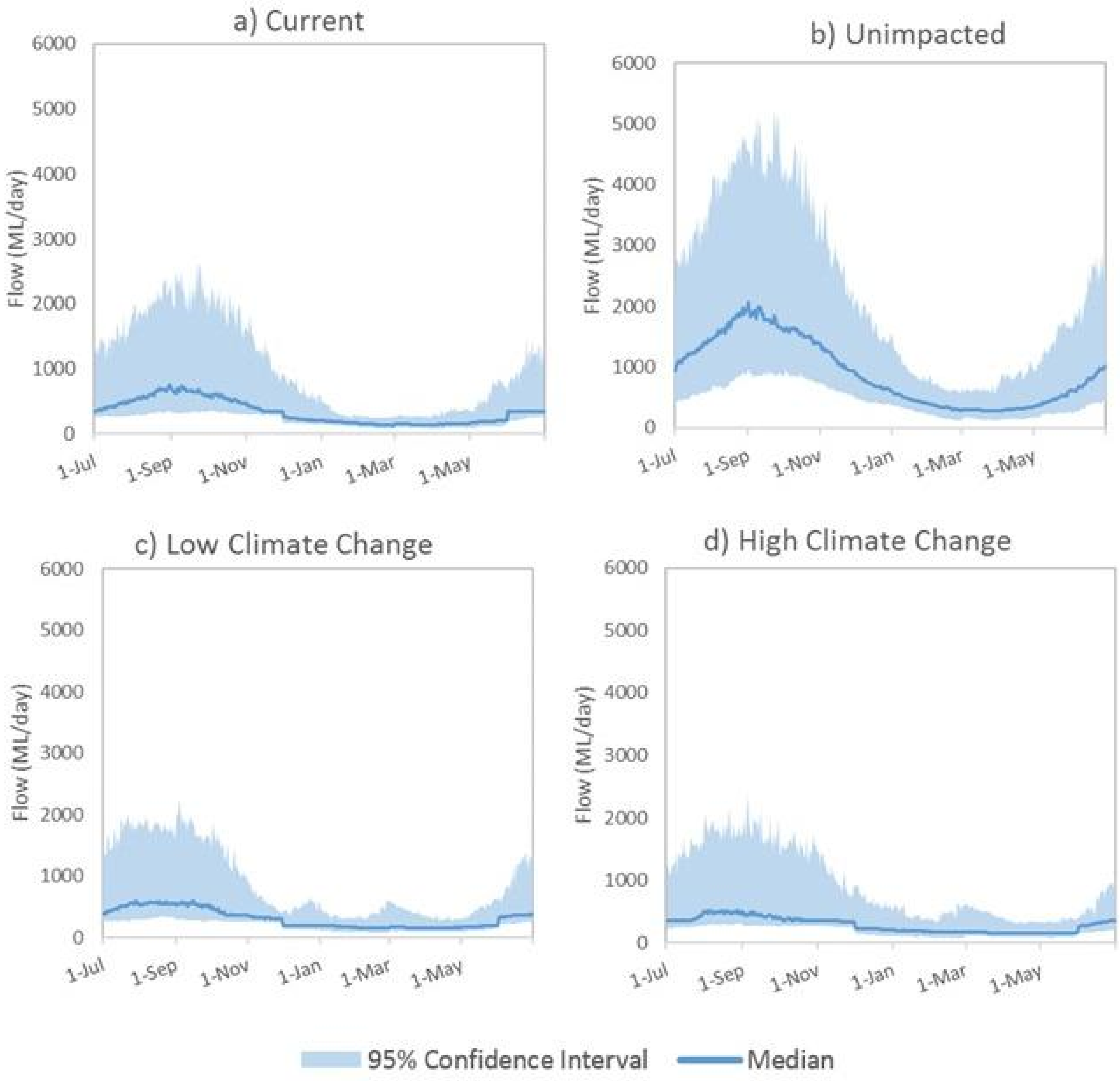

Figure 1.7 : Daily hydrograph at Reach 2 for a) Current, b) unimpacted, c) low climate change and d) high climate change scenarios (NB. Middle lines represent the median of 200 replicates and shaded area represents the range between the 5th and 95th percentile of 200 replicates).

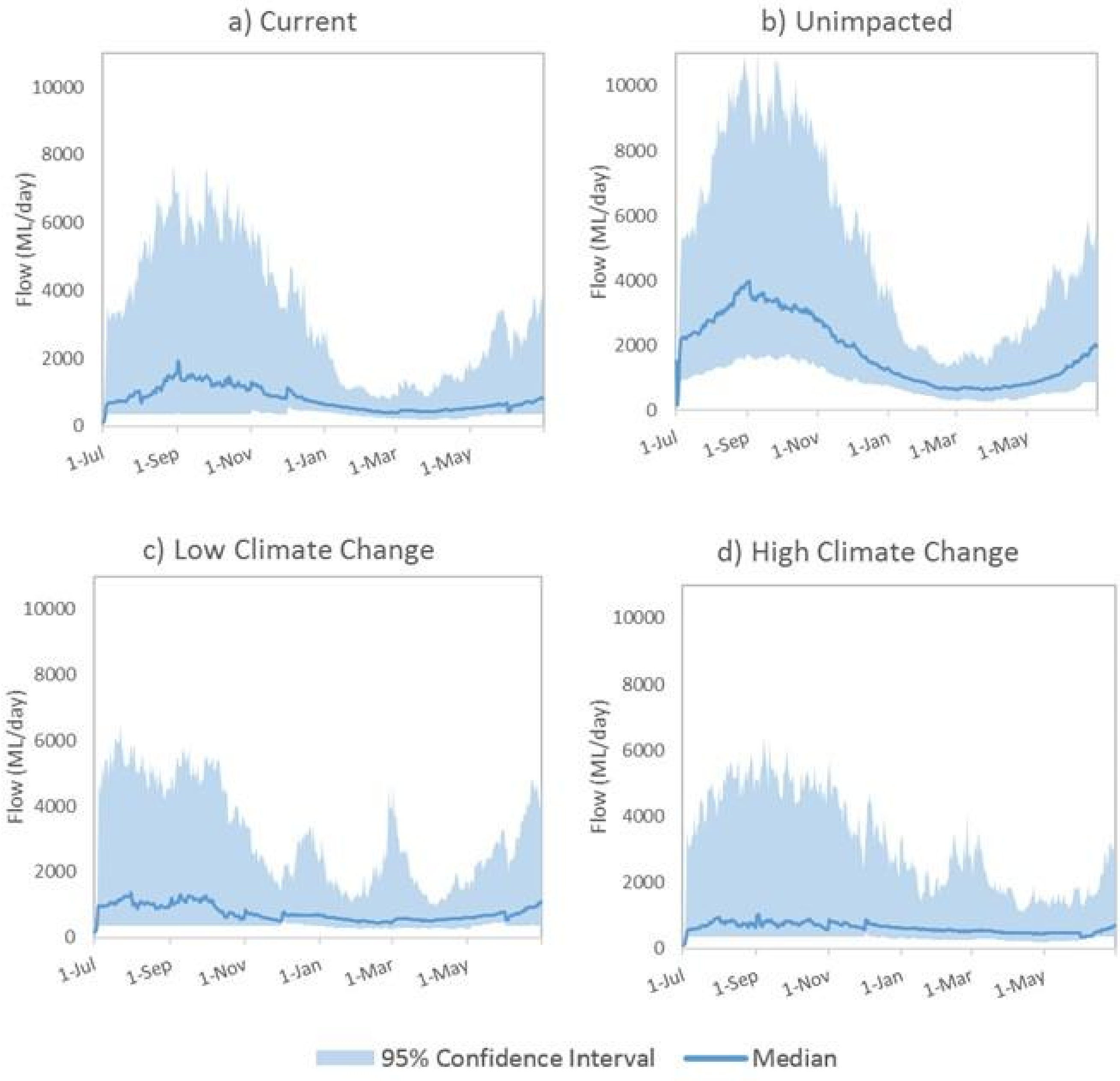

Figure 1.8 : Daily hydrograph at Reach 2 for a) Current, b) unimpacted, c) low climate change and d) high climate change scenarios (NB. Middle lines represent the median of 200 replicates and shaded area represents the range between the 5th and 95th percentile of 200 replicates).

Compliance, Shortfall and Environmental Entitlement Assessment

Reach 2 and 5 annual compliance boxplots using the 200 replicates, for low flows, and fresh and high flows are presented in Figure 1.9. In general, it can be seen that compliance reduces as the impact of climate change increases. This is specifically noticeable in Reach 2 (see plots a) and c)). Alternatively, Reach 5 low flows are generally 100% compliant for all scenarios, while the fresh and high flows reduce in compliance as the climate change outlooks increase from low to high. Under the unimpacted scenario, low flows are generally compliant however, fresh and high flows compliance is on average 70%. These results are consistent with distribution of streamflows shown in Figure 1.8, where the reduction in medium flows from unimpacted to the climate change outlooks is noticeable. As was the case in Section 1.3.2, compliance for fresh and high flows was more varied than low flows.

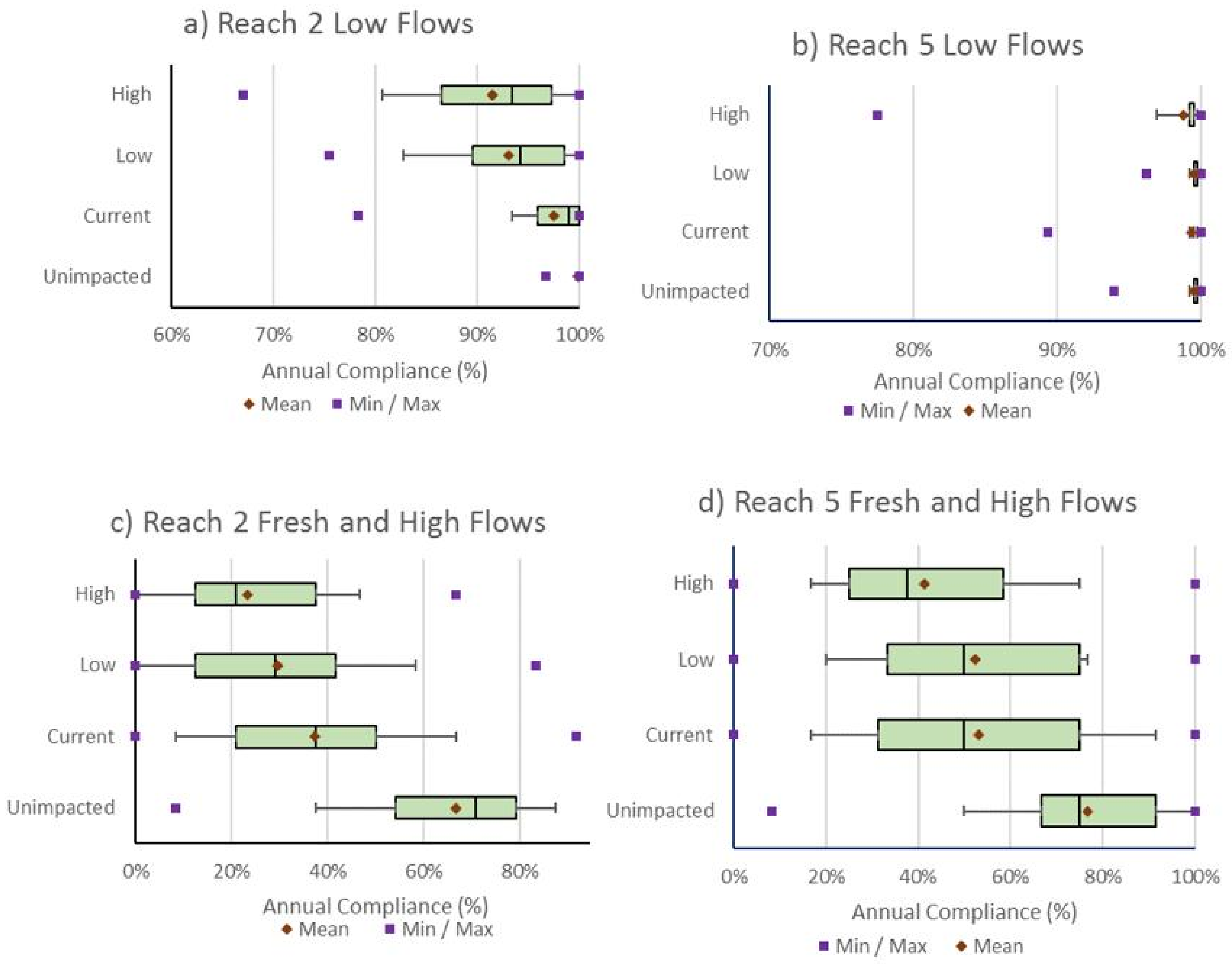

Figure 1.9 : Boxplots of low and high.

The distribution of annual shortfall for lows flows, and fresh and high flows events in Reach 2 were also analysed and are presented in Figure 1.10. It can be seen for both flow recommendations that annual shortfall volumes increase, from the unimpacted scenario to the climate change projections. Reach 5 annual shortfall distribution for low flows (plot a), and fresh and high flows (plot b) are presented in Figure 1.11. Unlike Reach 2, shortfall volumes for low flows are lower, since there are further contributing inflows downstream increasing streamflows to meet the low flow recommendations. On the other hand, shortfall volumes vary significantly for fresh and high flows recommendations, which is consistent with finding in

Section 1.3.2. However, the results suggest that using this method to assess shortfalls that the 17GL EE is enough to meet both low and fresh and high flows recommendations even when climate change is considered. Further discussion on the differences in using the climate change guidelines to scale runoff and the stochastically generated approach described in this section is presented in Section 1.3.4.

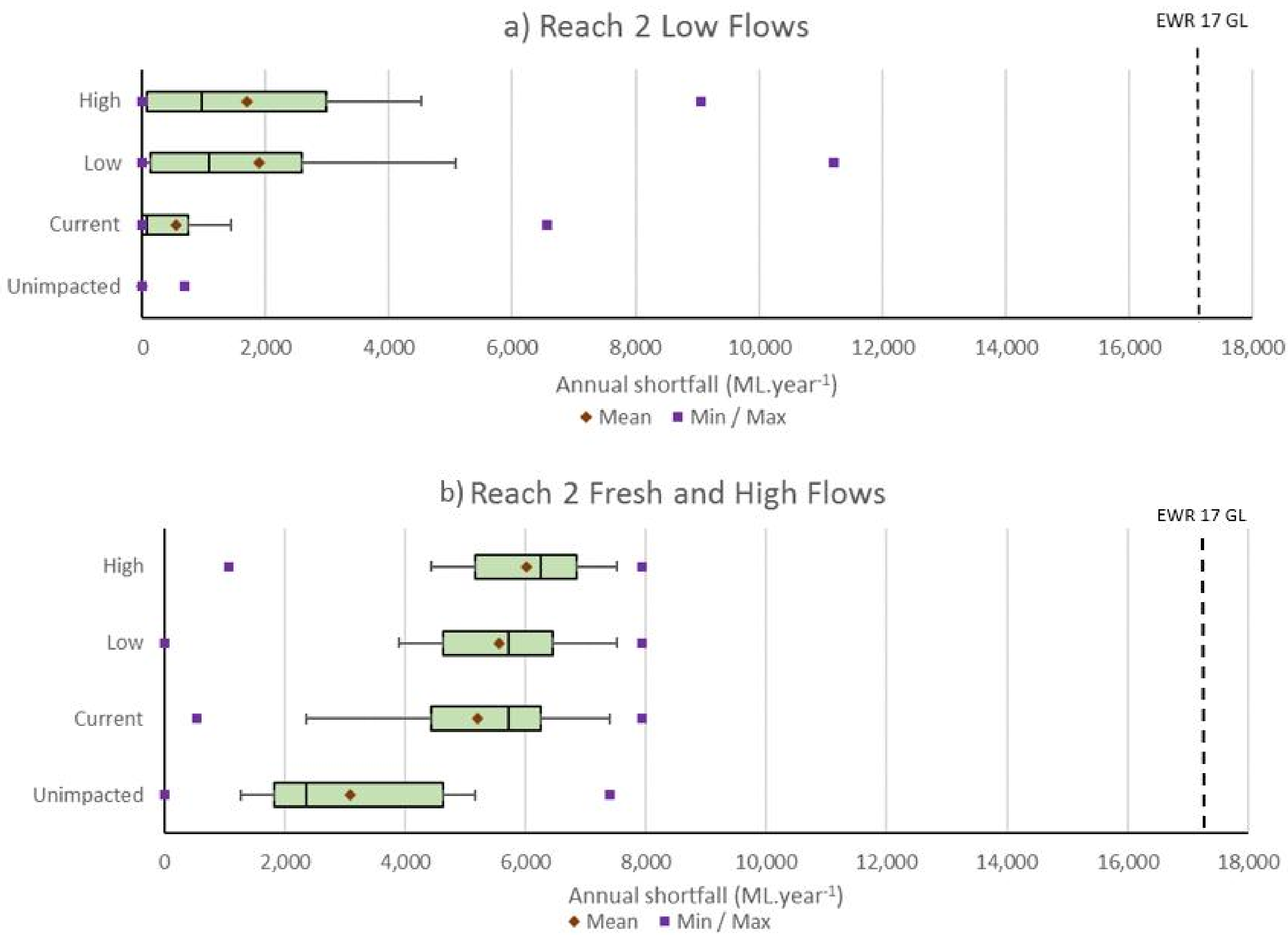

Figure 1.10 : Reach 2 shortfall for low flows (plot a) and fresh and high flows (plot b) for unimpacted, current, low and high climate change scenarios

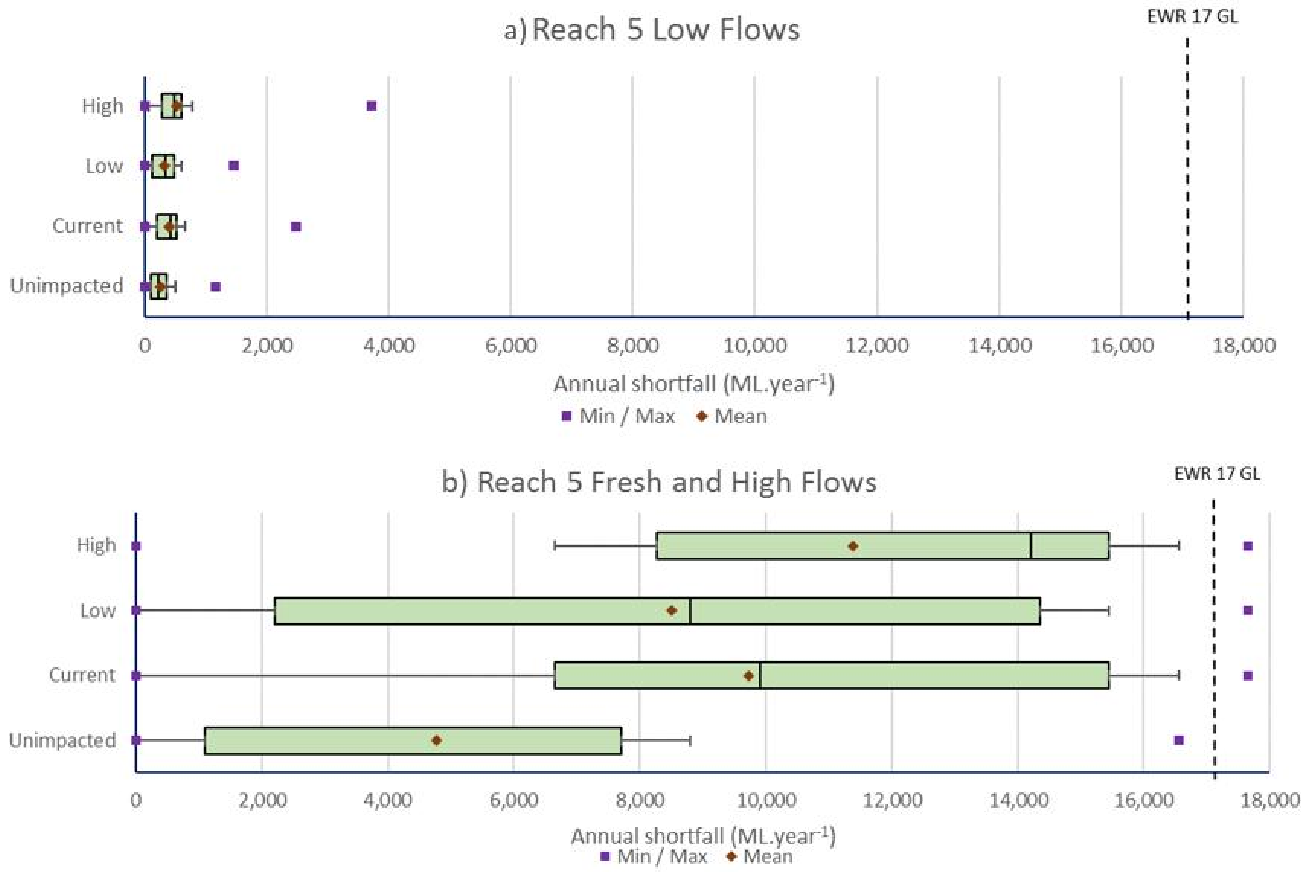

Figure 1.11 : Reach 5 shortfall for low flows (plot a) and fresh and high flows (plot b) for unimpacted, current, low and high climate change scenarios

1.3.4 Summary and conclusions

The analysis using the DELWP Climate Change guidelines (see Section 1.3.2), uses scaling factors to reduce streamflow to account for climate change outlooks. This assesses the worst case climate change scenario, indicating that it will become increasingly difficult to meet low flow recommendations and to maintain the current level of compliance with fresh and high flow recommendations with the existing volume of EE. If it is assumed that the EE is not required to deliver low flow recommendations (i.e. passing flow requirements), then an increase in the EE from 17 GL to 40-50 GL/annum is required to meet all flow recommendations. In Section 1.3.3, a sophisticated approach that accounts for not only reductions in streamflow but also the changes in variability under climate change is investigated. Unlike the DELWP climate change guidelines, the shortfalls are not as large, indicating that the EE may be sufficient to meet the majority of flow recommendations in most years.

The apparent differences in shortfall results, for example when comparing the current scenario, can be attributed to the different methods and data used in each assessment. The former (i.e. DELWP guidelines) used gauged historical streamflow data, whereas the sophisticated approach stochastically constructed modelled streamflow using a weather generator and rainfall-runoff model. By modelling the streamflow, errors could have been introduced thereby underestimating flows at Reach 5. A direct comparison of the two methods can thus not be fully undertaken. In addition, the sophisticated method attempts realistic representative changes in natural variability and rainfall frequencies under climate change. There still much research to be undertaken in this area. As methods, knowledge and data improve overtime, it is likely that these probabilistic streamflow estimates, and in turn compliance and shortfall estimates, will be more accurate in the future.

Overall, the climate change assessments investigation on compliance and shortfall of environmental flow recommendations in the Yarra River showcases different outcomes that could occur in the future depending on the method used. It should be noted, that there still remains a great amount of uncertainty associated with future climate change outlooks and research in this area is continuing. Table 1.10 shows the advantages and disadvantages of each approach. Because of this, when planning for climate change it is recommended to take a conservative and widely accepted approach, as proposed by the DELWP climate change guidelines and assume that current EE will not be able to meet all recommendations. However, as methods, tools and assumptions are refined and improved when new science becomes available, the amount of additional water that needs to be obtained to meet shortfalls will most likely need to be revisited. Improvements could include ensuring a realistic representation of current using the stochastically generated streamflow, or a method to assess meeting dry and average/wet recommendations using the stochastic approach.

Table 1.10 : Summary of advantages and disadvantages of each climate change approach

	DELWP Climate Change Guidelines Approach	Stochastically generated climate change approach
Advantages	· Simple · Wide accepted · Conservative · Realistic representation of current compliance because it is based on the measured historical flow	· Probability of the likely streamflows under different climate change scenarios is estimated. This can be used to assess climate change risk more accurately. · Incorporates changes in variability and rainfall extremes under climate change
Disadvantages	· Only uses one-time series for each climate change projection · Does not taking ton account natural variability or increases in rainfall extremes under climate change	· Dry, average and wet year compliance difficult to assess separately · Synthetically generated current streamflow, hence does not present current compliance well. · Further research required to refine approach

In future, developing a standardised method to assess climate change impacts on the environmental flow compliance, shortfalls and ultimately ecological condition that align with techniques/methods used in water resource planning and management is needed. One way forward could be to investigate the impact of scaling rainfall, as per the DELWP guidelines, and using a rainfall-runoff model to generate streamflow. This is currently being conducted as part of a separate Melbourne Water project. Being able to develop standards that aid climate change assessments for environmental flow management, but also water supply operations and other water sectors (e.g. floodplain management), would promote transparent and a consistent approach that support robust and informed long term decision making processes.

1.4 Guidance on prioritisation of watering actions

1.4.1 Review of prioritisation of environmental flow objectives under varying climatic scenarios

Environmental water delivery is monitored and adaptively managed as conditions unfold throughout the year and three management scenarios have been developed to cover a range of possible climatic conditions for the system. The scenarios and recommended watering actions associated with them are based on historic streamflow data for Reach 2 and Reach 5. Watering actions are prioritised against three scenarios:

1) Protect / Maintain – This scenario applies during dry conditions
2) Recover – This scenario applies for average conditions
3) Enhance – This scenario applies during wet conditions

It is recommended that there is a slight change in the water year classification for the protect/maintain (dry), recover (average) and enhance (wet) watering actions so there is consistency with the split in climate years used for the development of flow recommendations. The environmental flow recommendations have been developed using a lower third (dry), middle third (average) and highest third (wet) split. It is proposed that this split in water years is used to define the three watering scenarios.

Table 1.11 and Table 1.12 provides an overview of recommended priority watering actions and environmental objectives for each water management scenario for Reach 2 and 5. These tables also include revised figures of the estimated water volume required to achieve environmental objectives and expected water availability (carryover and allocation) for each water management scenario. It should be noted that the estimated water volumes are derived from the shortfall analysis, but this does not include additional volume that may be required to operationally deliver the flow recommendations, meaning the overall water cost to deliver particular events is likely to be higher. Carryover is calculated as 17 GL minus the estimated volume of water required to achieve the environmental objectives.

In a Protect / Maintain (Dry) scenario, the highest priority is the delivery of the Summer / Autumn low flow and freshes followed by the Winter / Spring low flow and freshes to protect priority species and critical refuge habitats.

The delivery of an Autumn high to trigger downstream spawning migration of Australian Grayling is also recommended. It is preferred that the Autumn high is delivered every year, if possible. If there are more than two years without an Autumn high, it is recommended that this spawning event is prioritised in the third year. These events should be prioritised over a Winter / Spring freshes for recruitment, as without spawning there will not be any recruits and this is particularly important for relatively short-lived species such as grayling. If the Autumn high event does occur, the next priority is Winter/Spring freshes.

This prioritisation of flows as outlined above and documented in Table 1.11 and Table 1.12, is also useful for thinking through decisions regarding carryover. For example, for Reach 2 in a dry year 13,109 ML is required to deliver recommended low flows and freshes, potentially leaving 3,891 ML as carryover for the following year (Table 1.11). Should an Autumn high flow not occur, and the forecast is for dry conditions to continue it is recommended that delivery of this high flow is prioritised in the following year using the carryover from the previous dry year.

Table 1.11 : Delivery of priority watering actions for Reach 2 under a range of watering scenarios. Estimated volume of water required to achieve objectives is based on the shortfall analysis - average total shortfalls for dry/average/wet year (this is not the same as the volume of water that is required to operationally deliver the flow recommendations). Carryover is 17 GL minus estimated water volume required to achieve environmental objectives.

	Protect / Maintain (Dry) (Driest third of rainfall years)		Recover (Average) (Middle third of rainfall years)		Enhance (Wet) (Wettest third of rainfall years)	
Expected water availability	**Carryover** 3,891 ML	**Allocation** 17,000 ML	**Carryover** 5,536 ML	**Allocation** 17,000 ML	**Carryover** 10,989 ML	**Allocation** 17,000 ML
Watering actions to be delivered	· Summer / Autumn low flow to maintain access to and quality of habitat (80 ML/day) · Summer / Autumn freshes to maintain habitat and vegetation (3 events, 350 ML/day, 2 days at peak) · Winter / Spring low flow to maintain access to and quality of habitat (80-350 ML/day) · Winter / Spring freshes to maintain habitats and provide opportunities for fish migration (2 events, June-August, 700 ML/day, 3 days at peak)		· Summer / Autumn low flow to maintain access to and quality of habitat (80 ML/day) · Summer / Autumn freshes to maintain habitat and vegetation (3 events, 350 ML/day, 2 days at peak) · Autumn high to trigger downstream spawning migration of Australian Grayling (1 event, Apr/May, 560 ML/day, 7 days at peak) - 1 event required 2 in 3 years, priority · Winter / Spring low flow to maintain access to and quality of habitat (200-350 ML/day) · Winter / Spring freshes to maintain habitats and provide opportunities for fish migration (2 events, June-August, 700 ML/day, 3 days at peak)		· Summer / Autumn low flow to maintain access to and quality of habitat (80 ML/day) · Summer / Autumn freshes to maintain habitat and vegetation (3 events, 350 ML/day, 2 days at peak) · Autumn high to trigger downstream spawning migration of Australian Grayling (1 event, Apr/May, 560 ML/day, 7 days at peak) - 1 event required 2 in 3 years, priority · Winter / Spring low flow to maintain access to and quality of habitat (200-350 ML/day) · Winter / Spring freshes to maintain habitats and provide opportunities for fish migration (2 events, June-August, 700 ML/day, 3 days at peak)	
Environmental objectives	· Protect priority species and critical refuge habitat · Prevent localised extinctions and catastrophic events, such as fish kills · Protect water quality to prevent impacts on priority species and habitats		· Improve access to suitable habitat for priority fauna · Maintain habitat connectivity · Increase zone of flood tolerant vegetation, by drowning out encroaching terrestrial species · Provide flows for spawning and migration of priority fish species		· Improve access to suitable habitat for priority fauna · Maintain habitat connectivity · Increase zone of flood tolerant vegetation, by drowning out encroaching terrestrial species · Provide flows for spawning and migration of priority fish species · Maintain channel geomorphology	
Estimated water volume required to achieve objectives	13,109 ML		11,644 ML		6,011 ML	
Additional watering actions that may be delivered if more environmental water was allocated	· Autumn high to trigger downstream spawning migration of Australian Grayling (1 event, Apr/May, 560 ML/day, 7 days at peak) - 1 event required 2 in 3 years, priority		· Winter / Spring high flow to provide prolonged disturbance to favour flood tolerant vegetation (1 event, Sep, 700 ML/day, 14 days at peak)		· Winter / Spring high flow to provide prolonged disturbance to favour flood tolerant vegetation (1 event, Sep, 700 ML/day, 14 days at peak) · Bankfull and overbank may occur naturally but will not be provided.	

Table 1.12 : Delivery of priority watering actions for Reach 5 under a range of watering scenarios. Estimated volume of water required to achieve objectives is based on the shortfall analysis - average total shortfalls for dry/average/wet year (this is not the same as the volume of water that is required to operationally deliver the flow recommendations). Carryover is 17 GL minus estimated water volume required to achieve environmental objectives.

	Protect / Maintain (Dry) **(Driest third of rainfall years)**		**Recover (Average)** **(Middle third of rainfall years)**		**Enhance (Wet)** **(Wettest third of rainfall years)**	
Expected water availability	**Carryover** 4,421 ML	**Allocation** 17,000 ML	**Carryover** 3,624 ML	**Allocation** 17,000 ML	**Carryover** 10,364 ML	**Allocation** 17,000 ML
Watering actions to be delivered	· Summer / Autumn low flow to maintain access to and quality of habitat (200 ML/day) · Summer / Autumn freshes to maintain habitat and vegetation (3 events, 750 ML/day, 2 days at peak) · Winter / Spring low flow to maintain access to and quality of habitat (350-600 ML/day) · Winter / Spring freshes to maintain habitats and provide opportunities for fish migration and maintain vegetation (2 events: 1300 ML/day, June/July, 7 days at peak; 2500 ML/day, June-Sep, 2 days at peak)		· Summer / Autumn low flow to maintain access to and quality of habitat (200 ML/day) · Summer / Autumn freshes to maintain habitat and vegetation (3 events, 750 ML/day, 2 days at peak) · Autumn high to trigger downstream spawning migration of Australian Grayling (1 event, Apr/May, 1300 ML/day, 7 days at peak) – 1 event required 2 in 3 years, priority · Winter / Spring low flow to maintain access to and quality of habitat (350-750 ML/day) · Winter / Spring freshes to maintain habitats and provide opportunities for fish migration and maintain vegetation (2 events: 1300 ML/day, June/July, 7 days at peak; 2500 ML/day, June-Sep, 2 days at peak)		· Summer / Autumn low flow to maintain access to and quality of habitat (200 ML/day) · Summer / Autumn freshes to maintain habitat and vegetation (3 events, 750 ML/day, 2 days at peak) · Autumn high to trigger downstream spawning migration of Australian Grayling (1 event, Apr/May, 1300 ML/day, 7 days at peak) – 1 event required 2 in 3 years, priority · Winter / Spring low flow to maintain access to and quality of habitat (350-750 ML/day) · Winter / Spring freshes to maintain habitats and provide opportunities for fish migration and maintain vegetation (2 events: 1300 ML/day, June/July, 7 days at peak; 2500 ML/day, June-Sep, 2 days at peak)	
Environmental objectives	· Protect priority species and critical refuge habitat · Prevent localised extinctions and catastrophic events, such as fish kills · Protect water quality to prevent impacts on priority species and habitats		· Improve access to suitable habitat for priority fauna · Maintain habitat connectivity · Increase zone of flood tolerant vegetation, by drowning out encroaching terrestrial species · Provide flows for spawning and migration of priority fish species		· Improve access to suitable habitat for priority fauna · Maintain habitat connectivity · Increase zone of flood tolerant vegetation, by drowning out encroaching terrestrial species · Provide flows for spawning and migration of priority fish species · Maintain channel geomorphology	
Estimated water volume required to achieve objectives	12,579 ML		13,376 ML		6,636 ML	
Additional watering actions that may be delivered if more environmental water was allocated	· Autumn high to trigger downstream spawning migration of Australian Grayling (1 event, Apr/May, 1300 ML/day, 7 days at peak) – 1 event required 2 in 3 years, priority		· Winter / Spring high flow to provide prolonged disturbance to favour flood tolerant vegetation (1 event, Sep-Oct, 2500 ML/day, 14 days at peak)		· Winter / Spring high flow to provide prolonged disturbance to favour flood tolerant vegetation (1 event, Sep-Oct, 2500 ML/day, 14 days at peak) · Bankfull and overbank may occur naturally but will not be provided.	

1.4.2 Additional considerations

The Victorian Environmental Water Holder (VEWH) also provided a number of comments on aspects they thought should be considered as part of this FLOWS Review. A response to each of these comments is included below.

- *The broader context in which the individual flow components sit (e.g. if you can't deliver the full suite of recommended flow components because of constraints or there isn't the water available, what does this mean in terms of achieving environmental outcomes?)*

  The prioritisation of watering actions outlined in Section 1.4.1 provides guidance as to recommended watering actions in response to changes in water availability. The flow recommendations have been broken down into those that can be managed (blue), from those that are expected to occur naturally and do not require active delivery (green). It is recognised that the entire flow regime cannot be delivered, but it is possible to deliver specific flow components to achieve targeted outcomes. Bankfull and overbank flows are not actively delivered, however it is possible through works and measures to deliver water to priority billabongs.

- *What is achievable from the flows that can be delivered within the physical and system constraints, if not the full suite of recommendations?*

  In the revised flow recommendations tables, the flow components have been colour coded to highlight those that can be delivered within the physical and system constraints - flows that are managed (blue) from those that are expected naturally and hence do not require active delivery (green).

- *How critical is delivery of environmental water to the overall health of the system (what other complimentary actions are needed/being undertaken and how do they interact with flow? Is flow the main issue or are there other issues within the system that are preventing the achievement of environmental outcomes from delivery of environmental water)*

  Delivery of environmental flows is critical to achievement of environmental objectives, however, this is just one aspect of what is needed to secure the health of flow-dependent values in the Yarra River. In addition to delivering environmental flows, a range of complementary actions are needed to assist in achieving the objectives outlined in this FLOWS Review and the Yarra River Environmental Management Plan (EWMP). In some cases, failure to deliver complementary actions will limit the benefits of delivering environmental flows. Complementary actions include riparian vegetation rehabilitation, addressing catchment sources of sediment pollution, and undertaking pest plant and animal eradication/control programs.

- *A focus on longer term planning rather than just the standard dry/average/wet scenario planning, what is the 5-10 year plan for the system?*

  The Yarra River Environmental Management Plan (EWMP) provides the overarching strategy for the management of environmental water and protection of flow-dependent values in the Yarra River for the next five to ten years. Melbourne Water take into account the antecedent climate conditions, the current condition of key values, and the amount of water held in storage to prioritise releases. These decisions are made by comparing current conditions and historic streamflow data for Reach 2 and Reach 5. Watering actions are prioritised against three scenarios, protect/maintain, recover and enhance as documented in Section 1.4.1.

Also discussed at the project inception meeting with Melbourne Water was overbank flows and their importance for the ecological health of the Yarra River.

- *If you do not have overbank flows and their assumed positive benefits (i.e. return of carbon to the river), does this then impact on ability to achieve ecological outcomes anticipated with the delivery of other flow recommendations?*

  Further research and monitoring is required to demonstrate that concepts elucidated elsewhere that overbank flows and associated return of organics to the channel environment are critical for the rivers ecosystems, is also applicable to the Yarra River. Melbourne Water are constrained in their ability to water floodplain areas as the delivery of bankfull or overbank flow events that allow water to run onto the floodplain and fill wetlands poses a potential risk of flooding private land in some part of the catchment. However, there may be opportunities to reconnect parts of the floodplain, for example the removal/rearrangement of levees improve connections to billabongs in some locations along the Yarra floodplain where flooding impacts can be effectively managed. It is recommended that Melbourne Water assess the feasibility of landscape scale floodplain re-engagement, or inundation of billabong complexes (rather than individual isolated billabongs as is currently occurring). The first step in such an investigation would be 2D hydraulic modelling of low overbank flow inundation to identify areas where re-engagement or complex billabong engagement could occur (Figure 1.12).

Figure 1.12 : Yarra River and floodplain in the Tarrawarra area. An opportunity exists at this site to improve flow connections to billabongs through the remodeling of inlet areas and removal/rearrangement of levees to increase opportunities for floodplain and complex billabong inundation.

1.5 Flow management tools

Melbourne Water currently use a number of documents and spreadsheets to assist in decision making about the managed use of the Environmental Entitlement and delivery of environmental flows in the Yarra River under various climatic scenarios. Existing documents and spreadsheets have been developed with reference to earlier objectives and flow recommendations.

In light of the revisions to environmental flow objectives and recommendations, Melbourne Water has identified the need to develop a robust scenario planning management framework to help in the management of the Environmental Entitlement and delivery of environmental flows. The framework is to consider: how watering actions should shift in different climatic scenarios (drought, dry, average and wet), the water requirements for each scenario and when carryover decisions should be made.

There is a wealth of existing information, data and tools available for the Yarra system that could be used in the development of the tool. An important advance is the recently completed ARC Linkage Project (“Seasonal Environmental Watering Decisions Support Tool”) at Melbourne University, which Melbourne Water was a partner. It offers data, information and sophisticated models for the Yarra system that could inform or be incorporated in the scenario planning and flow management framework.

It is recommended that the scenario planning management framework and information requirements identified above are developed further and consolidated in a Scenario Planning and Flow Management Tool. It is expected that this tool will achieve a number of purposes and requirements:

- Informative – Updated analysis of volumes to meet flow recommendations, compliance and short falls for different climatic scenarios (drought, dry, average and wet).
- Analytical – Provide summary reports on achievement of environmental flows against that documented in seasonal watering proposal (i.e. achievement of flow recommendations, volume of water used, amount remaining in environmental entitlement).
- Predictive – Forecasts of future streamflows to assist with ongoing management of environmental entitlement and decisions regarding carryover, timing, magnitude and duration of environmental flow releases.

The benefits of the development and documentation of such flow management tools are that they can improve the ability to learn from management decisions and they support dialogue between stakeholders. More importantly, it also allows for clear and transparent documentation of the current state of knowledge and would allow for it to be more easily shared, provide a record of management actions and facilitate ongoing environmental management and policy making.

1.6 Other recommendations

1.6.1 Monitoring and investigations

The following recommendations are made to assist in monitoring the environmental condition of the waterways and ecological responses to flows:

- Monitoring of channel form in Reach 1 to assess changes in the recommended flow regime and cumulative impact of high flow releases on the physical form and availability of habitat within the channel. This would also include monitoring of the channel in between high flow releases, to assess the rate of recovery between events (i.e. is there ongoing accumulation of sediment in pool/riffle areas, vegetation encroachment).
- Further monitoring of fish movements with flows, in particular to determine the location and extent of Australian Grayling spawning grounds in the lower Yarra River; linkages between the upstream migration of diadromous fishes and flow; and the timing and spatial extent of upstream migrations of adult lamprey and potential spawning sites.
- Spawning and recruitment surveys of Macquarie Perch to develop a better understanding of factors influencing spawning and recruitment (this is currently happening).
- Survey the occurrence of in-stream microbial biofilms and submerged vascular plants in Reaches 1 and 2, and the effectiveness of the recommended suite of flows in maintaining these poorly studied vegetation types in the upper Yarra.
- Monitoring the effectiveness of the recommended suite of flows (e.g. managed low flow, freshes and high flows; episodic bankfull and overbank events) in limiting encroachment of undesirable riparian or terrestrial vegetation into stream channel (all Reaches).
- Monitoring the effectiveness of the recommended suite of flows is providing the hydrological complexity required to maintain the critical in-stream and riparian vegetation characteristics, including vegetation zonation (all Reaches).
- Assess the options for improving lateral connectivity between river and floodplain/billabong habitats in Reaches 3, 4, 5 and 6
- The critical components of the flow regime and the mechanisms by which they impact platypuses are poorly understood. Further research is required to investigate the important flow components for platypuses and, critically, the effect on macroinvertebrate distribution and abundance and habitat availability (most flow recommendations for platypuses are directed towards supporting macroinvertebrate communities and maintaining habitat availability and connectivity).

- The Millennium Drought clearly had a significant detrimental impact on platypus populations throughout the greater Melbourne region. Identifying drought refuge areas for platypuses will help inform minimum flows required to sustain critical areas during dry periods and direct complementary management actions to preserve these areas.

1.6.2 Complementary management actions

Environmental flows alone are often not sufficient to achieve desirable ecological outcomes other actions are often required in order for objectives to be achieved. A range of complementary management actions are recommended in the Yarra EWMP and are repeated here:

- Remove willows and other invasive woody weeds from the waterway (while preventing bank erosion and maintaining adequate protective cover for platypus and waterbirds from predators).
- Reduce the adverse impacts of stock access along water courses by working with landowners to fence off waterways and creating off-stream watering points.
- Retain and potentially augment the amount of instream woody habitat (logs and large branches) present in stream and river channels and wetlands.
- Undertake community education programs to address illegal fishing nets use, and implement an education and involvement program with recreational fishing groups to ensure native fish are released but introduced fish are not released back in to the river.
- Through strategies such as Water Sensitive Urban Design (WSUD), control and treat urban stormwater and agricultural runoff as needed before it enters natural water courses to reduce litter and concentrations of sediment and chemical pollutants.
- Reduce the impact of introduced predators by implementing control programs for foxes/feral cats and by restoring/maintaining a dense band of plant cover along the edges of waterways to discourage easy access by foxes, dogs and cats, especially in places where water is shallow (seasonally or throughout the year). Undertake community awareness programs to raise dog and cat owners' understanding of the risks these pets can pose to platypus and waterbirds.

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Appendix A. Ecological objectives

Table A.1 : Reach 1 – downstream of Upper Yarra Reservoir ecological objectives.

Asset	Objective	No.	Function	Flow component	Timing	Expected response	Response time	Description of change
Geomorphology	Maintain existing channel dimensions and form	G1-1	Maintain existing channel dimensions and minimise further channel contraction	Bankfull flow	Winter / Spring	· No further contraction in channel geometry.	Medium to long	No change from SKM (2012)
	Rehabilitate instream habitat	G1-2	Scour fine sediment and biofilms from riffles	Freshes	Throughout year	· Prevent sediment build up on cobbles in riffle zone	Short	No change from SKM (2012)
		G1-3	Scour sediment from pools	High flow	Winter / Spring	· Flush fine sediment from pools and increased habitat availability.	Medium	No change from SKM (2012)
Macroinvertebrates	Rehabilitate macroinvertebrate community to maximum diversity & abundance possible downstream of a large dam with the aim of meeting Yarra SEPP Schedule F7 objectives.	M1-1	Access to and area of riffle habitat (Seasonal variation to inundate additional habitat area in Winter/Spring)	Low flow	Summer / Autumn	· Increase the diversity & abundance to the maximum possible based on the assumption that flows that reduce sediment accumulation will improve access to benthic habitats will result in an increase in invertebrate biodiversity & abundance.	Short to medium	Modified low flow objective and related 'Function' so as to capture assumed changes in Summer / Autumn and Winter / Spring macroinvertebrate biomass linked to inundation of habitat areas.
		M1-2		Low flow	Winter / Spring			
		M1-3	Clean cobbles in faster flowing reaches	Freshes	Throughout year			
		M1-4	Flush sediment from pools & entrain organic material from littoral zone	High flow	Winter / Spring			
Fish	Maintain or improve populations of native indigenous fish (river blackfish, Australian smelt, short-finned eel, and ornate galaxias), and comply with Yarra SEPP Schedule F7 objectives.	F1-1	Maintain hydraulic habitat (i.e. pool, riffle, run) and passage for local movement	Low flow	Summer / Autumn	· Maintenance of hydraulic habitat; Localised movements	Short to medium	Split low flow objective to distinguish Summer / Autumn and Winter / Spring low flow components
				Low flow	Winter / Spring			
		F1-2	Flush accumulated fine sediments to maintain or improve quality and availability of habitats	Freshes / High flow	Winter / Spring	· Accumulated fine sediments scoured from the river bed	Short to medium	Revised list of fish species documented in objective from SKM (2012). What was previously called mountain galaxias in the Yarra River is now called ornate galaxias. Added Australian smelt, short-finned eel, and ornate galaxias.
Vegetation	Maintain in-stream & riparian vegetation extent, structure & composition	V1-1	Provide shallow, permanently inundated in-stream environments over Summer/Autumn Dry low and medium-level banks to provide hydrological complexity	Low flow	Summer / Autumn	· Maintain in-stream and riparian vegetation characteristics such as species richness and abundance, structural complexity, vertical zonation & spatial extent. · Maintain in-stream microbial biofilms attached to submerged hard surfaces (e.g. cobbles and boulders). Note that these microbial biofilms are likely to be heterotrophic, because of the shaded nature of the stream in Reach 1.	Short to Medium	Restructured and revised objectives and related 'Functions' and 'Expected response' to reflect different vegetation components/habitats (in-stream, riparian, billabong/floodplain and terrestrial) and their contrasting watering requirements to promote or discourage each component. Explicit inclusion of in-stream biofilms as a component of aquatic vegetation. Division of low flow 'Functions' into Summer / Autumn and Winter / Spring flow components.
	Maintain in-stream microbial biofilms on submerged hard surfaces	V1-2	Prolonged inundation of instream channel, lower bench and bars to disadvantage terrestrial species and prevent their colonizing of instream channel Inundate low-level benches to ensure vertical zonation of inundation-tolerant fringing vegetation	Low flow	Winter / Spring			
		V1-3	Wet medium-level banks to provide periodically inundated environments at medium levels in-stream Promote inundation-tolerant aquatic or riparian vegetation and inhibit inundation-intolerant riparian or terrestrial vegetation	Freshes	Throughout year			

Asset	Objective	No.	Function	Flow component	Timing	Expected response	Response time	Description of change
			Transport plant propagules and plant detritus downstream Provide hydrological complexity (and therefore vegetation zonation)					
		V1-4	Provide deeper, permanently inundated in-stream environments over Winter/Spring Inundate medium-level banks to provide periodically inundated environments at higher levels in-stream Promote inundation-tolerant aquatic or riparian vegetation and inhibit inundation-intolerant riparian or terrestrial vegetation Transport plant propagules and plant detritus downstream Provide hydrological complexity (and therefore vegetation zonation)	High flow	Winter / Spring			
		V1-5	Wet highest-level banks to provide periodically inundated environments at highest levels in-stream Scour in-stream and top-of-bank environments to prevent undesirable plant encroachment into stream channel and onto banks Transport plant propagules and plant detritus downstream Provide hydrological complexity (and therefore vegetation zonation) Remove mud and silt from cobbles and boulders	Bankfull	Winter / Spring	· Provide hydrological disturbance. Specifically: 1) Maintain in-stream and riparian vegetation characteristics such species richness and abundance & structural complexity 2) Maintain clean submerged hard surfaces for microbial biofilms	Short	
	Limit encroachment of undesirable riparian or terrestrial vegetation into stream channel	V1-6	Provide permanently inundated in-stream environments all year	Low flow	All year	· Limit encroachment of sawsedges and other undesirable riparian or terrestrial vegetation into stream channel	Medium	
		V1-7	Inundate channel and low- and medium-level banks to prevent undesirable plant encroachment into stream channel	High flow	Winter / Spring			
		V1-8	Scour in-stream and top-of-bank environments to prevent undesirable plant encroachment into stream channel and onto banks	Bankfull	Winter / Spring			
Platypus	Maintain/improve current status of population	P1-1	Maintain platypus habitat, maintain longitudinal connectivity across riffle areas, minimise predation risk, allow juvenile dispersal, support macroinvertebrate populations.	Low flow	All year	· Maintain habitat quality and food resources for platypuses. · Current flow regimes for Reach 1 appear to be suitable to provide relatively high quality platypus habitat.	Short to medium	New objectives developed for Platypus, drawing upon insights from platypus surveys and conceptual models of platypus flow requirements (Jacobs et al. 2016).
		P1-2	Maintain minimum pool depth 0.5 m.	Low flow (extreme)	Extended dry periods (drought)	· Maintain refuge areas during drought.	Short to medium	

Asset	Objective	No.	Function	Flow component	Timing	Expected response	Response time	Description of change
		P1-3	Promote habitat diversity, scour fine sediment, promote macroinvertebrate diversity/abundance.	Freshes / High flow	All year	· Improve habitat quality and food resources for platypuses.	Short to medium	
		P1-4	Minimise bank erosion and in-stream sedimentation	Limit flows above scouring thresholds	All year	· Improve habitat quality for platypus food resources (macroinvertebrates)	Medium	
		P1-5	Prevent inundation of breeding burrows	Avoid bankfull or overbank flows	Nov-Feb	· Improved reproductive success.	Short	
Birds, Frogs and Amenity	Birds – Maintain or improve the species richness and abundance of streamside and wetland populations Frogs – Maintain diversity and improve the overall abundance and distribution of expected species Amenity – Maintain and/or improve condition	BFA1-1	Maintain access to good quality physical habitat, provide good water quality, and support the growth of instream vegetation, an important source of food resources and habitat	Low flow	Summer / Autumn	· Maintain permanent pools with an adequate depth of water for habitat for biota such as macroinvertebrates, an important food source for birds, and frogs · Provides disturbance to scour the river bed of sediment and improve the quality of instream habitat · Also provides a suitable range of depths for the growth of in-stream vegetation	Short to medium	New generic ecological objectives have been added for Birds, Frogs and Amenity as documented in the Yarra River EWMP (Jacobs 2017f)
		BFA1-2		Fresh	Summer / Autumn	· Provides disturbance to scour the river bed of sediment and improve the quality of habitat within the river · Provides a suitable depth of water for waterbirds, maintaining the extent of habitat range they can utilise · Provides flow variability to maintain a diversity of emergent and riparian vegetation and helps to influence vegetation zonation patterns across the channel, which then provides a variety of habitats.	Short to medium	
		BFA1-3	Rehabilitate and maintain habitat within the higher parts of the river channel	High flow	Summer / Autumn	· Entrains and transports sediment along the river improving the quality of, and access to, instream habitat · Sustains longitudinal connectivity, providing opportunities to move along and between habitats for waterbirds. · Helps to influence vegetation zonation patterns across the	Short to medium	

Asset	Objective	No.	Function	Flow component	Timing	Expected response	Response time	Description of change
						channel, which provides a variety of habitats.		
		BFA1-4	Maintain access to good quality physical habitat, provide good water quality, and support the growth of instream vegetation, an important source of food resources and habitat	Low flow	Winter / Spring	· Increase habitat area for instream flora and fauna including access to large woody debris and overhanging banks. · Encourages the die-back of terrestrial vegetation that has encroached down the bank during the Summer low flow period	Short to medium	
		BFA1-5		Fresh	Winter / Spring	· Provides flow variability to maintain a diversity of emergent and riparian vegetation and to influence vegetation zonation patterns across the channel, which provides a variety of habitats for birds · Entrains and transports terrestrial organic matter along that has accumulated on benches.	Short to medium	
		BFA1-6	Rehabilitate and maintain appropriate habitat within the higher parts of the river channel	High flow	Winter / Spring	· Entrains and transports sediment along the river improving the quality of, and access to, instream habitat. · Sustains longitudinal connectivity, providing opportunities to move along and between habitats. · Helps to influence vegetation zonation patterns across the channel, which provides a variety of habitats.	Short to medium	
		BFA1-7	Maintain instream habitats and improve the condition of billabongs connected around bankfull	Bankfull	Winter / Spring	· Increase habitat area, including access to large woody debris and overhanging banks for instream biota, and engage floodplain and billabong habitat for frogs and waterbirds. · Helps to disturb and reset aquatic and riparian vegetation communities, important for a range of diverse habitat types for birds and frogs. · Entrains and transports organic matter and sediment that has accumulated in pools and the	Short to medium	

Asset	Objective	No.	Function	Flow component	Timing	Expected response	Response time	Description of change
						upper channel, improving habitat quality.		

Table A.2 : Reach 2 – Armstrong Creek to Millgrove ecological objectives.

Asset	Objective	No.	Function	Flow component	Timing	Expected response	Response time	Description of change
Geomorphology	Maintain channel dimensions and form	G2-1	Maintain channel dimensions and minimise further channel contraction	Bankfull flow	Winter / Spring	· No further contraction in channel geometry.	Medium to long	No change from SKM (2012)
	Engage low level floodplains	G2-2	Connectivity	Bankfull / low overbank flow	Winter / Spring	· Appropriate frequency of inundation of low level floodplain & billabongs achieved	Short	No change from SKM (2012)
	Maintain access to riffle & pool habitat	G2-3	Scour fine sediment and biofilms from riffles	Freshes	Throughout year	· Prevent sediment build up on cobbles in riffle zone	Short	No change from SKM (2012)
		G2-4	Scour sediment from pools	High flow	Winter / Spring	· Flush fine sediment from pools and increased habitat availability.	Medium	No change from SKM (2012)
Macroinvertebrates	Maintain current macroinvertebrate community to comply with Yarra SEPP Schedule F7 objectives	M2-1	Access to and area of riffle habitat (Seasonal variation to inundate additional habitat area in Winter/Spring)	Low flow	Summer / Autumn	· Expect Macroinvertebrates scores to continue to meet SEPP objectives for composition, but improve with regard to SIGNAL scores	Short to medium	Modified low flow objective and related 'Function' so as to capture assumed changes in Summer / Autumn and Winter / Spring macroinvertebrate biomass linked to inundation of habitat areas.
		M2-2		Low flow	Winter / Spring			
		M2-3	Disturbance to scour biofilms & sediment	Freshes	Throughout year			
Fish	Maintain or improve populations of native indigenous fish (river blackfish, Australian smelt, ornate galaxias, Australian grayling, short-finned eel, short-headed lamprey, pouched lamprey, tupong, broad-finned galaxias, spotted galaxias & common galaxias), and comply with Yarra SEPP Schedule F7 objectives.	F2-1	Maintain hydraulic habitat (i.e. pool, riffle, run) and passage for local movement	Low flow	Summer / Autumn	· Maintenance of hydraulic habitat; Localised movements	Short to medium	Rewritten objectives and revised list of fish species. No longer include mountain galaxias as they have not recently been surveyed in this reach. Split low flow objective to distinguish Summer / Autumn and Winter / Spring low flow components.
				Low flow	Winter / Spring			
		F2-2	Flush accumulated fine sediments to maintain or improve quality and availability of habitats	Freshes / High flow	Winter / Spring	· Accumulated fine sediments scoured from the river bed	Short to medium	
		F2-3	Facilitate upstream immigration of juvenile catadromous (short-finned eel, common galaxias, tupong) and amphidromous (Australian grayling, broad-finned galaxias, spotted galaxias) fishes from downstream river reaches	Freshes / High flow	Spring / early Summer	· Upstream immigration from downstream river reaches	Short	Changed objective so that is it more explicit as to the species and timing of migration. Upstream movement of diadromous fishes occurs over a broad time frame (e.g. August to February), with greatest richness of species migrating around September-November (McDowall & Eldon. 1980, Sloane 1984, Zampatti et al. 2003)
		F2-4	Cue downstream spawning migration by Australian grayling to lower river reaches.	High flow	Autumn	· Downstream migration to lower river reaches to spawn	Short	Revised wording of objective and timing of high flow (from Autumn / Winter to Autumn). Australian grayling undertakes downstream migrations to spawn between late March and May (Koster et al. 2017, Koster et al. 2013)
		F2-5	Cue downstream migration by tupong to the sea to spawn	Freshes / High Flow	Late Autumn / Winter	· Downstream migration to the sea to spawn	Short	New objective to cue downstream migration by tupong. Tupong undertake downstream migrations between late May and August, associated with high river flows (Crook et al. 2010).

Asset	Objective	No.	Function	Flow component	Timing	Expected response	Response time	Description of change
		F2-6	Cue downstream migration by eels to the sea to spawn	Freshes / High flow	Throughout year, especially late Summer	· Downstream migration to the sea to spawn	Short	New objective to cue downstream migration by eels. Eels undertake downstream migrations throughout the year, with an increase in frequency over Summer and following high river flows (Crook et al. 2014).
Vegetation	Maintain or improve in-stream & riparian vegetation extent, structure & composition Maintain in-stream microbial biofilms on submerged hard surfaces	V2-1	Provide shallow, permanently inundated in-stream environments all year Dry low- and medium-level banks to provide hydrological complexity	Low flow	Summer / Autumn	· Maintain in-stream and riparian vegetation characteristics such as species richness and abundance, structural complexity, vertical zonation & spatial extent. Specifically: 1) Maintain or improve (e.g. increase in spatial extent) the currently small beds of submerged and semi-emergent native vegetation in-stream, such as Parrots Feather 2) Maintain inundation-tolerant terrestrial or riparian vegetation, such as water ferns, on lower- and middle-level banks · Maintain in-stream microbial biofilms attached to submerged hard surfaces (e.g. cobbles and boulders). Note that these microbial biofilms are likely to be a mixture of heterotrophic and autotrophic elements (e.g. bacterial fungi and algae), because of the more open nature of the stream in Reach 2	Short to Medium	Restructured objectives and related 'Functions' and 'Expected responses' to reflect different vegetation components/habitats (in-stream, riparian, billabong/floodplain and terrestrial) and their contrasting watering requirements to promote or discourage each component. Explicit inclusion of in-stream biofilms as a component of aquatic vegetation. Division of low flow 'Functions' into Summer / Autumn and Winter / Spring flow components.
		V2-2	Prolonged inundation of instream channel, lower bench and bars to disadvantage terrestrial species and prevent their colonizing of instream channel Inundate low-level benches to ensure vertical zonation of inundation-tolerant fringing vegetation	Low flow	Winter / Spring			
		V2-3	Wet medium-level banks to provide periodically inundated environments at various levels in-stream Promote inundation-tolerant aquatic or riparian vegetation and inhibit inundation-intolerant riparian or terrestrial vegetation Transport plant propagules and plant detritus downstream Provide hydrological complexity (and therefore vegetation zonation)	Freshes	All year			
		V2-4	Provide deeper, permanently inundated in-stream environments over Winter/Spring Inundate medium-level banks to provide periodically inundated environments at higher levels in-stream Promote inundation-tolerant aquatic or riparian vegetation and inhibit inundation-intolerant riparian or terrestrial vegetation Transport plant propagules and plant detritus downstream Provide hydrological complexity (and therefore vegetation zonation)	High flow	Winter / Spring	· Maintain in-stream and riparian vegetation characteristics such as species richness and abundance, structural complexity, vertical zonation & spatial extent	Short to medium	
		V2-5	Wet highest-level banks to provide periodically inundated environments at highest levels in-stream Scour in-stream and top-of-bank environments to prevent undesirable plant	Bankfull	Winter / Spring	· Provide hydrological disturbance. Specifically: 1) Maintain existing in-stream and riparian vegetation characteristics such species	Short	

Asset	Objective	No.	Function	Flow component	Timing	Expected response	Response time	Description of change
			encroachment into stream channel and onto banks Transport plant propagules and plant detritus downstream Provide hydrological complexity (and therefore vegetation zonation) Remove mud and silt from cobbles and boulders			richness and abundance & structural complexity · 2) Maintain clean submerged hard surfaces for microbial biofilms		
	Maintain inundation-tolerant vegetation in riparian zone at top of bank	V2-6	Maintain periodically wetted areas on top-of-bank to promote inundation-tolerant riparian vegetation on upper levels of bank and lower riparian zone Provide hydrological complexity (and therefore vegetation zonation)	Bankfull	Winter / Spring	· Maintain inundation-tolerant riparian species, such as Swamp Paperbark, at top-of bank	Medium	
Platypus	Maintain/improve current status of population	P2-1	Maintain platypus habitat, maintain longitudinal connectivity across riffle areas, minimise predation risk, allow juvenile dispersal, support macroinvertebrate populations.	Low flow	All year	· Maintain habitat quality and food resources for platypuses.	Short to medium	New objectives developed for Platypus, drawing upon insights from platypus surveys and conceptual models of platypus flow requirements (Jacobs et al. 2016).
		P2-2	Maintain minimum pool depth >1m.	Low flow (extreme)	Extended dry periods (drought)	· Maintain refuge areas during drought.	Short to medium	
		P2-3	Promote habitat diversity, scour fine sediment, promote macroinvertebrate diversity/abundance.	Freshes / High flow	All year	· Improve habitat quality and food resources for platypuses.	Short to medium	
		P2-4	Minimise bank erosion and in-stream sedimentation	Limit flows above scouring thresholds	All year	· Improve habitat quality for platypus food resources (macroinvertebrates)	Medium	
		P2-5	Prevent inundation of breeding burrows	Avoid bankfull or overbank flows	Nov-Feb	· Improved reproductive success.	Short	
Birds, Frogs and Amenity	Birds – Maintain or improve the species richness and abundance of streamside and wetland populations Frogs – Maintain diversity and improve the overall abundance and distribution of expected species	BFA2-1	Maintain access to good quality physical habitat, provide good water quality, and support the growth of instream vegetation, an important source of food resources and habitat	Low flow	Summer / Autumn	· Maintain permanent pools with an adequate depth of water for habitat for biota such as macroinvertebrates, an important food source for birds, and frogs · Provides disturbance to scour the river bed of sediment and improve the quality of instream habitat · Also provides a suitable range of depths for the growth of in-stream vegetation	Short to medium	New generic ecological objectives have been added for Birds, Frogs and Amenity as documented in the Yarra River EWMP (Jacobs 2017f)
		BFA2-2		Fresh	Summer / Autumn	· Provides disturbance to scour the river bed of sediment and improve the quality of habitat within the river	Short to medium	

Asset	Objective	No.	Function	Flow component	Timing	Expected response	Response time	Description of change
	Amenity – Maintain and/or improve condition					· Provides a suitable depth of water for waterbirds, maintaining the extent of habitat range they can utilise · Provides flow variability to maintain a diversity of emergent and riparian vegetation and helps to influence vegetation zonation patterns across the channel, which then provides a variety of habitats.		
		BFA2-3	Rehabilitate and maintain habitat within the higher parts of the river channel	High flow	Summer / Autumn	· Entrains and transports sediment along the river improving the quality of, and access to, instream habitat · Sustains longitudinal connectivity, providing opportunities to move along and between habitats for waterbirds. · Helps to influence vegetation zonation patterns across the channel, which provides a variety of habitats.	Short to medium	
		BFA2-4	Maintain access to good quality physical habitat, provide good water quality, and support the growth of instream vegetation, an important source of food resources and habitat	Low flow	Winter / Spring	· Increase habitat area for instream flora and fauna including access to large woody debris and overhanging banks. · Encourages the die-back of terrestrial vegetation that has encroached down the bank during the Summer low flow period	Short to medium	
		BFA2-5		Fresh	Winter / Spring	· Provides flow variability to maintain a diversity of emergent and riparian vegetation and to influence vegetation zonation patterns across the channel, which provides a variety of habitats for birds · Entrains and transports terrestrial organic matter along that has accumulated on benches.	Short to medium	
		BFA2-6	Rehabilitate and maintain appropriate habitat within the higher parts of the river channel	High flow	Winter / Spring	· Entrains and transports sediment along the river	Short to medium	

Asset	Objective	No.	Function	Flow component	Timing	Expected response	Response time	Description of change
						improving the quality of, and access to, instream habitat. · Sustains longitudinal connectivity, providing opportunities to move along and between habitats. · Helps to influence vegetation zonation patterns across the channel, which provides a variety of habitats.		
		BFA2-7	Maintain instream habitats and improve the condition of billabongs connected around bankfull	Bankfull	Winter / Spring	· Increase habitat area, including access to large woody debris and overhanging banks for instream biota, and engage floodplain and billabong habitat for frogs and waterbirds. · Helps to disturb and reset aquatic and riparian vegetation communities, important for a range of diverse habitat types for birds and frogs. · Entrains and transports organic matter and sediment that has accumulated in pools and the upper channel, improving habitat quality.	Short to medium	
		BFA2-8	Reconnect the floodplain and floodplain billabongs with the instream channel Maintain wetland/billabong species and communities	Overbank	Winter / Spring	· Improves the frequency and extent of flooding in floodplain wetlands and billabongs. · Provides water for flood-tolerant vegetation such as River Red Gum · Provides wetted habitat for waterbird and frog species who don't necessarily require instream habitat	Short to medium	

Table A.3 : Reach 3 – Millgrove to Watts River ecological objectives.

Asset	Objective	No.	Function	Flow component	Timing	Expected response	Response time	Description of change
Geomorphology	Maintain channel dimensions and form	G3-1	Maintain existing channel dimensions and minimise further channel contraction	High / bankfull flow	Winter / Spring	· No contraction in channel geometry.	Medium to long	No change from SKM (2012)
		G3-2	Bank stability	Rate of fall	Following flow events	· No increased rate or extent of bank scour above that expected naturally.	Medium	No change from SKM (2012)
	Rehabilitate lateral connectivity with billabongs connected around bankfull	G3-3	Form and maintain billabongs and meander train	Bankfull flow	Spring	· Maintenance of floodplain features through scour and deposition.	Short	No change from SKM (2012)
	Rehabilitate floodplains	G3-4	Form and maintain floodplain features	Overbank flow	Spring	· Increased frequency & duration of inundation of floodplain	Short	No change from SKM (2012)
Macroinvertebrates	Maintain and rehabilitate current macroinvertebrate community to comply with Yarra SEPP Schedule F7 objectives	M3-1	Access to and area of LWD & edge habitats (Seasonal variation to inundate additional habitat area in Winter/Spring)	Low flow	Summer / Autumn	~ Expect Macroinvertebrates scores to consistently meet SEPP objectives.	Short to medium	Modified low flow objective and related 'Function' so as to capture assumed changes in Summer / Autumn and Winter / Spring macroinvertebrate biomass linked to inundation of habitat areas.
		M3-2		Low flow	Winter / Spring			
		M3-3	Disturbance to scour biofilm & sediment from LWD	Freshes	Throughout year			
Fish	Maintain or improve populations of native indigenous fish (river blackfish, Australian smelt, ornate galaxias, Australian grayling, short-finned eel, short-headed lamprey, pouched lamprey, tupong, broad-finned galaxias, spotted galaxias & common galaxias), and comply with Yarra SEPP Schedule F7 objectives.	F3-1	Maintain hydraulic habitat (i.e. pool, riffle, run) and passage for local movement	Low flow	Summer / Autumn	· Maintenance of hydraulic habitat; Localised movements	Short to medium	Rewritten objectives and revised list of fish species. No longer include mountain galaxias as they have not recently been surveyed in this reach. Split low flow objective to distinguish Summer / Autumn and Winter / Spring low flow components
				Low flow	Winter / Spring			
		F3-2	Flush accumulated fine sediments to maintain or improve quality and availability of habitats	Freshes / High flow	Winter / Spring	· Accumulated fine sediments scoured from the river bed	Short to medium	
		F3-3	Facilitate upstream immigration of juvenile catadromous (short-finned eel, common galaxias, tupong) and amphidromous (Australian grayling, broad-finned galaxias, spotted galaxias) fishes from downstream river reaches	Freshes / High flow	Spring / early Summer	· Upstream immigration from downstream river reaches	Short	Changed objective so that is it more explicit as to the species and timing of migration. Upstream movement of diadromous fishes occurs over a broad time frame (e.g. August to February), with greatest richness of species migrating around September-November (McDowall & Eldon. 1980, Sloane 1984, Zampatti et al. 2003)
		F3-4	Cue downstream spawning migration by Australian grayling to lower river reaches	High flow	Autumn	· Downstream migration to lower river reaches to spawn	Short	Revised wording of objective and timing of high flow (from Autumn / Winter to Autumn). Australian grayling undertakes downstream migrations to spawn between late March and May (Koster et al. 2017, Koster et al. 2013)
		F3-5	Cue downstream migration by tupong to the sea to spawn	Freshes / High flow	Late Autumn / Winter	· Downstream migration to the sea to spawn	Short	New objective to cue downstream migration by tupong. Tupong undertake downstream migrations between late May and August, associated with high river flows (Crook et al. 2010).
		F3-6	Cue downstream migration by eels to the sea to spawn	Freshes / High flow	Throughout year, especially late Summer	· Downstream migration to the sea to spawn	Short	New objective to cue downstream migration by eels. Eels undertake downstream migrations throughout the

Asset	Objective	No.	Function	Flow component	Timing	Expected response	Response time	Description of change
								year, with an increase in frequency over Summer and following high river flows (Crook et al. 2014).
Vegetation	Maintain or improve in-stream & riparian vegetation extent, structure & composition	V3-1	Provide shallow, permanently inundated in-stream environments all year Dry low- and medium-level banks to provide hydrological complexity	Low flow	Summer / Autumn	· Maintain in-stream and riparian vegetation characteristics such as species richness and abundance, structural complexity, vertical zonation & spatial extent. Specifically: 1) Maintain or improve the currently small beds of submerged and semi-emergent native vegetation in-stream, such as Parrots Feather 2) Maintain fringing beds of Cumbungi and rehabilitate or facilitate the development of new beds of Common Reed and other diverse rush and sedge assemblages in the riparian zone	Short	Restructured objectives and related 'Functions' and 'Expected responses' to reflect different vegetation components/habitats (in-stream, riparian, billabong/floodplain and terrestrial) and their contrasting watering requirements to promote or discourage each component. Rationalisation of billabong/floodplain objectives and associated 'Functions' and 'Flow components'.
		V3-2	Prolonged inundation of instream channel, lower bench and bars to disadvantage terrestrial species and prevent their colonizing of instream channel Inundate low-level benches to ensure vertical zonation of inundation-tolerant fringing vegetation	Low flow	Winter / Spring			
		V3-3	Wet medium-level banks to provide periodically inundated environments at various levels in-stream Promote inundation-tolerant aquatic or riparian vegetation and inhibit inundation-intolerant riparian or terrestrial vegetation Transport plant propagules and plant detritus downstream Provide hydrological complexity (and therefore vegetation zonation)	Freshes	Summer / Autumn			
		V3-4	Wet higher benches to maintain fringing aquatic vegetation and ensure vertical zonation of fringing vegetation Facilitate dispersion of propagules	Fresh	Winter / Spring (June or July)			
		V3-5	Promote flood-tolerant vegetation higher on banks	Fresh	Winter / Spring (June – September)			
		V3-6	Provide deeper, permanently inundated in-stream environments over Winter/Spring Inundate medium-level banks to provide periodically inundated environments at higher levels in-stream Promote inundation-tolerant aquatic or riparian vegetation and inhibit inundation-intolerant riparian or terrestrial vegetation Transport plant propagules and plant detritus downstream Provide hydrological complexity (and therefore vegetation zonation)	High flow	Winter / Spring			
	Maintain inundation-tolerant vegetation in riparian zone at top of bank	V3-7	Maintain periodically wetted areas on top-of-bank to promote inundation-tolerant riparian vegetation on upper levels of bank and lower riparian zone	Bankfull	Winter / Spring	· Maintain inundation-tolerant riparian species, such as Swamp Paperbark, at top-of bank	Medium	

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Asset	Objective	No.	Function	Flow component	Timing	Expected response	Response time	Description of change
			Provide hydrological complexity (and therefore vegetation zonation)					
	Maintain or improve billabongs and floodplains	V3-8	Inundate specific billabongs	Bankfull and/or Overbank	Winter / Spring	· Improve the ecological structure and ecological function of specific billabongs (likely to require complementary works) · Improve the ecological structure and ecological function of the floodplain more generally (contingent upon ability to inundate large areas of floodplain without damage to infrastructure) · Improve lateral connectivity between river and floodplain/billabong habitats (likely to require complementary works)	Medium to Long	
		V3-9	Inundate areas of the floodplain in order to promote growth of inundation-tolerant taxa (e.g. rushes, reeds, sedges) over terrestrial taxa (e.g. Silver Wattle, Tree Violet) on the top-of-bank, on the floodplain and in billabongs	Bankfull and/or Overbank	Winter / Spring			
Platypus	Maintain/improve current status of population	P3-1	Maintain platypus habitat, maintain longitudinal connectivity across riffle areas, minimise predation risk, allow juvenile dispersal, support macroinvertebrate populations.	Low flow	All year	· Maintain habitat quality and food resources for platypuses.	Short to medium	New objectives developed for Platypus, drawing upon insights from platypus surveys and conceptual models of platypus flow requirements (Jacobs et al. 2016).
		P3-2	Maintain minimum pool depth >1m.	Low flow (extreme)	Extended dry periods (drought)	· Maintain refuge areas during drought.	Short to medium	
		P3-3	Promote habitat diversity, scour fine sediment, promote macroinvertebrate diversity/abundance.	Freshes / High flow	All year	· Improve habitat quality and food resources for platypuses.	Short to medium	
		P3-4	Minimise bank erosion and in-stream sedimentation	Limit flows above scouring thresholds	All year	· Improve habitat quality for platypus food resources (macroinvertebrates)	Medium	
		P3-5	Prevent inundation of breeding burrows	Avoid bankfull or overbank flows	Nov-Feb	· Improved reproductive success.	Short	
Birds, Frogs and Amenity	Birds – Maintain or improve the species richness and abundance of streamside and wetland populations Frogs – Maintain diversity and improve the overall abundance and	BFA3-1	Maintain access to good quality physical habitat, provide good water quality, and support the growth of instream vegetation, an important source of food resources and habitat	Low flow	Summer / Autumn	· Maintain permanent pools with an adequate depth of water for habitat for biota such as macroinvertebrates, an important food source for birds, and frogs · Provides disturbance to scour the river bed of sediment and improve the quality of instream habitat · Also provides a suitable range of depths for the growth of in-stream vegetation	Short to medium	New generic ecological objectives have been added for Birds, Frogs and Amenity as documented in the Yarra River EWMP (Jacobs 2017f)

Asset	Objective	No.	Function	Flow component	Timing	Expected response	Response time	Description of change
	distribution of expected species Amenity – Maintain and/or improve condition	BFA3-2		Fresh	Summer / Autumn	· Provides disturbance to scour the river bed of sediment and improve the quality of habitat within the river · Provides a suitable depth of water for waterbirds, maintaining the extent of habitat range they can utilise · Provides flow variability to maintain a diversity of emergent and riparian vegetation and helps to influence vegetation zonation patterns across the channel, which then provides a variety of habitats.	Short to medium	
		BFA3-3	Rehabilitate and maintain habitat within the higher parts of the river channel	High flow	Summer / Autumn	· Entrains and transports sediment along the river improving the quality of, and access to, instream habitat · Sustains longitudinal connectivity, providing opportunities to move along and between habitats for waterbirds. · Helps to influence vegetation zonation patterns across the channel, which provides a variety of habitats.	Short to medium	
		BFA3-4	Maintain access to good quality physical habitat, provide good water quality, and support the growth of instream vegetation, an important source of food resources and habitat	Low flow	Winter / Spring	· Increase habitat area for instream flora and fauna including access to large woody debris and overhanging banks. · Encourages the die-back of terrestrial vegetation that has encroached down the bank during the Summer low flow period	Short to medium	
		BFA3-5		Fresh	Winter / Spring	· Provides flow variability to maintain a diversity of emergent and riparian vegetation and to influence vegetation zonation patterns across the channel, which provides a variety of habitats for birds	Short to medium	

Asset	Objective	No.	Function	Flow component	Timing	Expected response	Response time	Description of change
						· Entrains and transports terrestrial organic matter along that has accumulated on benches.		
		BFA3-6	Rehabilitate and maintain appropriate habitat within the higher parts of the river channel	High flow	Winter / Spring	· Entrains and transports sediment along the river improving the quality of, and access to, instream habitat. · Sustains longitudinal connectivity, providing opportunities to move along and between habitats. · Helps to influence vegetation zonation patterns across the channel, which provides a variety of habitats.	Short to medium	
		BFA3-7	Maintain instream habitats and improve the condition of billabongs connected around bankfull	Bankfull	Winter / Spring	· Increase habitat area, including access to large woody debris and overhanging banks for instream biota, and engage floodplain and billabong habitat for frogs and waterbirds · Helps to disturb and reset aquatic and riparian vegetation communities, important for a range of diverse habitat types for birds, frogs and platypus · Provides flow cues for platypus behaviours, such as choice of burrow sites · Entrains and transports organic matter and sediment that has accumulated in pools and the upper channel, improving habitat quality for platypus.	Short to medium	
		BFA3-8	Reconnect the floodplain and floodplain billabongs with the instream channel Maintain wetland/billabong species and communities	Overbank	Winter / Spring	· Improves the frequency and extent of flooding in floodplain wetlands and billabongs. · Provides water for flood-tolerant vegetation such as River Red Gum · Provides wetted habitat for waterbird and frog species who don't necessarily require instream habitat	Short to medium	

Table A.4 : Reach 4 – Watts River to Yering Gorge ecological objectives.

Asset	Objective	No.	Function	Flow component	Timing	Expected response	Response time	Description of change
Geomorphology	Maintain channel dimensions and form	G4-1	Maintain existing channel dimensions and minimise bed and bank erosion Limit frequency and duration of flows above scouring thresholds	High / bankfull flow	Winter / Spring	· Maintain channel features	Medium to long	Current and future stormwater runoff may be contributing to flashier flows that scour the channel boundary. Revised wording of 'Function' to include reference to 'limit frequency and duration of flows above scouring thresholds'.
		G4-2	Protect existing substrates Limit frequency and duration of flows above scouring thresholds	Freshes	Throughout year	· Prevent any further increase in frequency of flows above scouring thresholds	Medium to long	Increased stormwater runoff from impervious areas may exacerbate bank stability. Revised wording of 'Function' to 'protect existing substrates' and 'limit frequency and duration of flows above scouring thresholds'.
	Rehabilitate lateral connectivity with billabongs connected around bankfull	G4-3	Form and maintain billabongs and meander train	Bankfull flow	Spring	· Increased frequency of inundation of billabongs & meander train	Short	No change from SKM (2012)
	Rehabilitate floodplains	G4-4	Form and maintain floodplain features	Overbank flow	Spring	· Increased frequency & duration of inundation of floodplain	Short	No change from SKM (2012)
Macroinvertebrates	Rehabilitate macroinvertebrate community to comply with Yarra SEPP Schedule F7 objectives	M4-1	Access to and area of riffle and edge habitats (Seasonal variation to inundate additional habitat area in Winter/Spring)	Low flow	Summer / Winter	~ Expect improvement in macroinvertebrates scores to comply with SEPP objectives, particularly towards bottom of reach.	Short to medium	Modified low flow objective and related 'Function' so as to capture assumed changes in Summer / Autumn and Winter / Spring macroinvertebrate biomass linked to inundation of habitat areas.
		M4-2		Low flow	Winter / Spring			
		M4-3	Disturbance to scour biofilm & sediment from LWD	Freshes	Throughout year			
Fish	Maintain or improve populations of native indigenous fish (river blackfish, Australian smelt, ornate galaxias, Australian grayling, short-finned eel, short-headed lamprey, pouched lamprey, tupong, broad-finned galaxias, spotted galaxias & common galaxias), and comply with Yarra SEPP Schedule F7 objectives.	F4-1	Maintain hydraulic habitat (i.e. pool, riffle, run) and passage for local movement	Low flow	Summer / Autumn	· Maintenance of hydraulic habitat; Localised movements	Short to medium	Rewritten objectives and revised list of fish species. No longer include mountain galaxias as they have not recently been surveyed in this reach. Split low flow objective to distinguish Summer / Autumn and Winter / Spring low flow components.
		F4-2		Low flow	Winter / Spring			
		F4-3	Flush accumulated fine sediments to maintain or improve quality and availability of habitats	Freshes / High flow	Winter / Spring	· Accumulated fine sediments scoured from the river bed	Short to medium	
		F4-4	Facilitate upstream immigration of juvenile catadromous (short-finned eel, common galaxias, tupong) and amphidromous (Australian grayling, broad-finned galaxias, spotted galaxias) fishes from downstream river reaches	Freshes / High flow	Spring / Early Summer	· Upstream immigration from downstream river reaches	Short	Changed objective so that is it more explicit as to the species and timing of migration. Upstream movement of diadromous fishes occurs over a broad time frame (e.g. August to February), with greatest richness of species migrating around September-November (McDowall & Eldon. 1980, Sloane 1984, Zampatti et al. 2003)
		F4-5	Cue downstream spawning migration by Australian grayling to lower river reaches.	High flow	Autumn	· Downstream migration to lower river reaches to spawn	Short	Revised wording of objective and timing of high flow (from Autumn / Winter to Autumn). Australian grayling undertakes downstream migrations to spawn between late March and May (Koster et al. 2017, Koster et al. 2013)

Asset	Objective	No.	Function	Flow component	Timing	Expected response	Response time	Description of change
		F4-6	Cue downstream migration by tupong to the sea to spawn	Freshes / High flow	Late Autumn / Winter	· Downstream migration to the sea to spawn	Short	New objective to cue downstream migration by tupong. Tupong undertake downstream migrations between late May and August, associated with high river flows (Crook et al. 2010).
		F4-7	Cue downstream migration by eels to the sea to spawn	Freshes / High flow	Throughout year, especially late Summer	· Downstream migration to the sea to spawn	Short	New objective to cue downstream migration by eels. Eels undertake downstream migrations throughout the year, with an increase in frequency over Summer and following high river flows (Crook et al. 2014).
Vegetation	Maintain or improve in-stream & riparian vegetation extent, structure & composition	V4-1	Provide shallow, permanently inundated in-stream environments all year Dry low- and medium-level banks to provide hydrological complexity	Low flow	Summer / Autumn	· Maintain or improve in-stream and riparian vegetation characteristics such as species richness and abundance, structural complexity, vertical zonation & spatial extent. Specifically: 1) Maintain or improve submerged and semi-emergent vegetation in-stream, such as Water Ribbons 2) Maintain or improve fringing beds of Cumbungi and rehabilitate or facilitate the development of new beds of Common Reed and other diverse rush and sedge assemblages in the riparian zone	Short	Restructured objectives and related 'Functions' and 'Expected responses' to reflect different vegetation components/habitats (in-stream, riparian, billabong/floodplain and terrestrial) and their contrasting watering requirements to promote or discourage each component. Rationalisation of billabong/floodplain objectives and associated 'Functions' and 'Flow components'
		V4-2	Prolonged inundation of instream channel, lower bench and bars to disadvantage terrestrial species and prevent their colonizing of instream channel Inundate low-level benches to ensure vertical zonation of inundation-tolerant fringing vegetation	Low flow	Winter / Spring			
		V4-3	Wet medium-level banks to provide periodically inundated environments at various levels in-stream Promote inundation-tolerant aquatic or riparian vegetation and inhibit inundation-intolerant riparian or terrestrial vegetation Transport plant propagules and plant detritus downstream Provide hydrological complexity	Fresh	Summer / Autumn			
		V4-4	Wet higher benches to maintain fringing aquatic vegetation and ensure vertical zonation of fringing vegetation Facilitate dispersion of propagules	Fresh	Winter / Spring (June/July)			
		V4-5	Promote flood-tolerant vegetation higher on banks	Fresh	Winter / Spring (June to September)			
		V4-6	Provide deeper, permanently inundated in-stream environments over Winter/Spring Inundate medium-level banks to provide periodically inundated environments at higher levels in-stream Promote inundation-tolerant aquatic or riparian vegetation and inhibit inundation-intolerant riparian or terrestrial vegetation Transport plant propagules and plant detritus downstream	High flow	Winter / Spring			

Asset	Objective	No.	Function	Flow component	Timing	Expected response	Response time	Description of change
			Provide hydrological complexity (and therefore vegetation zonation)					
	Maintain inundation-tolerant vegetation in riparian zone at top of bank	V4-7	Maintain periodically wetted areas on top-of-bank to promote inundation-tolerant riparian vegetation on upper levels of bank and lower riparian zone Provide hydrological complexity (and therefore vegetation zonation)	Bankfull	Winter / Spring	· Maintain inundation-tolerant riparian species, such as Swamp Paperbark, at top-of bank	Medium	
	Maintain or improve billabongs and floodplains	V4-8	Inundate specific billabongs	Bankfull and/or Overbank	Winter / Spring	· Improve the ecological structure and ecological function of specific billabongs (likely to require complementary works) · Improve the ecological structure and ecological function of the floodplain more generally (contingent upon ability to inundate large areas of floodplain without damage to infrastructure) · Improve lateral connectivity between river and floodplain/billabong habitats (likely to require complementary works – see Appendix B)	Medium to Long	
		V4-9	Inundate areas of the floodplain in order to promote growth of inundation-tolerant taxa (e.g. rushes, reeds, sedges) over terrestrial taxa (e.g. Silver Wattle, Tree Violet) on the top-of-bank, on the floodplain and in billabongs	Bankfull and/or Overbank	Winter / Spring			
Platypus	Maintain/improve current status of population	P4-1	Maintain platypus habitat, maintain longitudinal connectivity across riffle areas, minimise predation risk, allow juvenile dispersal, support macroinvertebrate populations.	Low flow	All year	· Maintain habitat quality and food resources for platypuses.	Short to medium	New objectives developed for Platypus, drawing upon insights from platypus surveys and conceptual models of platypus flow requirements (Jacobs et al. 2016). Maintaining drought refuges probably not required in Reaches 4-6 under current flow regimes but may be relevant in future.
		P4-2	Maintain minimum pool depth >1m.	Low flow (extreme)	Extended dry periods (drought)	· Maintain refuge areas during drought.	Short to medium	
		P4-3	Promote habitat diversity, scour fine sediment, promote macroinvertebrate diversity/abundance.	Freshes	All year	· Improve habitat quality and food resources for platypuses.	Short to medium	
		P4-4	Minimise bank erosion and in-stream sedimentation	Limit flows above scouring thresholds	All year	· Improve habitat quality for platypus food resources (macroinvertebrates)	Medium	
		P4-5	Prevent inundation of breeding burrows	Avoid bankfull or overbank flows	Nov-Feb	· Improved reproductive success.	Short	
Birds, Frogs and Amenity	Birds – Maintain or improve the species richness and abundance of streamside and wetland populations	BFA4-1	Maintain access to good quality physical habitat, provide good water quality, and support the growth of instream vegetation, an important source of food resources and habitat	Low flow	Summer / Autumn	· Maintain permanent pools with an adequate depth of water for habitat for biota such as macroinvertebrates, an important food source for birds, and frogs · Provides disturbance to scour the river bed of sediment and	Short to medium	New generic ecological objectives have been added for Birds, Frogs and Amenity as documented in the Yarra River EWMP (Jacobs 2017f)

Asset	Objective	No.	Function	Flow component	Timing	Expected response	Response time	Description of change
	Frogs – Maintain diversity and improve the overall abundance and distribution of expected species Amenity – Maintain and/or improve condition					improve the quality of instream habitat · Also provides a suitable range of depths for the growth of in-stream vegetation		
		BFA4-2		Fresh	Summer / Autumn	· Provides disturbance to scour the river bed of sediment and improve the quality of habitat within the river · Provides a suitable depth of water for waterbirds, maintaining the extent of habitat range they can utilise · Provides flow variability to maintain a diversity of emergent and riparian vegetation and helps to influence vegetation zonation patterns across the channel, which then provides a variety of habitats.	Short to medium	
		BFA4-3	Rehabilitate and maintain habitat within the higher parts of the river channel	High flow	Summer / Autumn	· Entrains and transports sediment along the river improving the quality of, and access to, instream habitat · Sustains longitudinal connectivity, providing opportunities to move along and between habitats for waterbirds. · Helps to influence vegetation zonation patterns across the channel, which provides a variety of habitats.	Short to medium	
		BFA4-4	Maintain access to good quality physical habitat, provide good water quality, and support the growth of instream vegetation, an important source of food resources and habitat	Low flow	Winter / Spring	· Increase habitat area for instream flora and fauna including access to large woody debris and overhanging banks. · Encourages the die-back of terrestrial vegetation that has encroached down the bank during the Summer low flow period	Short to medium	
		BFA4-5		Fresh	Winter / Spring	· Provides flow variability to maintain a diversity of emergent and riparian vegetation and to influence vegetation zonation patterns across the channel, which	Short to medium	

Asset	Objective	No.	Function	Flow component	Timing	Expected response	Response time	Description of change
						provides a variety of habitats for birds · Entrains and transports terrestrial organic matter along that has accumulated on benches.		
		BFA4-6	Rehabilitate and maintain appropriate habitat within the higher parts of the river channel	High flow	Winter / Spring	· Entrains and transports sediment along the river improving the quality of, and access to, instream habitat. · Sustains longitudinal connectivity, providing opportunities to move along and between habitats. · Helps to influence vegetation zonation patterns across the channel, which provides a variety of habitats.	Short to medium	
		BFA4-7	Maintain instream habitats and improve the condition of billabongs connected around bankfull	Bankfull	Winter / Spring	· Increase habitat area, including access to large woody debris and overhanging banks for instream biota, and engage floodplain and billabong habitat for frogs and waterbirds · Helps to disturb and reset aquatic and riparian vegetation communities, important for a range of diverse habitat types for birds, frogs and platypus · Provides flow cues for platypus behaviours, such as choice of burrow sites · Entrains and transports organic matter and sediment that has accumulated in pools and the upper channel, improving habitat quality for platypus.	Short to medium	
		BFA4-8	Reconnect the floodplain and floodplain billabongs with the instream channel Maintain wetland/billabong species and communities	Overbank	Winter / Spring	· Improves the frequency and extent of flooding in floodplain wetlands and billabongs. · Provides water for flood-tolerant vegetation such as River Red Gum · Provides wetted habitat for waterbird and frog species who don't necessarily require instream habitat	Short to medium	

Table A.5 : Reach 5– Yering Gorge to Mullum Mullum Creek ecological objectives.

Asset	Objective	No.	Function	Flow component	Timing	Expected response	Response time	Description of changes
Geomorphology	Maintain channel dimensions and form	G5-1	Maintain existing channel dimensions and minimise bed and bank erosion Limit frequency and duration of flows above scouring thresholds	High / bankfull flow	Winter / Spring	· Maintain channel features · No expansion in vegetated bars & island on riffles	Medium to long	Current and future stormwater runoff may be contributing to flashier flows that scour the channel boundary. Revised wording of 'Function' to include reference to 'limit frequency and duration of flows above scouring thresholds'.
		G5-2	Protect existing substrates Limit frequency and duration of flows above scouring thresholds	Freshes	Throughout year	· Pumping induced rate of rise & fall managed to minimise stranding fauna on riffles · Prevent any further increase in frequency of flows above scouring thresholds	Short	Increased stormwater runoff from impervious areas may exacerbate bank stability. Revised wording of 'Function' to 'protect existing substrates' and 'limit frequency and duration of flows above scouring thresholds'.
	Rehabilitate lateral connectivity with billabongs on Henley floodplain	G5-3	Form and maintain billabongs and meander train	Bankfull flow	Spring	· Increased frequency of inundation of billabongs & meander train.	Short	No change from SKM (2012)
Macroinvertebrates	Rehabilitate macroinvertebrate community to comply with Yarra SEPP Schedule F7 objectives	M5-1	Access to and area of riffle and edge habitats (Seasonal variation to inundate additional habitat area in Winter/Spring)	Low flow	Summer / Winter	· Expect improvement in macroinvertebrate scores to meet SEPP objectives - May require cease to pump in Yering Gorge to protect wetted width of riffle habitat.	Short to medium	Modified low flow objective and related 'Function' so as to capture assumed changes in Summer / Autumn and Winter / Spring macroinvertebrate biomass linked to inundation of habitat areas.
		M5-2		Low flow	Winter / Spring			
		M5-3	Disturbance to scour biofilm & sediment from riffles & LWD	Freshes	Throughout year			
Fish	Maintain or improve populations of native indigenous fish (river blackfish, Australian smelt, ornate galaxias, Australian grayling, short-finned eel, short-headed lamprey, pouched lamprey, tupong, broad-finned galaxias, spotted galaxias & common galaxias), and native non- indigenous fish (Macquarie perch and Murray cod), and comply with Yarra SEPP Schedule F7 objectives.	F5-1	Maintain hydraulic habitat (i.e. pool, riffle, run) and passage for local movement	Low flow	Summer / Autumn	· Maintenance of hydraulic habitat; Localised movements	Short to medium	Rewritten objectives and revised list of fish species. No longer include mountain galaxias as they have not recently been surveyed in this reach. Split low flow objective to distinguish Summer / Autumn and Winter / Spring low flow components.
		F5-2		Low flow	Winter / Spring			
		F5-3	Flush accumulated fine sediments to maintain or improve quality and availability of habitats, including Macquarie perch spawning habitats	Freshes / High flow	Winter / Spring	· Accumulated fine sediments scoured from the river bed	Short to medium	Revised objective so that it is more explicit to Macquarie Perch and timing. For Macquarie perch, minimize large flow releases and change in flows during November and December which have been shown to negatively influence recruitment. In warmer years extend this period from mid-October to December (Tonkin et al. 2015).
		F5-4	Facilitate upstream immigration of juvenile catadromous (short-finned eel, common galaxias, tupong) and amphidromous (Australian grayling, broad-finned galaxias, spotted galaxias) fishes from downstream river reaches	Freshes / High flow	Spring / Early Summer	· Upstream immigration from downstream river reaches	Short	Changed objective so that is it more explicit as to the species and timing of migration. Upstream movement of diadromous fishes occurs over a broad time frame (e.g. August to February), with greatest richness of species migrating around September-November (McDowall & Eldon. 1980, Sloane 1984, Zampatti et al. 2003)

Asset	Objective	No.	Function	Flow component	Timing	Expected response	Response time	Description of changes
		F5-5	Cue downstream spawning migration by Australian grayling to lower river reaches.	High flow	Autumn	· Downstream migration to lower river reaches to spawn	Short	Revised wording of objective and timing of high flow (from Autumn / Winter to Autumn). Australian grayling undertakes downstream migrations to spawn between late March and May (Koster et al. 2017, Koster et al. 2013)
		F5-6	Cue downstream migration by tupong to the sea to spawn	Freshes / High flow	Late Autumn / Winter	· Downstream migration to the sea to spawn	Short	New objective to cue downstream migration by tupong. Tupong undertake downstream migrations between late May and August, associated with high river flows (Crook et al. 2010).
		F5-7	Cue downstream migration by eels to the sea to spawn	Freshes / High Flow	Throughout year, especially late Summer	· Downstream migration to the sea to spawn	Short	New objective to cue downstream migration by eels. Eels undertake downstream migrations throughout the year, with an increase in frequency over Summer and following high river flows (Crook et al. 2014).
Vegetation	Maintain or improve in-stream & riparian vegetation extent, structure & composition	V5-1	Provide shallow, permanently inundated in-stream environments all year Dry low- and medium-level banks to provide hydrological complexity	Low flow	Summer / Autumn	· Maintain or improve in-stream and riparian vegetation characteristics such as species richness and abundance, structural complexity, vertical zonation & spatial extent. Specifically: 1) Maintain or improve submerged and semi-emergent vegetation in-stream, such as Water Ribbons. 2) Maintain or improve fringing beds of Cumbungi and rehabilitate or facilitate the development of new beds of Common Reed and other diverse rush and sedge assemblages in the riparian zone	Short	Restructured objectives and related 'Functions' and 'Expected responses' to reflect different vegetation components/habitats (in-stream, riparian, billabong/floodplain and terrestrial) and their contrasting watering requirements to promote or discourage each component. Rationalisation of billabong/floodplain objectives and associated 'Functions' and 'Flow components'.
		V5-2	Prolonged inundation of instream channel, lower bench and bars to disadvantage terrestrial species and prevent their colonizing of instream channel Inundate low-level benches to ensure vertical zonation of inundation-tolerant fringing vegetation	Low flow	Winter / Spring			
		V5-3	Wet medium-level banks to provide periodically inundated environments at various levels in-stream Promote inundation-tolerant aquatic or riparian vegetation and inhibit inundation-intolerant riparian or terrestrial vegetation Transport plant propagules and plant detritus downstream Provide hydrological complexity (and therefore vegetation zonation)	Fresh	Summer / Autumn			
		V5-4	Wet higher benches to maintain fringing aquatic vegetation and ensure vertical zonation of fringing vegetation Facilitate dispersion of propagules	Fresh	Winter / Spring (June/July)			
		V5-5	Promote flood-tolerant vegetation higher on banks	Fresh	Winter / Spring (June to September)			
		V5-6	Provide deeper, permanently inundated in-stream environments over Winter/Spring	High flow	Winter / Spring			

Asset	Objective	No.	Function	Flow component	Timing	Expected response	Response time	Description of changes
			Inundate medium-level banks to provide periodically inundated environments at higher levels in-stream Promote inundation-tolerant aquatic or riparian vegetation and inhibit inundation-intolerant riparian or terrestrial vegetation Transport plant propagules and plant detritus downstream Provide hydrological complexity (and therefore vegetation zonation)					
	Maintain or improve inundation-tolerant vegetation in riparian zone at top of bank	V5-7	Maintain periodically wetted areas on top-of-bank to promote inundation-tolerant riparian vegetation on upper levels of bank and lower riparian zone Provide hydrological complexity (and therefore vegetation zonation)	Bankfull	Winter / Spring	· Maintain or improve inundation-tolerant riparian species, such as Swamp Paperbark, at top-of bank	Medium	
	Maintain or improve billabongs and floodplains (of limited importance in this reach)	V5-8	Inundate specific billabongs	Bankfull and/or Overbank	Winter / Spring	· Improve the ecological structure and ecological function of specific billabongs (likely to require complementary works) · Improve the ecological structure and ecological function of the floodplain more generally (contingent upon ability to inundate large areas of floodplain without damage to infrastructure) · Improve lateral connectivity between river and floodplain/billabong habitats (likely to require complementary works; see Appendix B)	Medium to Long	
		V5-9	Inundate areas of the floodplain in order to promote growth of inundation-tolerant taxa (e.g. rushes, reeds, sedges) over terrestrial taxa (e.g. Silver Wattle, Tree Violet) on the top-of-bank, on the floodplain and in billabongs	Bankfull and/or Overbank	Winter / Spring			
Water quality	Minimise risk of stratification and low dissolved oxygen in pools through Yering and Warrandyte gorges	W5-1	Fish and macroinvertebrate health	Low flow	All year	· Pools fully mixed at all times	Short	No change from SKM (2012)
Platypus	Maintain/improve current status of population	P5-1	Maintain platypus habitat, maintain longitudinal connectivity across riffle areas, minimise predation risk, allow juvenile dispersal, support macroinvertebrate populations.	Low flow	All year	· Maintain habitat quality and food resources for platypuses.	Short to medium	New objectives developed for Platypus, drawing upon insights from platypus surveys and conceptual models of platypus flow requirements (Jacobs et al. 2016). Maintaining drought refuges probably not required in Reaches 4-6 under current flow regimes but may be relevant in future.
		P5-2	Maintain minimum pool depth >1m.	Low flow (extreme)	Extended dry periods (drought)	· Maintain refuge areas during drought.	Short to medium	
		P5-3	Promote habitat diversity, scour fine sediment, promote macroinvertebrate diversity/abundance.	Freshes	All year	· Improve habitat quality and food resources for platypuses.	Short to medium	

Asset	Objective	No.	Function	Flow component	Timing	Expected response	Response time	Description of changes
		P5-4	Minimise bank erosion and in-stream sedimentation	Limit flows above scouring thresholds	All year	· Improve habitat quality for platypus food resources (macroinvertebrates)	Medium	
		P5-5	Prevent inundation of breeding burrows	Avoid bankfull or overbank flows	Nov-Feb	· Improved reproductive success.	Short	
Birds, Frogs and Amenity	Birds – Maintain or improve the species richness and abundance of streamside and wetland populations Frogs – Maintain diversity and improve the overall abundance and distribution of expected species Amenity – Maintain and/or improve condition	BFA5-1	Maintain access to good quality physical habitat, provide good water quality, and support the growth of instream vegetation, an important source of food resources and habitat	Low flow	Summer / Autumn	· Maintain permanent pools with an adequate depth of water for habitat for biota such as macroinvertebrates, an important food source for birds, and frogs · Provides disturbance to scour the river bed of sediment and improve the quality of instream habitat · Also provides a suitable range of depths for the growth of in-stream vegetation	Short to medium	New generic ecological objectives have been added for Birds, Frogs and Amenity as documented in the Yarra River EWMP (Jacobs 2017f)
		BFA5-2		Fresh	Summer / Autumn	· Provides disturbance to scour the river bed of sediment and improve the quality of habitat within the river · Provides a suitable depth of water for waterbirds, maintaining the extent of habitat range they can utilise · Provides flow variability to maintain a diversity of emergent and riparian vegetation and helps to influence vegetation zonation patterns across the channel, which then provides a variety of habitats.	Short to medium	
		BFA5-3	Rehabilitate and maintain habitat within the higher parts of the river channel	High flow	Summer / Autumn	· Entrains and transports sediment along the river improving the quality of, and access to, instream habitat · Sustains longitudinal connectivity, providing opportunities to move along and between habitats for waterbirds. · Helps to influence vegetation zonation patterns across the channel, which provides a variety of habitats.	Short to medium	
		BFA5-4	Maintain access to good quality physical habitat, provide good water quality, and	Low flow	Winter / Spring	· Increase habitat area for instream flora and fauna	Short to medium	

Asset	Objective	No.	Function	Flow component	Timing	Expected response	Response time	Description of changes
			support the growth of instream vegetation, an important source of food resources and habitat			including access to large woody debris and overhanging banks. · Encourages the die-back of terrestrial vegetation that has encroached down the bank during the Summer low flow period		
		BFA5-5		Fresh	Winter / Spring	· Provides flow variability to maintain a diversity of emergent and riparian vegetation and to influence vegetation zonation patterns across the channel, which provides a variety of habitats for birds · Entrains and transports terrestrial organic matter along that has accumulated on benches.	Short to medium	
		BFA5-6	Rehabilitate and maintain appropriate habitat within the higher parts of the river channel	High flow	Winter / Spring	· Entrains and transports sediment along the river improving the quality of, and access to, instream habitat. · Sustains longitudinal connectivity, providing opportunities to move along and between habitats. · Helps to influence vegetation zonation patterns across the channel, which provides a variety of habitats.	Short to medium	
		BFA5-7	Maintain instream habitats and improve the condition of billabongs connected around bankfull	Bankfull	Winter / Spring	· Increase habitat area, including access to large woody debris and overhanging banks for instream biota, and engage floodplain and billabong habitat for frogs and waterbirds · Helps to disturb and reset aquatic and riparian vegetation communities, important for a range of diverse habitat types for birds, frogs and platypus · Provides flow cues for platypus behaviours, such as choice of burrow sites · Entrains and transports organic matter and sediment that has accumulated in pools and the	Short to medium	

Asset	Objective	No.	Function	Flow component	Timing	Expected response	Response time	Description of changes
						upper channel, improving habitat quality for platypus.		
		BFA5-8	Reconnect the floodplain and floodplain billabongs with the instream channel Maintain wetland/billabong species and communities	Overbank	Winter / Spring	· Improves the frequency and extent of flooding in floodplain wetlands and billabongs. · Provides water for flood-tolerant vegetation such as River Red Gum · Provides wetted habitat for waterbird and frog species who don't necessarily require instream habitat	Short to medium	

Table A.6 : Reach 6– Mullum Mullum Creek to Dights Falls ecological objectives.

Asset	Objective	No.	Function	Flow component	Timing	Expected response	Response time	Description of changes
Geomorphology	Maintain channel dimensions and form	G6-1	Maintain existing channel dimensions and minimise bed and bank erosion Limit frequency and duration of flows above scouring thresholds	High / bankfull flow	Winter / Spring	· Maintain channel features	Medium to long	Current and future stormwater runoff may be contributing to flashier flows that scour the channel boundary. Revised wording of 'Functions' to include reference to 'limit frequency and duration of flows above scouring thresholds'.
		G6-2	Protect existing substrates Limit frequency and duration of flows above scouring thresholds	Freshes	Throughout year	· Prevent any further increase in frequency of flows above scouring thresholds	Medium to long	Increased stormwater runoff from impervious areas may exacerbate bank stability. Revised wording of 'Functions' to 'protect existing substrates' and 'limit frequency and duration of flows above scouring thresholds'.
	Rehabilitate lateral connectivity with billabongs connected around bankfull	G6-3	Form and maintain billabongs and meander train	Bankfull / overbank flow	Spring	· Increased frequency of inundation of billabongs & meander train	Short	No change from SKM (2012)
Macroinvertebrates	Rehabilitate macroinvertebrate community to comply with Yarra SEPP Schedule F7 objectives	M6-1	Access to and area of LWD, riffles & edge habitats (Seasonal variation to inundate additional habitat area in Winter/Spring)	Low flow	Summer / Winter	- Achieve maximum possible macroinvertebrate score to the extent possible given level of urban impact	Short to medium	Modified low flow objective and related 'Functions' and 'Expected responses' so as to capture assumed changes in Summer / Autumn and Winter / Spring macroinvertebrate biomass linked to inundation of habitat areas.
		M6-2		Low flow	Winter / Spring			
		M6-3	Disturbance to scour biofilm & sediment from riffles & LWD	Freshes	Throughout year			
Fish	Maintain or improve populations of native indigenous fish (river blackfish, Australian smelt, ornate galaxias, Australian grayling, short-finned eel, short-headed lamprey, pouched lamprey, tupong, broad-finned galaxias, spotted galaxias & common galaxias), and native non- indigenous fish (Macquarie perch and Murray cod), and comply with Yarra SEPP Schedule F7 objectives.	F6-1	Maintain hydraulic habitat (i.e. pool, riffle, run) and passage for local movement	Low flow	Summer / Autumn	· Maintenance of hydraulic habitat; Localised movements	Short to medium	Rewritten objectives and revised list of fish species. No longer include mountain galaxias as they have not recently been surveyed in this reach. Split low flow objective to distinguish Summer / Autumn and Winter / Spring low flow components.
		F6-2		Low flow	Winter / Spring			
		F6-3	Flush accumulated fine sediments to maintain or improve quality and availability of habitats, including Macquarie perch spawning habitats.	Freshes / High flow	Winter / Spring	· Accumulated fine sediments scoured from the river bed	Short to medium	Revised objective so that it is more explicit to Macquarie Perch and timing. For Macquarie perch, minimize large flow releases and change in flows during November and December which have been shown to negatively influence recruitment. In warmer years extend this period from mid-October to December (Tonkin et al. 2015).
		F6-4	Facilitate upstream immigration of juvenile catadromous (short-finned eel, common galaxias, tupong) and amphidromous (Australian grayling, broad-finned galaxias, spotted galaxias) and adult anadromous (short-headed lamprey, pouched lamprey) fishes from downstream river reaches	Freshes / High flow	Spring / early Summer	· Upstream immigration from the sea	Short	Changed objective so that is it more explicit as to the species and timing of migration. Upstream movement of diadromous fishes occurs over a broad time frame (e.g. August to February), with greatest richness of species migrating around September-November (McDowall & Eldon. 1980, Sloane 1984, Zampatti et al. 2003)
		F6-5	Cue upstream spawning migration by short-headed lamprey from the sea	Freshes / High flow	Late Winter to Spring	· Upstream immigration from the sea	Short	

Asset	Objective	No.	Function	Flow component	Timing	Expected response	Response time	Description of changes
		F6-6	Cue upstream spawning migration by pouched lamprey from the sea	Freshes / High flow	Winter / Spring	· Upstream immigration from the sea	Short	
		F6-7	Cue downstream spawning migration by Australian grayling to lower river reaches.	High flow	Autumn	· Downstream migration to lower river reaches to spawn	Short	Revised wording of objective and timing of high flow (from Autumn / Winter to Autumn). Australian grayling undertakes downstream migrations to spawn between late March and May (Koster et al. 2017, Koster et al. 2013)
		F6-8	Cue downstream migration by tupong to the sea to spawn	Freshes / High flow	Late Autumn / Winter	· Downstream migration to the sea to spawn	Short	New objective to cue downstream migration by tupong. Tupong undertake downstream migrations between late May and August, associated with high river flows (Crook et al. 2010).
		F6-9	Cue downstream migration by eels to the sea to spawn	Freshes / High Flow	Throughout year, especially late Summer	· Downstream migration to the sea to spawn	Short	New objective to cue downstream migration by eels. Eels undertake downstream migrations throughout the year, with an increase in frequency over Summer and following high river flows (Crook et al. 2014).
Vegetation	Maintain or improve in-stream & riparian vegetation extent, structure & composition	V6-1	Provide shallow, permanently inundated in-stream environments all year Dry low- and medium-level banks to provide hydrological complexity	Low flow	Summer / Autumn	· Maintain or improve in-stream and riparian vegetation characteristics such as species richness and abundance, structural complexity, vertical zonation & spatial extent. Specifically: 1) Maintain or improve submerged and semi-emergent vegetation in-stream, such as Water Ribbons 2) Maintain or improve fringing beds of Cumbungi and rehabilitate or facilitate the development of new beds of Common Reed and other diverse rush and sedge assemblages in the riparian zone	Short	Restructured objectives and related 'Functions' and 'Expected responses' to reflect different vegetation components/habitats (in-stream, riparian, billabong/floodplain and terrestrial) and their contrasting watering requirements to promote or discourage each component. Rationalisation of billabong/floodplain objectives and associated 'Functions' and 'Flow components'.
		V6-2	Prolonged inundation of instream channel, lower bench and bars to disadvantage terrestrial species and prevent their colonizing of instream channel Inundate low-level benches to ensure vertical zonation of inundation-tolerant fringing vegetation	Low flow	Winter / Spring			
		V6-3	Wet medium-level banks to provide periodically inundated environments at various levels in-stream Promote inundation-tolerant aquatic or riparian vegetation and inhibit inundation-intolerant riparian or terrestrial vegetation Transport plant propagules and plant detritus downstream Provide hydrological complexity (and therefore vegetation zonation)	Fresh	Summer / Autumn			
		V6-4	Wet higher benches to maintain fringing aquatic vegetation and ensure vertical zonation of fringing vegetation Facilitate dispersion of propagules	Fresh	Winter / Spring (June/July)			
		V6-5	Promote flood-tolerant vegetation higher on banks	Fresh	Winter / Spring (June to September)			

Asset	Objective	No.	Function	Flow component	Timing	Expected response	Response time	Description of changes
		V6-6	Provide deeper, permanently inundated in-stream environments over Winter/Spring Inundate medium-level banks to provide periodically inundated environments at higher levels in-stream Promote inundation-tolerant aquatic or riparian vegetation and inhibit inundation-intolerant riparian or terrestrial vegetation Transport plant propagules and plant detritus downstream Provide hydrological complexity (and therefore vegetation zonation)	High flow	Winter / Spring			
	Maintain or improve inundation-tolerant vegetation in riparian zone at top of bank	V6-7	Maintain periodically wetted areas on top-of-bank to promote inundation-tolerant riparian vegetation on upper levels of bank and lower riparian zone	Bankfull	Winter / Spring	· Maintain or improve inundation-tolerant riparian species, such as Swamp Paperbark, at top-of bank	Medium	
	Maintain or improve billabongs and floodplains (critically important for billabongs in this reach)	V6-8	Inundate specific billabongs	Bankfull and/or Overbank	Winter / Spring	· Improve the ecological structure and ecological function of specific billabongs (likely to require complementary works) · Improve the ecological structure and ecological function of the floodplain more generally (contingent upon ability to inundate large areas of floodplain without damage to infrastructure) · Improve lateral connectivity between river and floodplain/billabong habitats (likely to require complementary works: see Appendix B)	Medium to Long	
		V6-9	Inundate areas of the floodplain in order to promote growth of inundation-tolerant taxa (e.g. rushes, reeds, sedges) over terrestrial taxa (e.g. Silver Wattle, Tree Violet) on the top-of-bank, on the floodplain and in billabongs	Bankfull and/or Overbank	Winter / Spring			
Water quality	Minimise risk of stratification and low dissolved oxygen in pools upstream of Chandler Highway	W6-1a	Fish and macroinvertebrate health	Low flow	All year	· Pools fully mixed at all times	Short	No change from SKM (2012)
	Minimise risk of stratification and low dissolved oxygen in Dights Falls Weir Pool	W6-1b	Fish and macroinvertebrate health	Low flow	All year	· Pools fully mixed at all times	Short	No change from SKM (2012)
				Freshes	All year	· Mix pools if stratification does occur	Short	No change from SKM (2012)
Platypus	Improve current status of population	P6-1	Maintain platypus habitat, maintain longitudinal connectivity across riffle areas, minimise predation risk, allow juvenile dispersal, support macroinvertebrate populations.	Low flow	All year	· Maintain habitat quality and food resources for platypuses.	Short to medium	New objectives developed for Platypus, drawing upon insights from platypus surveys and conceptual models of platypus flow requirements (Jacobs et al. 2016).

Asset	Objective	No.	Function	Flow component	Timing	Expected response	Response time	Description of changes
		P6-2	Maintain minimum pool depth >1m.	Low flow (extreme)	Extended dry periods (drought)	· Maintain refuge areas during drought.	Short to medium	Maintaining drought refuges probably not required in Reaches 4-6 under current flow regimes but may be relevant in future.
		P6-3	Promote habitat diversity, scour fine sediment, promote macroinvertebrate diversity/abundance.	Freshes	All year	· Improve habitat quality and food resources for platypuses.	Short to medium	
		P6-4	Minimise bank erosion and in-stream sedimentation	Limit flows above scouring thresholds	All year	· Improve habitat quality for platypus food resources (macroinvertebrates)	Medium	
		P6-5	Prevent inundation of breeding burrows	Avoid bankfull or overbank flows	Nov-Feb	· Improved reproductive success.	Short	
Birds, Frogs and Amenity	Birds – Maintain or improve the species richness and abundance of streamside and wetland populations Frogs – Maintain diversity and improve the overall abundance and distribution of expected species Amenity – Maintain and/or improve condition	BFA6-1	Maintain access to good quality physical habitat, provide good water quality, and support the growth of instream vegetation, an important source of food resources and habitat	Low flow	Summer / Autumn	· Maintain permanent pools with an adequate depth of water for habitat for biota such as macroinvertebrates, an important food source for birds, and frogs · Provide disturbance to scour the river bed of sediment and improve the quality of instream habitat · Provide a suitable range of depths for the growth of in-stream vegetation	Short to medium	New generic ecological objectives have been added for Birds, Frogs and Amenity as documented in the Yarra River EWMP (Jacobs 2017f)
		BFA6-2		Fresh	Summer / Autumn	· Provide disturbance to scour the river bed of sediment and improve the quality of habitat within the river · Provide a suitable depth of water for waterbirds, maintaining the extent of habitat range they can utilise · Provide flow variability to maintain a diversity of emergent and riparian vegetation and helps to influence vegetation zonation patterns across the channel, which then provides a variety of habitats.	Short to medium	
		BFA6-3	Rehabilitate and maintain habitat within the higher parts of the river channel	High flow	Summer / Autumn	· Entrains and transports sediment along the river improving the quality of, and access to, instream habitat · Sustains longitudinal connectivity, providing opportunities to move along and between habitats for waterbirds.	Short to medium	

Asset	Objective	No.	Function	Flow component	Timing	Expected response	Response time	Description of changes
						· Helps to influence vegetation zonation patterns across the channel, which provides a variety of habitats.		
		BFA6-4	Maintain access to good quality physical habitat, provide good water quality, and support the growth of instream vegetation, an important source of food resources and habitat	Low flow	Winter / Spring	· Increase habitat area for instream flora and fauna including access to large woody debris and overhanging banks. · Encourages the die-back of terrestrial vegetation that has encroached down the bank during the Summer low flow period	Short to medium	
		BFA6-5		Fresh	Winter / Spring	· Provide flow variability to maintain a diversity of emergent and riparian vegetation and to influence vegetation zonation patterns across the channel, which provides a variety of habitats for birds · Moves terrestrial organic matter along that has accumulated on benches.	Short to medium	
		BFA6-6	Rehabilitate and maintain appropriate habitat within the higher parts of the river channel	High flow	Winter / Spring	· Entrains and transports sediment along the river improving the quality of, and access to, instream habitat. · Sustains longitudinal connectivity, providing opportunities to move along and between habitats. · Helps to influence vegetation zonation patterns across the channel, which provides a variety of habitats.	Short to medium	
		BFA6-7	Maintain instream habitats and improve the condition of billabongs connected around bankfull	Bankfull	Winter / Spring	· Increase habitat area, including access to large woody debris and overhanging banks for instream biota, and engage floodplain and billabong habitat for frogs and waterbirds · Helps to disturb and reset aquatic and riparian vegetation communities, important for a range of diverse habitat types for birds, frogs and platypus	Short to medium	

Asset	Objective	No.	Function	Flow component	Timing	Expected response	Response time	Description of changes
						· Provide flow cues for platypus behaviours, such as choice of burrow sites · Entrains and transports organic matter and sediment that has accumulated in pools and the upper channel, improving habitat quality for platypus.		
		BFA6-8	Reconnect the floodplain and floodplain billabongs with the instream channel Maintain wetland/billabong species and communities	Overbank	Winter / Spring	· Improves the frequency and extent of flooding in floodplain wetlands and billabongs. · Provide water for flood-tolerant vegetation such as River Red Gum · Provide wetted habitat for waterbird and frog species who don't necessarily require instream habitat	Short to medium	

Appendix B. Complementary management objectives

Table B.1 : Complementary management objectives.

Reach	Asset	Objective	No.	Function	Expected response	Response time
1	**Geomorphology**	Rehabilitate in-stream habitat	C1-1	Limit sediment sources	· Reduced sediment input from Doctors Creek catchment. Promote Best Practice Guidelines for roading & timber harvesting. Identify specific sediment sources (given impact on reach) & manage appropriately	Medium
	Water quality	Maintain current water quality to meet Yarra SEPP Schedule F7 objectives	C1-2	Ecological processes & beneficial uses	· No decline in current water quality	Short
			C1-3	Limit effect of cold water releases	· No detrimental impacts of cold water releases from reservoir	Short
	Platypus	Maintain/improve current status of population	C1-4	Education	· Increased public awareness of impacts of litter and enclosed yabby traps.	Medium
2	**Water Quality**	Maintain current water quality to meet Yarra SEPP Schedule F7 objectives	C2-1	Ecological processes & beneficial uses	· No decline in current water quality. · Implementation of catchment strategies to limit stock access, agricultural runoff & septic tank effluent inputs to river to reduce nutrient & sediment levels & limit excessive algal growth.	Short to medium
3	**Macroinvertebrates**	Maintain and rehabilitate current macroinvertebrate community to comply with Yarra SEPP Schedule F7 objectives	C3-1	Reintroduce LWD to channel	· LWD reintroduction should be undertaken in conjunction with fencing & revegetation of riparian zone	Short to medium
	Vegetation	Rehabilitate billabong vegetation	C3-2	Revegetation, grazing/browsing control (including of feral animals such as deer), possible levee removal	· Complementary works required to fence meander train (billabongs / floodplain located close to channel), remove stock, limit if possible browsing by feral animals (especially deer) & revegetate with species appropriate for the EVC to take greatest advantage of provision of bankfull flows. Consider targeted removal of levees to take advantage of bankfull or overbank flows for individual billabongs.	Medium to Long
	Vegetation	Rehabilitate floodplain vegetation	C3-3	Revegetation, grazing/browsing control (including of feral animals such as deer), possible levee removal	· Complementary works required to fence, remove stock and limit if possible browsing by feral animals (especially deer) & revegetate floodplain with species appropriate for the EVC & remove levees to take advantage of overbank flows.	Medium to Long
	Water Quality	Improve water quality to meet Yarra SEPP Schedule F7 objectives	C3-4	Ecological processes & beneficial uses	· Increased nutrient compliance with SEPP objectives. · Implementation of catchment strategies to reduce stock access, agricultural runoff & localised urban stormwater inputs to river to reduce nutrient levels & limit excessive algal growth.	Medium
	Platypus	Maintain/improve current status of population	C3-5	Habitat enhancement	· Improve riparian zone (>20 m) through stock exclusion, weed removal, native revegetation to improve habitat for platypuses and macroinvertebrates.	Medium to Long
4	**Geomorphology / Macroinvertebrates**	Maintain channel dimensions and form Rehabilitate macroinvertebrate community to comply with Yarra SEPP Schedule F7 objectives	C4-1	Reduce direct connectedness to impervious surfaces in urban areas	· Maintain channel features, prevent any further increase in frequency of flows above scouring thresholds. · LWD reintroduction to be undertaken in conjunction with fencing & revegetation of riparian zone.	Short to medium
			C4-2	Reintroduce LWD to channel		
	Water Quality	Improve water quality to meet Yarra SEPP Schedule F7	C4-3	Ecological processes & beneficial uses	· Increased nutrient compliance with SEPP objectives. · Implementation of catchment strategies to reduce stock access, agricultural runoff & localised urban stormwater inputs to river to reduce nutrient levels & limit excessive algal growth.	Medium to long
	Vegetation	Rehabilitate billabong vegetation	C4-4	Revegetation, grazing/browsing control (including of feral animals such as deer), possible levee removal	· Complementary works required to fence meander train (billabongs / floodplain located close to channel), remove stock, limit if possible browsing by feral animals (especially deer) & revegetate with species appropriate for the EVC to take greatest advantage of provision of bankfull flows. Consider targeted removal of levees to take advantage of bankfull or overbank flows for individual billabongs.	Medium to Long
		Rehabilitate floodplain vegetation	C4-5	Revegetation, grazing/browsing control (including of feral animals	· Complementary works required to fence, remove stock, limit if possible browsing by feral animals (especially deer) & revegetate floodplain with species appropriate for the EVC & remove levees to take advantage of overbank flows.	

Reach	Asset	Objective	No.	Function	Expected response	Response time
				such as deer), possible levee removal		
	Platypus	Maintain/improve current status of population	C4-6	Habitat enhancement	· Improve riparian zone (>20 m) through stock exclusion, weed removal, native revegetation to improve habitat for platypuses and macroinvertebrates.	Medium to Long
5	**Geomorphology / Macroinvertebrates**	Maintain channel dimensions and form Rehabilitate macroinvertebrate community to comply with Yarra SEPP Schedule F7 objectives	C5-1	Reduce direct connectedness to impervious surfaces in urban areas	· Maintain channel features, prevent any further increase in frequency of flows above scouring thresholds. · LWD reintroduction to be undertaken in conjunction with fencing & revegetation of riparian zone.	Short to medium
			C5-2	Reintroduce LWD to channel		
	Vegetation	Rehabilitate billabong vegetation (of limited importance in this reach)	C5-3	Revegetation, grazing/browsing control (including of feral animals such as deer), possible levee removal	· Complementary works required to fence meander train (billabongs / floodplain located close to channel), remove stock, limit if possible browsing by feral animals (especially deer) & revegetate with species appropriate for the EVC to take greatest advantage of provision of bankfull flows. Consider targeted removal of levees to take advantage of bankfull or overbank flows for individual billabongs.	Medium to Long
		Rehabilitate floodplain vegetation (of limited importance in this reach)	C5-4	Revegetation, grazing/browsing control (including of feral animals such as deer), possible levee removal	· Complementary works required to fence, remove stock, limit if possible browsing by feral animals (especially deer) & revegetate floodplain with species appropriate for the EVC & remove levees to take advantage of overbank flows.	
	Water Quality	Improve water quality to meet Yarra SEPP Schedule F7 objectives (nutrients and turbidity)	C5-5	Ecological processes, fish health & primary contact beneficial use	· Increase nutrient compliance with SEPP objectives. · Continue to improve management of Sewerage Plant effluent to river, septic tank management & urban stormwater to limit nutrient levels & excessive algal growth.	Medium to long
	Platypus	Maintain/improve current status of population	C5-6	Improve water quality	· Reduce sediment input from tributaries to improve water quality in Yarra River. · Employ WSUD to prevent further increases to catchment DCI with urban development.	Medium to long
6	**Geomorphology / Macroinvertebrates**	Maintain channel dimensions and form Rehabilitate macroinvertebrate community to comply with Yarra SEPP Schedule F7 objectives	C6-1	Reduce direct connectedness to impervious surfaces in urban areas	· LWD reintroduction to be undertaken in conjunction with fencing & revegetation of riparian zone (see V6-4).	Short to medium
			C6-2	Reintroduce LWD to channel		
	Vegetation	Rehabilitate billabong vegetation	C6-3	Revegetation, grazing/browsing control (including of feral animals such as deer), possible levee removal	· Complementary works required to fence meander train (billabongs / floodplain located close to channel), remove stock, limit if possible browsing by feral animals (especially deer) & revegetate with species appropriate for the EVC to take greatest advantage of provision of bankfull flows. Consider targeted removal of levees to take advantage of bankfull or overbank flows for individual billabongs.	Medium to Long
	Vegetation	Rehabilitate floodplain vegetation	C6-4	Revegetation, grazing/browsing control (including of feral animals such as deer), possible levee removal	· Complementary works required to fence, remove stock, limit if possible browsing by feral animals (especially deer) & revegetate floodplain with species appropriate for the EVC & remove levees to take advantage of overbank flows.	
	Water Quality	Improve water quality to meet Yarra SEPP Schedule F7 objectives (Nutrients, turbidity & bacteriological),	C6-5	Ecological processes, fish health & primary contact beneficial use	· Reduce effective catchment imperviousness in tributary streams. · Increase nutrient & suspended solids compliance with SEPP objectives through improved stormwater management & reduced sewerage overflows	Medium to long
	Platypus	Maintain/improve current status of population	C6-6	Improve water quality	· Reduce sediment input from tributaries to improve water quality in Yarra River. · Employ WSUD to reduce catchment DCI with urban development.	Medium to long

Appendix C. Summary Flow Recommendations

Table C.1 : Summary of revised flow recommendations. Flow components have been colour coded to highlight those that are managed (blue) from those that are natural (green).

Season	Flow	Wet/Avg/Dry	Reach					
			1	2	3	4	5	6
Summer / Autumn (Dec- May)	Low flow	Wet/Avg	10 ML/day	80 ML/day	Min 120 ML/day at Woori Yallock and 150 ML/day at Everard Park	Min 200 ML/day	Min 200 ML/day	Min 300 – 450 ML/day
		Dry						
	Fresh	Wet/Avg	60 ML/day (4/yr, min 1 day at peak)	350 ML/day (3/yr, min 2 days at peak)	350 ML/day at Woori Yallock and 450 ML/day at Everard Park (3/yr, min 2 days at peak)	Min 450 ML/day (3/yr, min 2 days at peak)	Min 750 ML/day (3/yr, min 2 days at peak)	Min 750 ML/day (3/yr, min 2 days at peak)
		Dry						
	High	Wet/Avg	Not recommended	560 ML/day (1/yr in Apr/May, must occur 2 in 3 yrs, min 7 day duration)	900-1100 ML/day to ensure minimum flow of 1300 ML/day at Chandler Hwy (1/yr in Apr/May, must occur 2 in 3 yrs, min 7 days at peak, Event 14 days duration)	900-1100 ML/day to ensure minimum flow of 1300 ML/day at Chandler Hwy (1/yr in Apr/May, must occur 2 in 3 yrs, min 7 days at peak, Event 14 days duration)	1300 ML/day (1/yr in Apr/May, must occur 2 in 3 yrs, min 7 days at peak)	1300 ML/day (1/yr in Apr/May, must occur 2 in 3 yrs, min 7 days at peak)
		Dry						
Winter / Spring (Jun-Nov)	Low flow	Wet/Avg	10 ML/day	Min 200-350 ML/day (200 ML/day Jun, 350 ML/day Jul-Nov)	Min 200-350 ML/day (200 ML/day Jun, 350 ML/day Jul-Nov)	Min 350 ML/day	Median 750 ML/day with a min 350 ML/day	Median 750 ML/day with a min 350 ML/day
		Dry		Min 80-350 ML/day (80 ML/day Jun/Jul, 200 ML/day Jul, 350 ML/day Aug-Oct, 200 ML/day Nov)	Min 80-350 ML/day (80 ML/day Jun/Jul, 200 ML/day Jul, 350 ML/day Aug-Oct, 200 ML/day Nov)	Min 350 ML/day, but may not reach this magnitude until late June or mid July	Median 600 ML/day with a min 350 ML/day	Median 600 ML/day with a min 350 ML/day
	Fresh	Wet/Avg	100 ML/day (3/yr, min 2 day at peak)	700 ML/day (2/yr Jun-Aug, 3 days at peak)	1100 ML/day (Min 700 ML/day) (1/yr in Jun/Jul, min 7 days at peak)	1100 ML/day (1/yr in Jun/Jul, min 7 days at peak)	1300 ML/day (1/yr in Jun/Jul, min 7 days at peak)	1300 ML/day (1/yr in Jun/Jul, min 7 days at peak)
					1800 ML/day (1/yr in Jun-Sep, min 2 days at peak)	2000 ML/day (1/yr in Jun-Sep, min 2 days at peak)	2500 ML/day (1/yr in Jun-Sep, min 2 days at peak)	2500 ML/day (1/yr in Jun-Sep, min 2 days at peak)
		Dry						
	High	Wet/Avg	300 ML/day (1/yr or min 1 in 2 yrs, 3 days at peak)	700 ML/day (1/yr in Sep, 14 days duration)	1800 ML/day (1/yr in Sep/Oct, 14 days duration)	2000 ML/day (1/yr in Sep/Oct, 14 days duration)	2500 ML/day (1/yr in Sep/Oct, 14 days duration)	2500 ML/day (1/yr in Sep/Oct, 14 days duration)
		Dry		Not necessary to deliver but allow to occur naturally				
	Bankfull	Wet/Avg	600 ML/day (1 in 2-5 yrs in June-Sept, 3 days)	2700 ML/day (1 in 2 yrs, 2 days at peak)	4000 ML/day (1/yr, 2 days duration)	5000 ML/day (1/yr, 2 days duration)	5000 ML/day (1/yr, 2 days duration)	11,000 ML/day (1/yr, 2 days duration)
		Dry		Not expected, but let it occur naturally.				
	Bankfull / Overbank	Wet/Avg	Not recommended	2700 ML/day (1 in 2 yrs, 2 days at peak)	4000-6000 ML/day (1 in 1-2 yrs, 1-2 days duration)	8000-10,000 ML/day (1 in 1-2 yrs, 1-2 days duration)	5000-14,000 ML/day (1/yr, 1-2 days duration)	11,000-16,000 ML/day (1/yr, 1-2 days duration)
		Dry		Not expected, but let it occur naturally.				

Table C.2 : Flow recommendations for Reach 1. Flow components have been colour coded to highlight those that are managed (blue) from those that are natural (green).

Stream	Yarra River		Reach	Upper Yarra Dam to Armstrong Creek confluence			
Compliance point	Doctors Creek Gauge		Gauge No.	229103			
Season	Flow	Wet/Avg/Dry	Volume	Frequency and when	Duration	Rise/Fall	Objective (refer to objectives tables for id reference)
Summer / Autumn (Dec-May)	**Low flow**	Wet/Avg/Dry	10 ML/day released from storage. Inflow from Doctors Creek and local catchment run-off provide additional flow and the required flow variation.				Maintain access to and area of habitat for bugs, fish (river blackfish, Australian smelt, short-finned eel, and ornate galaxias) platypus, birds and frogs, maintain drought refuge pool, instream vegetation and drying period for bank vegetation. (M1-1, F1-1, V1-1, V1-6, P1-1, P1-2, BFA1-1)
	Fresh	Wet/Avg	60 ML/day released from storage plus Doctors Creek flow on top of this to provide increased magnitude and variability during average and wet years.	Minimum 4 events delivered + additional events provided by Doctors Creek. One event could be up to 300 ML/day without posing additional risk	Min 1 day at peak, additional duration provided by Doctors Creek.	2.0/0.8	Maintain suitable riffle habitat by periodically scouring sediment and biofilms, maintain flood-tolerant vegetation on banks. (G1-2, M1-3, V1-3, P1-3, P1-4, BFA1-2)
		Dry	60 ML/day	4 events	1 day		
	High	Not recommended					
Winter / Spring (Jun-Nov)	**Low flow**	Wet/Avg/Dry	10 ML/day released from storage. Inflow from Doctors Creek and local catchment run-off provide additional flow and required flow variation expected with greater tributary flows in Winter / Spring compared to Summer / Autumn season.				Maintain access to habitat for bugs, fish (river blackfish, Australian smelt, short-finned eel, and ornate galaxias), and native non- indigenous fish (Macquarie perch and Murray cod) platypus, birds and frogs, maintain instream vegetation. (M1-2, F1-1, V1-2, V1-6, P1-1, P1-2, BFA1-4)
	Fresh	Wet/Avg	100 ML/day releases from storage with Doctors Creek flow on top of this provide increased magnitude and variability during average and wet years.	Minimum 3 events delivered + additional events provided by Doctors Creek.	Min 2 day at peak, additional duration provided by Doctors Creek.	2.0/0.8	Maintain suitable riffle habitat by periodically scouring sediment & biofilms, maintain flood-tolerant vegetation on banks. (G1-2, M1-3, F1-2, V1-3, P1-3, BFA1-5)
		Dry	100 ML/day	3	2		
	High	Wet/Avg/Dry	300 ML/day	Once every year or 1 in 2 years (minimum) Restrict to June-September period.	3 days	2.0/0.8	Scour sediment from pools to increase habitat availability, provide a disturbance regime to promote flood-tolerant species and limit encroachment of terrestrial vegetation and entrain organic material. (G1-3, M1-4, F1-2, V1-4, V1-7, P1-3, P1-4, BFA1-6)
	Bankfull[1]	Wet/Avg/Dry	600 ML/day	1 in 2-5 years, Restrict to June-Sept period (peak of event prior to Mid October) to mitigate risks to platypus.	3 days	2.0/0.8	Maintain existing channel geometry & prevent further vegetation encroachment in channel. (G1-1, V1-5, V1-8, P1-4, P1-5, BFA1-7)
	Overbank[1]	Not recommended					

[1]Bankfull and Overbank flows could occur at any time (in Summer also)

Table C.3 : Flow recommendations for Reach 2. Flow components have been colour coded to highlight those that are managed (blue) from those that are natural (green).

Stream	Yarra River		Reach	Armstrong Creek confluence to Millgrove			
Compliance point	Millgrove Gauge		Gauge No.	229212			
Season	Flow	Wet/Avg/Dry	Volume	Frequency and when	Duration	Rise/Fall	Objective (refer to objectives tables for id reference)
Summer / Autumn (Dec-May)	**Low flow**	Wet/Avg/Dry	Minimum recommendation of 80 ML/day, allow tributaries to provide variation greater than 80 ML/day in average and wet years.				Maintain access to habitat for bugs, fish (river blackfish, Australian smelt, ornate galaxias, Australian grayling, short-finned eel, short-headed lamprey, pouched lamprey, tupong, broad-finned galaxias, spotted galaxias & common galaxias) platypus, birds and frogs, maintain drought refuge pools, drying period for bank vegetation. (M2-1, F2-1, V2-1, P2-1, P2-2, BFA2-1)
	Fresh	Wet/Avg	350 ML/day, tributary inflows provide variation during average and wet years. Higher magnitude and longer duration flows are acceptable and beneficial in average and wet years.	Minimum 3 events + additional events provided by Tributaries.	Min 2 days at peak. Longer duration flows acceptable in average and wet years.	2.0/0.8	Maintain suitable riffle habitat by periodically scouring sediment & biofilms, maintain flood-tolerant vegetation on banks, provide opportunities for fish movement. Cue downstream migration of eels. (G2-3, M2-3, F2-3, F2-6, V2-3, P2-3, BFA2-2)
		Dry	350 ML/day	3 events	2 days		
	High	Wet/Avg/Dry	560 ML/day tributary inflows provide variation during average and wet years. Higher magnitude and longer duration flows are acceptable and beneficial in average and wet years.	1 (April/May), every year. Must occur 2 in 3 years.	Min 7 day at peak. Longer duration flows acceptable in average and wet years.	2.0/0.8	Trigger downstream spawning migration of Australian Grayling. Cue downstream migration of eels. May facilitate juvenile platypus dispersal. (F2-4, F2-6, P2-3, BFA2-3)
Winter / Spring (Jun-Nov)	**Low flow**	Wet/Avg	Minimum recommendation of 200-350 ML/day (200 ML/day in June transitioning to 350 ML/day in July), allow tributaries to provide additional flow and variation in average and wet years.				Higher flows increase access to habitat for bugs, fish (river blackfish, Australian smelt, ornate galaxias, Australian grayling, short-finned eel, short-headed lamprey, pouched lamprey, tupong, broad-finned galaxias, spotted galaxias & common galaxias) platypus, birds and frogs, wet bank vegetation. (M2-2, F2-1, V2-2, P2-1, BFA2-4)
		Dry	Minimum recommendation of 80-350 ML/day with transitional flows in June/July and November (80 ML/day June, 200 ML/Day July, 350 ML/day August – October and 200 ML/day in November)				
	Fresh	Wet/Avg/Dry	700 ML/day tributary inflows provide variation during average and wet years. Higher magnitude and longer duration flows are acceptable and beneficial in average and wet years.	Minimum 2 events between June and August.	3 days at peak. Longer duration flows acceptable in average and wet years.	2.0/0.8	Maintain suitable riffle habitat by periodically scouring sediment & biofilms. Provide fish passage, facilitate upstream immigration of juvenile catadromous (short-finned eel, common galaxias, tupong) and amphidromous (Australian grayling, broad-finned galaxias, spotted galaxias) fishes from downstream river reaches, cue downstream migration by Tupong and eels to the sea to spawn. Maintain flood-tolerant vegetation on banks and entrain organic material (G2-3, M2-3, F2-2, F2-3, F2-5, F2-6, V2-3, P2-3, BFA2-5)
	High	Wet/Avg	700 ML/day	Minimum 1 event in September, allow to occur naturally at other times.	14 days	2.0/0.8	As per fresh but provides prolonged disturbance to favour flood-tolerant vegetation (G2-4, F2-2, F2-3, F2-5, F2-6, V2-4, P2-3, BFA2-6)
		Dry	Not necessary to deliver but allow to occur naturally				
	Bankfull / overbank[1]	Wet/Avg	2700 ML/day. Higher magnitude and longer duration flows are acceptable and beneficial in average and wet years.	1 in 2 years. Expect to occur naturally, not a delivered event.	2 days at peak. Longer duration flows acceptable in average and wet years.	N/A	Maintain existing channel geometry & prevent further vegetation encroachment in channel, entrain organic material, engage high flow channels and provide wetted habitat for waterbirds and frogs (G2-1, V2-5, V2-6, P2-4, P2-5, BFA2-6, BFA2-7)
		Dry	Not expected, but let it occur naturally.				

[1]Bankfull / overbank flows could occur at any time (in Summer also).

Table C.4 : Flow recommendations for Reach 3. Flow components have been colour coded to highlight those that are managed (blue) from those that are natural (green).

Stream	Yarra River		Reach	Millgrove to Watts River confluence			
Compliance point	Yarra Grange		Gauge No.	229653			
Season	Flow	Wet/Avg/Dry	Volume	Frequency and when	Duration	Rise/Fall	Objective (refer to objectives tables for id reference)
Summer / Autumn (Dec-May)	**Low flow**	Wet/Avg/Dry	Minimum recommendation of 120 ML/day at Woori Yallock and 150 ML/day at Everard Park, allow tributaries to provide additional flow above the minimum recommendation in average and wet years. Tributary inflows will contribute to important flow variation.				Maintain access to habitat for bugs, fish (river blackfish, Australian smelt, ornate galaxias, Australian grayling, short-finned eel, short-headed lamprey, pouched lamprey, tupong, broad-finned galaxias, spotted galaxias & common galaxias) platypus, birds and frogs, maintain drought refuge pools and aquatic vegetation (M3-1, F3-1, V3-1, P3-1, P3-2, BFA3-1)
	Fresh	Wet/Avg	350 ML/day at Woori Yallock and 450 ML/day at Everard Park.	Minimum 3 events	Min 2 days at peak	2.0/0.8	Maintain suitable riffle and LWD habitat by periodically scouring sediment & biofilms, maintain flood-tolerant vegetation on banks, provide opportunities for fish movement and cue downstream migration of eels (M3-3, F3-6, V3-3, P3-3, BFA3-2)
		Dry		3 events	2 days at peak		
	High	Wet/Avg/Dry	900-1100 ML/day to ensure minimum flow of 1300 ML/day at Chandler Hwy.	1 April/May, every year. Must occur 2 in 3 years.	Min 7 days at peak and event should last for 14 days from start to finish.	2.0/0.8	Trigger downstream migration and spawning by Australian Grayling and transport larvae to sea. May facilitate juvenile platypus dispersal. Cue downstream migration of eels (F3-4, F3-6, P3-3, BFA3-3)
Winter / Spring (Jun-Nov)	**Low flow**	Wet/Avg	Minimum recommendation of 200-350 ML/day (200 ML/day in June transitioning to 350 ML/day in July), allow tributaries to provide additional flow and variation in average and wet years.				Higher flows increase access to habitat for bugs, fish (river blackfish, Australian smelt, ornate galaxias, Australian grayling, short-finned eel, short-headed lamprey, pouched lamprey, tupong, broad-finned galaxias, spotted galaxias & common galaxias) platypus, birds and frogs, inundate bank vegetation (M3-2, F3-1, V3-2, P3-1, BFA3-4)
		Dry	Minimum recommendation of 80-350 ML/day with transitional flows in June/July and November (80 ML/day June, 200 ML/Day July, 350 ML/day August – October and 200 ML/day in November)				
	Fresh	Wet/Avg/Dry	1100 ML/day (Minimum 700 ML/day)	1 event in June or July to facilitate migration of fish.	Min 7 day at peak, additional duration provided by tributaries.	2.0/0.8	Maintain suitable habitat for bugs, fish & platypus. Provide fish passage, facilitate upstream immigration of juvenile catadromous (short-finned eel, common galaxias, tupong) and amphidromous (Australian grayling, broad-finned galaxias, spotted galaxias) fishes from downstream river reaches, cue downstream migration by tupong and eels to the sea to spawn. Maintain flood-tolerant vegetation on banks and entrain organic material. (G3-2, M3-3, F3-2, F3-3, F3-5, F3-6, V3-4, P3-3, BFA3-5)
			1800 ML/day	1 event between June and September	Min 2 day at peak, additional duration provided by tributaries.		As per fresh above, but higher flow to maintain flood-tolerant vegetation on banks (G3-2, M3-3, F3-2, F3-3, F3-5, F3-6, V3-4, V3-5, P3-3, BFA3-5)
	High	Wet/Avg	1800 ML/day	Minimum 1 event in September/October, prior to Macquarie Perch spawning further downstream (November to December)	14 days	2.0/0.8	As per fresh but provides prolonged disturbance to favour flood-tolerant vegetation (G3-1, G3-2, F3-2, F3-3, F3-5, F3-6, V3-6, P3-3, BFA3-6)
		Dry	Not expected to occur in dry years, but allow to occur naturally.				
	Bankfull[1,2]	Wet/Avg	4000 ML/day	1 per year	2 days	N/A	Maintain existing channel geometry & prevent further vegetation encroachment in channel, entrain organic material, deliver water to billabongs via flood-runners and provide wetted habitat for waterbirds and frogs (G3-1, G3-3, V3-3, V3-4, V3-5, P3-5, BFA3-7)
		Dry	Not expected, but let it occur naturally.				
	Overbank[1,2]	Wet/Avg	4000-6000 ML/day	1 event every 1-2 years	1-2 days	N/A	Engage and provide flow through billabongs and inundate low level floodplains, provide wetted habitat area for waterbirds and frogs (G3-4, V3-8, V3-9, P3-5, BFA3-8)
		Dry	Not expected, but let it occur naturally.				

[1] Bankfull and Overbank flows could occur at any time (in Summer also).

[2] Events that fill billabongs may be managed through site specific water management strategies.

Table C.5 : Flow recommendations for Reach 4. Flow components have been colour coded to highlight those that are managed (blue) from those that are natural (green).

Stream	Yarra River		Reach	Watts River to Yering Gorge			
Compliance point	Yarra Glen		Gauge No.	229206			
Season	Flow	Wet/Avg/Dry	Volume	Frequency and when	Duration	Rise/Fall	Objective (refer to objectives tables for id reference)
Summer / Autumn (Dec-May)	**Low flow**	Wet/Avg/Dry	Minimum flow of 200 ML/day, allow tributaries to provide variation above 200 ML/day in average and wet years.				Maintain access to habitat for bugs, fish (river blackfish, Australian smelt, ornate galaxias, Australian grayling, short-finned eel, short-headed lamprey, pouched lamprey, tupong, broad-finned galaxias, spotted galaxias & common galaxias) platypus, birds and frogs, maintain drought refuge pools, drying period for bank vegetation (M4-1, F4-1, V4-1, P4-1, P4-2, BFA4-1)
	Fresh	Wet/Avg	Minimum of 450 ML/day	Minimum 3 events	Min 2 days at peak	2.0/0.8	Maintain suitable riffle and LWD habitat by periodically scouring sediment & biofilms, maintain flood-tolerant vegetation on banks, provide opportunities for local fish movement and cue downstream migration of eels. (G4-2, M4-3, F4-7, F4-6, V4-3, P4-3, BFA4-2)
		Dry	450 ML/day	3 events	2 days		
	High	Wet/Avg/Dry	900-1100 ML/day to ensure minimum flow of 1300 ML/day at Chandler Hwy.	1 (April/May), every year. Must occur 2 in 3 years.	Min 7 day at peak and event should last for 14 days from start to finish.	2.0/0.8	Trigger downstream migration and spawning by Australian Grayling and transport larvae to sea. Cue downstream migration of eels. May facilitate juvenile platypus dispersal. (F4-5, F4-7, P4-3, BFA4-3)
Winter / Spring (Jun-Nov)	**Low flow**	Wet/Avg	Minimum recommendation of 350 ML/day, allow tributaries to provide additional variation above 350 ML/day in average and wet years.				Higher flows increase access to habitat for bugs & fish (river blackfish, Australian smelt, ornate galaxias, Australian grayling, short-finned eel, short-headed lamprey, pouched lamprey, tupong, broad-finned galaxias, spotted galaxias & common galaxias) platypus, birds and frogs, inundate bank vegetation (M4-2, F4-1, V4-2, P4-1, BFA4-4)
		Dry	Minimum flow 350 ML/day, but may not reach this magnitude until late June or mid July.				
	Fresh	Wet/Avg/Dry	1100 ML/day	1 event occurring in June or July to facilitate migration of fish.	Min 7 day at peak, additional duration provided by tributaries.	2.0/0.8	Maintain suitable habitat for bugs, fish & platypus. Provide fish passage, facilitate upstream immigration of juvenile catadromous (short-finned eel, common galaxias, tupong) and amphidromous (Australian grayling, broad-finned galaxias, spotted galaxias) fishes from downstream river reaches, cue downstream migration by tupong and eels to the sea to spawn. Maintain flood-tolerant vegetation on banks and entrain organic material. (G4-2, M4-3, F4-3, F4-4, F4-6, F4-7, V4-4, P4-3, BFA4-5)
			2000 ML/day	1 event between June and September	Min 2 day at peak, additional duration provided by tributaries.		As per fresh above, but higher flow to maintain flood-tolerant vegetation on banks (G4-2, M4-3, F4-3, F4-4, F4-6, F4-7, V4-4, V4-5, P4-3, BFA4-5)
	High	Wet/Avg	2000 ML/day	Minimum 1 event in September/October, prior to Macquarie Perch spawning further downstream (November to December)	14 days	2.0/0.8	As per fresh but provides prolonged disturbance to favour flood-tolerant vegetation (G4-1, F4-3, F4-4, F4-6, F4-7, V4-6, P4-3, P4-4, BFA4-6)
		Dry	Not expected to occur in dry years, but allow to occur naturally.				
	Bankfull[1,2]	Wet/Avg	5000 ML/day	1 per year	2 days	N/A	Maintain existing channel geometry & prevent further vegetation encroachment in channel, entrain organic material, deliver water to billabongs via flood-runners and provided wetted habitat for waterbirds and frogs (G4-1, G4-3, V4-7, V4-8, V4-9, P4-5, BFA4-7)
		Dry	Not expected, but let it occur naturally.				
	Overbank[1,2]	Wet/Avg	8000-10,000 ML/d	1 event every 1-2 years	1-2 days	N/A	Engage and provide flow through billabongs and inundate low level floodplains, provide wetted habitat area for waterbirds and frogs (G4-4, V4-7, V4-8, V4-9, P4-5, BFA4-8)
		Dry	Not expected, but let it occur naturally.				

[1] Bankfull and Overbank flows could occur at any time (in Summer also).

[2] Events that fill billabongs may be managed through site specific water management strategies.

Table C.6 : Flow recommendations for Reach 5. Flow components have been colour coded to highlight those that are managed (blue) from those that are natural (green).

Stream	Yarra River		Reach	Yering Gorge to Mullum Mullum Creek			
Compliance point	Yering Gorge		Gauge No.	229200			
Season	Flow	Wet/Avg/Dry	Volume	Frequency and when	Duration	Rise/Fall	Objective (refer to objectives tables for id reference)
Summer / Autumn (Dec-May)	**Low flow**	Wet/Avg/Dry	Minimum flow of 200 ML/day, allow tributaries to provide additional variation above 200 ML/day in average and wet years. Note – higher flows may be needed to meet flow recommendations for water quality in the Dights Falls Weir pool (Reach 6), but 200 ML/day is adequate to meet the objectives for Reach 5.				Maintain access to habitat for bugs, native indigenous fish (river blackfish, Australian smelt, ornate galaxias, Australian grayling, short-finned eel, short-headed lamprey, pouched lamprey, tupong, broad-finned galaxias, spotted galaxias & common galaxias), native non- indigenous fish (Macquarie perch and Murray cod) platypus, birds and frogs. Maintain aquatic vegetation and water quality. (M5-1, F5-1, V5-1, W5-1, P5-1, P5-2, BFA5-1)
	Fresh	Wet/Avg	Minimum of 750 ML/day	Minimum 3 events	Min 2 day at peak	2.0/0.8	Maintain suitable riffle and LWD habitat by periodically scouring sediment & biofilms, maintain flood-tolerant vegetation on banks, provide opportunities for local fish movement and cue downstream migration of eels (G5-2, M5-3, F5-4, F5-7, V5-3, P5-3, BFA5-2)
		Dry	750 ML/day	3 events	2 days		
	High	Wet/Avg/Dry	1300 ML/day	1 (April/May) every year. Must occur 2 in 3 years.	Min 7 day at peak. Event should last for 14 days from start to finish.	2.0/0.8	Trigger downstream migration and spawning by Australian Grayling and transport larvae to sea. Cue downstream migration of eels. May facilitate juvenile platypus dispersal. (G5-1, F5-5, F5-7, BFA5-3)
Winter / Spring (Jun-Nov)	**Low flow**	Wet/Avg	Median flow 750 ML/day with a minimum flow of 350 ML/day.				Higher flows increase access to habitat for bugs, native indigenous fish (river blackfish, Australian smelt, ornate galaxias, Australian grayling, short-finned eel, short-headed lamprey, pouched lamprey, tupong, broad-finned galaxias, spotted galaxias & common galaxias), native non- indigenous fish (Macquarie perch and Murray cod) platypus, birds and frogs, wet bank vegetation (M5-2, F5-2, V5-2, W5-1, P5-1, P5-2, BFA5-4)
		Dry	Median flow 600 ML/day with a minimum flow of 350 ML/day.				
	Fresh	Wet/Avg/Dry	1300 ML/day	1 event occurring in June or July to facilitate migration of fish.	Min 7 day at peak	2.0/0.8	Maintain suitable habitat for bugs, fish & platypus, scour gravels to improve Macquarie perch spawning. Provide fish passage, facilitate upstream immigration of juvenile catadromous (short-finned eel, common galaxias, tupong) and amphidromous (Australian grayling, broad-finned galaxias, spotted galaxias) fishes from downstream river reaches, cue downstream migration by Tupong and eels to the sea to spawn. Maintain flood-tolerant vegetation on banks and entrain organic material. (G5-2, M5-3, F5-3, F5-4, F5-6, F5-7, V5-4, P5-3, BFA5-5)
			2500 ML/day	1 event between June and September	Min 2 day at peak		As per fresh above, but higher flow to maintain flood-tolerant vegetation on banks (G5-2, M5-3, F5-3, F5-4, F5-6, F5-7, V5-4, V5-5, P5-3, BFA5-5)
	High[1]	Wet/Avg	2500 ML/day	Minimum 1 event in September-October, prior to Macquarie Perch spawning (November-December).	14 days	2.0/0.8	As per fresh but provides prolonged disturbance to favour flood-tolerant vegetation. Also flushes accumulated fine sediments to maintain or improve quality and availability of habitats, including Macquarie perch spawning habitats. (G5-1, F5-3, F5-3, F5-4, F5-6, F5-7, V5-6, P5-3, BFA5-6)
		Dry	Not expected to occur in dry years, but allow to occur naturally.				
	Bankfull/ Overbank[1]	Wet/Avg	5000-14,000 ML/day	1 per year	1-2 days	N/A	Maintain existing channel geometry & prevent further vegetation encroachment in channel, entrain organic material, deliver water to billabongs via flood-runners, provide wetted habitat area for waterbirds and frogs (G5-1, G5-3, V5-6, V5-7, V5-8, V5-9, P5-5, BFA5-7, BFA5-8)
		Dry	Not expected, but let it occur naturally.				

[1] High, Bankfull and Overbank flows could occur at any time (in Summer also).

Table C.7 : Flow recommendations for Reach 6. Flow components have been colour coded to highlight those that are managed (blue) from those that are natural (green).

Stream	Yarra River		Reach	Mullum Mullum Creek to Dights Fall Weir			
Compliance point	Chandler Highway		Gauge No.	229143			
Season	Flow	Wet/Avg/Dry	Volume	Frequency and when	Duration	Rise/Fall	Objective (refer to objectives tables for id reference)
Summer / Autumn (Dec-May)	**Low flow**	Wet/Avg/Dry	Minimum recommendation of 300 ML/day to minimise risk of low DO in pools upstream of Chandler Highway. Minimum recommendation of 450 ML/day in December to February if considered necessary to maintain mixed conditions in the Dights Falls Weir Pool, downstream of Chandler Highway. Higher magnitude flows are acceptable.				Maintain access to habitat for bugs, native indigenous fish (river blackfish, Australian smelt, ornate galaxias, Australian grayling, short-finned eel, short-headed lamprey, pouched lamprey, tupong, broad-finned galaxias, spotted galaxias & common galaxias), native non- indigenous fish (Macquarie perch and Murray cod) platypus, birds and frogs, drying period for bank vegetation, minimise risk of low DO conditions (M6-1, F6-1, V6-1, W6-1, P6-1, P6-2, BFA6-1)
	Fresh	Wet/Avg	Minimum of 750 ML/day	Minimum 3 events	Min 2 days at peak	2.0/0.8	Maintain suitable riffle habitat by periodically scouring sediment & biofilms, maintain flood-tolerant vegetation on banks, provide occasional fish passage for larger bodied fish and cue downstream migration of eels. (G6-2, M6-3, F6-9, V6-3, P6-3, BFA6-2)
		Dry	750 ML/day	3 events	2 days		
	High	Wet/Avg/Dry	1300 ML/day minimum flow	1 (April/May), every year. Must occur 2 in 3 years.	Min 7 day at peak. Longer duration flows acceptable in average and wet years.	2.0/0.8	Trigger downstream migration and spawning by Australian Grayling and transport larvae to sea. Cue downstream migration of eels. May facilitate juvenile platypus dispersal. (G6-1, F6-7, F6-9, BFA6-3)
Winter / Spring (Jun-Nov)	**Low flow**	Wet/Avg	Median flow 750 ML/day, daily minimum flow of 350 ML/day, allow tributaries to provide additional variation above 750 ML/day in average and wet years. Higher magnitude flows are acceptable. Maximises habitat availability.				Higher flows increase access to habitat for bugs, native indigenous fish (river blackfish, Australian smelt, ornate galaxias, Australian grayling, short-finned eel, short-headed lamprey, pouched lamprey, tupong, broad-finned galaxias, spotted galaxias & common galaxias), native non- indigenous fish (Macquarie perch and Murray cod) platypus, birds and frogs, wet bank vegetation (M6-2, F6-1, V6-2, P6-1, P6-2, BFA6-4)
		Dry	Median flow 600 ML/day, daily minimum 350 ML/day.				
	Fresh	Wet/Avg/Dry	1300 ML/day	1 event occurring in June or July to facilitate migration of fish.	Min 7 day at peak	2.0/0.8	Maintain suitable habitat for bugs, fish & platypus, scour gravels to improve Macquarie perch spawning. Provide fish passage, facilitate upstream immigration of juvenile catadromous (short-finned eel, common galaxias, tupong) and amphidromous (Australian grayling, broad-finned galaxias, spotted galaxias) and adult anadromous (short-headed lamprey, pouched lamprey) fishes from downstream river reaches, cue upstream spawning migration by short-headed lamprey and pouched lamprey from the sea, cue downstream migration by tupong and eels to the sea to spawn. Maintain flood-tolerant vegetation on banks and entrain organic material. (G6-2, M6-3, F6-3, F6-4, F6-5, F6-6, F6-8, F6-9, V6-4, W6-1b, P6-3, BFA6-5)
			2500 ML/day	1 event between June and September	Min 2 day at peak		As per fresh above, but higher flow to maintain flood-tolerant vegetation on banks (G6-2, M6-3, F6-3, F6-4, F6-5, F6-6, F6-8, F6-9, V6-4, V6-5, W6-1b, P6-3, BFA6-5)
	High[1]	Wet/Avg	2500 ML/day	Minimum 1 event in September-October, prior to Macquarie Perch spawning (November-December).	14 days	N/A	As per fresh but provides prolonged disturbance to favour flood-tolerant vegetation. Also flushes accumulated fine sediments to maintain or improve quality and availability of habitats, including Macquarie perch spawning habitats. (G6-1, F63, F6-4, F6-5, F6-6, F6-8, F6-9, V6-6, P6-4, BFA6-6)
		Dry	Not expected to occur in dry years, but allow to occur naturally.				
	Bankfull/ Overbank[1,2]	Wet/Avg	11,000 – 16,000 ML/day	1 per year	1-2 days	N/A	Maintain existing channel geometry & prevent further vegetation encroachment in channel, entrain organic material, engage high flow channels, billabongs and low level floodplains, provide wetted habitat for waterbirds and frogs. (G6-1, G6-3, V6-3, V6-4, V6-5, P6-5, BFA6-7, BFA6-8)
		Dry	Not expected, but let it occur naturally.				

[1] High, Bankfull and Overbank flows could occur at any time (in Summer also).

Appendix D. Flow recommendations

Table D.1 : Flow recommendations for Reach 1. Flow components have been colour coded to highlight those that are managed (blue) from those that are natural (green).

Stream	Yarra River			Reach	Upper Yarra Dam to Armstrong Creek confluence			
Compliance point	Doctors Creek Gauge			Gauge No.	229103			
Season	Flow	Objective (refer to objectives tables for id reference)	Wet/Avg/Dry	Volume	Frequency and when	Duration	Rise/Fall	Description of changes
Summer / Autumn (Dec-May)	**Low flow**	Maintain access to and area of habitat for bugs, fish (river blackfish, Australian smelt, short-finned eel, and ornate galaxias) platypus, birds and frogs, maintain drought refuge pool, instream vegetation and drying period for bank vegetation. (M1-1, F1-1, V1-1, V1-6, P1-1, P1-2, BFA1-1)	Wet/Avg/Dry	10 ML/day released from storage. Inflow from Doctors Creek and local catchment run-off provide additional flow and the required flow variation.				Revised objective, includes explicit reference to native fish species in this reach, platypus, birds and frogs. No change in recommended volume from SKM (2012).
	Fresh	Maintain suitable riffle habitat by periodically scouring sediment and biofilms, maintain flood-tolerant vegetation on banks. (G1-2, M1-3, V1-3, P1-3, P1-4, BFA1-2)	Wet/Avg	60 ML/day released from storage plus Doctors Creek flow on top of this to provide increased magnitude and variability during average and wet years.	Minimum 4 events delivered + additional events provided by Doctors Creek. One event could be up to 300 ML/day without posing additional risk	Min 1 day at peak, additional duration provided by Doctors Creek.	2.0/0.8	Minor changes to the wording of objective. No change in recommended volume from SKM (2012). Added in note that one event could be up to 300 ML/day without posing additional risk. Revised rise/fall from 1.6/0.7 to 2.0/0.8. These still lie within the 50-80th percentile and are considered conservative.
			Dry	60 ML/day	4 events	1 day		
	High	Not recommended						No change, but as noted above, one of the fresh events could be up to 300 ML/Day
Winter / Spring (Jun-Nov)	**Low flow**	Maintain access to habitat for bugs, fish (river blackfish, Australian smelt, short-finned eel, and ornate galaxias), and native non-indigenous fish (Macquarie perch and Murray cod) platypus, birds and frogs, maintain instream vegetation. (M1-2, F1-1, V1-2, V1-6, P1-1, P1-2, BFA1-4)	Wet/Avg/Dry	10 ML/day released from storage. Inflow from Doctors Creek and local catchment run-off provide additional flow and required flow variation expected with greater tributary flows in Winter / Spring compared to Summer / Autumn season.				Revised objective, includes explicit reference to native fish species in this reach, platypus, birds and frogs. Expectation that low flow will be higher in Winter / Spring than Summer / Autumn season with greater tributary flows in Winter / Spring compared to Summer / Autumn season. No change in recommended volume from SKM (2012).
	Fresh	Maintain suitable riffle habitat by periodically scouring sediment & biofilms, maintain flood-tolerant vegetation on banks. (G1-2, M1-3, F1-2, V1-3, P1-3, BFA1-5)	Wet/Avg	100 ML/day releases from storage with Doctors Creek flow on top of this provide increased magnitude and variability during average and wet years.	Minimum 3 events delivered + additional events provided by Doctors Creek.	Min 2 day at peak, additional duration provided by Doctors Creek.	2.0/0.8	No change in recommended volume from SKM (2012). Revised rise/fall from 1.6/0.7 to 2.0/0.8. These still lie within the 50-80th percentile and are considered conservative.
			Dry	100 ML/day	3 events	2 days		
	High	Scour sediment from pools to increase habitat availability, provide a disturbance regime to promote flood-tolerant species and limit encroachment of terrestrial vegetation and entrain organic material. (G1-3, M1-4, F1-2, V1-4, V1-7, P1-3, P1-4, BFA1-6)	Wet/Avg/Dry	300 ML/day	Once every year or 1 in 2 years (minimum) Restrict to June-September period.	3 days	2.0/0.8	Revised recommended frequency from 1 in 2 years (SKM 2012) to once every year or 1 in 2 years (minimum). Revised rise/fall from 1.6/0.7 to 2.0/0.8. These still lie within the 50-80th percentile and are considered conservative.

Stream	Yarra River			Reach	Upper Yarra Dam to Armstrong Creek confluence			
Compliance point	Doctors Creek Gauge			Gauge No.	229103			
Season	Flow	Objective (refer to objectives tables for id reference)	Wet/Avg/Dry	Volume	Frequency and when	Duration	Rise/Fall	Description of changes
	Bankfull[1]	Maintain existing channel geometry & prevent further vegetation encroachment in channel. (G1-1, V1-5, V1-8, P1-4, P1-5, BFA1-7)	Wet/Avg/Dry	600 ML/day	1 in 2-5 years, restrict to June-Sept period (peak of event prior to Mid October) to mitigate risks to platypus.	3 days	2.0/0.8	Changed from 1100 ML/day to 600 ML/day based on results of recent monitoring of 600 ML/day flow release which had little impact on channel (GHD 2016). Also recommend that this is delivered more frequently, 1 in 2-5 years. This change in recommended higher frequency of high and bankfull flows should be monitored to assess the cumulative impact of these releases on the channel and rate of recovery between events. Added restriction to June-September period to mitigate risks to platypus or fish. Revised rise/fall from 1.6/0.7 to 2.0/0.8. These still lie within the 50-80th percentile and are considered conservative.
	Overbank[1]	Not recommended						

[1]Bankfull and Overbank flows could occur at any time (in Summer also)

Table D.2 : Flow recommendations for Reach 2. Flow components have been colour coded to highlight those that are managed (blue) from those that are natural (green).

Stream	Yarra River			Reach	Armstrong Creek confluence to Millgrove			
Compliance point	Millgrove Gauge			Gauge No.	229212			
Season	Flow	Objective (refer to objectives tables for id reference)	Wet/Avg/Dry	Volume	Frequency and when	Duration	Rise/Fall	Description of changes
Summer / Autumn (Dec-May)	**Low flow**	Maintain access to habitat for bugs, fish (river blackfish, Australian smelt, ornate galaxias, Australian grayling, short-finned eel, short-headed lamprey, pouched lamprey, tupong, broad-finned galaxias, spotted galaxias & common galaxias) platypus, birds and frogs, maintain drought refuge pools, drying period for bank vegetation. (M2-1, F2-1, V2-1, P2-1, P2-2, BFA2-1)	Wet/Avg/Dry	Minimum recommendation of 80 ML/day, allow tributaries to provide variation greater than 80 ML/day in average and wet years.				Revised objective, includes explicit reference to native fish species in this reach, platypus, birds and frogs. No change in recommended volume from SKM (2012).
	Fresh	Maintain suitable riffle habitat by periodically scouring sediment & biofilms, maintain flood-tolerant vegetation on banks, provide opportunities for fish movement. Cue downstream migration of eels. (G2-3, M2-3, F2-3, F2-6, V2-3, P2-3, BFA2-2)	Wet/Avg	350 ML/day, tributary inflows provide variation during average and wet years. Higher magnitude and longer duration flows are acceptable and beneficial in average and wet years.	Minimum 3 events + additional events provided by Tributaries.	Min 2 day at peak. Longer duration flows acceptable in average and wet years.	2.0/0.8	Minor changes to the wording of objective, noting that freshes also cue downstream migration of eels. No change in recommended volume, frequency and duration from SKM (2012). Revised rise/fall from 1.4/0.85 to 2.0/0.8. These still lie within the 50-80th percentile and are considered conservative.
			Dry	350 ML/day	3 events	2 days		
	High	Trigger downstream spawning migration of Australian Grayling. Cue downstream migration of eels. May facilitate juvenile platypus dispersal. (F2-4, F2-6, P2-3, BFA2-3)	Wet/Avg/Dry	560 ML/day tributary inflows provide variation during average and wet years. Higher magnitude and longer duration flows are acceptable and beneficial in average and wet years.	1 (April/May), every year. Must occur 2 in 3 years.	Min 7 day at peak. Longer duration flows acceptable in average and wet years.	2.0/0.8	Minor changes to the wording of objective, noting that high flow also cue for downstream migration of eels and may facilitate juvenile platypus dispersal. No change in recommended volume, frequency and duration from SKM (2012). Event required 2 in 3 years to trigger downstream spawning migration of Australian Grayling, prioritise this. Revised rise/fall from 1.4/0.85 to 2.0/0.8. These still lie within the 50-80th percentile and are considered conservative.
Winter / Spring (Jun-Nov)	**Low flow**	Higher flows increase access to habitat for bugs, fish (river blackfish, Australian smelt, ornate galaxias, Australian grayling, short-finned eel, short-headed lamprey, pouched lamprey, tupong, broad-finned galaxias, spotted galaxias & common galaxias) platypus, birds and frogs, wet bank vegetation. (M2-2, F2-1, V2-2, P2-1, BFA2-4)	Wet/Avg	Minimum recommendation of 200-350 ML/day (200 ML/day in June transitioning to 350 ML/day in July), allow tributaries to provide additional flow and variation in average and wet years.				Revised objective, includes explicit reference to native fish species in this reach, platypus, birds and frogs. Expectation that low flow will be higher in Winter / Spring than Summer / Autumn season. Low flow recommendation in Wet/Average years changed to allow for lower minimum flow in June (200 ML/day) transitioning to 350 ML/day in July. Low flow recommendation in Dry years changed to allow for transitioning between Summer / Autumn and Winter / Spring (80 ML/day June, 200 ML/Day July, 350 ML/day August – October and 200 ML/day in November).
			Dry	Minimum recommendation of 80-350 ML/day with transitional flows in June/July and November (80 ML/day June, 200 ML/Day July, 350 ML/day August – October and 200 ML/day in November)				

Stream	Yarra River			Reach	Armstrong Creek confluence to Millgrove			
Compliance point	Millgrove Gauge			Gauge No.	229212			
Season	Flow	Objective (refer to objectives tables for id reference)	Wet/Avg/Dry	Volume	Frequency and when	Duration	Rise/Fall	Description of changes
	Fresh	Maintain suitable riffle habitat by periodically scouring sediment & biofilms. Provide fish passage, facilitate upstream immigration of juvenile catadromous (short-finned eel, common galaxias, tupong) and amphidromous (Australian grayling, broad-finned galaxias, spotted galaxias) fishes from downstream river reaches, cue downstream migration by Tupong and eels to the sea to spawn. Maintain flood-tolerant vegetation on banks and entrain organic material (G2-3, M2-3, F2-2, F2-3, F2-5, F2-6, V2-3, P2-3, BFA2-5)	Wet/Avg/Dry	700 ML/day tributary inflows provide variation during average and wet years. Higher magnitude and longer duration flows are acceptable and beneficial in average and wet years.	Minimum 2 events between June and August.	3 days at peak. Longer duration flows acceptable in average and wet years.	2.0/0.8	Includes explicit reference to fish species and expected migrations in response to fresh. No change in recommended volume from SKM (2012). Changed timing of freshes from between June and September to between June and August and shortened recommended duration from 7 days to 3 days at peak (since this shorter duration is likely to be sufficient to meet the vegetation and fish objectives). Revised rise/fall from 1.4/0.85 to 2.0/0.8. These still lie within the 50-80th percentile and are considered conservative.
	High	As per fresh but provides prolonged disturbance to favour flood-tolerant vegetation (G2-4, F2-2, F2-3, F2-5, F2-6, V2-4, P2-3, BFA2-6)	Wet/Avg	700 ML/day	Minimum 1 event in September, allow to occur naturally at other times.	14 days	2.0/0.8	No change in recommended volume, frequency and duration from SKM (2012). 14 day duration is required to prevent terrestrialisation of the riparian zone. The validity of the original recommended duration of 14 days was discussed during the EFTP workshop. The subsequent literature search of the time required to drown-out terrestrial vegetation indicated that the physiological consequences of prolonged inundation on vegetation are well understood at a conceptual level (Etherington 1982) and that inundation can reduce or control encroachment by terrestrial species (MIller et al. 2013)but that inundation impacts were affected by a wide suite of factors, including time of year, plant species and variety, stage of growth and life cycle of the targeted plants, preceding conditions etc. Some terrestrial/riparian species are tolerant of prolonged inundation whereas others are highly sensitive to even minor flooding (e.g. see Cowie et al. 1996, Craine & Orians 2006, Esteban & Edwin 2016, Gerurts et al. 2005, Hare et al. 2004, Lenssen et al. 1998, Lynne & Waldren 2003, McDaniel et al. 2016, Shiferaw et al. 1992). The 14-day period is a reasonable compromise duration that will likely limit terrestrialisation by herbs, forbs, grasses and trees/shrub species. Monitoring is strongly recommended to test this recommendation, as the literature review was not unequivocal in its findings and there were few published reports that quantified the optimal duration to prevent encroachment. Revised rise/fall from 1.4/0.85 to 2.0/0.8. These still lie within the 50-80th percentile and are
			Dry	Not necessary to deliver but allow to occur naturally				

Stream	Yarra River			Reach	Armstrong Creek confluence to Millgrove			
Compliance point	Millgrove Gauge			Gauge No.	229212			
Season	Flow	Objective (refer to objectives tables for id reference)	Wet/Avg/Dry	Volume	Frequency and when	Duration	Rise/Fall	Description of changes
								considered conservative. Active delivery of these events may be contingent on resolving capacity constraints in the headworks system.
	Bankfull / overbank[1]	Maintain existing channel geometry & prevent further vegetation encroachment in channel, entrain organic material, engage high flow channels and provide wetted habitat for waterbirds and frogs (G2-1, V2-5, V2-6, P2-4, P2-5, BFA2-6, BFA2-7)	Wet/Avg	2700 ML/day. Higher magnitude and longer duration flows are acceptable and beneficial in average and wet years.	1 in 2 years. Expect to occur naturally, not a delivered event.	2 days at peak. Longer duration flows acceptable in average and wet years.	N/A	No change in recommended volume, frequency and duration from SKM (2012). Emphasised that these flows will occur naturally, not a delivered event. Changed rise/fall to N/A as there is no control over this.
			Dry	Not expected, but let it occur naturally.				

[1]Bankfull / overbank flows could occur at any time (in Summer also).

Table D.3 : Flow recommendations for Reach 3. Flow components have been colour coded to highlight those that are managed (blue) from those that are natural (green).

Stream	Yarra River			Reach	Millgrove to Watts River confluence			
Compliance point	Yarra Grange			Gauge No.	229653			
Season	Flow	Objective (refer to objectives tables for id reference)	Wet/Avg/Dry	Volume	Frequency and when	Duration	Rise/Fall	Description of changes
Summer / Autumn (Dec-May)	**Low flow**	Maintain access to habitat for bugs, fish (river blackfish, Australian smelt, ornate galaxias, Australian grayling, short-finned eel, short-headed lamprey, pouched lamprey, tupong, broad-finned galaxias, spotted galaxias & common galaxias) platypus, birds and frogs, maintain drought refuge pools and aquatic vegetation (M3-1, F3-1, V3-1, P3-1, P3-2, BFA3-1)	Wet/Avg/Dry	Minimum recommendation of 120 ML/day at Woori Yallock and 150 ML/day at Everard Park, allow tributaries to provide additional flow above the minimum recommendation in average and wet years. Tributary inflows will contribute to important flow variation.				Revised objective, includes explicit reference to native fish species in this reach, platypus, birds and frogs. No change in recommended volume from SKM (2012).
	Fresh	Maintain suitable riffle and LWD habitat by periodically scouring sediment & biofilms, maintain flood-tolerant vegetation on banks, provide opportunities for fish movement and cue downstream migration of eels (M3-3, F3-6, V3-3, P3-3, BFA3-2)	Wet/Avg	350 ML/day at Woori Yallock and 450 ML/day at Everard Park, tributary inflows provide variation during average and wet years. Higher magnitude and longer duration flows are acceptable and beneficial in average and wet years.	Minimum 3 events + additional events provided by Tributaries.	Min 2 days at peak, additional duration provided by tributaries. Longer duration flows acceptable in average and wet years.	2.0/0.8	Minor changes to the wording of objective, noting that freshes also cue downstream migration of eels. No change in recommended volume, frequency and duration from SKM (2012). Revised rise/fall from 1.4/0.85 to 2.0/0.8. These still lie within the 50-80th percentile and are considered conservative.
			Dry	350 ML/day at Woori Yallock and 450 ML/day at Everard Park	3 events	2 days		
	High	Trigger downstream migration and spawning by Australian Grayling and transport larvae to sea. May facilitate juvenile platypus dispersal. Cue downstream migration of eels (F3-4, F3-6, P3-3, BFA3-3)	Wet/Avg	900-1100 ML/day to ensure minimum flow of 1300 ML/day at Chandler Hwy. Events that exceed the recommendation should be protected through downstream reaches. Higher magnitude and longer duration flows are beneficial in average and wet years.	1 (April/May), every year. Must occur 2 in 3 years.	Min 7 day at peak and event should last for 14 days from start to finish. Higher and longer duration flows are desirable in average and wet years.	2.0/0.8	Minor changes to the wording of objective, noting that high flow also cue for downstream migration of eels and may facilitate juvenile platypus dispersal. No change in recommended volume, frequency and duration from SKM (2012). Event required 2 in 3 years to trigger downstream spawning migration of Australian Grayling, prioritise this. Revised rise/fall from 1.4/0.85 to 2.0/0.8. These still lie within the 50-80th percentile and are considered conservative.
			Dry	900-1100 ML/day to ensure minimum flow of 1300 ML/day at Chandler Hwy. Larger magnitude flows should be passed and protected through downstream reaches.	1 (April/May), every year. Must occur 2 in 3 years.			
Winter / Spring (Jun-Nov)	**Low flow**	Higher flows increase access to habitat for bugs, fish (river blackfish, Australian smelt, ornate galaxias, Australian grayling, short-finned eel, short-headed lamprey, pouched lamprey, tupong, broad-finned galaxias, spotted galaxias & common galaxias) platypus, birds and frogs, inundate bank vegetation	Wet/Avg	Minimum recommendation of 200-350 ML/day (200 ML/day in June transitioning to 350 ML/day in July), allow tributaries to provide additional flow and variation in average and wet years.				Revised objective, includes explicit reference to native fish species in this reach, platypus, birds and frogs. Expectation that low flow will be higher in Winter / Spring than Summer / Autumn season. Low flow recommendation in wet/average years changed to allow for lower minimum flow in
			Dry	Minimum recommendation of 80-350 ML/day with transitional flows in June/July and November (80 ML/day June, 200 ML/Day July, 350 ML/day August – October and 200 ML/day in November)				

Stream	Yarra River	Reach	Millgrove to Watts River confluence
Compliance point	Yarra Grange	Gauge No.	229653

Season	Flow	Objective (refer to objectives tables for id reference)	Wet/Avg/Dry	Volume	Frequency and when	Duration	Rise/Fall	Description of changes
		(M3-2, F3-1, V3-2, P3-1, BFA3-4)						June (200 ML/day) transitioning to 350 ML/day in July. Low flow recommendation in Dry years changed to allow for transitioning between Summer / Autumn and Winter / Spring (80 ML/day June, 200 ML/Day July, 350 ML/day August – October and 200 ML/day in November).
	Fresh	Maintain suitable habitat for bugs, fish & platypus. Provide fish passage, facilitate upstream immigration of juvenile catadromous (short-finned eel, common galaxias, tupong) and amphidromous (Australian grayling, broad-finned galaxias, spotted galaxias) fishes from downstream river reaches, cue downstream migration by tupong and eels to the sea to spawn. Maintain flood-tolerant vegetation on banks and entrain organic material. (G3-2, M3-3, F3-2, F3-3, F3-5, F3-6, V3-4, P3-3, BFA3-5)	Wet/Avg/Dry	1100 ML/day (Minimum 700 ML/day) – tributary inflows provide variation during average and wet years. Higher magnitude and longer duration flows are beneficial in average and wet years.	1 event occurring in June or July to facilitate migration of fish.	Min 7 day at peak, additional duration provided by tributaries. Longer duration flows acceptable in average and wet years.	2.0/0.8	Includes explicit reference to fish species and expected migrations in response to fresh. Revised volume, timing and duration of Winter / Spring fresh recommendation documented in SKM (2012). Changed from 2 Freshes of 1800 M/Day for seven days at peak to: · 1100 ML/day fresh, in June or July to facilitate migration of fish, min 7 days at peak (Minimum of 700 ML/day is that which comes out of Reach 2, acknowledging that tributary inflows provide additional water). · 1800 ML/day fresh between June and September, min 2 days at peak – higher but shorter duration fresh to maintain flood-tolerant vegetation higher on banks. Revised rise/fall from 1.4/0.85 to 2.0/0.8. These still lie within the 50-80th percentile and are considered conservative. This event can potentially be delivered as a result of tributary flows plus top up flow release.
		As per fresh above, but higher flow to maintain flood-tolerant vegetation on banks (G3-2, M3-3, F3-2, F3-3, F3-5, F3-6, V3-4, V3-5, P3-3, BFA3-5)		1800 ML/day - as per fresh above, but higher flow to maintain flood-tolerant vegetation on banks. Tributary inflows provide variation during average and wet years. Higher magnitude and longer duration flows are beneficial in average and wet years.	1 event between June and September	Min 2 day at peak, additional duration provided by tributaries. Longer duration flows acceptable in average and wet years.		
	High	As per fresh but provides prolonged disturbance to favour flood-tolerant vegetation (G3-1, G3-2, F3-2, F3-3, F3-5, F3-6, V3-6, P3-3, BFA3-6)	Wet/Avg	1800 ML/day	Minimum 1 event in September/October, prior to Macquarie Perch spawning further downstream (November to December)	14 days	2.0/0.8	Changed timing of high flow from October-November (SKM 2012) to September-October (prior to Macquarie Perch spawning). 14 day duration is required to prevent terrestrialisation of the riparian zone. The rationalisation for retaining the original 14-day duration is the same as that provided for Reach 2. Revised rise/fall from 1.4/0.85 to 2.0/0.8. These still lie within the 50-80th percentile and are considered conservative. This event can potentially be delivered as a result of tributary flows plus top up flow release.
			Dry	Not expected to occur in dry years, but allow to occur naturally.				
	Bankfull[1,2]	Maintain existing channel geometry & prevent further vegetation encroachment in channel, entrain organic material, deliver water to billabongs via flood-runners and	Wet/Avg	4000 ML/day	1 per year	2 days	N/A	These are natural flow events not managed flows. Deleted "but avoid during October and November if possible" as previously stated in SKM (2012) as there is no control over timing of
			Dry	Not expected, but let it occur naturally.				

Stream	Yarra River			Reach	Millgrove to Watts River confluence			
Compliance point	Yarra Grange			Gauge No.	229653			
Season	Flow	Objective (refer to objectives tables for id reference)	Wet/Avg/Dry	Volume	Frequency and when	Duration	Rise/Fall	Description of changes
		provide wetted habitat for waterbirds and frogs (G3-1, G3-3, V3-3, V3-4, V3-5, P3-5, BFA3-7)						flows. Similarly, changed rise/fall to N/A as there is no control over this.
	Overbank[1,2]	Engage and provide flow through billabongs and inundate low level floodplains, provide wetted habitat area for waterbirds and frogs (G3-4, V3-8, V3-9, P3-5, BFA3-8)	Wet/Avg	4000-6000 ML/day	1 event every 1-2 years	1-2 days	N/A	These are natural flow events not managed flows. Deleted “but avoid during October and November if possible” as previously stated in SKM (2012) as there is no control over timing of flows. Similarly, changed rise/fall to N/A as there is no control over this. Changed volume from 9000 ML/day previously stated in SKM (2012) to 4000-6000 ML/day as a result of more recent investigations into the water regime of Yarra Bridge Billabong (Jacobs 2017e). Uncalibrated hydraulic model indicates overbank flows 7,500-8,500 ML/Day (inlet level from inlet channel 87.791 m AHD), however considered likely that overbank flow threshold is much lower - in the range of 4000-6000 ML/D (based on analysis of wet and dry periods).
			Dry	Not expected, but let it occur naturally.				

[1] Bankfull and Overbank flows could occur at any time (in Summer also).

[2] Events that fill billabongs may be managed through site specific water management strategies.

Table D.4 : Flow recommendations for Reach 4. Flow components have been colour coded to highlight those that are managed (blue) from those that are natural (green).

Stream	Yarra River			Reach	Watts River to Yering Gorge			
Compliance point	Yarra Glen			Gauge No.	229206			
Season	**Flow**	**Objective (refer to objectives tables for id reference)**	**Wet/Avg/Dry**	**Volume**	**Frequency and when**	**Duration**	**Rise/Fall**	**Description of changes**
Summer / Autumn (Dec-May)	**Low flow**	Maintain access to habitat for bugs, fish (river blackfish, Australian smelt, ornate galaxias, Australian grayling, short-finned eel, short-headed lamprey, pouched lamprey, tupong, broad-finned galaxias, spotted galaxias & common galaxias) platypus, birds and frogs, maintain drought refuge pools, drying period for bank vegetation (M4-1, F4-1, V4-1, P4-1, P4-2, BFA4-1)	Wet/Avg/Dry	Minimum flow of 200 ML/day, allow tributaries to provide variation above 200 ML/day in average and wet years.				Revised objective, includes explicit reference to native fish species in this reach, platypus, birds and frogs. No change in recommended volume from SKM (2012).
	Fresh	Maintain suitable riffle and LWD habitat by periodically scouring sediment & biofilms, maintain flood-tolerant vegetation on banks, provide opportunities for local fish movement and cue downstream migration of eels. (G4-2, M4-3, F4-7, F4-6, V4-3, P4-3, BFA4-2)	Wet/Avg	Minimum of 450 ML/day, tributary inflows provide variation during average and wet years. Higher magnitude and longer duration flows are beneficial in average and wet years.	Minimum 3 events + additional events provided by tributaries.	Min 2 days at peak, additional duration provided by tributaries. Longer duration flows acceptable in average and wet years.	2.0/0.8	Minor changes to the wording of objective, noting that freshes also cue downstream migration of eels. No change in recommended volume, frequency and duration from SKM (2012). Revised rise/fall from 1.4/0.85 to 2.0/0.8. These still lie within the 50-80th percentile and are considered conservative.
			Dry	450 ML/day	3 events	2 days		
	High	Trigger downstream migration and spawning by Australian Grayling and transport larvae to sea. Cue downstream migration of eels. May facilitate juvenile platypus dispersal. (F4-5, F4-7, P4-3, BFA4-3)	Wet/Avg	900-1100 ML/day to ensure minimum flow of 1300 ML/day at Chandler Hwy. Events that exceed the recommendation should be protected through downstream reaches.	1 (April/May), every year. Must occur 2 in 3 years.	Min 7 day at peak and event should last for 14 days from start to finish.	2.0/0.8	Minor changes to the wording of objective, noting that high flow also cue for downstream migration of eels and may facilitate juvenile platypus dispersal. No change in recommended volume, frequency and duration from SKM (2012). Event required 2 in 3 years to trigger downstream spawning migration of Australian Grayling, prioritise this. Note: In relation to Grayling, median travel speed 7-8 km per day, so flow duration needs to be sufficient to allow for long-distance. e.g. if fish travelling 80 km, need 10 day rising flows. Prefer flow event to be continuous so as to not disrupt cue. There's little data available of flows associated with spawning of grayling in the Yarra. The average flow (Fairfield) when grayling spawning detected was about 1500 ML/day. Revised rise/fall from 1.4/0.85 to 2.0/0.8. These still lie within the 50-80th percentile and are considered conservative.
			Dry	900-1100 ML/day to ensure minimum flow of 1300 ML/day at Chandler Hwy. Larger magnitude flows should be passed and protected through downstream reaches.	1 (April/May), every year. Must occur 2 in 3 years.	Higher and longer duration flows are desirable in average and wet years.		

Stream	Yarra River	Reach	Watts River to Yering Gorge
Compliance point	Yarra Glen	Gauge No.	229206

Season	Flow	Objective (refer to objectives tables for id reference)	Wet/Avg/Dry	Volume	Frequency and when	Duration	Rise/Fall	Description of changes
Winter / Spring (Jun-Nov)	**Low flow**	Higher flows increase access to habitat for bugs & fish (river blackfish, Australian smelt, ornate galaxias, Australian grayling, short-finned eel, short-headed lamprey, pouched lamprey, tupong, broad-finned galaxias, spotted galaxias & common galaxias) platypus, birds and frogs, inundate bank vegetation (M4-2, F4-1, V4-2, P4-1, BFA4-4)	Wet/Avg	Minimum recommendation of 350 ML/day, allow tributaries to provide additional variation above 350 ML/day in average and wet years.				Revised objective, includes explicit reference to native fish species in this reach, platypus, birds and frogs. Expectation that low flow will be higher in Winter / Spring than Summer / Autumn season.
			Dry	Minimum flow 350 ML/day, but may not reach this magnitude until late June or mid July.				
	Fresh	Maintain suitable habitat for bugs, fish & platypus. Provide fish passage, facilitate upstream immigration of juvenile catadromous (short-finned eel, common galaxias, tupong) and amphidromous (Australian grayling, broad-finned galaxias, spotted galaxias) fishes from downstream river reaches, cue downstream migration by tupong and eels to the sea to spawn. Maintain flood-tolerant vegetation on banks and entrain organic material. (G4-2, M4-3, F4-3, F4-4, F4-6, F4-7, V4-4, P4-3, BFA4-5)	Wet/Avg/Dry	1100 ML/day- tributary inflows provide variation during average and wet years. Higher magnitude and longer duration flows are acceptable and likely to be beneficial in average and wet years.	1 event occurring in June or July to facilitate migration of fish.	Min 7 day at peak, additional duration provided by tributaries. Longer duration flows acceptable in average and wet years.	2.0/0.8	Includes explicit reference to fish species and expected migrations in response to fresh. Revised volume, timing and duration of Winter / Spring fresh recommendation documented in SKM (2012). Changed from 2 Freshes of 2000 M/Day for seven days at peak to: · 1000 ML/day fresh, in June or July to facilitate migration of fish, min 7 days at peak. · 2000 ML/day fresh between June and September, min 2 days at peak – higher but shorter duration fresh to maintain flood-tolerant vegetation higher on banks. Revised rise/fall from 1.4/0.85 to 2.0/0.8. These still lie within the 50-80th percentile and are considered conservative. This event can potentially be delivered as a result of tributary flows plus top up flow release (greater flexibility with inputs from Watts River).
		As per fresh above, but higher flow to maintain flood-tolerant vegetation on banks (G4-2, M4-3, F4-3, F4-4, F4-6, F4-7, V4-4, V4-5, P4-3, BFA4-5)		2000 ML/day- tributary inflows provide variation during average and wet years. Higher magnitude and longer duration flows are acceptable and likely to be beneficial in average and wet years.	1 event between June and September	Min 2 day at peak, additional duration provided by tributaries. Longer duration flows acceptable in average and wet years.		
	High	As per fresh but provides prolonged disturbance to favour flood-tolerant vegetation (G4-1, F4-3, F4-4, F4-6, F4-7, V4-6, P4-3, P4-4, BFA4-6)	Wet/Avg	2000 ML/day	Minimum 1 event in September/October, prior to Macquarie Perch spawning further downstream (November to December)	14 days	2.0/0.8	Changed timing of high flow from October-November (SKM 2012) to September-October (prior to Macquarie Perch spawning). 14 day duration is required to prevent terrestrialisation of the riparian zone. The rationalisation for retaining the original 14-day duration is the same as that provided for Reach 2. Revised rise/fall from 1.4/0.85 to 2.0/0.8. These still lie within the 50-80th percentile and are considered conservative. This event can potentially be delivered as a result of tributary flows plus top up flow release (greater flexibility with inputs from Watts River).
			Dry	Not expected to occur in dry years, but allow to occur naturally.				

Stream	Yarra River			Reach	Watts River to Yering Gorge			
Compliance point	Yarra Glen			Gauge No.	229206			
Season	Flow	Objective (refer to objectives tables for id reference)	Wet/Avg/Dry	Volume	Frequency and when	Duration	Rise/Fall	Description of changes
	Bankfull[1,2]	Maintain existing channel geometry & prevent further vegetation encroachment in channel, entrain organic material, deliver water to billabongs via flood-runners and provided wetted habitat for waterbirds and frogs (G4-1, G4-3, V4-7, V4-8, V4-9, P4-5, BFA4-7)	Wet/Avg	5000 ML/day	1 per year	2 days	N/A	These are natural flow events not managed flows. Revised frequency to 1 per year, consistent with upstream reach. Changed rise/fall to N/A as there is no control over this
			Dry	Not expected, but let it occur naturally.				
	Overbank[1,2]	Engage and provide flow through billabongs and inundate low level floodplains, provide wetted habitat area for waterbirds and frogs (G4-4, V4-7, V4-8, V4-9, P4-5, BFA4-8)	Wet/Avg	8000-10,000 ML/d	1 event every 1-2 years	1-2 days	N/A	These are natural flow events not managed flows. Deleted “but avoid during October and November if possible” as previously stated in SKM (2012) as there is no control over timing of flows. Similarly, changed rise/fall to N/A as there is no control over this. Changed volume from 10,000 ML/day previously stated in SKM (2012) to 8000-10000 ML/day as a result of more recent investigations into the water regime of Yering Swamp (Jacobs 2015a). Estimated that 8,300 ML/Day is needed to water swamp (based on review of terrain data and environmental watering event, inlet level 62.4 m AHD). Can also be filled by water via pump and pipeline from the Maroondah Aquaduct (20 ML). Note also recent Spadoni’s Billabong Investigations (Jacobs 2015b, 2015c, 2015d)– suggest overbank flow of 10,300 ML/Day (inlet level of 63.7 m AHD) to engage billabong but have also suggested a range of other options to fill (i.e. inlet that transfers water at lower river flows)
			Dry	Not expected, but let it occur naturally.				

[1] Bankfull and Overbank flows could occur at any time (in Summer also).

[2] Events that fill billabongs may be managed through site specific water management strategies.

Table D.5 : Flow recommendations for Reach 5. Flow components have been colour coded to highlight those that are managed (blue) from those that are natural (green).

Stream	Yarra River			Reach	Yering Gorge to Mullum Mullum Creek			
Compliance point	Yering Gorge			Gauge No.	229200			
Season	Flow	Objective (refer to objectives tables for id reference)	Wet/Avg/Dry	Volume	Frequency and when	Duration	Rise/Fall	Description of changes
Summer / Autumn (Dec-May)	**Low flow**	Maintain access to habitat for bugs, native indigenous fish (river blackfish, Australian smelt, ornate galaxias, Australian grayling, short-finned eel, short-headed lamprey, pouched lamprey, tupong, broad-finned galaxias, spotted galaxias & common galaxias), native non- indigenous fish (Macquarie perch and Murray cod) platypus, birds and frogs. Maintain aquatic vegetation and water quality. (M5-1, F5-1, V5-1, W5-1, P5-1, P5-2, BFA5-1)	Wet/Avg/Dry	Minimum flow of 200 ML/day, allow tributaries to provide additional variation above 200 ML/day in average and wet years. Note – higher flows may be needed to meet flow recommendations for water quality in the Dights Falls Weir pool (Reach 6), but 200 ML/day is adequate to meet the objectives for Reach 5.				Revised objective, includes explicit reference to native fish species in this reach, platypus, birds and frogs. No change in recommended volume from SKM (2012).
	Fresh	Maintain suitable riffle and LWD habitat by periodically scouring sediment & biofilms, maintain flood-tolerant vegetation on banks, provide opportunities for local fish movement and cue downstream migration of eels (G5-2, M5-3, F5-4, F5-7, V5-3, P5-3, BFA5-2)	Wet/Avg	Minimum of 750 ML/day, tributary inflows provide variation during average and wet years. Higher magnitude and longer duration flows are beneficial in average and wet years.	Minimum 3 events + additional events provided by tributaries.	Min 2 days at peak, additional duration provided by tributaries. Longer duration flows acceptable in average and wet years.	2.0/0.8	Minor changes to the wording of objective, noting that freshes also cue downstream migration of eels. Updated wording of recommended volume, frequency and duration so that it is consistent with what is written for Reach 4. Revised rise/fall from 1.4/0.85 to 2.0/0.8. These still lie within the 50-80th percentile and are considered conservative.
			Dry	750 ML/day	3 events	2 days		
	High	Trigger downstream migration and spawning by Australian Grayling and transport larvae to sea. Cue downstream migration of eels. May facilitate juvenile platypus dispersal. (G5-1, F5-5, F5-7, BFA5-3)	Wet/Avg	1300 ML/day. Larger magnitude flows should be passed.	1 (April/May) every year. Must occur 2 in 3 years.	Min 7 day at peak. Event should last for 14 days from start to finish. Higher and longer duration flows are desirable in average and wet years.	2.0/0.8	Minor changes to the wording of objective, noting that high flow also cue for downstream migration of eels and may facilitate juvenile platypus dispersal. No change in recommended volume, frequency and duration from SKM (2012). Event required 2 in 3 years to trigger downstream spawning migration of Australian Grayling, prioritise this. Note: In relation to Grayling, median travel speed 7-8 km per day, so flow duration needs to be sufficient to allow for long-distance. e.g. if fish travelling 80 km, need 10 day rising flows. Prefer flow event to be continuous so as to not disrupt cue. There's little data available of flows associated with spawning of grayling in the Yarra. The average flow (Fairfield) when grayling spawning detected was about 1500 ML/day. Revised rise/fall from 1.4/0.85 to 2.0/0.8. These still lie within the 50-80th percentile and are considered conservative.
			Dry	1300 ML/day. Larger magnitude flows should be passed.	1 (April/May). Must occur 2 in 3 years.			

Stream	Yarra River			Reach	Yering Gorge to Mullum Mullum Creek			
Compliance point	Yering Gorge			Gauge No.	229200			
Season	Flow	Objective (refer to objectives tables for id reference)	Wet/Avg/Dry	Volume	Frequency and when	Duration	Rise/Fall	Description of changes
								This event can potentially be delivered as a result of tributary flows plus top up flow release.
Winter / Spring (Jun-Nov)	**Low flow**	Higher flows increase access to habitat for bugs, native indigenous fish (river blackfish, Australian smelt, ornate galaxias, Australian grayling, short-finned eel, short-headed lamprey, pouched lamprey, tupong, broad-finned galaxias, spotted galaxias & common galaxias), native non- indigenous fish (Macquarie perch and Murray cod) platypus, birds and frogs, wet bank vegetation (M5-2, F5-2, V5-2, W5-1, P5-1, P5-2, BFA5-4)	Wet/Avg	Median flow 750 ML/day with a minimum flow of 350 ML/day.				Revised objective, includes explicit reference to native fish species in this reach, platypus, birds and frogs. Expectation that low flow will be higher in Winter / Spring than Summer / Autumn season.
			Dry	Median flow 600 ML/day with a minimum flow of 350 ML/day.				
	Fresh	Maintain suitable habitat for bugs, fish & platypus, scour gravels to improve Macquarie perch spawning. Provide fish passage, facilitate upstream immigration of juvenile catadromous (short-finned eel, common galaxias, tupong) and amphidromous (Australian grayling, broad-finned galaxias, spotted galaxias) fishes from downstream river reaches, cue downstream migration by Tupong and eels to the sea to spawn. Maintain flood-tolerant vegetation on banks and entrain organic material. (G5-2, M5-3, F5-3, F5-4, F5-6, F5-7, V5-4, P5-3, BFA5-5)	Wet/Avg/Dry	1300 ML/day- tributary inflows provide variation during average and wet years. Higher magnitude and longer duration flows are acceptable and beneficial in average and wet years.	1 event occurring in June or July to facilitate migration of fish.	Min 7 day at peak, additional duration provided by tributaries. Longer duration flows acceptable in average and wet years.	2.0/0.8	Includes explicit reference to fish species and expected migrations in response to fresh. Revised volume, timing and duration of Winter / Spring fresh recommendation documented in SKM (2012). Changed from 2 Freshes of 2500 M/Day for seven days at peak to: · 1300 ML/day fresh, in June or July to facilitate migration of fish, min 7 days at peak (Minimum of 700 ML/day is that which comes out of Reach 2, acknowledging that tributary inflows provide additional water). · 2500 ML/day fresh between June and September, min 2 days at peak – higher but shorter duration fresh to maintain flood-tolerant vegetation higher on banks. Revised rise/fall from 1.4/0.85 to 2.0/0.8. These still lie within the 50-80th percentile and are considered conservative. This event can potentially be delivered as a result of tributary flows plus top up flow release.
		As per fresh above, but higher flow to maintain flood-tolerant vegetation on banks (G5-2, M5-3, F5-3, F5-4, F5-6, F5-7, V5-4, V5-5, P5-3, BFA5-5)		2500 ML/day- tributary inflows provide variation during average and wet years. Higher magnitude and longer duration flows are acceptable and likely to be beneficial in average and wet years.	1 event between June and September	Min 2 day at peak, additional duration provided by tributaries. Longer duration flows acceptable in average and wet years.		
	High[1]	As per fresh but provides prolonged disturbance to favour flood-tolerant vegetation. Also flushes accumulated fine sediments to maintain or improve quality and availability of habitats, including Macquarie perch spawning habitats.	Wet/Avg	2500 ML/day	Minimum 1 event in September-October, prior to Macquarie Perch spawning (November-December).	14 days	2.0/0.8	Changed timing of high flow from October-November (SKM 2012) to September-October (prior to Macquarie Perch spawning). 14 day duration is required to prevent terrestrialisation of the riparian zone. The rationalisation for retaining the original 14-day duration is the same as that provided for Reach 2.
			Dry	Not expected to occur in dry years, but allow to occur naturally.				

Stream	Yarra River			Reach	Yering Gorge to Mullum Mullum Creek			
Compliance point	Yering Gorge			Gauge No.	229200			
Season	Flow	Objective (refer to objectives tables for id reference)	Wet/Avg/Dry	Volume	Frequency and when	Duration	Rise/Fall	Description of changes
		(G5-1, F5-3, F5-3, F5-4, F5-6, F5-7, V5-6, P5-3, BFA5-6)						Revised rise/fall from 1.4/0.85 to 2.0/0.8. These still lie within the 50-80th percentile and are considered conservative. This event can potentially be delivered as a result of tributary flows plus top up flow release.
	Bankfull/ Overbank[1]	Maintain existing channel geometry & prevent further vegetation encroachment in channel, entrain organic material, deliver water to billabongs via flood-runners, provide wetted habitat area for waterbirds and frogs (G5-1, G5-3, V5-6, V5-7, V5-8, V5-9, P5-5, BFA5-7, BFA5-8)	Wet/Avg	5000-14,000 ML/day	1 per year	1-2 days	N/A	These are natural flow events not managed flows. Combined 'Small Bankfull' and 'Large Bankfull' to create new recommendation for 'Bankfull/Overbank' events. Revised frequency to 1 per year, consistent with upstream reach. Deleted "but avoid during October and November if possible" as previously stated in SKM (2012) as there is no control over timing of flows. Similarly, changed rise/fall to N/A as there is no control over this.
			Dry	Not expected, but let it occur naturally.				

[1] High, Bankfull and Overbank flows could occur at any time (in Summer also).

Table D.6 : Flow recommendations for Reach 6. Flow components have been colour coded to highlight those that are managed (blue) from those that are natural (green).

Stream	Yarra River			Reach	Mullum Mullum Creek to Dights Fall Weir			
Compliance point	Chandler Highway			Gauge No.	229143			
Season	Flow	Objective (refer to objectives tables for id reference)	Wet/Avg/Dry	Volume	Frequency and when	Duration	Rise/Fall	Description of changes
Summer / Autumn (Dec-May)	**Low flow**	Maintain access to habitat for bugs, native indigenous fish (river blackfish, Australian smelt, ornate galaxias, Australian grayling, short-finned eel, short-headed lamprey, pouched lamprey, tupong, broad-finned galaxias, spotted galaxias & common galaxias), native non- indigenous fish (Macquarie perch and Murray cod) platypus, birds and frogs, drying period for bank vegetation, minimise risk of low DO conditions (M6-1, F6-1, V6-1, W6-1, P6-1, P6-2, BFA6-1)	Wet/Avg/Dry	Minimum recommendation of 300 ML/day to minimise risk of low DO in pools upstream of Chandler Highway. Minimum recommendation of 450 ML/day in December to February if considered necessary to maintain mixed conditions in the Dights Falls Weir Pool, downstream of Chandler Highway. Higher magnitude flows are acceptable.				Revised objective, includes explicit reference to native fish species in this reach, platypus, birds and frogs. No change in recommended volume from SKM (2012).
	Fresh	Maintain suitable riffle habitat by periodically scouring sediment & biofilms, maintain flood-tolerant vegetation on banks, provide occasional fish passage for larger bodied fish and cue downstream migration of eels. (G6-2, M6-3, F6-9, V6-3, P6-3, BFA6-2)	Wet/Avg	Minimum of 750 ML/day, tributary inflows provide variation during average and wet years. Higher magnitude and longer duration flows are acceptable and beneficial in average and wet years.	Minimum 3 events + additional events provided by tributaries.	Min 2 days at peak, additional duration provided by tributaries. Longer duration flows acceptable in average and wet years.	2.0/0.8	Minor changes to the wording of objective, noting that freshes also cue downstream migration of eels. Updated wording of recommended volume, frequency and duration so that it is consistent with what is written for Reach 4 and 5. Revised rise/fall from 1.4/0.85 to 2.0/0.8. These still lie within the 50-80th percentile and are considered conservative. This event can potentially be delivered as a result of tributary flows plus top up flow release.
			Dry	750 ML/day	3 events	2 days		
	High	Trigger downstream migration and spawning by Australian Grayling and transport larvae to sea. Cue downstream migration of eels. May facilitate juvenile platypus dispersal. (G6-1, F6-7, F6-9, BFA6-3)	Wet/Avg/Dry	1300 ML/day minimum flow, all events with a magnitude greater than this should be protected. This event will be higher and last longer in average and wet years.	1 (April/May), every year. Must occur 2 in 3 years.	Min 7 day at peak. Longer duration flows acceptable in average and wet years.	2.0/0.8	Minor changes to the wording of objective, noting that high flow also cue for downstream migration of eels and may facilitate juvenile platypus dispersal. No change in recommended volume, frequency and duration from SKM (2012). Event required 2 in 3 years to trigger downstream spawning migration of Australian Grayling, prioritise this. Note: In relation to Grayling, median travel speed 7-8 km per day, so flow duration needs to be sufficient to allow for long-distance. e.g. if fish travelling 80 km, need 10 day rising flows. Prefer flow event to be continuous so as to not disrupt cue. There's little data available of flows associated with spawning of grayling in the Yarra. The average flow (Fairfield) when grayling spawning detected was about 1500 ML/day.

Stream	Yarra River			Reach	Mullum Mullum Creek to Dights Fall Weir			
Compliance point	Chandler Highway			Gauge No.	229143			
Season	Flow	Objective (refer to objectives tables for id reference)	Wet/Avg/Dry	Volume	Frequency and when	Duration	Rise/Fall	Description of changes
								Revised rise/fall from 1.4/0.85 to 2.0/0.8. These still lie within the 50-80th percentile and are considered conservative. This event can potentially be delivered as a result of tributary flows plus top up flow release.
Winter / Spring (Jun-Nov)	**Low flow**	Higher flows increase access to habitat for bugs, native indigenous fish (river blackfish, Australian smelt, ornate galaxias, Australian grayling, short-finned eel, short-headed lamprey, pouched lamprey, tupong, broad-finned galaxias, spotted galaxias & common galaxias), native non- indigenous fish (Macquarie perch and Murray cod) platypus, birds and frogs, wet bank vegetation (M6-2, F6-1, V6-2, P6-1, P6-2, BFA6-4)	Wet/Avg	Median flow 750 ML/day, daily minimum flow of 350 ML/day, allow tributaries to provide additional variation above 750 ML/day in average and wet years. Higher magnitude flows are acceptable. Maximises habitat availability.				Revised objective, includes explicit reference to native fish species in this reach, platypus, birds and frogs. Expectation that low flow will be higher in Winter / Spring than Summer / Autumn season.
			Dry	Median flow 600 ML/day, daily minimum 350 ML/day.				
	Fresh	Maintain suitable habitat for bugs, fish & platypus, scour gravels to improve Macquarie perch spawning. Provide fish passage, facilitate upstream immigration of juvenile catadromous (short-finned eel, common galaxias, tupong) and amphidromous (Australian grayling, broad-finned galaxias, spotted galaxias) and adult anadromous (short-headed lamprey, pouched lamprey) fishes from downstream river reaches, cue upstream spawning migration by short-headed lamprey and pouched lamprey from the sea, cue downstream migration by tupong and eels to the sea to spawn. Maintain flood-tolerant vegetation on banks and entrain organic material. (G6-2, M6-3, F6-3, F6-4, F6-5, F6-6, F6-8, F6-9, V6-4, W6-1b, P6-3, BFA6-5)	Wet/Avg/Dry	1300 ML/day tributary inflows and provide variation during average wet years. Do not manipulate flows down to meet recommendation. Higher and longer duration flows are acceptable in average and wet years.	1 event occurring in June or July to facilitate migration of fish.	Min 7 day at peak, additional duration provided by tributaries. Longer duration flows acceptable in average and wet years.	2.0/0.8	Includes explicit reference to fish species and expected migrations in response to fresh. Revised volume, timing and duration of Winter / Spring fresh recommendation documented in SKM (2012). Changed from 2 Freshes of 2500 M/Day for seven days at peak to: · 1300 ML/day fresh, in June or July to facilitate migration of fish, min 7 days at peak (Minimum of 700 ML/day is that which comes out of Reach 2, acknowledging that tributary inflows provide additional water). · 2500 ML/day fresh between June and September, min 2 days at peak – higher but shorter duration fresh to maintain flood-tolerant vegetation higher on banks. Revised rise/fall from 1.4/0.85 to 2.0/0.8. These still lie within the 50-80th percentile and are considered conservative.

Stream	Yarra River			Reach	Mullum Mullum Creek to Dights Fall Weir			
Compliance point	Chandler Highway			Gauge No.	229143			
Season	Flow	Objective (refer to objectives tables for id reference)	Wet/Avg/Dry	Volume	Frequency and when	Duration	Rise/Fall	Description of changes
		As per fresh above, but higher flow to maintain flood-tolerant vegetation on banks (G6-2, M6-3, F6-3, F6-4, F6-5, F6-6, F6-8, F6-9, V6-4, V6-5, W6-1b, P6-3, BFA6-5)		2500 ML/day- tributary inflows provide variation during average and wet years. Higher magnitude and longer duration flows are acceptable and likely to be beneficial in average and wet years.	1 event between June and September	Min 2 day at peak, additional duration provided by tributaries. Longer duration flows acceptable in average and wet years.		These events can potentially be delivered as a result of tributary flows plus top up flow release.
	High[1]	As per fresh but provides prolonged disturbance to favour flood-tolerant vegetation. Also flushes accumulated fine sediments to maintain or improve quality and availability of habitats, including Macquarie perch spawning habitats. (G6-1, F63, F6-4, F6-5, F6-6, F6-8, F6-9, V6-6, P6-4, BFA6-6)	Wet/Avg	2500 ML/day	Minimum 1 event in September-October, prior to Macquarie Perch spawning (November-December).	14 days	N/A	Changed timing of high flow from October-November (SKM 2012) to September-October (prior to Macquarie Perch spawning). 14 day duration is required to prevent terrestrialisation of the riparian zone. The rationalisation for retaining the original 14-day duration is the same as that provided for Reach 2. Changed rise/fall to N/A as there is no control over this.
			Dry	Not expected to occur in dry years, but allow to occur naturally.				
	Bankfull/ Overbank[1,2]	Maintain existing channel geometry & prevent further vegetation encroachment in channel, entrain organic material, engage high flow channels, billabongs and low level floodplains, provide wetted habitat for waterbirds and frogs. (G6-1, G6-3, V6-3, V6-4, V6-5, P6-5, BFA6-7, BFA6-8)	Wet/Avg	11,000 – 16,000 ML/day. Higher and longer duration flows are acceptable and likely to be beneficial.	1 per year	1-2 days	N/A	These are natural flow events not managed flows. Combined 'Bankfull' and 'Overbank' to create new recommendation for 'Bankfull/Overbank' events. Revised frequency to 1 per year, consistent with upstream reach. Changed rise/fall to N/A as there is no control over this. Changed volume from 13,000 ML/day (Bankfull) and 21,500 ML/day (Overbank) to 11,000 to 16,000 ML/day as a result of more recent investigations at Bollin Bollin and Bunyule Billabong. Under current conditions water enters Bolin Bolin Billabong when flow on the Yarra River (at the nearby Heidelberg gauge) exceeds approximately 11,300 ML/day (corresponding inlet levels unknown) (Jacobs 2017d). Under current conditions water enters the Banyule Billabong when flow on the Yarra River exceeds 24,000 ML/day (12.2 m AHD at Bunyule Billabong). There is also a pipe connecting the Yarra River to the billabong, which is estimated to trigger once flow on the Yarra River exceeds 16,000 ML/day (11.4 m AHD) (Jacobs 2017a).
			Dry	Not expected, but let it occur naturally.				

[1] High, Bankfull and Overbank flows could occur at any time (in Summer also).