Australian Government

MURRAY–DARLING BASIN AUTHORITY

Benchmark conditions of development for assessment of the SDL supply contribution

October 2017

TECHNICAL REPORT - The Benchmark report is a model of a fully implemented Basin Plan. The report describes how changes were included into the Basin Plan Benchmark scenario to produce the Sustainable Diversion Limit Benchmark scenario. This represents the implementation of the Basin Plan to achieve 2,750 GL of water recovery for the environment. This model was agreed to by all Basin governments.

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Acknowledgement of the Traditional Owners of the Murray–Darling Basin

The Murray−Darling Basin Authority pays respect to the Traditional Owners and their Nations of the Murray−Darling Basin. We acknowledge their deep cultural, social, environmental, spiritual and economic connection to their lands and waters.

The guidance and support received from the Murray Lower Darling Rivers Indigenous Nations, the Northern Basin Aboriginal Nations and our many Traditional Owner friends and colleagues is very much valued and appreciated.

Cover image: Top of Barmah Lake

Summary

Chapter 7, Part 1 of the Basin Plan requires that the Murray–Darling Basin Authority (MDBA) in consultation with the Basin Officials Committee prepares and publishes a report detailing benchmark conditions of development assumed in the benchmark model described in Schedule 6 of the Basin Plan.

For the development of the Basin Plan, the MDBA carried out a number of modelling scenarios described in MDBA (2012b). Schedule 6 (S6.02) of the Basin Plan states that the benchmark model for the sustainable diversion limit (SDL) adjustment run will comprise the MDBA model run 847, described as the BP-2800 scenario in MDBA (2012b) with a number of specified refinements.

The refinements mentioned in Schedule 6.02 have been referred to as the ‘mandated changes’. A number of additional changes have been made to make the model fit-for-purpose for SDL adjustment assessment. These changes have been reviewed through an extended consultation process with jurisdictions to agree on the definition of the benchmark conditions for the purpose of calculating the SDL adjustment.

Basin Officials Committee and the MDBA agreed final changes to the benchmark conditions in mid-June 2017, and the Basin Officials Committee re-affirmed the specific change for the recalibration of operation loss on 27 September 2017.

This report does not document the political and technical discussions that led to Basin governments endorsing changes to the final benchmark model for SDL adjustment assessment (SDL_{BM}). Rather the report describes how the mandated and non-mandated changes to BP-2800 scenario were included in the modelling system to develop the final SDL Benchmark scenario to be used for SDL adjustment. For the northern system, the MDBA undertook a review of SDLs in the Northern Basin. The review has resulted in the MDBA recommending a new SDL for the northern Basin as a proposed amendment to the Basin Plan. The hydrologic models supporting this program have been documented in MDBA (2016a).

At the time of preparing the draft determination of adjustment amounts, these amendments had not been submitted to the Commonwealth minister responsible for water. As a result, the MDBA has used the original Basin Plan northern resource unit SDLs in modelling the SDL adjustment. As the SDL Adjustment Mechanism operates as a relative test against the SDL_{BM} outcomes, it is anticipated its impact on the mechanism would be negligible. Therefore this report only describes the benchmark model used to calculate the SDL adjustment in the southern connected system.

Results of the SDL_{BM} and the BP-2800 scenarios are presented in this report, consistent with results reported in MDBA (2012b).

In addition, benchmark scores for ecological outcomes to be used for SDL adjustment assessments have been presented. It should be noted that the model and results described in this report are relevant only for the purposes of SDL-adjustment determination.

The results do not represent estimates of the SDL as defined in the Basin Plan. The baseline diversion limit and SDL estimates are dependent on the developmental conditions as described in Schedule 2 and Schedule 3 of the Basin Plan.

Contents

1 Background

A central component of the Basin Plan (Water Act 2007 – Basin Plan 2012 (Cwth)) is the establishment of sustainable diversion limits (SDLs) that specify the maximum amount of water that can be taken from water resources, while leaving enough water for the environment. The Basin Plan includes flexibility to adjust the SDL if environmental outcomes can be achieved with less water which is the focus of this report.

Governments can also propose projects that provide more water for the environment by making consumptive water use more effective and efficient, providing those water savings to the environment (referred to as efficiency measures). As part of the Council of Australian Government commitment to implementing the Basin Plan, governments are currently reviewing how efficiency measures can be designed and targeted to achieve their aims including the requirement to have neutral or improved socio-economic outcomes. Efficiency measures are not considered in this report.

Basin state governments and the Commonwealth government have identified a range of proposals to make the delivery of water more efficient and flexible. The combination of these proposals will allow environmental outcomes to be achieved with less water. The MDBA assessed a single package of these proposals in 2017 to determine the level of SDL adjustment achievable.

Chapter 7, Part 2 (Divisions1, 2, 3 and 4) of the Basin Plan outlines the provisions to enable surface water SDLs to be adjusted, including the steps the MDBA must take to determine the SDL adjustment amounts as a result of the proposed supply and efficiency measures.

A default method for calculating the contributions of supply measures to the SDL adjustment, is described in Schedule 6 of the Plan. The assessment will be conducted within a hydrological modelling environment using comparative analysis between two model scenarios:

1. The benchmark scenario (SDL_{BM}), and
2. The SDL adjustment scenario (SDL_{A}).

The SDL_{BM} represents the best estimate of the potential changes to the flow regime in the river systems, if the settings outlined in the Basin Plan are implemented.

SDL_{BM} includes:

- The Basin-wide recovery of 2,750 GL/y (long term average) of water for the environment, and
- A watering strategy in which the recovered water is used to deliver specific environmental outcomes.

The SDL_{A} represents the impact of the proposed SDL adjustment proposals on the volume of environmental water required to achieve environmental outcomes equivalent to the SDL_{BM}. The difference in environmental water required between the SDL_{A} and SDL_{BM} defines the level of SDL adjustment.

The purpose of this report is to document the final benchmark scenario which is used for assessing the final package of agreed SDL adjustment supply measures.

2 Scope of the report

Chapter 7, Part 1 of the Basin Plan requires that the MDBA in consultation with the Basin Officials Committee prepare and publish a report detailing benchmark conditions of development. This report addresses this requirement.

This report documents the outcomes from an extended consultation period with Basin governments to agree on the definition of the benchmark conditions for the purpose of calculating the SDL adjustment. The Basin Officials Committee and the MDBA agreed final changes to the benchmark conditions in mid-June 2017, and the Basin Officials Committee re-affirmed the specific change for the recalibration of operation loss on 27 September 2017. The report does not document the political and technical discussions that led to Basin governments endorsing changes to the SDL_{BM}. Rather the report identifies how these changes to SDL_{BM} were included into the modelling system.

The MDBA and the Basin Officials Committee agreed to review the SDL in the northern Basin, rather than adopt the default method set out in Schedule 6. The hydrologic models supporting this review program have been documented separately (MDBA, 2016a). This report only describes the benchmark model used to calculate the SDL adjustment in the southern system.

The Northern Basin Review has resulted in the MDBA recommending a new SDL for the northern Basin. However, the proposed amendment to the Basin Plan to implement this new SDL was not submitted to the Commonwealth minister responsible for water in time for the change to be accounted for in the determination of the supply contribution. Consequently, the MDBA used the SDLs of Basin Plan northern SDL resource units in determining the supply contribution in the southern connected system. The SDL Adjustment Mechanism operates as a relative test against the SDL_{BM} outcomes. Any changes to Menindee inflows resulting from changes in the Northern Basin would apply to both the SDL_{BM} and SDL_{A} scenarios. The impact of any change in Menindee inflows would be negligible on the level of adjustment determined.

Figure 1: Southern connected system

The SDL_{BM} comprises the MDBA BP-2800 scenario, with some agreed refinements. This BP-2800 scenario has been comprehensively documented in MDBA (2012b). This report focuses on the refinements made to BP-2800 to derive the SDL_{BM}. The reader is referred to MDBA (2012b) for full documentation of BP-2800.

3 Model scenarios

A number of model scenarios are referenced in this report. The 'without development', 'baseline' and BP-2800 scenarios were carried out to inform the development of the Basin Plan and are described in MDBA (2012b). A short description is included below.

The **without development** (WOD) scenario represents a near natural condition. It is based on the baseline scenario, but with infrastructure, water use and capacity constraints removed (MDBA 2012b).

The **baseline** scenario represents the starting point for determining the volume of water that should be recovered to achieve SDLs. The baseline scenario is represented using models provided by State Agencies and the River Murray and Lower Darling system model developed by MDBA. The baseline scenario represents the baseline conditions as specified in the proposed Basin Plan (MDBA 2012b). Detailed discussion on the baseline models is available in MDBA (2011a) and differences between baseline diversion limit (BDL) estimates and earlier published diversion estimates have been explained in MDBA (2011b). An independent review of these models to assess their representations of the baseline conditions specified in the Basin Plan was performed by Barma (2012). The baseline scenario used in this report (run 845) is consistent with the models used for Basin Plan scenarios (MDBA 2012b).

The **BP-2800** scenario represents 2800 GL of water recovery Basin wide, and a watering strategy in which the recovered water is used to deliver specific environmental outcomes. This scenario is the starting point for the Benchmark scenario for SDL adjustment, as specified in Schedule 6 (Part 2) of the Basin Plan (model run 847; MDBA 2012b).

The benchmark model (SDL_{BM}) is a modification of the BP-2800 scenario, with a set of mandated changes described in Schedule 6.02 and a number of non-mandated changes that jurisdictions have agreed to include in the benchmark model. These changes are described in detail in Section 4 of this report. An overview of modelling scenarios is provided in Table 1.

Table 1: Overview of modelling scenarios

Name	Run number	Description	Reference
WOD	844	Without development	MDBA 2011a, MDBA 2012b
Baseline	845	Baseline – represents baseline conditions as specified in the Basin Plan	MDBA 2011a, MDBA 2012b
BP-2800	847	Basin Plan scenario with 2800 GL of water recover	MDBA 2012b
SDL_{BM}	1132	SDL Benchmark scenario for Southern Basin	This report
SDL_{A}	1138	SDL Adjustment scenario	MDBA (2017d)

4 Benchmark conditions of development – models and methods

The SDL_{BM} represents the policy and development conditions (the benchmark conditions of development) assumed to result from implementation of the Basin Plan. This includes the infrastructure, rules and practices that were assumed in the Basin Plan modelling. Based on these settings, the model provides a set of environmental outcomes that could be achieved through the Basin Plan at a level of water recovery.

Schedule 6.02 of the Basin Plan explicitly defines the benchmark conditions of development to be applied in SDL_{BM}. Specifically, the SDL_{BM} comprises the MDBA model run 847 (MDBA 2012b), with a number of agreed refinements. Two types of refinements to run 847 are identified:

- Mandated changes – these refinements are described in S6.02 (1a to 1g) and section 6.05 of the Basin Plan.
- Non-mandated changes – these changes were identified by an inter-jurisdictional working group as being necessary to make the models fit-for-purpose for SDL adjustment modelling.

Both mandated and non-mandated changes to the SDL_{BM} were undertaken in consultation with Basin jurisdictions. A Benchmark Model Working Group (BMWG) was set up comprising of representatives from the Basin states, Commonwealth and MDBA. In January 2014, the BMWG was replaced with the SDL-Adjustment Technical Working Group (SDLA TWG), comprising similar membership. These groups identified and progressed technical issues that should be included in the SDL_{BM} to ensure that it would be fit-for-purpose for SDL adjustment assessments. Subsequently, all mandated and non-mandated changes to SDL_{BM} were reviewed and endorsed by the Sustainable Diversion Limit Adjustment Advisory Committee (SDLAAC), Basin Officials Committee and the MDBA.

The hydrologic modelling report (MDBA 2012b) described the model set-up for run 847 (BP-2800) including details of models and methods used. These details are not repeated here.

4.1 Mandated changes

Seven required refinements to run 847 (BP-2800) were identified in Schedule 6.02 of the Basin Plan. These were:

a) adjust the overall reduction from 2,800 GL/year to 2,750 GL/year
b) incorporate appropriate rules for delivery of water from the Lower Lakes into the Coorong, including relating Lake level to release volumes
c) incorporate Upper South East inflows as at 30 June 2009
d) incorporate updated environmental watering event time-series for without development and baseline model runs in the environmental event selection tool
e) remove the operation of the Living Murray works and use the component of the Living Murray water that was used by the works for floodplain outcomes
f) incorporate environmental demand sequences that manage for maximum dry spell as well as frequency, and
g) set environmental flow demands for the Goulburn River consistent with the flow event targets described in MDBA (2012a).

In addition, section 6.05(3) of the Basin Plan describes a default approach for apportioning the shared reduction amount. In accordance with s7.23, South Australia has requested a change to the default approach within the South Australia zone. As the apportionment of the shared reduction in BP-2800 was not consistent with this, the Benchmark has been revised to match the advice from states.

The implementation of these mandated changes to BP-2800 are described in the following sections.

4.1.1 Adjusting the overall reduction from 2800 GL/y to 2750 GL/y (S6.02-1a)

BP-2800 represented 2,800 GL of water recovery Basin wide. Adjusting the overall reduction from 2,800 GL/y to 2,750 GL/y was modelled by reducing the targeted reduction in the Condamine-Balonne. For the BP-2800 scenario, baseline diversions in the Condamine-Balonne were reduced by 203 GL/y (74 GL/y from the Upper and Middle Condamine systems, 2 GL/y from St George and 127 GL/y from Lower Balonne). Considering that the Upper and Middle Condamine do not supply recovered water to the Barwon-Darling as efficiently as the St. George and Lower Balonne (MDBA 2011d), the 150 GL recovery from Condamine-Balonne was modelled from St. George and Lower Balonne only (MDBA 2012b).

4.1.2 Lower Lakes operating rules for releasing water through the barrages (S6.02-1b)

The Murray model includes targets for barrage flow releases, as well as for maintaining minimum levels in the Lower Lakes. In BP-2800, there was an allowance of 20 cm to prioritise barrage flow targets over the minimum lake level target. This allowed releasing water over the barrages even when lake level was less than 0.3 mAHD, which may not be possible in practice due to downstream water level changes by tidal influences. For the SDL_{BM}, that allowance is removed and water is not released when the lake level is lower than the monthly minimum target levels (0.35 mAHD between March and May and higher for the other months).

When the allowance is removed from the model, the lakes are maintained at a higher level, barrage flows are reduced and periods with zero flow are extended. It should also be noted that The Living Murray water delivery to the lakes is mostly based on the minimum target levels. Therefore, changing lake level as a result of removing the allowance leads to different patterns (both in timing and volume) of The Living Murray water delivered.

4.1.3 Upper South East inflows and salinity as of June 2009 (S6.02-1c)

There have been recent changes to the drainage network in the Upper South East area of South Australia. These changes have resulted in increased inflows into the Coorong, which were not taken into account in BP-2800. In addition, the inflows used for BP-2800 were derived on a monthly timescale, based on a regression relationship using monthly rainfall and temperature data (MDBA, 2009). The monthly inflow estimates were disaggregated into constant daily values for a given month.

Improved estimates of daily inflows from the Upper South East Drainage area were developed to represent conditions in June 2009 (Montazeri et al, 2011 and Gibbs, 2013). As required by the mandated changes to the benchmark model, these Upper South East Drainage inflows (USEDI) are based on daily time-step rainfall-runoff and water balance models representing the drainage network as at June 2009.

The USEDI replaces the monthly regression approach for estimating inflows. The average annual USEDI increased to 26 GL/y (average over 114 year period), compared to 10.9 GL/y under BP-2800.

Changing estimates of USEDI necessitated changes to how salinity of the inflows was modelled. A new flow-salinity relationship was developed in consultation with the SA Government to model the salinity of USEDI (MDBA 2013d). The previous regression relationship used in BP-2800 was developed between observed average monthly flow and salinity data for the period of 2000-2008. The observed data set had large gaps and the relationship resulted in unrealistically high salinity for certain periods. To minimise the effect of large data gaps, average flow weighted salinity for the month was considered to be more representative. Also, the observed data set had been extended to June 2010, which provides a longer period of data to develop a regression relationship. The final regression relationships between flow and flow weighted salinity are given in Table 2. A log curve (Log Natural) with an intercept of 17,766 fitted best to the measured salinity for the months of December to May with a R^2 value of 0.58. An average salinity for each month from June to November was used due to the absence of any significant curve fit.

Table 2: Regression models for estimation of USEDI salinity (using natural log function)

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Coefficient	2095.5	2095.5	2095.5	2095.5	2095.5	0	0	0	0	0	0	2095.5
Intercept	17766	17766	17766	17766	17766	12204	14763	12284	13812	19115	22113	17766

The new flow-salinity relationship improves the previous estimates of salinity of USEDI and is based on the best available information. However, because of gaps in the recorded data and changes in operations during the period of observations, there are still some discrepancies between the estimated and observed salinities:

- Salinity for low flows is generally overestimated for the first three years (August 2000 to August 2003) and generally under-estimated for flow peaks for the rest of the modelled period.
- Very high (greater than 42,500 EC) salinities are not captured well, however, based on observed data; there is only a 1% likelihood of measured salinity to exceed 42,500 EC.
- Salinity in the range from 30,000 EC to 40000 EC is slightly underestimated, but again there is only 2% to 8% likelihood of observed salinity to fall in this range.
- Salinity values falling in mid to low magnitude range (that correspond to mid to high frequency of percent exceedance range) are slightly overestimated.

For further details refer to MDBA (2013d).

4.1.4 Updating without development and baseline flows in the Environmental Event Selection Tool (S6.02-1d)

The Environmental Event Selection Tool (EEST) was originally developed as a manual tool to develop environmental watering demands for Basin Plan model scenarios. The Basin Plan scenarios that informed the development of the Basin Plan (BP-2400, 2800 and 3200; MDBA 2012b) were completed with the assistance of this tool. The events available for selection in the EEST are based on events which occurred in the without development scenario, but were lost under baseline conditions (MDBA 2012b).

The estimated 'cost' of each event (i.e. the volume of environmental water required to deliver the event) is calculated based on the difference between the environmental–demand time series and the baseline–flow time series at each site. The version of the EEST used for BP-2800 made use of without development and baseline results from runs that preceded the scenarios reported in MDBA (2012b). The event sequences and time-series in the EEST have been updated and are now based on model scenarios 844 (without development) and 845 (baseline).

4.1.5 Removing The Living Murray works and using The Living Murray water to achieve floodplain outcomes (S6.02-1e)

The baseline and BP-2800 scenarios included the operation of The Living Murray (TLM) works. However, the Basin Plan mandated that TLM works and their operations would be removed from SDL_{BM} and that TLM water used by the works in BP-2800 would be used for floodplain outcomes. Therefore, the operation of all TLM works is turned off in SDL_{BM}, but the SDL_{BM} still coordinates TLM water delivery to Lower Lakes in order to best meet TLM objectives as described in MDBA (2011c).

4.1.6 Environmental demand sequencing to address maximum dry spell and frequency (S6.02-1f)

The development of environmental–demand time series with the manual version of the EEST used for BP-2800 was based primarily on the target frequency of events for each site-specific flow indicator (SFI). Reducing the length of dry periods (i.e. number of years between environmental watering events) was also considered to some extent, but its contribution to the selection of events was irregular.

To also specifically target reduction of the length of dry spells in the development of the demands, the user of the EEST gives a higher preference to events that would reduce the length of dry spells, with the overall aim to reduce the maximum dry spell for each environmental flow indicator. This change was incorporated in the manual EEST underlying the Mandated Changed Only (MCO) scenario. The EEST was subsequently automated to remove subjectivity of event selection and ensure that the event selection process was deterministic and repeatable (see section 4.2.1.2). As part of this automation, reducing the length of dry spells was included in the event selection, whereby meeting the SFI frequency targets is still the primary aim, but dry spells were included as a secondary parameter.

4.1.7 Update environmental flow demands for the Goulburn River (S6.02-1g)

The environmental demands for the Lower Goulburn Floodplain used in the BP-2800 scenario were based on an initial set of specific flow indicators (SFIs) measured at McCoys Bridge and including overbank flow requirements up to 60,000 ML/day (MDBA 2012b). However, new flow indicators were adopted for the Lower Goulburn Floodplain drawn primarily from work by Cottingham et al. (2010), Water Technology (2010) and DSE (2011) and described in MDBA (2012a). These flow indicators are based on flows at Shepparton (Table 3). The new Shepparton flow indicators have since been included in the EEST. While frequency and dry spell were used to select Goulburn events, consistent with the selection of events for all other SFIs across the Southern Basin, the Goulburn flow indicators for 25,000 and 40,000 ML/day also include median event duration as a target parameter. Therefore, a second step was added in the selection of 25,000 and 40,000 ML/day events for the Goulburn, in which the duration of each selected event was lengthened to up to three times the target median duration.

The environmental outcomes reported for the Goulburn in the hydrological modelling report (MDBA 2012b) are based on a Goulburn-only scenario with in-valley demands based on these new indicators. This scenario did not include any downstream demands for the River Murray. The SDL_{BM} includes updated flow indicators for in-valley requirements, in combination with a downstream demand.

Table 3: Flow indicators for the Lower Goulburn River channel and floodplain, including target Low and High Uncertainty (LU & HU) frequencies expressed as a proportion of years.

Flow indicator	Start Month	End Month	Threshold (ML/day) at Shepparton	Duration (days)	LU Freq (% years)	HU Freq (% years)	Maximum period between events (years)
1	Dec	Apr	2,500	8 (2 events min 4 days duration)	48	36	NA
2	Oct	Nov	5,000	14 (min 14)	66	49	NA
3	Jun	Nov	25,000	≥ 5 (median)	80	70	3
4	Jun	Nov	40,000	≥ 4 (median)	60	40	5

4.1.8 Change in apportionment of shared reduction

Even though it is not specified in Schedule 6.02 as a mandated change, s6.05(3) of the Basin Plan specifies the default apportionment of the shared reduction. The total SDL resource unit shared reduction amount for the Southern Connected Basin is 971 GL. In the BP-2800 scenario, this shared reduction was apportioned between the SDL resources units proportional to their baseline diversion limit, with some exceptions, as no reduction in diversions was modelled in the Kiewa, Ovens and Broken systems, and the Australian Capital Territory that had its own zone shared reduction target.

As per s7.23 of the Basin Plan, Basin governments advised the MDBA on how to allocate the shared reduction amount for the purposes of the SDL Adjustment Mechanism (SDLAM). The default approach was applied to the southern NSW and Victorian zones, and the South Australian zone share was apportioned fully to the South Australian Murray resource unit. Apportionment for the benchmark scenario has been revised to be consistent to the advice from the state, but without apportionment to the Kiewa, Ovens and Broken systems (Table 4).

Table 4: The modelled local, shared and total reduction in diversions BP-2800 and SDL_{BM}

Catchment	BDL (excluding inter-ception)	Local reduction	Shared reduction			Total reduction = local reduction + shared reduction		
			BP-2800*	Default (C6.05)	SDL_{BM}^	BP-2800*	Default (C6.05)	SDL_{BM}^
Ovens	25	0	0	3.0	0.0	0.0	3.0	0.0
Goulburn	1580	344	115	192.4	195.1	459.0	536.4	539.1
Broken	13	0	0	1.6	0.0	0.0	1.6	0.0
Loddon	89	12	15	10.8	11.0	27.0	22.8	23.0
Campaspe	113	18	14	13.8	14.0	32.0	31.8	32.0
Vic Murray	1662	253	240	202.4	205.2	493.0	455.4	458.2
Kiewa	11	0	0	1.3	0.0	0.0	1.3	0.0
Victorian Total	**3493**	**627**	**384**	**425.3**	**425.3**	**1011.0**	**1052.3**	**1052.3**
NSW Murray	1708	262	254	207.9	207.9	516.0	469.9	469.9
Murrumbidgee	2000	320	273	243.4	243.4	593.0	563.4	563.4
Lower Darling	55	8	7	6.7	6.7	15.0	14.7	14.7
NSW Total	**3763**	**590**	**534**	**458.0**	**458.0**	**1124.0**	**1048.0**	**1048.0**
SA Murray	665	101	53	82.84	82.8	154.0	183.8	183.8
EMLR	15.3	0	0	0	0.0	0.0	0.0	0.0
SA Total	**680.3**	**101**	**53**	**82.8**	**82.8**	**154.0**	**183.8**	**183.8**
ACT	**40.5**	**0**	**0**	**4.9**	**4.9**	**0.0**	**4.9**	**4.9**
Total	**7976.8**	**1318**	**971**	**971**	**971**	**2289.0**	**2289.0**	**2289.0**

* As in run 847 based on proportion of BDL

^ Victorian catchment redistributed as no reduction is modelled for Ovens, Broken and Kiewa

4.2 Non-mandated changes

A number of additional non-mandated changes to the benchmark have been made. A number of these changes were considered and agreed by the Benchmark Modelling Working Group to be included in an interim benchmark model used by the MDBA for a trial of the default method for SDL adjustment assessment (these include changes in both the northern and southern systems). Subsequently, during the implementation of the SDL adjustment proposals in the SDL_A model, further benchmark changes (in the Murray and Murrumbidgee) were identified, which were necessary to make the models fit-for-purpose for the assessment of the SDL adjustment proposals. All the changes have been endorsed by the SDL Adjustment Advisory Committee (SDLAAC), Basin Officials Committee (BOC) and the MDBA (Table 5).

Table 5: Non-mandated changes to the benchmark model

Valley	Description of changes	Status
Southern system	Adjust the EEST accounting to July-June water year, to be consistent with section 3.08 of the Basin Plan.	Agreed at BMWG #3 (item 5) Endorsed by SDLAAC #6 Noted by BOC #23 & #24 Endorsed MDBA #110, June 2017 Endorsed BOC #50 22 June 2017
Southern system	Automation of event selection tool	Agreed at TWG #3 Endorsed MDBA #110 June 2017 Endorsed BOC #50 22 June 2017
Murrumbidgee	Inclusion of an environmental account	Agreed at BMWG #4 (item22) Endorsed by SDLAAC #6 Noted by BOC #24 Endorsed MDBA #110 June 2017 Endorsed BOC #50 22 June 2017
Murrumbidgee	Model refinements: - Calculation of Low-Bidgee demands in the EEST - Node-link relationship - Lag time in inflow files	Agreed at BMWG #3 (items 10, 12, 13) Endorsed by SDLAAC #6 Noted by BOC #23 & #24 Endorsed MDBA #110 June 2017 Endorsed BOC #50 22 June 2017
Murrumbidgee	Update TLM recovery to be consistent with BDL model and Murray model	Agreed at BMWG #4 (item14) Endorsed by SDLAAC #6 Noted by BOC #24 Endorsed MDBA #110 June 2017 Endorsed BOC #50 22 June 2017
Murrumbidgee	Match reduction in diversions based on net diversions	Rejected at BMWG #3 (item 21) Noted by SDLAAC #5 and BOC #23/24 Agreed at TWG #13 Endorsed MDBA #110 June 2017 Endorsed BOC #50 22 June 2017

Valley	Description of changes	Status

Murrumbidgee	Fit for purpose changes to assess Murrumbidgee supply measures:
	• Nimmie-Caira:
	  ○ Revise high flow effluent and returns
	  ○ Locate environmental demands upstream of Maude weir
	• CARM:
	  ○ Adjust accounting for Reduced Snowy Inflows
	  ○ Review and report tributary utilization
	  ○ Review Yanco Regulator impact on mid-Murrumbidgee inundation mapping
		Agreed at OoS of TWG #20
		Endorsed MDBA #110 June 2017
		Endorsed BOC #50 22 June 2017

Murray	Inclusion of an environmental account	Was awaiting further discussion at BMWG #4 (item 1) Noted BOC #24 Agreed 'in principle' at TWG #2 Endorsed MDBA #110 June 2017 Endorsed BOC #50 22 June 2017
Murray	Lower Murray Accounts to protect environmental water being reregulated at Lake Victoria and to fix issues with special accounting. This change allows other projects (especially Menindee) to be assessed in a more technically sound manner	Agreed at TWG – SDLAAC workshop 31 May 2017 Endorsed by SDLAAC #31 Endorsed MDBA #110 June 2017 Endorsed BOC #50 22 June 2017
Murray	Inclusion of detailed water balance models for the Icon Sites and update on The Living Murray operating strategies	Agreed out of session after TWG #2 Endorsed MDBA #110 June 2017 Endorsed BOC #50 22 June 2017
Murray and Murrumbidgee	Finley Escape flow: Recalibration of the escape flows in the Murray model and associated update of Finley escape inflow in Murrumbidgee model	Agreed at TWG #20 Endorsed MDBA #110 June 2017 Endorsed BOC #50 22 June 2017
Murray	Corrections and required changes to assess the callable RMIF from Snowy	Agreed at TWG #15 Endorsed MDBA #110 June 2017 Endorsed BOC #50 22 June 2017
Murray	Work sites representation: - Gunbower National Park - Lindsay Stage 2 - Wallpolla Island	Agreed at TWG #9a Endorsed MDBA #110 June 2017 Endorsed BOC #50 22 June 2017
Murray	Inclusion of water balance representation of Guttrum–Benwell	Agreed at TWG #15 Endorsed MDBA #110 June 2017 Endorsed BOC #50 22 June 2017

Valley	Description of changes	Status
Murray	Update the equation used to calculate operational loss to reflect changes and increased efficiency in system operation. This change allows other projects (especially Menindee) to be assessed in a more technically sound manner	Technical solution agreed at BOC #47 Endorsed MDBA #110 June 2017 Endorsed BOC #50 22 June 2017 Re-affirmed BOC #53 27 September 2017

4.2.1 Southern Basin

4.2.1.1 Adjustment of EEST account to July-June water year

There was an inconsistency in the EEST used for the BP-2800 scenario, whereby the annual Basin-Plan Environmental Water Account (BP-EWA) calculated available water based on baseline diversions for the July-June water year, while environmental water use was accounted for based on a June-May water year. This has been corrected for SDL_{BM}, so that both water availability and water use are based on the July-June water year, consistent with section 3.08 of the Basin Plan.

4.2.1.2 Automation of the Environmental Event Selection Tool

The Environmental Event Selection Tool (EEST) used for the BP-2800 scenario was a manual tool which required a user to select an environmental watering sequence based on a set of guiding principles. The main disadvantages of the manual EEST process are:

- **Non-determinism** — given the same EEST tool and the same guidelines, two users will almost always produce two distinct environmental watering sequences. Both sequences can represent environmental water use with the same level of plausibility, but provide different environmental flow results.
- **Lengthy processing time** — a single EEST sequence can require a period of one week to complete. Also, the environmental water accounting included in the EEST is a first estimate, and there can be multiple model iterations to ensure the demand series are using the requisite volume of water.

In order to overcome these disadvantages, the manual EEST process is codified in Fortran which reproduces the environmental accounting and hydrologic connectivity calculations as they exist in the manual version. Furthermore, the automated tool reproduces the manual selection principles in the form of mathematical functions, and then uses these functions to automatically select environmental watering events over the 114 year period. The three mathematical functions represent the criteria:

- Frequency — aim to deliver events with a frequency between the high and low uncertainty frequencies
- Dry spell — minimise the length of dry spells, where the function is based on the maximum dry spells achieved under without development and baseline conditions
- Volume — preferentially deliver those events which require the least change to the existing hydrograph; i.e. opportunistic environmental watering.

Given the number of unique combinations of events available for selection (millions), it would have been possible to design an algorithm to provide the maximum possible environmental outcomes, greater than that which could be achieved through a manual event selection process. However, one of the guiding principles underlying the automated EEST was that it could not optimise the event selection process. A comparison of the benchmark sequence to five individual manual sequences indicated that the automated process was providing a set of environmental events consistent with the manual approach.

4.2.2 Murrumbidgee system

Early in the process of Benchmark model development, the MDBA identified a number of non-mandated changes to the Murrumbidgee model, which could make the model fit-for-purpose for assessing SDL adjustment supply measures. These changes were approved and included in the Benchmark by the MDBA before SDL adjustment business cases were completed. These changes are described in sections 4.2.2.1 to 4.2.2.4. Subsequently, further fit-for-purpose changes were identified in relation to the proposed SDL supply measures. These have been implemented in the model by New South Wales and have been summarised in section 4.2.2.5.

4.2.2.1 Inclusion of environmental accounting

In the BP-2800 scenario, the Murrumbidgee model had no environmental accounting mechanism that could limit environmental water use to water available for the environment. Even though the possible impact of this was minimised through the use of the EEST and storage level checks, there could have been over-use of water by the environment at times, and modelled allocations would not be reliable. Therefore, the BMWG agreed that the addition of an accounting mechanism into the Murrumbidgee model for the benchmark would make the model more fit-for-purpose for SDL adjustment modelling.

With the help of modellers from the NSW Department of Primary Industries (Water), a method was developed to include an environmental account. The volume of water in the account is equivalent to the degree of water recovery (buyback) modelled and the environmental account is subject to the same rules applicable to the bulk irrigation licences.

The Murrumbidgee environmental requirements consist of demand time-series located at:

- Narrandera (mid-Murrumbidgee wetlands)
- Maude Weir (Lowbidgee Floodplain)
- Balranald Weir (local requirements plus downstream Murray)

The main environmental account was included at Narrandera, with two sub-accounts at Maude Weir and Balranald Weir to account for use at those locations. These sub-accounts were linked to the main account, so that the most upstream site has first access to the account with sites further downstream able to access the remaining balance.

Modelled time-series of flows at these locations under baseline conditions are used to estimate the environmental water use. Any volume of water in addition to baseline flows during an environmental event is accounted against available water in the environmental account. A main assumption underlying this method is that without Basin Plan environmental demand, the flow would have been the same as under baseline conditions.

Given that the implemented accounting method will limit environmental delivery to the available volume in the account, some events that could be delivered in the BP-2800 scenario may not be delivered in the benchmark. However, similar events could possibly be delivered at other times, through demands or spills. The MDBA carried out comparative model runs with and without the environmental account and found that, although there were small variations in year-to-year outcomes, the overall impact on environmental outcomes was minimal (MDBA 2013b).

4.2.2.2 Other model refinements

There were minor inconsistencies in modelled inputs and node-link relationships identified in BP-2800 and corrected in SDL_{BM}. The combined impact of these changes was a decrease in Balranald flow by 0.3 GL/year.

BP-2800 environmental demand series for Narrandera included flow events of 63,250 GL/day (for 3 days) which cannot be delivered under regulated conditions. The EEST has been changed so that these events are not available for selection. This also ensures that these events are treated consistently with other ‘beyond regulating capacity’ events in the Murray (e.g. 125,000 ML/d at the Riverland-Chowilla Floodplain).

The BP-2800 scenario demand series at Maude Weir was limited to 20,000 ML/d (MDBA 2012b, p. 130). This corresponds to bank-full flows at Maude Weir, and the purpose of this limit was to ensure that water was efficiently delivered to the Lower Murrumbidgee Floodplain (i.e. minimal losses). However, in a small number of years the BP-2800 environmental demand series included flows of 30,000 ML/d. This was an experimental demand series which formed part of the iterative scenarios completed during the Basin Plan modelling process and should not have been included in the BP-2800 scenario. The demand series included in the benchmark scenario has been revised to ensure that it is limited to 20,000 ML/d at all times.

4.2.2.3 Update to The Living Murray water recovery

The Murrumbidgee model used for Basin Plan modelling is based on the Water Sharing Plan version of the model. This version of the model does not include water recovery for The Living Murray (TLM) (MDBA 2011a). For the BP-2800 scenario, 48.9 GL/y (long term average water use) water recovery for TLM was included, in conjunction with advice from the NSW Office of Water (MDBA 2012b). The TLM water recovery was subsequently updated to 52.1 GL/y (average annual use) for the baseline diversion limit (BDL) version of the baseline model (#871), which also corresponded to the TLM water recovery represented in the Murray model. The Benchmark model has been updated to be consistent with the BDL and Murray models.

4.2.2.4 Model reduction in diversions based on net diversions

In the hydrologic modelling report describing the Basin Plan model scenarios that informed the Basin Plan (MDBA 2012b), the Murrumbidgee diversions were reported as gross diversions, and for Basin Plan scenarios (BP-2400, BP-2800, BP-3200) the targeted reduction in diversions was also modelled based on gross diversions. However, for the BDL (#871 and MDBA 2011a), the reporting of Murrumbidgee diversions was changed to net reporting, to be consistent with diversion reporting under the Water Sharing Plan and the Cap (MDBA 2011b). Therefore, the Benchmark was also changed to model the required reduction in diversions using net diversions.

4.2.2.5 Fit-for-purpose changes to assess Murrumbidgee supply measures

A number of non-mandated changes to the Murrumbidgee integrated water quality and quantity simulation model (IQQM) were identified as necessary to ensure the model was fit for purpose for assessing the proposed supply measures. The issues were identified by the MDBA and NSW in June 2016. NSW hosted a modelling workshop in September 2016 to progress these issues. Subsequently, NSW and the MDBA worked closely to refine the Murrumbidgee Benchmark model and ensure it was fit for the purpose of assessing supply measures.

Table 6 presents an overview of all these changes to the benchmark model. Key changes made are summarised below.

- Nimmie-Caira representation:
    - There were a number of issues with the representation of Nimmie-Caira in the original benchmark which were preventing sensible modelling assessment of the project. These include:
        - Not fully recovering the Nimmie-Caira entitlement that has been already purchased by the Commonwealth,
        - Not diverting environmental water to achieve the Basin Plan intended inundation area and
        - Not fully describing high flow effluent dynamics.
    - NSW and the MDBA have reviewed data available and added a high flow effluent to Nimmie-Caira
    - The model has been updated to fully recover the Nimmie-Caira entitlement and to actively divert environmental water into the site to achieve the original Basin Plan intended inundation area.

- Reflection of tributary utilisation for implementing the Computer Aided River Management (CARM) project:
    - The current model has been reviewed and found that improvement is required to correctly represent the use of tributary inflows in making decisions on releases required from dams.
    - NSW has developed the relationship for Benchmark changes based on operators' CAIRO data. Subsequently, MDBA has gone through independent calculation and fixed some inconsistency issues for the final proposed Benchmark.

Table 6: Fit for purpose changes made to Murrumbidgee Benchmark model

Projects	Reasons	Changes made
Water for Rivers (WfR, ~2009)	Representing 2009 conditions & Fit for purpose changes to assess the CARM project	Representing WfR recovered prior to 2009 including: - Market purchase - Physical works to yielding conveyance license - Forest creek rule changes

Projects	Reasons	Changes made

Water for Rivers (WfR, 2009~)	Fit for purpose changes to assess the CARM project	Model's representation of some physical processes at more detailed scales.
		- Wilson Anabranch and associated losses
		- Beavers Creek existing offtake structure with a limit of 60,000 ML/d ordering capacity, and losses and return flows on the Beavers/Old Man Creek system
		- Augmented supply via Irrigation Corporations:
		    o Coleambally Irrigation Area escape drain operation and historical loss provision, and
		    o Murray Irrigation Finley Escape drain operation,
		- Oak and Gras Innes Wetland losses on Bundidgerry Creek
		- Tributary utilisation for regulated orders
		- Yanco Offtake operation
		- Rainfall rejection from Murrumbidgee Irrigation

Loss relation along Yanco Creek	Fit for purpose changes to assess the modernisation project	Revision of flat loss representation to flow dependent loss functions with some model refinements including: - Effluent from Colombo to Yanco Creek, - Flow routing from Yanco Reach to Morundah and better loss representation and - Two storage nodes to describe interaction between surface water and groundwater.

Lower Bidgee	Fit for purpose changes to assess the Nimmie-Caira and Yanga NP projects	Changes required for environmental water diverted to Nimmie-Caira and protecting existing supplementary access
		- Revision of high flow effluent to Nimmie-Caira and returns
		- Moving Maude Balranald demands upstream of Maude weir to:
		    o Deliver Basin Plan intended environmental water to Nimmie-Caira and
		    o Maintain Redbank diversions to Baseline level
		- Implementing fully water recovery of the Nimmie-Caira entitlement and adjusting other entitlements to maintain environmental water recovery required under Benchmark
		    o Adjusting storage nodes to reflect removing irrigators

Model refinements	Rectification of model errors	Non mass balancing issues at KEA nodes

4.2.3 Murray and Lower Darling systems

4.2.3.1 Improved method for environmental accounting

The BP-2800 scenario included an environmental account to account for The Living Murray and Basin Plan environmental water use. Some major limitations in the method used for environmental accounting were identified and the account was never used to limit the supply of environmental water.

The BMWG agreed that including an improved environmental accounting method was required to make the model fit-for-purpose.

This section first explains the accounting method used for the BP-2800 scenario and its limitation. The new method as implemented in the benchmark model is then described. It should be noted that this new accounting method is closely aligned with the key assumptions used in Environmental Event Selection Tool (EEST; MDBA 2012b).

BP-2800 method: accounting at the sites

As described in Section 5.12.4 of MDBA (2012b), the Basin Plan environmental water requirements were described in the model as minimum flow requirements and water used for meeting environmental water demands. The environmental water demand was calculated based on the incremental water order at the location where the demand is generated.

A simple example of how the accounting approach works is illustrated in Figure 2. This example includes one irrigation demand (IR) and three environmental demands (Env). In this example, a constant conveyance loss of 10 GL is assumed. Environmental water use for each Env is calculated as follows:

- Env1 requires a total order of 150 GL. Of this total order, 100 GL is already being delivered to meet irrigation in the most downstream reach. Env1 requires an additional 50 GL to meet the 150 GL target. The additional 50 GL ordered at this site is accounted as environmental use.
- The combined order (150 GL) is propagated upstream to Env2. Adjusting for tributary inflow (20 GL) and conveyance loss (10 GL), the combined order becomes 140 GL (=150-20+10) at the location of Env2. This combined order exceeds the environmental demand at Env2 (100 GL). Therefore no accountable environmental use is incurred at Env2.
- Similar to the previous step, the combined order (140 GL) increases to 150 GL due to conveyance losses in the upstream reach. The environmental demand at Env3 (200 GL) exceeds the combined order by 50 GL. Env3 orders an additional 50 GL, which is accounted as environmental water use.
- In this example, the total water accounted as environment use is 100 GL (50 GL to Env1, 50 GL to Env3). The head storage has to release 90 GL to meet all downstream needs.

Figure 2: Ordering system for downstream needs with assumption of 10 GL loss per reach and water used for environment as per the existing method

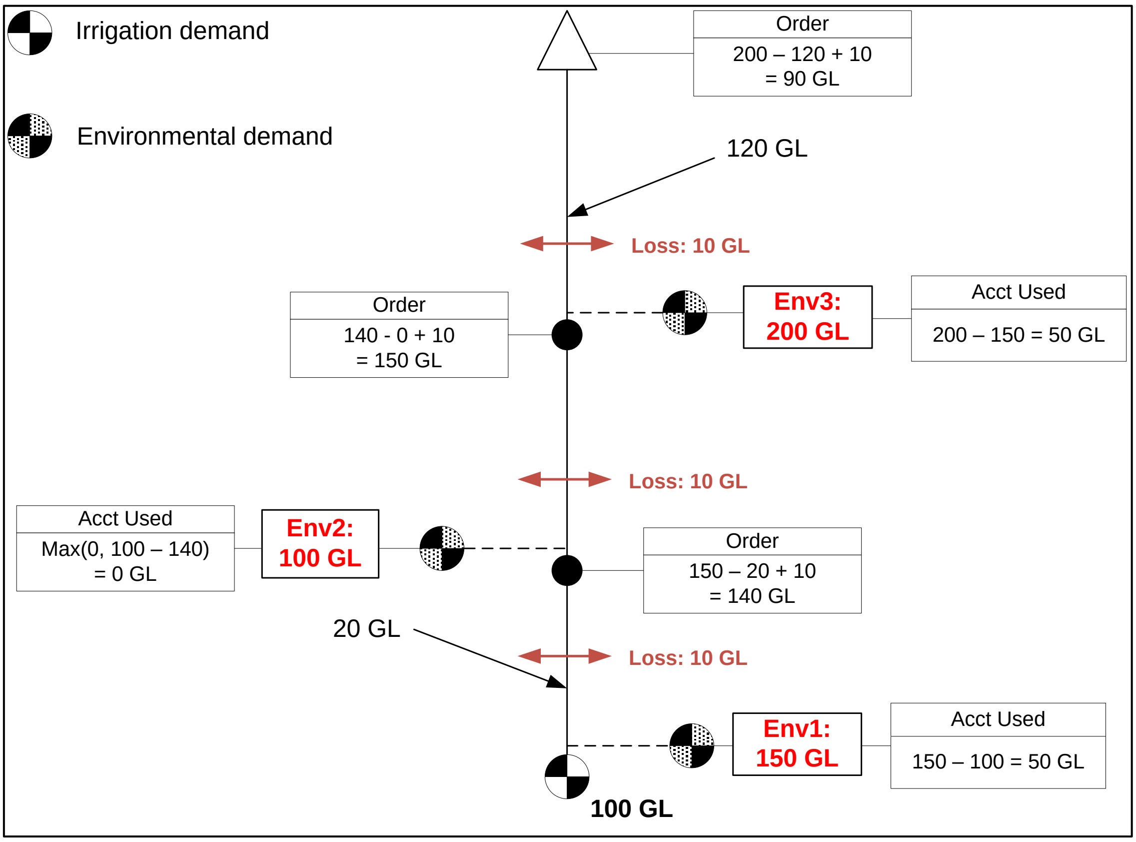


Figure 3 illustrates the flows resulting from the above described orders assuming that the head storage makes regulated release as ordered. The flow arriving at the end of each reach meets all required downstream water needs, but shows some excessive flow volumes at the two downstream locations. The excessive flows are because the upstream demand (i.e. ED 3) dominates regulated release required from the head storage.

This accounting method may be reasonable when the river system is under regulated conditions. During unregulated events, accounted use can be over-estimated because unregulated events can meet at least part of the environmental flow requirements. As described earlier, the EEST looks at an opportunity to reinstate events which occurred under without development conditions, but were removed under baseline conditions. As such, environment demands are most likely to build on unregulated events caused by a combination of spill from the head storages and inflows from tributaries. The accounting approach described above (Figure 2) resulted in over-estimates of accounted environmental use and caused inaccurate calculation during the resource assessment process. This subsequently affected the model calculation of irrigation allocations and diversions.

Figure 3: Flow routing with regulated release from head storage as per Figure 2.

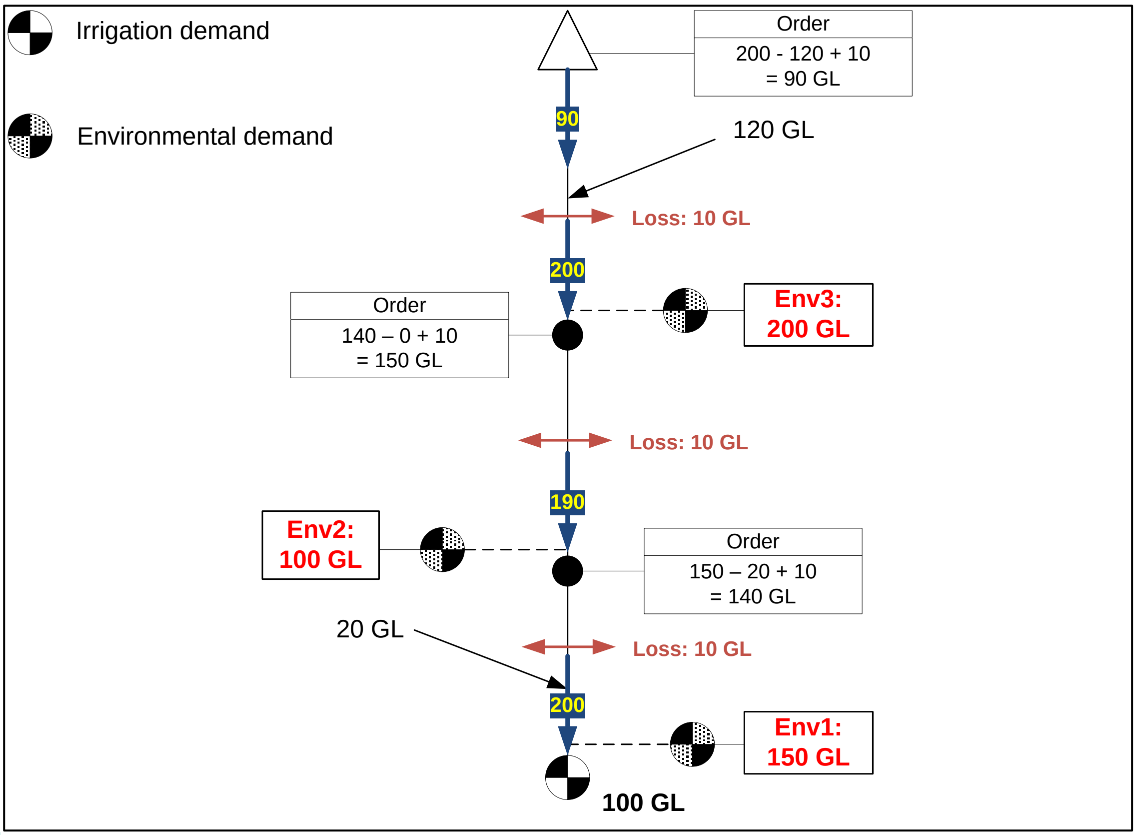


Figure 2

Benchmark model method: accounting at the sources

A new environmental accounting method was developed which accounts for environment water as the additional releases made from storages. This approach better aligns with the assumptions used in the EEST.

To implement this approach, Murray Monthly Simulation Model (MSM) was modified to iterate through the entire ordering phase twice. The first iteration calculates the required release from storages to meet irrigation demands and operational requirements, but assumes environmental demands are zero. The second iteration repeats the first iteration, but sets the environmental demands to the required volume. The additional release from storage in the second iteration, relative to iteration 1, is the additional water released from storages to meet environmental demands.

Figure 4: Ordering system for irrigation needs only with assumption of 10 GL loss per reach at the first iteration of the proposed accounting method

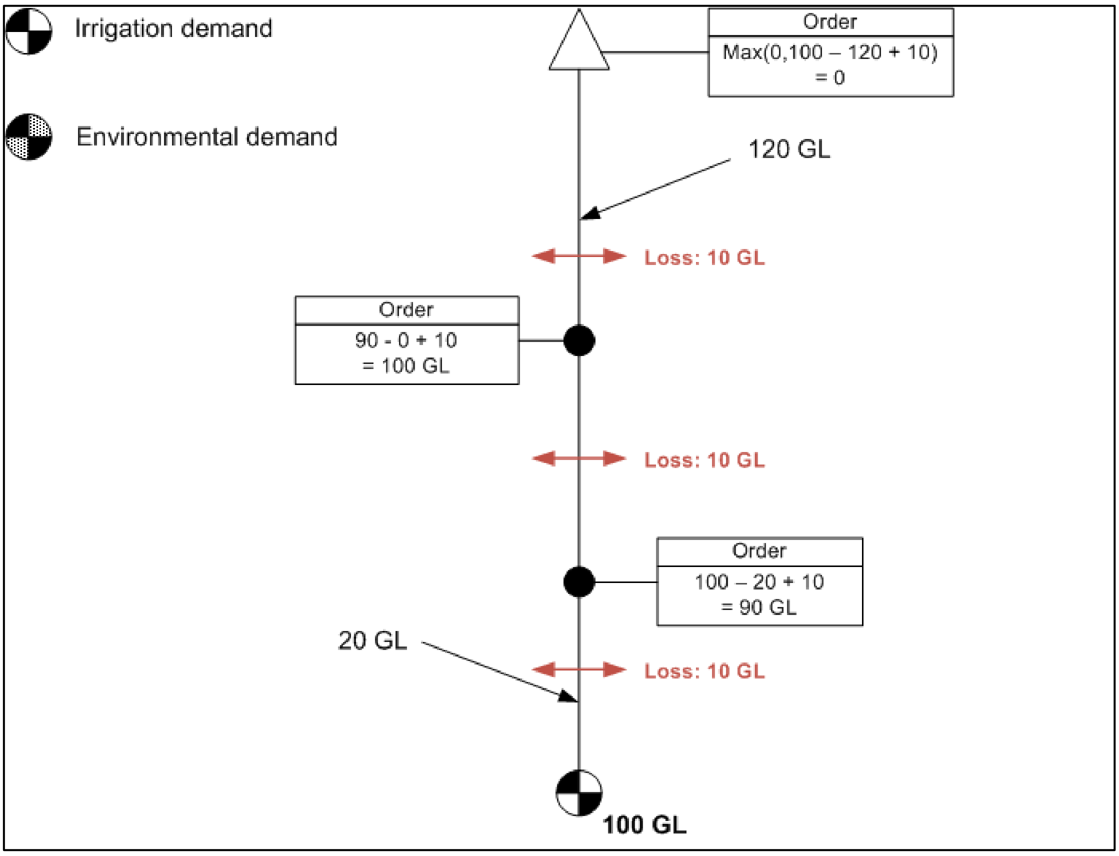


Figure 4 shows the same example used before (Figure 2) but the environmental demands are set to zero. The 100 GL irrigation order is adjusted for conveyance losses (10 GL+10 GL +10 GL) and tributary inflows (20 GL +120 GL). No release is required from the head storage in this example as the irrigation demand and losses are met by tributary inflows. When the environmental demands are considered in the second iteration, the release from the head storage becomes 90 GL as shown in Figure 2. Therefore 90 GL would be accountable at the storage which should be compared with 100 GL from the BP-2800 method. If the storage spills, the accounted volume will be reduced and if the spill is bigger than 90 GL, nothing will be accounted.

For the Murray system, there are two storages located near the SA border (Menindee Lakes and Lake Victoria) where no information of Hume releases is available during the ordering phase, due to the nature of the ordering calculation. In this case, the initial estimations are revisited when flows are known. When Menindee Lakes cut back releases, because enough water is coming down from the main river system, the initial estimate is reduced by the cut back volume. For accounting at Lake Victoria, it is assumed that the volume of environmental water available to meet demands downstream of Lake Victoria is the sum of 70% of environmental water released from Hume, 70% of environmental flow delivered to McCoy's Bridge (Goulburn) and 85% of environmental flow delivered to Balranald (Murrumbidgee).

In the benchmark model environmental water delivery is limited to available water in the environmental account. When there is not enough water to fully meet environmental demands, partial watering is modelled using as much environmental water as is available. MDBA carried out comparative model runs with and without environmental demands and found that the impact on environmental outcomes was minimal.

Lower Murray account changes

A further refinement to the environmental accounting was required on the Murray to prevent environmental water from being re-regulated at Lake Victoria. The volume of environmental flow in the Murray is calculated and rules are implemented to prevent the volume from being stored in Lake Victoria.

The calculated volume of environmental flow is based on the additional release from Hume to meet environmental demands (as described above), as well as estimates of Basin Plan environmental water entering the Murray from the main tributaries (Goulburn and Murrumbidgee).

The Goulburn Simulation Model (GSM) includes an environmental account, which keeps track of the volume of environmental water supplied to the Murray. In the SDL_{BM} model, the link between the GSM and Murray model was updated, so that the environmental flow volume is extracted from the GSM output and provided as an input the Murray model. For the Murrumbidgee, a similar process to the environmental account (section 4.2.2.1) is used to separate environmental flows from total flows at Balranald.

4.2.3.2 Updated The Living Murray modelling

The Murray model used for BP-2800 already included operating strategies for delivering The Living Murray (TLM) water to the Icon Sites, described in the TLM Stage 2 report (MDBA 2008 & 2013a). However, since implementing the TLM Stage 2 modelling, the model's representation of the Icon Sites and the TLM operation strategies were further developed. Based on hydrodynamic modelling, more explicit and detailed representations of the TLM icon sites were included in the Murray model and were calibrated against existing data such as historical flows and results from hydrodynamic models. Subsequently, the representation of proposed operating strategies was improved in consultation with States and Catchment Management Authorities. With detailed water balance models for the Icon Sites, the model is able to calculate overbank flows naturally occurring to the sites more accurately, thereby allowing more accurate estimation of TLM water required to achieve targeted environmental outcomes. SDLA TWG members agreed on the use of the latest TLM icon site representation and operating strategies for assessing SDL adjustment of the TLM works on the basis of their close resemblance of how the works will be operated. For the benchmark outcomes to be compatible with SDL adjustment scenarios, it was necessary to bring the detailed representation of the water balance models for the Icon Sites into the benchmark model.

In order not to alter the model's overall calculation by calibration at the local scale, high flow losses in the reach were adjusted, making sure that the resulting long-term average of total losses in the reach were similar to the previous model. This still resulted in some differences in modelled flows and environmental outcomes, mostly due to changes made to Koondrook-Perricoota Forest, where overbank flows are diverted from upstream and downstream of Torrumbarry Weir and returned to the Edward-Wakool system. The new model with explicit representation and calibration of the Koondrook-Perricoota Forest results in more water being passed through the Edward-Wakool system (MDBA 2010, MDBA 2011c). Comparison between modelled and historical flows at Swan

Hill and Kyalite (Figure 5 and Figure 6) indicates model performance improved after adding the Icon Sites explicitly.

The Murray model, with updated icon site representations for all icon sites except Chowilla was submitted to an independent auditor for Cap and BSMS accreditations (MDBA 2013c). These reports include more detailed information on changes of TLM modelling approaches.

Since then, the MDBA has been working with South Australian members of the SDLA TWG to also refine the representation of the Chowilla floodplain and Chowilla operation strategies, based on results from a detailed hydrodynamic model (MDBA 2016c). This more detailed floodplain representation has also been included in the Benchmark model. Details can be found in MDBA (2014, 2016d).

Figure 5: Modelled versus historical monthly flows at Swan Hill, for the period from 1983 to 2009, with diversions and releases from Dams fixed to historical data.

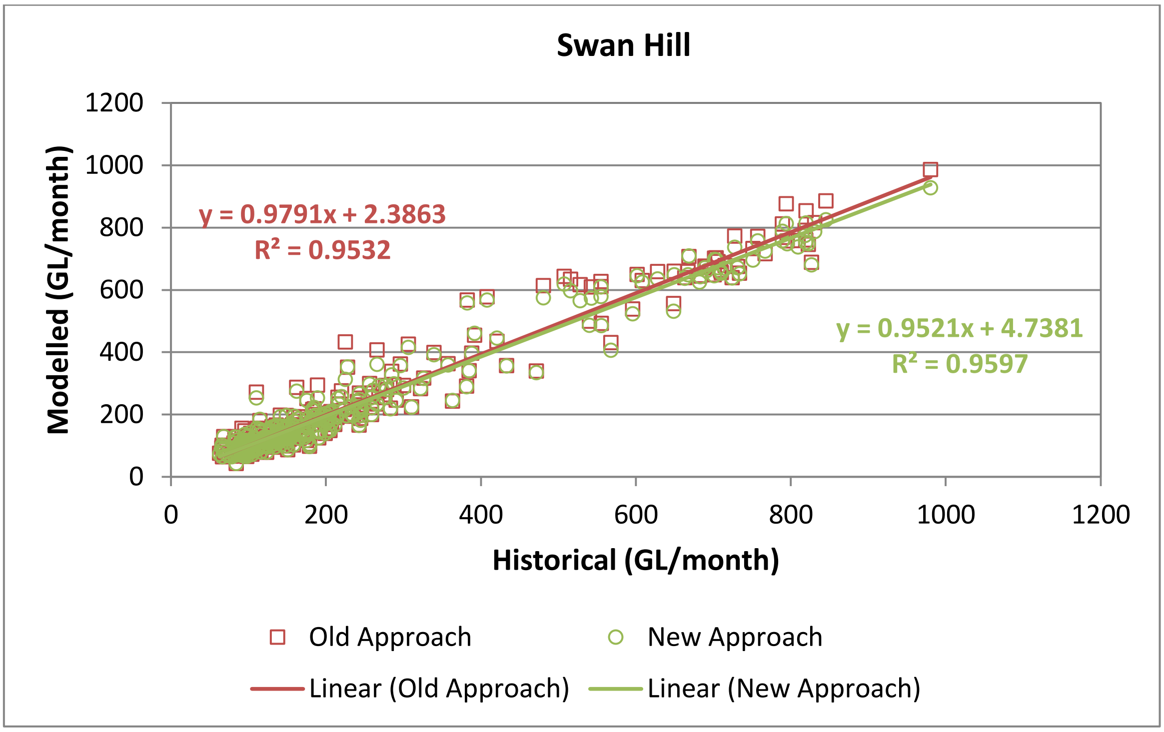
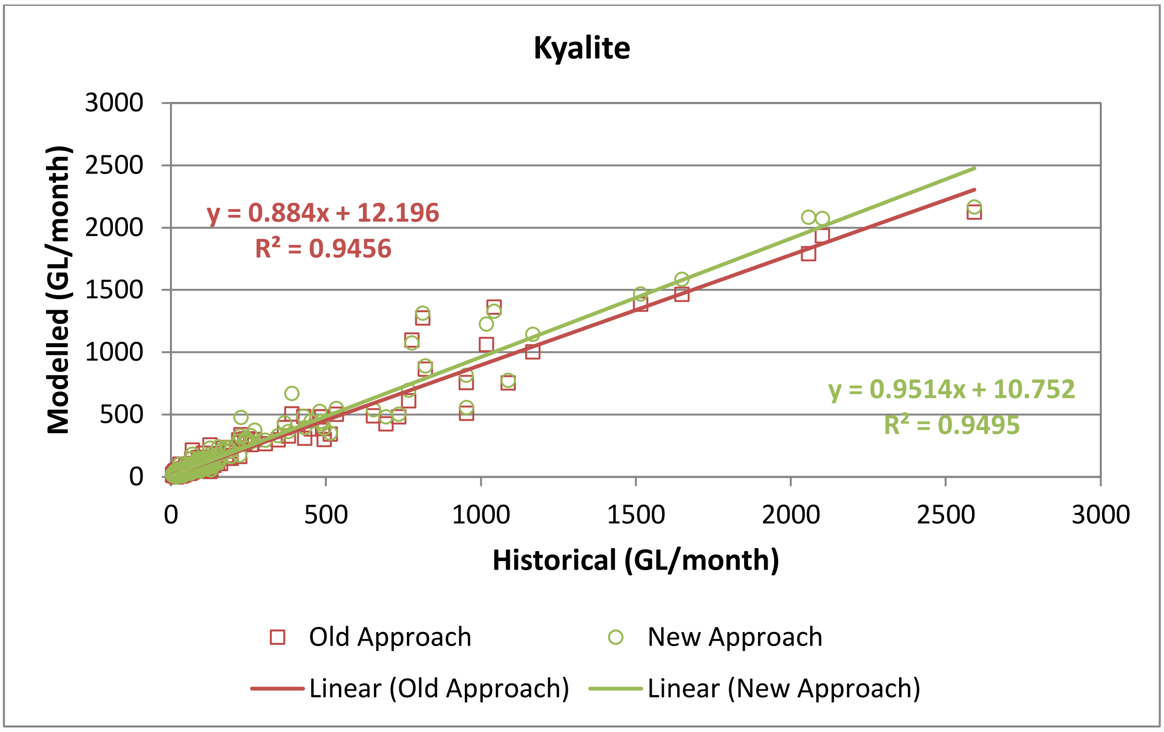


Figure 6: Modelled versus historical monthly flows at Kyalite, for the period from 1983 to 2009, with diversions and releases from Dams fixed to historical data.



4.2.3.3 Finley escape

At Finley escape channel, water flows from the Murray to the Murrumbidgee. In the BP-2800 scenario, flows from Finley escape were modelled (in the Murray model) based on the historical data up to 2000. Even though it was based on the best available data at the time of calibration, it was highly affected by a historical peak in 1995, leading to an elevated long term average. As a non-mandated change, the inflows were recalibrated against the historical data up to June 2009 to improve the inflow estimate and better reflect benchmark conditions (Figure 7 and Table 7). The Finley escape inflow in the Murrumbidgee model has been updated with the updated Finley escape flow as calculated in the Murray model.

Figure 7: Historical and modelled flows in Finley escape

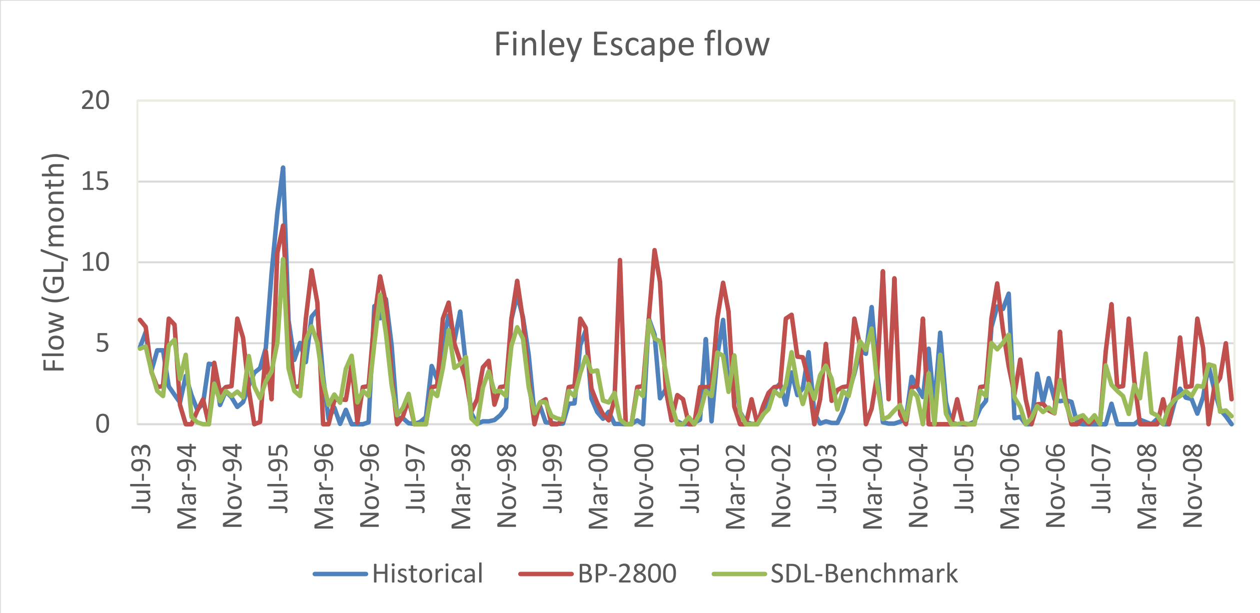


Table 7: Annual average flow in Finley escape over the 1993-2009 period and the 1895-2009 period

Flow (GL/y)	Historical	BP-2800	SDL_{BM}
Average over 1993-2009 period	26	34	26
Average over 1895-2009 period	-	42	28

4.2.3.4 River Murray Increased Flows (RMIF)

In 2002, the Snowy Water Initiative was established to achieve improvements in river health by releasing environmental water to the Snowy, Murrumbidgee and Murray Rivers. This program recovered a significant volume of water and allowed up to an additional 70 GL each year to be released to the Murray for environmental purposes. Rules governing the release of this water are known as the River Murray Increased Flows (RMIF).

In 2011, Schedule 4 of the Snowy Water License (SWL) was amended. The variation included five key changes:

- The removal of the requirement to release any accumulated Dry Inflow Sequence Volume (DISV), as soon as the inflows to the Snowy Scheme allow
- The establishment of a Drought Account to be used when inflows to the scheme are at critically low levels
- Call out provision of water recovered under RMIF (previously the release of this water was at the discretion of Snowy Hydro Limited)
- An option for Snowy Hydro Limited (SHL) to release water in excess of the Required Annual Release (RAR) with the additional release treated as an early delivery of the next year's RAR, called as "Flexibility Release", and
- When the Flexibility Release results in spill from Hume in the following water year, the release does not count as the next year's RAR, known as "wet sequence protection".

Based on these variations, NSW and Victorian governments put forward a supply measure using the call out provision of RMIF for meeting environmental needs in contrast to being released at SHL's discretion. In order for the measure to be modelled in a technically sound and robust manner, the Murray model (MSM) had been updated to simulate the variations with best information available. MDBA (2016e) and MDBA (2016f) describe assumptions used in the model and the changes required to the SDL_{BM}.

4.2.3.5 Work sites representation

There are a number of SDL adjustment proposals that involve environmental works to be able to deliver water to the sites at lower river flows than required under natural conditions. These proposals are:

- Belsar-Yungera Floodplain management project
- Burra Creek Floodplain management project
- Gunbower National Park environmental works project
- Guttrum and Benwell Forests environmental works project
- Hattah Lakes North Floodplain management project
- Lindsay Island Floodplain management project
- Nyah Floodplain management project
- Vinifera Floodplain management project
- South Australian Riverland Floodplain Integrated Infrastructure Program (SARFIIP): Pike and Katarapko Floodplain project
- South east flows restoration project
- Wallpolla Island Floodplain management project

To be able to model the SDL adjustment works proposals, these work sites had to be represented explicitly in the model. A description of the implementation of the works in the Murray model is provided in the report describing the Modelling Assessment to determine SDL adjustment volumes (MDBA, 2017c). The more detailed representation of the work sites has also been included in the Benchmark model. However, given the works are not operated in the Benchmark scenario these changes would have a limited impact on the Benchmark model results.

4.2.3.6 Operational loss recalibration

Operational loss is the term used to describe the volume of water released from storage in excess of the release required to meet the downstream demands. In determining releases from Hume, river operators need to make forecasts of the demands, tributary inflows, river losses and changes in river storage. In making these forecasts, operators balance risks of having adverse impacts on water supply reliability and failing to meet demands. With uncertainty in each of these inputs and a conservative approach to ensuring demands can be met, river operators may make releases in excess of what is required to meet demands.

MDBA's Monthly Simulation Model (MSM) (used for BP-2800) includes a regression equation to predict the operational loss in the River Murray System. This regression equation includes the following variables:

- Modelled orders to Hume
- Inflows from Kiewa and Ovens
- A product of gross diversions and rainfall
- Monthly constants

It has been proven that the representation of operational loss in the model by the fitted equation worked very well for most model applications. However, recent modelling for Basin Plan development and SDL adjustment found that the application of the regression equation may be limited if operations are changed significantly from those the regression was based on. It was found that the regression relationship in the model may not be applicable for SDL adjustment assessment, due to a number of factors including evolutionary improvements to operator skill, operational changes triggered by the millennium drought, and shifts in traditional demand patterns as entitlement moves from irrigation to the environment.

In response, the MDBA established a review committee involving the State jurisdictions, tasked with identifying and resolving the key issues impacting on the fitness of the regression model to predict future operating losses. The technical issues discussed and materials provided to the committee are described in MDBA (2017c).

Three key factors were identified as having the greatest influence on the predictive capability of the model, and in regard to those the review committee agreed that:

- the regression equation should be calibrated for the 2000-2016 period, to incorporate the full range of seasonal conditions and better reflect the change in operations driven by the Millennium drought.
- omitting environmental diversions in the equation would not be appropriate, in light of the significant and increasing volume of entitlement now controlled for environmental purposes.
- the regression equation should exclude water ordering, but should include a water availability term (NSW + VIC allocation), in addition to the Kiewa and Ovens inflows, and the product of diversions and rainfall and monthly constants.

The recommendations and agreed position (including agreed coefficients and constants) have been documented in MDBA (2017c and 2017d).

4.3 Other key assumptions

MDBA (2012b) describes key modelling assumptions and methods used to develop BP-2800 in detail. Therefore, they are not repeated here except for the changes made to the model as identified in Sections 4.1 and 0. However, there are some assumptions that are not described in MDBA (2012b) but included in BP-2800 and SDL_{BM}.

4.3.1 Pre-requisite policy measures

Section 7.15 of the Basin Plan requires the MDBA to remove any unimplemented policy measures from the benchmark model prior to calculation of the amount of SDL adjustment.

Unimplemented policy measures means an anticipated measure consisting of a policy to:

a) Credit environmental return flows for downstream environmental use;
b) Allow the call of held environmental water from storage during un-regulated flow events.

Pre-requisite policy measures (PPMs) is the term used to describe these unimplemented policy measures which were assumed to be addressed when establishing the SDL. The first PPM is reflected in the model as an environmental accounting treatment which is described in section 4.2.3.1. When environmental water use is accounted against additional water released from head storages, return flows from an upstream site are protected to help meet downstream environmental requirements. Additional environmental water protection is included in the model using the Lower Murray account. This account protects environmental return flows from being re-regulated at Lake Victoria so that additional environmental water releases from storages can reach the Lower Lakes, providing the additional releases are not consumed to meet environmental demands at upstream sites.

The second PPM is inherent in the development of the EEST. The selection of environmental demands in the EEST is based on reinstating events that existed under the Without Development conditions, but are captured by river regulation under the Baseline conditions. The environmental demands, especially for floodplain outcomes, coincide with un-regulated flow conditions so that spill events can be boosted or extended to provide bigger environmental outcomes.

PPM implementation plans have been developed for the southern system. These plans describe how the states and the MDBA will implemented the required PPMs by June 2019. The MDBA has assessed these plans and concluded that the plans provide a credible for implementing the PPMs assumed in the Basin Plan by June 2019.

5 Environmental outcomes for valleys of the Southern Connected system

This section presents environmental outcomes achieved for the southern connected basin for the BP-2800 and the final SDL_{BM} scenario that includes all described (mandated and non-mandated) changes to BP-2800.

5.1 Specific flow indicators

5.1.1 Overbank flow indicators

In developing the Basin Plan, environmental outcomes were evaluated through achievement of site-specific flow indicators (SFIs). Specific flow indicators define events as a specified combination of flow magnitude, timing, duration and frequency and were developed for 9 hydrological indicator sites within the Southern Basin. The environmental outcomes were evaluated by comparing how frequently the SFIs were achieved (over the 114 years of climate records) against a target frequency specified as part of the SFI.

Results for SFIs for overbank flow events are summarised in Table 8. Results presented for BP-2800 are slightly different from that reported in MDBA (2012b), due to an error correction. This correction ensures that the BP-2800 (847) result reported here is comparable to those for the benchmark scenario.

Table 8: Proportion of years with a successful event for overbank flow indicators in the southern connected basin.

Upper Murray Reach (measured at Yarrawonga DS)	BP-2800	SDL_{BM}
12,500 ML/d for a total duration of 70 days (with min duration of 7 consecutive days) between Jun & Nov	83%	76%
16,000 ML/d for a total duration of 98 days (with min duration of 7 consecutive days) between Jun & Nov	58%	53%
25,000 ML/d for a total duration of 42 days (with min duration of 7 consecutive days) between Jun & Nov	43%	50%
35,000 ML/d for a total duration of 30 days (with min duration of 7 consecutive days) between Jun & May	30%	36%
50,000 ML/d for a total duration of 21 days (with min duration of 7 consecutive days) between Jun & May	16%	17%
60,000 ML/d for a total duration of 14 days (with min duration of 7 consecutive days) between Jun & May	11%	14%
15,000 ML/d for a total duration of 150 days (with min duration of 7 consecutive days) between Jun & Dec	38%	35%

Upper Central Murray Reach (measured at Torrumbarry DS)	BP-2800	SDL_{BM}
16,000 ML/d for a total duration of 90 days (with min duration of 7 consecutive days) between Jun & Nov	68%	68%
20,000 ML/d for a total duration of 60 days (with min duration of 7 consecutive days) between Jun & Nov	60%	64%
30,000 ML/d for a total duration of 60 days (with min duration of 7 consecutive days) between Jun & May	38%	40%
40,000 ML/d for a total duration of 60 days (with min duration of 7 consecutive days) between Jun & May	18%	24%
20,000 ML/d for a total duration of 150 days (with min duration of 7 consecutive days) between Jun & Dec	27%	26%

Lower Central Murray Reach (measured at Euston DS)	BP-2800	SDL_{BM}
40,000 ML/d for a total duration of 60 days (with min duration of 7 consecutive days) between Jun & Dec	46%	46%
50,000 ML/d for a total duration of 60 days (with min duration of 7 consecutive days) between Jun & Dec	32%	30%
70,000 ML/d for a total duration of 42 days (with min duration of 7 consecutive days) between Jun & Dec	17%	18%
85,000 ML/d for a total duration of 30 days (with min duration of 7 consecutive days) between Jun & May	13%	11%
120,000 ML/d for a total duration of 14 days (with min duration of 7 consecutive days) between Jun & May	8%	8%
150,000 ML/d for a total duration of 7 days (with min duration of 7 consecutive days) between Jun & May	5%	6%

Lower Murray Reach (measured with flow to SA)	BP-2800	SDL_{BM}
40,000 ML/d for a total duration of 30 days (with min duration of 7 consecutive days) between Jun & Dec	61%	55%
40,000 ML/d for a total duration of 90 days (with min duration of 7 consecutive days) between Jun & Dec	35%	38%
60,000 ML/d for a total duration of 60 days (with min duration of 7 consecutive days) between Jun & Dec	25%	27%
80,000 ML/d for a total duration of 30 days (with min duration of 7 consecutive days) between Jun & May	14%	15%
100,000 ML/d for a total duration of 21 days (with min duration of 1 day) between Jun & May	5%	7%
125,000 ML/d for a total duration of 7 days (with min duration of 1 day) between Jun & May	4%	5%

Edward-Wakool Reach (measured at Deniliquin)	BP-2800	SDL_{BM}
5,000 ML/d for a total duration of 60 days (with min duration of 7 consecutive days) between Jun & Dec	63%	66%
5,000 ML/d for a total duration of 120 days (with min duration of 7 consecutive days) between Jun & Dec	36%	36%
18,000 ML/d for a total duration of 28 days (with min duration of 5 consecutive days) between Jun & Dec	16%	16%
30,000 ML/d for a total duration of 21 days (with min duration of 6 consecutive days) between Jun & Dec	11%	13%

Lower Darling (measured at Weir32)	BP-2800	SDL_{BM}
17,000 ML/d for 18 consecutive days between Jun & May	24%	21%
20,000 ML/d for 30 consecutive days between Jun & May	11%	11%
25,000 ML/d for 45 consecutive days between Jun & May	8%	8%
45,000 ML/d for 2 consecutive days between Jun & May	7%	7%

Mid-Murrumbidgee (measured at Narrandera)	BP-2800	SDL_{BM}
26,850 ML/d for a total duration of 45 days (with min duration of 1 day) between Jul & Nov	14%	11%
26,850 ML/d for 5 consecutive days between Jun & Nov	59%	60%
34,650 ML/d for 5 consecutive days between Jun & Nov	40%	41%
44,000 ML/d for 3 consecutive days between Jun & Nov	28%	23%
63,250 ML/d for 3 consecutive days between Jun & Nov	13%	10%

Lower Murrumbidgee (measured at Maude Weir)	BP-2800	SDL_{BM}
Total volume of 175 GL (flow > 5,000 ML/d) between Jul & Sep	92%	94%
Total volume of 270 GL (flow > 5,000 ML/d) between Jul & Sep	85%	86%
Total volume of 400 GL (flow > 5,000 ML/d) between Jul & Oct	82%	83%
Total volume of 800 GL (flow > 5,000 ML/d) between Jul & Oct	56%	60%
Total volume of 1,700 GL (flow > 5,000 ML/d) between Jul & Nov	30%	30%
Total volume of 2,700 GL (flow > 5,000 ML/d) between May & Feb	17%	18%

Lower Goulburn floodplain (measured at Shepparton)	BP-2800	SDL_{BM}
25,000 ML/d for a median duration of 5 days between Jun & Nov	62%	82%
40,000 ML/d for a median duration of 4 days between Jun & Nov	38%	61%

5.1.2 Fresh flows requirement

There are separate indicators developed for fresh flow requirements across the Southern Basin which are provided in Table 9.

Table 9: Proportion of years with a successful event for fresh flow indicators in the southern connected basin.

Murray (measured with flow to SA)	**BP-2800**	**SDL_{BM} 1132**
20,000 ML/d for 60 consecutive days between Aug & Dec	72%	69%

Edward-Wakool (measured at Deniliquin)	**BP-2800**	**SDL_{BM} 1132**
1,500 ML/d for a total duration of 180 days (with min duration of 1 day) between Jun & Mar	95%	94%

Lower Darling (measured at Weir 32)	BP-2800	SDL$_{BM}$ 1132
7,000 ML/d for 10 consecutive days between Jun & May	57%	54%

Lower Murrumbidgee (measured at Maude Weir)	BP-2800	SDL$_{BM}$
1,100 ML/d for 25 consecutive days between Dec & May	68%	47%
4,500 ML/d for 20 consecutive days between Oct & Dec	69%	53%
3,100 ML/d for 30 consecutive days between Oct & Mar	68%	42%

Lower Goulburn floodplain (measured at Shepparton)	BP-2800	SDL$_{BM}$
Two events annually of 2,500 ML/d for 4 consecutive days (with min duration of 30 days between events) between Dec & Apr	26%	56%
5,000 ML/d for 14 consecutive days between Oct & Nov	35%	59%

The indictors to determine the limits of change for the CLLMM (Basin Plan S6.07c) are shown in Table 10.

Table 10: Flow and Salinity limits of change indicator achievement for the Coorong, Lower Lakes and Murray Mouth

CLLMM – limits of change indicators	BP-2800	SDL$_{BM}$
% of time salinity in Lake Alexandrina < 1500 EC	100%	100%
% of time salinity in Lake Alexandrina < 1000 EC	99%	99%
% of years with 3yr rolling average barrage flow > 2,000 GL/y, with a minimum of 650 GL/y	97%	97%
% of years with 2yr rolling Barrage flow > 600 GL	100%	100%
% of time when salinity in south Coorong < 100 g/L	99%	100%
% of years with average annual depth at Murray Mouth > 1 m	96%	93%
% of years with average annual depth at Murray Mouth > 0.7 m	98%	96%

5.2 Baseflow shortfalls

The achievement of baseflow requirements was assessed via volumetric shortfalls, defined as the mean annual volume of additional water required to meet the baseflow requirement time-series (MDBA 2012b). The annual average requirement and shortfalls are presented in Table 11.

Table 11: Annual average baseflow requirement and baseflow shortfalls for BP-2800 and SDL_{BM} (GL/y).

Site description	Baseflow requirement	BP-2800	SDL_{BM}
Murrumbidgee @ Darlington Point	645	4	1
Murrumbidgee @ Balranald	597	27	21
Goulburn @ U/S Goulburn Weir	757	1	0
Goulburn @ McCoys Bridge	746	2	0
Campaspe @ U/S Campaspe Weir	19	0	0
Campaspe @ Rochester	36	0	0
Loddon @ U/S Serpentine Weir	12	0	0
Loddon @ Appin South	12	0	0
Murray @ D/S Yarrawonga Weir	1469	3	2
Murray River @ D/S Torrumbarry	2002	17	4
Murray River @ D/S Euston	2999	0	9
Murray River @ Flow to SA	3220	4	9
Darling @ Burtundy	151	4	1

5.3 Ecological outcome scores

For the assessment of SDL adjustment scenarios, an ecological element scoring method is to be used to determine whether the overall environmental scores are equivalent to ones achieved under the Benchmark conditions (Schedule S6.05 of the Basin Plan). The MDBA commissioned CSIRO to develop a science based and fit for purpose method of calculating ecological element scores (Overton et al., 2015). The ecological outcomes scores based on this method are reported for the SDL_{BM} scenario only. Ecological outcome scores are not reported for the BP-2800 scenario, as this scenario preceded the development of the ecological outcome scoring method and included different specific flow indicators for Goulburn (section 0) and operation of the TLM works (section 4.1.5), which would lead to inconsistencies in the calculation of scores.

The ecological outcomes assessment required determination of the ecological outcome scores for three different starting conditions (minimum-poor, medium-average and maximum-good condition) and the test of equivalence requires the scores to be met for all three cases (Overton et al., 2015). The overall outcome scores for the three starting conditions are reported in Table 12.

Table 12: Ecological outcomes scores for the reaches, based on the maximum starting condition.

Reach	Minimum starting conditions	Medium starting conditions	Maximum starting conditions
Upper Murray	4933	5100	5188
Upper Central Murray	5408	5567	5685
Lower Central Murray	3278	3387	3505
Lower Murray	3860	3970	4067
Edward Wakool river system	4009	4169	4246
Goulburn River	8077	8219	8219
Lower Darling River	2685	2791	2874
Mid- Murrumbidgee River	4487	4646	4864
Lower Murrumbidgee River	6345	6502	6582
Southern basin region score	**4787**	**4928**	**5026**

Detailed outcome scores for each ecological element and ecological class are reported in Appendix 1.

6 Final remarks

This report describes the benchmark conditions of development assumed in the SDL benchmark model scenario, which is to be used for calculating the amount of SDL adjustment of supply measures in the southern connected basin (as described in Schedule 6 of the Basin Plan). This model scenario is based on MDBA model run 847 (the BP-2800 scenario described in MDBA, 2012b) with a number of mandated and non-mandated refinements.
This report describes how the mandated and non-mandated changes to BP-2800 were included into the models to develop the SDL Benchmark scenario (SDL_{BM}).

The model and results described in this report are relevant only for the purposes of SDL-adjustment determination. The results do not represent estimates of the SDL as defined in the Basin Plan. The BDL and SDL estimates are dependent on the developmental conditions as described in Schedule 2 and Schedule 3 of the Basin Plan.

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Appendix 1: Ecological element and ecological class scores for all for each reach

Starting condition			Minimum starting condition			Medium starting condition			Maximum starting condition		
Region score:			**4787**			**4928**			**5026**		
Reach	**Class**	**Ecological element**	**EE-score**	**EC-score**	**Reach score**	**EE-score**	**EC-score**	**Reach score**	**EE-score**	**EC-score**	**Reach score**
River Murray Upper Reach (Barmah-Millewa Forest)	Bird	Waterbirds - health	4372	3301	4933	4456	3485	5100	4622	3526	5188
		Bitterns, crakes and rails	2219			2868			2868		
		Colonial-nesting waterbirds	3140			3140			3140		
		Waterbirds - breeding	3474			3474			3474		
	Vegetation	River Red Gum forests	5096	4741		5371	4986		5566	5158	
		River Red Gum woodlands	4269			4534			4844		
		Blackbox -forests and woodlands	4036			4335			4644		
		Shrublands	na			na			na		
		Tall Grasslands, sedge and rushlands	4234			4426			4460		
		Benthic herbland	6068			6263			6274		
	Fish	Short-lived fish	6917	6759		6961	6831		7006	6880	
		Long-lived fish	6600			6701			6753		
River Murray Upper Central Reach (Gunbower-Koondrook-Perricoota)	Bird	Waterbirds - health	4560	3114	5408	4637	3161	5567	4848	3226	5685
		Bitterns, crakes and rails	2833			2947			2996		
		Colonial-nesting Waterbirds	2351			2351			2351		
		Waterbirds - breeding	2711			2711			2711		
	Vegetation	River Red Gum forests	6139	6040		6568	6396		6812	6636	
		River Red Gum woodlands	6052			6422			6786		
		Blackbox -forests and woodlands	6883			7263			7572		
		Shrublands	na			na			na		
		Tall Grasslands, sedge and rushlands	5085			5332			5375		
		Benthic herblands	na			na			na		
	Fish	Short-lived fish	7188	7071		7233	7142		7275	7192	
		Long-lived fish	6954			7051			7109		
River Murray Lower Central Reach (Hatah-	Bird	Waterbirds - health	1726	1830	3278	1797	1853	3387	1944	1903	3505
		Bitterns, crakes and rails	na			na			na		
		Colonial-nesting waterbirds	1500			1500			1500		
		Waterbirds - breeding	2263			2263			2263		
	Ve ge	River Red Gum forests	3326	2962		3500	3186		3945	3431	

		River Red Gum woodlands	3124			3333			3832		
		Blackbox -forests and woodlands	2457			2733			3142		
		Shrublands	3352			3671			3710		
		Tall Grasslands, sedge and rushlands	2647			2850			2891		
		Benthic herblands	2865			3029			3066		
	Fish	Short-lived fish	5197	5043		5250	5122		5302	5183	
		Long-lived fish	4890			4995			5063		
River Murray Lower Reach (Riverland Chowilla Floodplain)	Bird	Waterbirds - health	2113	2589	3860	2183	2611	3970	2330	2660	4067
		Bitterns, crakes and rails	2382			2399			2452		
		Colonial-nesting waterbirds	2570			2570			2570		
		Waterbirds - breeding	3289			3289			3289		
	Vegetation	River Red Gum forests	3276	3495		3456	3725		3721	3912	
		River Red Gum woodlands	3668			3881			4279		
		Blackbox -forests and woodlands	2429			2704			3053		
		Shrublands	3818			4115			4156		
		Tall grasslands, sedge and rushlands	3500			3705			3743		
		Benthic herblands	4282			4488			4518		
	Fish	Short-lived fish	5863	5495		5916	5575		5968	5630	
		Long-lived fish	5128			5234			5292		
Edward Wakool Reach	Bird	Waterbirds - health	2232	3220	4009	2306	3401	4169	2432	3433	4246
		Bitterns, crakes and rails	5096			5746			5746		
		Colonial-nesting waterbirds	2026			2026			2026		
		Waterbirds - breeding	3526			3526			3526		
	Vegetation	River Red Gum forests	3042	3268		3248	3495		3414	3649	
		River Red Gum woodlands	2868			3099			3417		
		Blackbox -forests and woodlands	2879			3155			3477		
		Shrublands	3611			3897			3941		
		Tall Grasslands, sedge and rushlands	3447			3635			3675		
		Benthic herblands	3760			3936			3968		
	Fish	Short-lived fish	5930	5537		5973	5611		6017	5658	
		Long-lived fish	5145			5248			5298		
Goulburn Reach (Lower Goulburn	Bird	Waterbirds - health	8252	7521	8077	8419	7604	8219	8419	7604	8219
		Bitterns, crakes and rails	na			na			na		
		Colonial-nesting waterbirds	na			na			na		
		Waterbirds - breeding	6789			6789			6789		

	Vegetation	River Red Gum forests	8379	8098		8765	8413		8765	8413	
		River Red Gum woodlands	8430			8816			8816		
		Blackbox -forests and woodlands	8528			8914			8914		
		Shrublands	na			na			na		
		Tall Grasslands, sedge and rushlands	7665			7875			7875		
		Benthic herblands	7486			7697			7697		
	Fish	Short-lived fish	8651	8613		8651	8639		8651	8639	
		Long-lived fish	8574			8627			8627		
Lower Darling Reach	Bird	Waterbirds - health	970	1432	2685	1040	1467	2791	1172	1533	2874
		Bitterns, crakes and rails	na			na			na		
		Colonial-nesting waterbirds	na			na			na		
		Waterbirds - breeding	1895			1895			1895		
	Vegetation	River Red Gum forests	1870	1985		2028	2188		2212	2319	
		River Red Gum woodlands	na			na			na		
		Blackbox -forests and woodlands	1524			1788			2125		
		Shrublands	2887			3176			3220		
		Tall Grasslands, sedge and rushlands	2001			2185			2229		
		Benthic herblands	1642			1764			1808		
	Fish	Short-lived fish	4767	4637		4820	4716		4872	4769	
		Long-lived fish	4508			4613			4666		
Mid-Murrumbidgee Reach	Bird	Waterbirds - health	1619	2614	4487	1690	2723	4646	1902	2778	4864
		Bitterns, crakes and rails	4496			4861			4867		
		Colonial-nesting Waterbirds	2000			2000			2000		
		Waterbirds - breeding	2342			2342			2342		
	Vegetation	River Red Gum forests	4319	4704		4603	5008		5101	5530	
		River Red Gum woodlands	4818			5122			5837		
		Blackbox -forests and woodlands	5434			5881			6734		
		Shrublands	na			na			na		
		Tall Grasslands, sedge and rushlands	4247			4427			4450		
		Benthic herblands	na			na			na		
	Fish	Short-lived fish	6563	6143		6596	6207		6629	6285	
		Long-lived fish	5723			5819			5942		
Lower Murrumbidgee Reach	Bird	Waterbirds - health	5880	5233	6345	6117	5340	6502	6206	5362	6582
		Bitterns, crakes and rails	3702			3890			3890		
		Colonial-nesting Waterbirds	4811			4811			4811		

		Waterbirds - breeding	6541			6541			6541		
	Vegetation	River Red Gum forests	7051	6443		7462	6772		7663	6952	
		River Red Gum woodlands	6747			7210			7586		
		Blackbox -forests and woodlands	7036			7515			8014		
		Shrublands	5978			6369			6369		
		Tall Grasslands, sedge and rushlands	6780			6929			6933		
		Benthic herblands	5066			5146			5147		
	Fish	Short-lived fish	7498	7359		7505	7394		7512	7432	
		Long-lived fish	7221			7284			7352		