# TECHNICAL NOTE 2012/01

Department of Environment, Water and Natural Resources

## SCIENCE REVIEW OF MDBA MODELLING OF RELAXING CONSTRAINTS FOR BASIN PLAN SCENARIOS

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- Jim Cox (Chair), SARDI/ University of Adelaide
- Qifeng Ye, SARDI
- Jason Nicol, SARDI
- Ian Overton, CSIRO
- Todd Wallace, University of Adelaide
- David Paton, University of Adelaide

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# EXECUTIVE SUMMARY

This report presents a science analysis and interpretation of ecological outcomes for key environmental assets in the River Murray, South Australia, based on modelling outputs generated by the Murray-Darling Basin Authority (MDBA). This modelling expanded on the previously modelled water recovery scenarios of 2800 GL and 3200 GL, and tested whether the relaxation of key river system constraints would improve the delivery of environmental watering events, in particular those that inundate mid- to upper-floodplain habitats. This comparative analysis has focussed on the following scenarios:

- BP2800: representative of the current proposed Basin Plan with a water recovery volume of 2800 GL (expressed as 2750 GL in the current proposed Basin Plan document)
- BP2800RC: a water recovery volume of 2800 GL with key constraints relaxed
- BP3200: a water recovery volume of 3200 GL, i.e. an increase of 400 GL compared to the current proposed Basin Plan scenario (BP2800)
- BP3200RC: both an increase in the water recovery volume and relaxation of key constraints compared to the current proposed Basin Plan scenario (BP2800)

The improvements or differences in ecological outcomes from the different scenarios have been assessed for the environmental watering demands in South Australia: the Riverland-Chowilla site (representing the South Australian River Murray floodplain and channel), the Coorong, Lower Lakes and the Murray Mouth. These assessments have considered:

- South Australian River Murray floodplain and channel
    - changes in flow to South Australia and the improved delivery of environmental watering events
    - frequency of events meeting floodplain Environmental Water Requirements (EWRs) defined by South Australia
    - flow rates (representing an area of floodplain) that had a component of each EWR met
    - an analysis of partially successful events using the Murray Flow Assessment Tool over both the whole modelled period, as well as individual requested watering events
- Lower Lakes
    - barrage outflows
    - water levels
    - salinity and salt export
- Coorong and Murray Mouth
    - mouth openness
    - water levels
    - salinity

When assessed against MDBA's flow indicators for environmental water requirements for the floodplain, the BP3200RC scenario resulted in achievement of 17 out of 18 flow indicators for the River Murray in the Southern System, compared to 11 for the current proposed Basin Plan scenario (BP2800) and BP2800RC scenarios and 13 for the BP3200 scenario. This demonstrates the benefits of additional water recovery and relaxation of constraints to key floodplain environments throughout the Southern System of the Murray Darling Basin. The BP3200RC scenario was the only scenario able to achieve the 80,000 ML/d Riverland-Chowilla target relating to mid-floodplain habitats.

Analyses by South Australia supported MDBA's assessment that the relaxing of constraints BP3200RC scenario delivered the greatest benefit to the South Australian River Murray floodplain. The analyses has focused on improvements to the mid-level floodplain habitat inundated by flows of 40 000 ML/d to 80 000 ML/d. Improvement in this range is expected to benefit key vegetation communities such as red gum and lignum and support bird breeding habitat, temporary wetlands and support a mosaic of habitats. The improvement in lateral connectivity between the main channel and off-channel habitats would also benefit native fish by enhancing habitat diversity and riverine productivity in the main channel. The scenario with the next-best level of improvement was the BP3200 scenario, demonstrating that recovery of additional water provides better outcomes compared with relaxing constraints with the level of proposed water recovery under the current proposed Basin Plan scenario.

There was little difference between the four scenarios for the habitat in the river channel (below 40 000 ML/d) or for the high-level floodplain (over 80 000 ML/d).

Analysis for the Coorong, Lower Lakes and Murray Mouth site focussed on the assessment and comparison of metrics relating to water levels and salinity of Lake Alexandrina and Lake Albert, salinity of Coorong North and South Lagoons, water level in South Lagoon, as well as barrage outflows and Mouth openness. It has been demonstrated that increasing the water recovery volume to 3200 GL maximises the benefits to the Coorong, Lakes Alexandrina and Albert together with the Murray Mouth.

The comparative analysis undertaken here has shown that scenarios where constraints are relaxed (BP2800RC and BP3200RC) show some changes in outcomes achieved. Water levels, salinity, mouth openness and barrage releases were all improved compared to the recovery of 2800 GL. Changes to flow delivery sequences under the relaxed constraints scenarios have altered the timing of flow reaching the site in the model resulting in both positive and negative changes compared to scenarios with constraints. This demonstrates that outcomes at the site are sensitive to upstream watering decisions.

As such, although the CLLMM continues to remain at risk of impact during drought, the 3200 GL scenarios (BP3200 and BP3200RC) represents the lowest risk to maintaining the Coorong as healthy and resilient wetland of international importance.

The analysis indicates that recovery of a water volume of 3200 GL and removing key constraints has the potential to achieve greater environmental benefit for South Australian ecological assets, relative to the current proposed Basin Plan BP2800 scenario.

# 1. BACKGROUND AND PURPOSE OF ANALYSIS

## *1.1. BACKGROUND*

In November 2011, the MDBA released the proposed Basin Plan which included an environmental water recovery volume of 2750 GL across the Murray-Darling Basin (MDB). At that time, the MDBA also released a series of model outputs to demonstrate the environmental outcomes to key hydrologic indicator sites in the MDB.

Environmental outcomes in South Australia are represented by two hydrologic indicator sites: the Riverland-Chowilla site (representing the South Australian River Murray floodplain) and the Coorong, Lower Lakes and Murray Mouth (CLLMM). The South Australian Government, through the Department for Water (DFW) and the Department of Environment and Natural Resources (DENR), undertook hydrological and ecological analysis and interpretation of the ecological outcomes for the South Australian River Murray floodplain and CLLMM region (Bloss *et al.* 2012; Heneker and Higham 2012; Higham 2012).

The model outputs received by the South Australian Government represented water recovery volumes of 2750 GL, 2800 GL, 2400 GL, and 3200 GL, as well as Baseline conditions (similar to current conditions) and Without Development conditions (similar to natural conditions). While 2750 GL was the volume included in the proposed Basin Plan, modelling prior to its release was based on 2800 GL. It was understood the 2750 GL model run was based on the 2800 GL run, with inflows from the Northern Basin reduced in the model by an average of 50 GL per year and no change to environmental watering events in the Southern Basin. The 2400 GL and 3200 GL runs were generated to test the sensitivity of the outcomes to the volume of recovered water.

Analysis of the modelled outcomes by both MDBA and DFW/DENR demonstrated that environmental water delivery under the 2750 GL Basin Plan scenario did not meet all South Australian environmental watering targets for the Riverland-Chowilla and CLLMM sites (MDBA 2011a, Bloss *et al.* 2012; Heneker and Higham 2012; Higham 2012). Assessment of a higher water recovery volume of 3200 GL showed that an increase in recovered environmental water would likely provide better outcomes for the CLLMM sites. For the floodplain, mid-to-high floodplain EWRs, such as those inundated by greater than 60 000 ML/d, were not met by any modelled Basin Plan scenarios, with minimal difference to meet these EWRs between the 2400 GL, 2750 GL and 3200 GL water recovery scenarios.

MDBA (2011a) reported that environmental outcomes for mid- to high-level floodplain habitats could not be met due to the impact of flow constraints in the river system (such as rules which prevent the flooding of private property with deliberate water releases), which limit the ability of river operators to influence and manage large flow events, particularly in the Murray. Analysis undertaken by DFW/DENR was unable to confirm this finding, nor demonstrate that additional water would be able to achieve the environmental targets set (Bloss *et al.* 2012). Based on MDBA advice, flows greater than 80 000 ML/d may be difficult to actively deliver in the current regulated system, even if constraints could be addressed. Consequently, South Australian Government submissions emphasised the need to improve delivery of flows in the 40 000 ML/d to 80 000 ML/d range. The recommendation to undertake further investigation and modelling into the relaxation of these constraints was included in the South Australian Government submission on the proposed Basin Plan.

In June 2012, the Ministerial Council requested the MDBA to model a ‘relaxed constraint’ scenario with a sustainable diversion limit (SDL) reduction of 3200 GL. The MDBA subsequently completed and provided model data to South Australia in August 2012: the 2800 GL model run was provided on 23

August 2012 and the 3200 GL run on 30 August 2012. Outputs received from the MDBA included MSM-BIGMOD outputs of flow, water level and salinity in the Murray system, environmental flow selection spreadsheets (‘pick-a-box’) and Coorong hydrodynamic model outputs.

The following abbreviations are used for the modelled scenarios throughout this document: BP2800 and BP3200 refer to the modelled scenarios for the proposed Basin Plan (late 2011) with constraints included and SDL reductions of 2800 GL and 3200 GL respectively; BP2800RC and BP3200RC refer to modelled scenarios with key flow constraints relaxed (August 2012) for SDL reductions of 2800 GL and 3200 GL respectively; BSL refers to Baseline conditions (representative of current development conditions) and WoD refers to Without Development conditions.

## *1.2. PURPOSE OF ANALYSIS*

The analysis focuses on comparing the ecological outcomes of BP2800, BP2800RC, BP3200 and BP3200RC scenarios in South Australia. This analysis is intended to help inform the following questions:

- What are the points of difference between scenarios?
- Are there improvements in the ecological outcomes? Why and where?
- What is the impact of relaxing constraints?
- What is the impact of more water and how does this interface with the presence of constraints?
- How significant are the improvements?

The relaxation of constraints was anticipated to improve the delivery of managed flow events to the mid to high floodplain habitats. Only minor changes to ecological outcomes were expected for the CLLMM region due to the relaxation of constraints since these outcomes were understood to be mainly influenced by annual volumes rather than changes to daily flow rates. Nonetheless, intra- and inter-annual variations in environmental water delivery could influence ecological outcomes. Similarly, outcomes for the River Murray channel and low-level floodplain were not expected to be significantly altered by the relaxation of constraints.

Recommendation 4 from the South Australian Government submission on the proposed Basin Plan recommends securing delivery for flow regimes up 40 000 ML/d and between 40 000 ML/d and 80 000 ML/d to support a range of floodplain habitats. As flow regimes up to 40 000 ML/d are largely met under water recovery of 2800 GL, the analysis has focused on reporting outcomes for the floodplain inundated by flows ranging from 40 000 ML/d to 80 000 ML/d, herein referred to as the ‘managed floodplain’. For floodplain environments inundated at flows greater than 80 000 ML/d, the analysis sought to confirm that the frequency of inundation would not be reduced compared to Baseline conditions.

Analysis undertaken by DFW/DENR published in March 2012 used outputs of the recovery of 2750 GL to represent the proposed Basin Plan. However, for the relaxed constraints scenario, a water recovery of 2800 GL was used by the MDBA. To achieve a ‘like-with-like’ comparison (and based on advice from MDBA), the 2800 GL scenario (BP2800) is used for comparison and to represent the current proposed Basin Plan, rather than previously reported 2750 GL scenario. The differences between these two scenarios are discussed in Bloss *et al.* (2012) and Heneker and Higham (2012). There are no apparent differences in outcomes for the Riverland-Chowilla hydrologic indicator site; however, some differences were observed for the CLLMM site. This difference (i.e. 2750 vs. 2800 GL) may cause some discrepancies between values reported in previous reports (Bloss *et al.* 2012; Heneker and Higham 2012; Higham 2012), and the values presented in this work.

The analyses have included comparison to Without Development and Baseline scenarios where deemed relevant.

# BACKGROUND AND PURPOSE OF ANALYSIS

The analyses presented are primarily comparative analyses between the Basin Plan scenarios. It should be noted that it is not the aim of the analysis to assess absolute levels of risk or acceptability for South Australian ecological outcomes.

It should be noted that this document is a Technical Note, as opposed to a Technical Report. The main points of difference between these two are that data and information are presented without making recommendations in a Technical Note, and that the document generally contributes to a larger program of existing work. For this document, the existing work is the previous Science Review undertaken by South Australia (Bloss *et al.* 2012, Heneker and Higham 2012, Higham 2012), where more details were provided on the suitability and limitations of the modelling underlying these assessments, the methodologies and assumptions used in this work, as well as the ecological interpretations and risks involved in the outcomes represented by the modelled results.

# 2.REPORT OUTLINE

A short description of the content of each chapter in the remainder of this report is provided in this section. The next chapter provides an outline of the constraints that have been relaxed in the BP2800RC and BP3200RC scenarios, and how the watering plan has been changed to take advantage of the relaxation of constraints. This is followed by analyses of metrics representing ecological outcomes for each of the key environments in South Australia, the South Australian floodplain and channel, Lower Lakes, and Coorong and Murray Mouth. The report is then concluded with a summary of the findings from the analyses for each of the key environments.

**Description of Model Changes for Relaxation of Constraints**

One of the main purposes of this report is to identity the points of difference and improvements in ecological outcomes that occur from the relaxation of constraints in the River Murray. Constraints such as dam outlet capacities and requirements not to flood private land and infrastructure have been relaxed at seven locations in the Murray system, and a regulator was also included to reduce losses to the Darling Anabranch when environmental water was supplied from Menindee Lakes. This section begins with a summary of these changes in the modelling.

This section also provides a summary of the changes in the Environmental Event Selection Tool that were made by the MDBA to make use of the relaxed constraints, and target higher floodplain watering events that were not possible while environmental water releases were being limited by existing flow constraints. The MDBA's assessment of the four water-recovery scenarios in meeting their indicators is also presented.

**South Australian River Murray Floodplain and Channel**

The greatest impact of the relaxation of constraints was expected to be seen in the ecological outcomes for the mid-floodplain environment. Throughout this report, flows to South Australia up to 40 000 ML/d refer to channel requirements, flows from 40 000 ML/d to 80 000 ML/d refer to mid-floodplain requirements, while flows greater than 80 000 ML/d are termed high-level floodplain requirements.

The section begins with an introduction and outline of the EWRs that have been identified for the South Australian River Murray floodplain and channel. Different methods have been used to assess the hydrological and ecological outcomes relative to EWRs defined by South Australia each exploring different components of the EWRs. In summary these analyses were:

- comparison of flow statistics for annual and daily flow to South Australia (Section 4.5.1, 4.6.1)
- analysis of improved delivery of unsuccessful environmental watering events (Section 4.5.2, 4.6.2)
- frequency of meeting target flow rates for all SA EWRs (Section 4.5.3, 4.6.3)
- number of events meeting all metrics of SA EWRs (Section 4.5.4, 4.6.4)
- floodplain area (i.e. flow rate) at which key EWR metrics are maintained (Section 4.5.5, 4.6.5)
    - flow rate at which average frequency and duration metrics are met
    - flow rate at which maximum interval and duration metrics are met

- number of events of all durations that achieved the flow target for red gum and lignum (Section 4.5.6, 4.6.6)

- analysis of specific requested flow peaks (Section 4.5.7, 4.6.7)

**Lower Lakes**

The analysis for the Lower Lakes has followed that of Heneker and Higham (2012). Water level and salinity are critical parameters in the assessment of changes to ecological conditions in the Lower Lakes, and these parameters are largely driven by lake inflow and barrage outflow. As such, changes to the following modelled outputs for each scenario are reported:

- barrage outflows, including changes to annual barrage outflows and periods of no barrage outflow for the different scenarios
- water levels, including the periods of time where critical water levels of 0.0 m AHD and 0.4 m AHD
- salinities, including periods of time where salinity thresholds are exceeded in Lake Alexandrina and Lake Albert, as well as the salt exported through the Murray Mouth.

The section is concluded by reporting on the SA EWRs for the Lower Lakes, consisting of frequencies of high barrage flows, and frequency of meeting flow relationships relating to salinity thresholds in Lake Alexandrina.

**Coorong and Murray Mouth**

As with the Lower Lakes, water levels and salinities are critical parameters in the assessment of changes to ecological conditions, and as such have also been assessed in this section. Murray Mouth openness has also been reported, as this feature influences the ecology of the Coorong (Higham, 2012).

The impact of changes in the following modelled outputs on ecological outcomes in the Coorong have been assessed for the four water-recovery scenarios considered:

- Murray Mouth openness, both directly through outputs from the hydrodynamic model, as well as indirectly using barrage outflows greater than 2000 GL/y
- average annual water levels in the Coorong South Lagoon, where changes between the scenarios are analysed to assess the comparative performance of scenarios to support *Ruppia tuberosa*
- salinities in the North and South Lagoons, as there are a number of salinity thresholds for key biota in both lagoons.

**Summary of Key Findings**

The changes identified between the model scenarios and implications for environmental outcomes for each region considered, are summarised in this final chapter.

# 3. DESCRIPTION OF MDBA MODEL CHANGES FOR RELAXING CONSTRAINTS

## 3.1. RELAXATION OF CONSTRAINTS

The MDBA has identified that in some locations, there are existing physical and operational constraints that limit the ability to deliver flows that inundate the high level floodplain through active environmental water management (2011a). These constraints include dam outlet capacities and requirements not to flood private land and infrastructure, and are described in more detail in MDBA (2011b). System constraints and potential management options are discussed in MDBA (2011b).

For South Australia, the MDBA considers flows of around 80 000 ML/d are likely to be the upper limit to be delivered for managed environmental watering events (informed by MDBA 2011a and MDBA 2011b). Flows greater than this magnitude are generally reliant on unregulated flows generated by large rainfall events.

For events in the 40 000 to 80 000 ML/d range which inundate mid- to high-floodplain habitat in South Australia, it was considered that better delivery of watering events could be achieved by relaxing these constraints (MDBA, 2011b). Work undertaken by the MDBA has identified a number of locations in the Southern Connected System where opportunities exist to relax flow constraints included in the previous Basin Plan modelling. Locations of current flow constraints, and how these constraints have been relaxed in the MDBA modelling considered in this report, are shown in Figure 1, and described in Table 1. Further information on the current constraints is provided by MDBA (2011a, 2011b).

The cumulative total of potential improvements in maximum flow delivered to South Australia from the above relaxations is 50 000 ML/d. This increase in flow is unlikely to be achieved consistently, as:

- it is unlikely that the timing of increased flows from all tributaries would coincide
- attenuation (reduction) of flow peak occurs between the constraint location and the South Australian border
- relaxation of constraints provides little benefit when the constraint is already being exceeded in a particularly tributary, such as during unregulated flows.

To illustrate how the relaxation of constraints affected flows in the River Murray, hydrographs at locations where constraints were relaxed are shown in Figure 2 for the year 1951, when a 80 000 ML/d for 30 days watering event was requested for Riverland-Chowilla. The resulting flows at Riverland-Chowilla can be seen in Figure 3. It can be seen that the relaxation of constraints downstream of Hume Dam allowed flows to be increased from 25 000 ML/d in BP2800 and BP3200 to 40 000 ML/d for some periods in both BP2800RC and BP3200RC scenarios. At Yarrawonga, unregulated flows exceed the 22 000 ML/d for all scenarios for part of the time, however, the constraint relaxation allows the duration of these higher flows to be extended for both BP2800RC and BP3200RC scenarios, and the relaxed constraint of 40 000 ML/d can be seen to be active in September.

Releases from Menindee Lakes, as demonstrated by the flow hydrograph at Weir 32, are significantly increased for BP2800RC scenario, although not for BP3200RC, the reasons for which are unclear. The constraint relaxation at Balranald allows for the extension of higher flows, while at McCoys Bridge on the Goulburn River, the improvements are modest due to unregulated flows already occurring.


**Figure 1. Map of where constraints have been relaxed in the Southern Connected System. Flows presented in ML/d (source: MDBA 29 August 2012)**

**Table 1. Locations of Relaxed Constraints (source: MDBA 29 August 2012)**

| **Region/Model** | **Location** | **Existing Constraint (ML/d) or Issue** | **Relaxed Constraint in Model (ML/d) or alternative** |
|---|---|---|---|
| Murray | Hume to Yarrawonga | 25 000 | 40 000 |
| | Downstream of Yarrawonga | 22 000 | 40 000 |
| Darling | Weir 32/Increase Menindee outlet capacity | 9 300 | 18 000 |
| | Darling Anabranch | Water flows into the anabranch at flows over 9300 ML/d leading to high losses | Regulator added and closed above 9300 ML/d when environmental water supplied from Menindee |
| Murrumbidgee | Gundagai | 30 000 | 50 000 |
| | Balranald | 9 000 | 13 000 |
| Goulburn | Seymour | 12 000 | 15 000 |
| | McCoys Bridge | 20 000 | 40 000 |

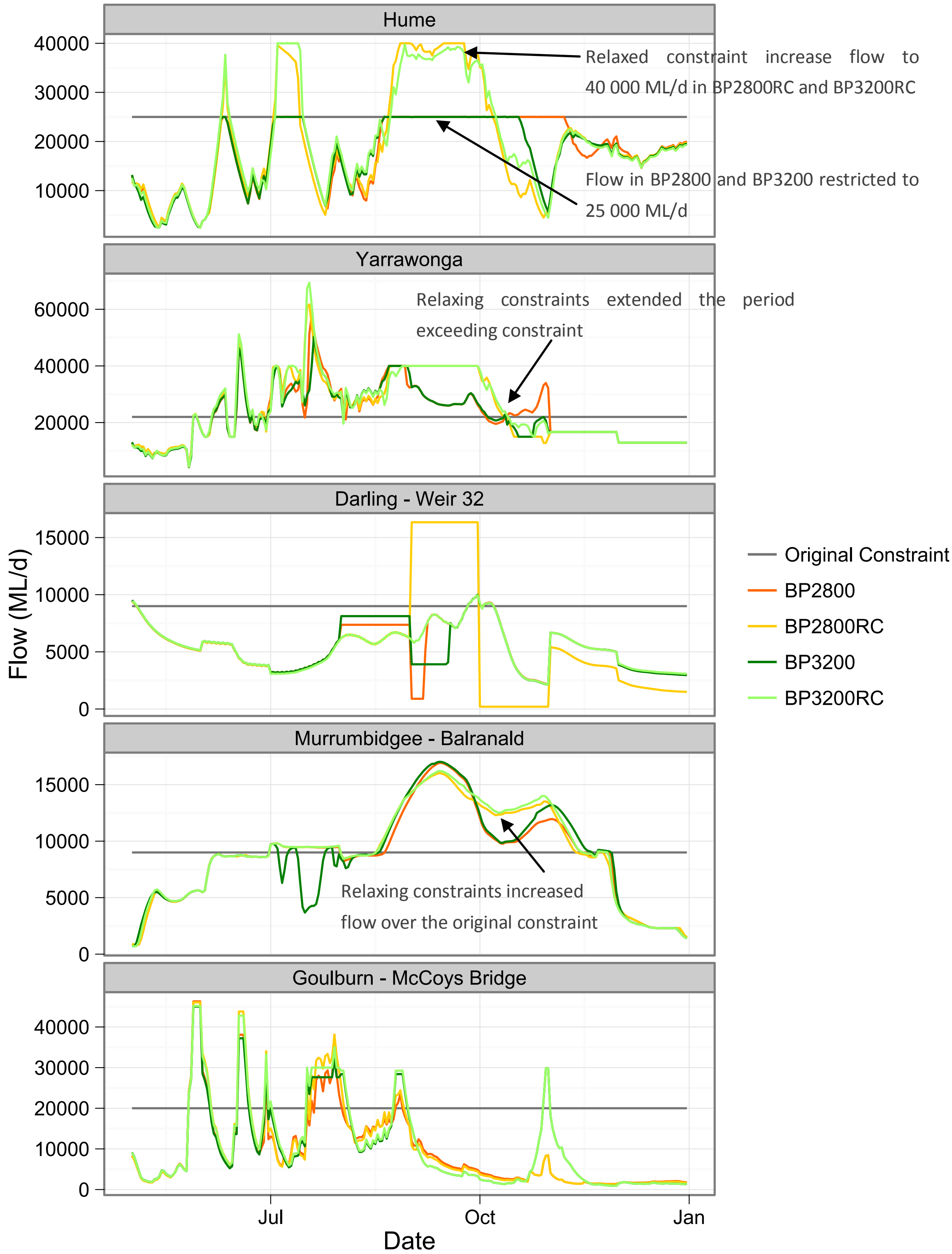



**Figure 2.** **Flows in 1951 for each scenario at locations impacted by constraints.**

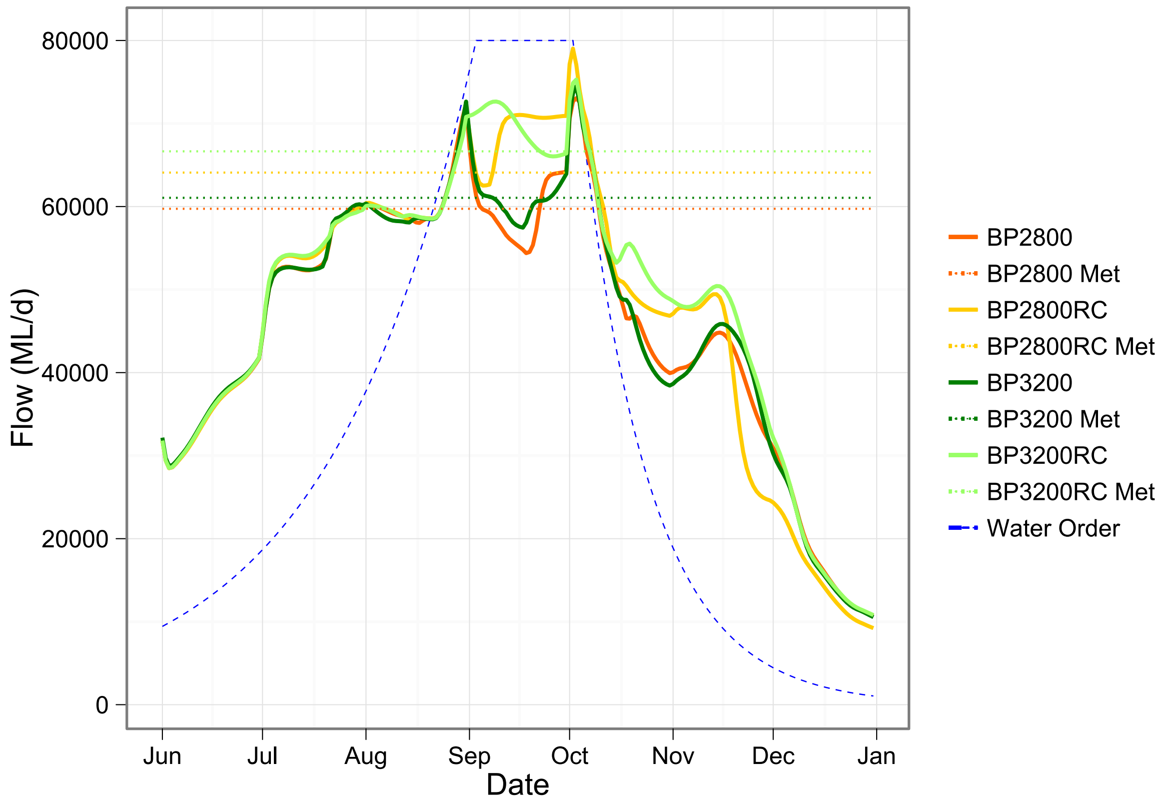



**Figure 3.** **Hydrograph of flows delivered to Riverland-Chowilla in 1951. For each scenario, the horizontal dotted line (e.g. BP2800 Met) represents the flow exceeded for 30 days.**

## *3.2. MDBA MODELLING AND OUTCOMES*

The relaxation of constraints has sought to improve the delivery of environmental water requirements to the River Murray in the Southern Basin. This is measured by the MDBA by the achievement of flow indicator targets for Hydrologic Indicator Sites (HIS) which are specified as demands in the modelling. Flow delivery to South Australia is influenced by the delivery of flow events for both Riverland-Chowilla as well as upstream Murray sites. Indicator sites for the River Murray are shown in Figure 4.

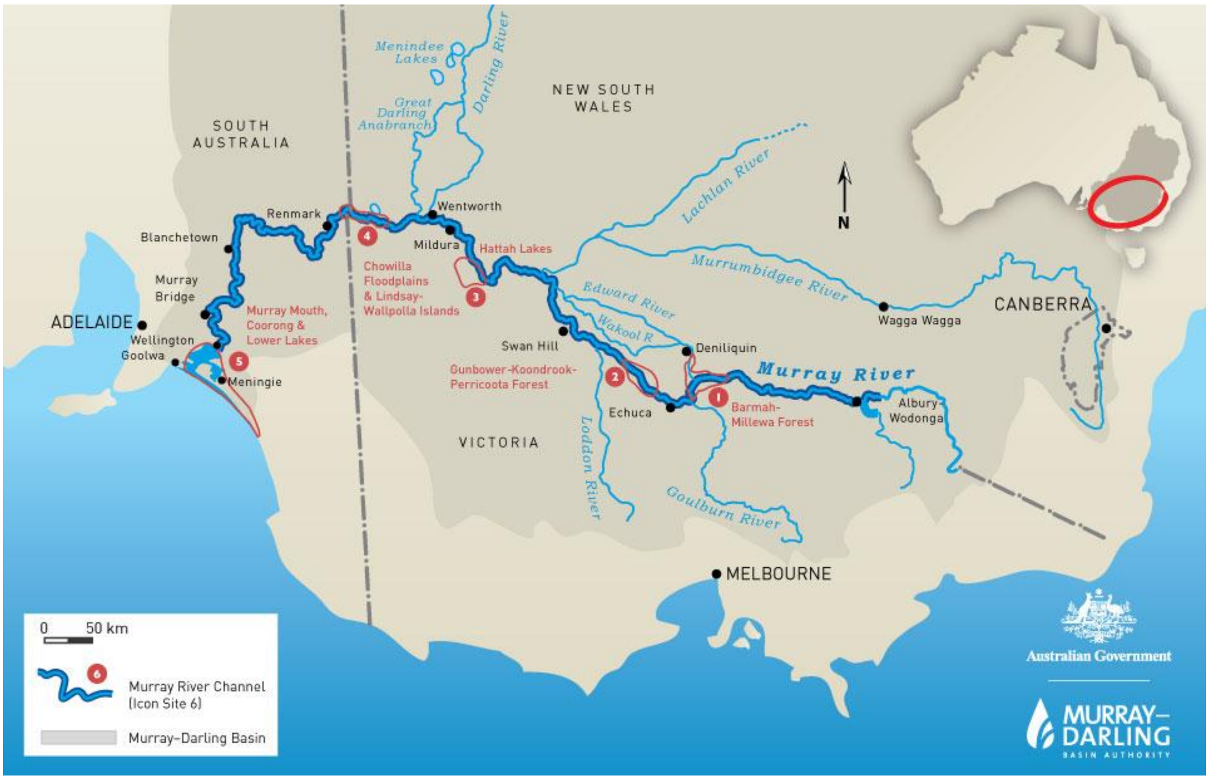



**Figure 4. River Murray Hydrologic Indicator Sites used for Basin Plan event ordering (also The Living Murray Icon Sites) (source: http://www.mdba.gov.au/programs/tlm/icon_sites)**

Through the relaxation of constraints and recovery of 3200 GL of water, the MDBA demonstrated that 17 of 18 targeted MDBA River Murray flow indicator targets could be achieved. The achievement of these targets is shown in Table 2. The indicators shaded in grey in Table 2 were not actively targeted in the watering plan, and as such are not included in the assessment of indicators that are met. It can be seen that using the MDBA's assessment, all of Riverland-Chowilla's flow indicators are achieved under the BP3200RC scenario (with only this scenario achieving all four indicators), as well as resulting in increased achievement of targets for all upstream Murray sites.

**Table 2. Frequency of events (% of years) for MDBA floodplain indicators (Source: MDBA 29 August 2012)**

| Site | Flow Indicator | Target: High to Low Uncertainty | Without Develop -ment | Base-line | BP2800 | BP2800RC | BP3200 | BP3200RC |
|---|---|---|---|---|---|---|---|---|
| Barmah-Millewa Forest | 12 500 ML/d for 70 days | 70–80% | 87% | 50% | 83% | 82% | 83% | 82% |
| | 16 000 ML/d for 98 days | 40–50% | 66% | 30% | 58% | 52% | 61% | 55% |
| | 25 000 ML/d for 42 days | 40–50% | 66% | 30% | 44% | 46% | 47% | 46% |
| | 35 000 ML/d for 30 days | 33–40% | 53% | 24% | 30% | 33% | 31% | 35% |
| | 50 000 ML/d for 21 days | 25–30% | 39% | 18% | 16% | 14% | 18% | 16% |
| | 60 000 ML/d for 14 days | 25–30% | 33% | 14% | 11% | 11% | 11% | 11% |
| | 15 000 ML/d for 150 days | 30% | 44% | 11% | 38% | 39% | 36% | 39% |
| Gunbower-Koondrook-Perricoota | 16 000 ML/d for 90 days | 70–80% | 86% | 31% | 68% | 67% | 71% | 71% |
| | 20 000 ML/d for 60 days | 60–70% | 87% | 34% | 60% | 59% | 61% | 61% |
| | 30 000 ML/d for 60 days | 33–50% | 60% | 25% | 38% | 36% | 39% | 38% |
| | 40 000 ML/d for 60 days | 25–33% | 39% | 11% | 18% | 20% | 24% | 25% |
| | 20 000 ML/d for 150 days | 30% | 43% | 7% | 27% | 25% | 29% | 32% |
| Hattah Lakes | 40 000 ML/d for 60 days | 40–50% | 67% | 30% | 46% | 45% | 50% | 46% |
| | 50 000 ML/d for 60 days | 30–40% | 47% | 19% | 32% | 32% | 33% | 35% |
| | 70 000 ML/d for 42 days | 20–33% | 38% | 11% | 18% | 17% | 21% | 20% |
| | 85 000 ML/d for 30 days | 20–30% | 33% | 10% | 13% | 13% | 14% | 15% |
| | 120 000 ML/d for 14 days | 14–20% | 23% | 8% | 8% | 8% | 8% | 8% |
| | 150 000 ML/d for 7 days | 10–13% | 17% | 5% | 5% | 5% | 6% | 6% |
| Riverland-Chowilla Floodplain | 20 000 ML/d for 60 days | 72–80% | 89% | 43% | 72% | 68% | 75% | 74% |
| | 40 000 ML/d for 30 days | 50–70% | 80% | 37% | 61% | 58% | 61% | 57% |
| | 40 000 ML/d for 90 days | 33–50% | 58% | 22% | 36% | 34% | 39% | 36% |
| | 60 000 ML/d for 60 days | 25–33% | 41% | 12% | 25% | 25% | 27% | 25% |
| | 80 000 ML/d for 30 days | 17–25% | 34% | 10% | 14% | 13% | 14% | 18% |
| | 100 000 ML/d for 21 days | 13–17% | 19% | 6% | 5% | 6% | 7% | 6% |
| | 125 000 ML/d for 7 days | 10–13% | 17% | 4% | 4% | 4% | 4% | 4% |
| **Murray Flow Indicators Met (out of 18 'active management' targets with 10% allowance)** | | | | **0** | **11** | **11** | **13** | **17** |

Meets Low Uncertainty Target

Meets High Uncertainty Target

Target not met

Not targeted for 'active management'

It is important to note that with respect to the Riverland-Chowilla site, modelling has focussed on achieving the 80 000 ML/d for 30 days target, with all other targets previously being met by the BP2800 scenario. The effect of redistributing the environmental water available from low flow indicators to high flow indicators (described further below), can be seen in the MDBA's assessment of their metrics presented in Table 2. It can be seen that the frequency of meeting the 40 000 ML/d for 30 and 90 day indicators at Riverland-Chowilla has reduced from occurring in 61% to 57% of years simulated when comparing BP3200 to BP3200RC for the 30 day duration indicator, and from 39% to 36% when comparing the 90-day duration indicator. Similar decreases can be seen between the BP2800 and BP2800RC scenarios. This is as a result of reducing the number of ordered events for these targets (described in more detail in the following section). However, the MDBA's high uncertainty target frequencies were still met for these two indicators, and as such were deemed as acceptable outcomes by the MDBA when developing the watering plan.

The reduced number of events requested for these indicators that were met for the high uncertainty frequency at Riverland-Chowilla (along with other indicators in the Murray system) has allowed the extra events to be requested, including for the 80 000 ML/d for 30 day indicator. It is important to recognise the deliberate redistribution of water to meet MDBA flow targets when considering the ability of the modelled scenarios to meet the indicators representing environmental outcomes, such as the SA EWRs. Similarly, the CLLMM site is not included as an explicit demand in the model.

The MDBA assessment framework allowed a 10% variation for both flow rate and duration for classifying events as successful if the event was targeted in the environmental watering sequence (see Appendix B). South Australian analyses don't include the same allowance. Consequently, in consideration of the MDBA flow indicator results presented in Table 2, it would be expected that the frequency of events greater than 72 000 ML/d for 27 days (i.e. 80 000 ML/d minus 10% and 30 days minus 10%) would be most improved under the BP3200RC scenario compared to BP2800.

## *3.3. CHANGES TO EVENT ORDERING*

The modelling approach developed by the MDBA using the Environmental Event Selection Tool (also referred to as 'Pick-a-box') is an iterative process where on an annual basis, the modeller evaluates the available volume of environmental water held in storage, the volume of water from unregulated tributary flows, an estimate of the volume required to reinstate events that occurred in the Without Development scenario compared to Baseline, and the frequency at which environmental watering targets need to be achieved for HIS (Figure 4). Using this information the modeller makes a decision on which sites and flow events to target for that year, which are input into the model as demands. In order to provide additional water for environmental watering events with higher flow demands, it was necessary for the modellers to 'deselect' some low flow events to ensure that the usage of environmental water didn't exceed the available volume.

The number of watering events requested for each target at each HIS in the Southern Connected System of the River Murray for each scenario is presented in Table 3. Events that have been removed relative to the BP2800 GL scenario (shaded in red) were removed for targets that were met above the MDBA's high uncertainty target, to free up environmental water to deliver to higher flow targets that were previously not targeted, in part due to the constraints active in the system.

From Table 3 it can be seen that the increase in water recovery volume from 2800 GL to 3200 GL allowed extra water events to be requested for the majority of the targets in the Murray system (shaded in green). Those that were not targeted were the low flow targets that were already met, or close to being met, at the high uncertainty frequency (as reported by MDBA 2012), and as such did not require further events to be requested.

When comparing BP2800RC to BP2800, it can be seen that after removing a number of low flow watering events (shaded in red), only two extra events could be targeted over the 114-year series for one of the Barmah-Millewa Forest targets. As such, no extra events were specifically targeted to be delivered for Riverland-Chowilla for BP2800RC compared to BP2800. Nonetheless, the environmental water freed up by reducing the number of requested events, as well as increased flow rates at the constraint locations, has resulted in improved delivery of some targets already requested.

In contrast to the 2800 GL scenarios, in the BP3200RC scenario enough environmental water was available to request more of the high flow targets compared to BP3200 (shaded dark green). These high flow targets inundate a greater proportion of the floodplain. The high flow target at Riverland-Chowilla, Hattah and Gunbower-Koondrook-Perricoota all had two or more extra events requested over the 114-period to meet the environmental water requirements represented by the flow targets in the BP3200RC scenario compared to the BP3200 scenario. The improvements in ecological outcomes from having the environmental water available to request extra watering events, as well as the improved ability to deliver corresponding watering events, is discussed further in Section 4.6.2.

As an example of the increase in flow resulting from ordering an event, the flow at Riverland-Chowilla in 1983 is presented in Figure 5. For this year, there was an event requested in the BP3200RC scenario only. The flows that meets the 30 day duration target in the three scenarios where an event was not ordered were 67 352 ML/d, 69 451 ML/d, 70 058 ML/d for BP2800, BP2800RC, BP3200, respectively. From these results it can be seen that for this event there was an increase in the flow meeting the 30 day duration in the order of 2 000 - 3 000 ML/d when either constraints relaxed or an increase in the water recovery volume, even when a watering event was not targeted. For the BP3200RC scenario where the event was actually ordered, the flow meeting the 30 day duration was 75 885 ML/d and as this is within the 10% allowance for ordered events adopted by the MDBA, the event would be assessed as successfully delivered in this context.

**Table 3. Number of watering events requested in the 114 year period modelled for each scenario for the River Murray Hydrologic Indicator Sites**

| Site | Target | BP2800 | BP2800RC | BP3200 | BP3200RC |
|---|---|---|---|---|---|
| Barmah-Millewa Forest | 12 500 ML/d for 70 days | 27 | 27 | 27 | 27 |
| | 16 000 ML/d for 98 days | 19 | 9 | 20 | 9 |
| | 25 000 ML/d for 42 days | 12 | 9 | 14 | 9 |
| | 35 000 ML/d for 30 days | 9 | 11 | 11 | 11 |
| | 50 000 ML/d for 21 days | 0 | 0 | 0 | 0 |
| | 60 000 ML/d for 14 days | 0 | 0 | 0 | 0 |
| | 15 000 ML/d for 150 days | 26 | 26 | 26 | 30 |
| Gunbower-Koondrook-Perricoota | 16 000 ML/d for 90 days | 45 | 44 | 45 | 57 |
| | 20 000 ML/d for 60 days | 30 | 30 | 32 | 34 |
| | 30 000 ML/d for 60 days | 8 | 7 | 13 | 8 |
| | 40 000 ML/d for 60 days | 7 | 7 | 12 | 15 |
| | 20 000 ML/d for 150 days | 23 | 22 | 26 | 29 |
| Hattah Lakes | 40 000 ML/d for 60 days | 16 | 10 | 17 | 10 |
| | 50 000 ML/d for 60 days | 22 | 19 | 26 | 19 |
| | 70 000 ML/d for 42 days | 7 | 7 | 13 | 13 |
| | 85 000 ML/d for 30 days | 4 | 4 | 7 | 11 |
| | 120 000 ML/d for 14 days | 0 | 0 | 0 | 0 |
| | 150 000 ML/d for 7 days | 0 | 0 | 0 | 0 |
| Riverland-Chowilla Floodplain | 20 000 ML/d for 30 days | 0 | 0 | 0 | 0 |
| | 40 000 ML/d for 30 days | 25 | 17 | 25 | 17 |
| | 40 000 ML/d for 90 days | 10 | 8 | 14 | 8 |
| | 60 000 ML/d for 60 days | 10 | 10 | 14 | 14 |
| | 80 000 ML/d for 30 days | 6 | 6 | 8 | 10 |
| | 100 000 ML/d for 21 days | 0 | 0 | 0 | 0 |
| | 125 000 ML/d for 7 days | 0 | 0 | 0 | 0 |

| | |
|---|---|
| Not targeted for 'active management' | Number of events increased relative to BP2800 |
| Number of events reduced relative to BP2800 | Number of events increased relative to BP3200 |

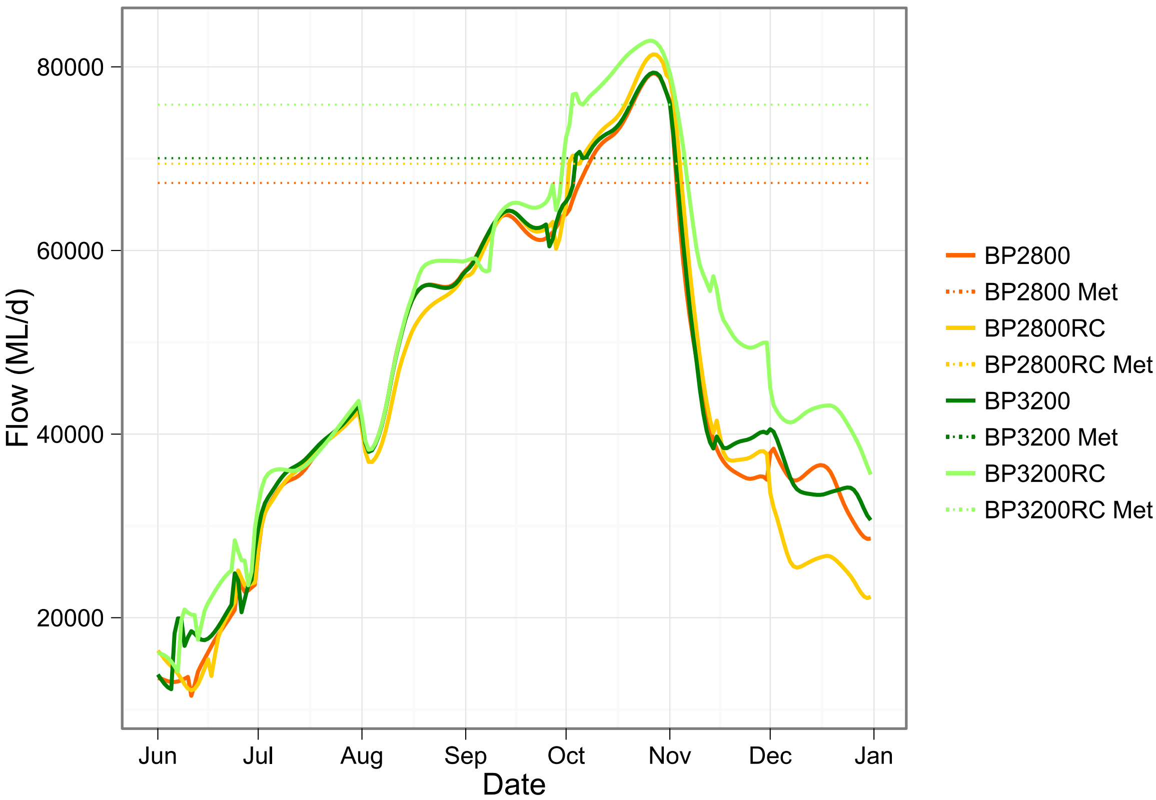



**Figure 5. Hydrograph at Riverland-Chowilla in 1983, where a watering event was requested for the BP3200RC scenario only. Dotted lines (e.g. BP2800 Met) indicate the flow rate exceeded for 30 days.**

## *3.4. COMPARISON BETWEEN SCENARIOS*

The MDBA note that the model outputs for each scenario represents just one realisation of the water recovery profile and the use of that water to meet environmental requirements (MDBA, 2012). A different distribution of entitlements recovered in the system (from where and what type) and the delivery of that water through the modelled environmental demand sequence may result in different outcomes. Ideally, multiple realisations of each scenario would be compared, to provide a more complete representation of the outcomes that could be achieved for the different scenarios. However, given the time taken to produce just one model run, this is not currently feasible.

These issues can be alleviated to some extent by undertaking 'like with like' comparisons. For example, the water recovery profile has been modelled on a pro-rata basis, and as such is the same for the scenarios when comparing with and without constraints relaxed, and a similar distribution when comparing increased water recovery volumes (i.e. BP2800 to BP3200). It is understood that the modelled environmental demand sequences for each new scenario were based on those developed for existing model runs to allow for the most direct comparisons possible. For example, it is understood that the modelled environmental demand sequence for BP2800RC was based on the BP2800 model run, and the modelled environmental demand sequence for BP3200RC started from that used for BP2800RC. However, as seen in Table 3 there are differences between the number of events requested for each indicator to make use of the increased water recovery and/or relaxation of constraints simulated in that scenario, which may lead to differences in the hydrographs modelled at a fine scale (i.e. annual compared to the full 114 year period).

Differences in the modelled environmental demand sequence from year to year means that care is required when considering the results at this fine scale. In this work, when differences between watering events has occurred the modelled environmental demand sequence has been interrogated to ensure that 'like with like' comparisons are being undertaken. For example, it was checked that a watering event was requested in the same year for all scenarios. Individual events, such the maximum or minimum values, may be in part influenced by the sequencing of events occurring in the different modelled environmental demand sequences. However, average statistics calculated over the full record of 114 years are expected to provide for robust comparisons between the scenarios. As such the majority of metrics reported in this work are expected to be suitable for comparisons between the water scenarios, even if the magnitude of metrics change slightly for a different realisation of the same scenario.

# 4. SOUTH AUSTRALIAN RIVER MURRAY FLOODPLAIN AND CHANNEL

## 4.1. GENERAL INTRODUCTION

For the purposes of this analysis, the South Australian River Murray floodplain is defined as the area within the 1956 flood boundary but not including permanent water or lower Murray irrigated pastures. The floodplain covers a total area of 80 042 ha. The managed floodplain is defined as the area inundated between flow of 40 000 ML/d and 80 000 ML/d, and comprises an area of 41 846 ha.

In this section DEWNR has undertaken analysis of the impact of increasing the water recovery volume and/or relaxing constraints on the potential to achieve environmental outcomes for the South Australian River Murray floodplain and channel.

EWRs have been developed for the Riverland-Chowilla Floodplain by the MDBA. South Australia has provided additional advice to the MDBA on EWRs relevant to the Riverland-Chowilla site (DWLBC 2010) and these are referred to as the South Australian EWRs (referred to as SA EWRs). Overall, both sets of EWRs are aimed at providing a range of flows to sustain populations, promote ecosystem functions and deliver inundation of wetlands and habitats. An explanation of the MDBA EWRs is contained in MDBA (2011a), SA EWRs are described in the South Australian government's report (DWLBC, 2010). The report prepared by the Goyder Institute for Water Research as part of their review of the Guide to the Basin Plan (Pollino *et al.* 2011) contains a description of both MDBA and SA EWRs. The Goyder Institute reviewed both the MDBA and the SA EWRs and considered the SA EWRs to be more representative of the ecological character of the Riverland-Chowilla site (CSIRO 2011), due to their inclusion of additional species requirements for the site.

The MDBA EWRs have been used in the MDBA modelling process to develop an environmental-water demand sequence ("pick-a-box") series for the Riverland-Chowilla site. As such, these EWRs are in part driving the delivery of flow to South Australia in the years when watering events are requested. Some SA EWRs are aligned with MDBA EWRs, whereas other SA EWRs are different and as such were not specifically targeted in the environmental watering demand sequence. The MDBA has also developed a set of key ecosystem-function targets and EWRs for sites along the Murray in South Australia, which are typically lower-flow targets, such as baseflows and freshes.

## *4.2. SOUTH AUSTRALIAN ENVIRONMENTAL WATER REQUIREMENTS*

Twenty South Australian floodplain and channel targets and their associated environmental water requirements were used in the hydrological and ecological analyses.

The targets and EWRs are made up of several components:

1. An ecological objective – most objectives relate to a desired condition or outcome and are quantified in terms of proportion of habitat (e.g. red gum forest/woodland) to be maintained and/or improved, unless the objective relates to an ecosystem function (e.g. provide access to the floodplain for spawning).

2. The EWR metrics – generally specify the required duration and frequency of inundation, timing and maximum interval between inundation events. Together these metrics describe the flow regime required by the taxa or habitat in order to support the desired condition or the hydrological conditions needed to trigger a function (e.g. spawning)

3. A flow rate – for the majority of the objectives, the flow rate is a surrogate for a certain extent of inundation and relates to the proportion of habitat identified within the target. Exceptions to this statement are EWRs associated with floodplain functions and in-channel habitat.

It was recognised by the Goyder expert review (Lamontagne *et al.* 2012) of Bloss *et al.* (2012) that there were few targets relating to in-channel requirements. To begin to address this, two additional targets and EWRs relating to recruitment by large-bodied native fish were defined in consultation with representatives from the Goyder Institute. These can be seen as FSr and MCr in Table 4 (Dr Qifeng Ye (SARDI) 2012, pers. comm., 28 August). These two new in-channel EWRs provide a means of assessing the potential improvements at lower flow bands. Two of the targets previously identified in Bloss *et al.* (2012), one relating to lignum recruitment and one to flow variability were excluded from analysis in this report. The lignum recruitment target requires validation and further investigation, while the flow variability target was in part replaced by MCr and Fsr. Additional in-channel targets and EWRs still need to be identified, particularly relating to processes supported by within-channel water level variations. These will be addressed as part of future work.

**Table 4. South Australian targets and environmental water requirements for the SA River Murray channel and floodplain**

| Label | Target | Flow (ML/d) | Duration (days) | Timing | Average Frequency (years) |
|---|---|---|---|---|---|
| BB1 | Maintain and improve the health of 80% of the black box woodlands | >100 000 | 20 | Spring or summer | 1-in-6 years (max interval 8 years) |
| BB2 | Maintain and improve the health of ~60% of the black box woodlands | 100 000 | 20 | Spring or summer | 1-in-5 years (max interval 8 years) |
| BB3 | Maintain and improve the health of ~50% of the black box woodlands | 85 000 | 30 | Spring or summer | 1-in-5 years (max interval 8 years) |
| BBr1 | Successful recruitment of cohorts of black box at lower elevations | 85 000 | 20 | Spring or early summer | 1-in-10 (+ successive years[1]) |
| BBr2 | Successful recruitment of cohorts of black box at higher elevations | >100 000 | 20 | Spring or early summer | 1-in-10 (+ successive years [1]) |
| FSr | Support spawning and recruitment by native fish that are characterised as flow-cued spawners (i.e. golden perch and silver perch) | 15 000 | 60 | Oct - Feb | 1-in-3 (max interval 5 years) |
| FP | Stimulate fish spawning, provide access to the floodplain and provide nutrients and resources | 80 000 | >30 | Jun – Dec | 1-in-4 (max interval 5 years) |
| Lig1 | Maintain and improve the health of ~50% of the lignum shrubland | 70 000 | 30 | Spring or early summer | 1-in-3 (max interval 5 years) |
| Lig2 | Maintain and improve the health of 80% of the lignum shrubland | 80 000 | 30 | Spring or early summer | 1-in-5 (max interval 8 years) |
| MCr | Support spawning and recruitment by Murray cod | 40 000 | 60 | Sep - Dec | 1-in-4 years (max interval 5 years) |

[1] EWR for black box and red gum recruitment includes the need for flooding in successive years, i.e. floods must occur in at least 2 consecutive years for successful recruitment. However, the successive requirement has not been assessed.

| Label | Target | Flow (ML/d) | Duration (days) | Timing | Average Frequency (years) |
|---|---|---|---|---|---|
| Mos1 | Provide mosaic of habitats (i.e. larger proportions of various habitat types are inundated) | 90 000 | 30 | Spring or early summer | 1-in-5 (max interval 6 years) |
| Mos2 | Provide mosaic of habitats (i.e. larger proportions of various habitat types are inundated) | 80 000 | >30 | Spring or early summer | 1-in-4 (max interval 5 years) |
| Mos3 | Provide mosaic of habitats (i.e. larger proportions of various habitat types are inundated) | 70 000 | 60 | Spring or early summer | 1-in-4 (max interval 6 years) |
| Mos4 | Provide mosaic of habitats (i.e. larger proportions of various habitat types are inundated) | 60 000 | 60 | Spring or early summer | 1-in-3 (max interval 4 years) |
| RG | Maintain and improve the health of 80% of the red gum woodlands and forests (adult tree survival) | 80 000 to 90 000 | >30 | Jun - Dec | 1-in-4 (max interval 5 yrs) |
| RGr | Successful recruitment of cohorts of red gums | 80 000 | 60 | Aug – Oct | 1-in-5[2] (+ successive years[1]) |
| TW1 | Inundation of (~80%) temporary wetlands for large scale bird and fish breeding events | 80 000 | >30 | Jun – Dec | 1-in-4 (max interval 5 years) |
| TW2 | Maintain and improve majority of lower elevation (~20%) temporary wetlands in healthy condition; and<br>Inundation of lower elevation temporary wetlands for small scale bird and fish breeding events, and microbial decay/export of organic matter | 40 000 | 90 | Aug – Jan | 1-in-2 (max interval 3 years) |
| WB1 | Maintain lignum inundation for waterbird breeding events | 70 000 | 60 | Aug – Oct | 1-in-4 (max interval 6 years) |
| WB2 | Provide habitat (red gum communities) for waterbird breeding events | 70 000 | 60 | Aug – Oct | 1-in-4 (max interval 6 years) |

[2] The EWR for red gum recruitment in DWLBC 2010 did not specify preferred frequency, however to enable analysis the frequency provided within EA 2010 was used

## 4.3. TARGETED AREA FOR IMPROVEMENT OF FLOODPLAIN HABITATS

The floodplain analysis presented in this section targets the managed floodplain represented by the area inundated between 40 000 ML/d and 80 000 ML/d. Figure 6 and Figure 7 show that there are substantial increases in the area and proportion of habitats inundated at flows above 40 000 ML/d and even more so above approximately 55 000 ML/d. Flows that are improved in this range between the different scenarios are therefore of particular importance, as large areas are further inundated for relatively moderate increases in flow. The improvement in lateral connectivity between the main channel and off-channel habitats would also benefit native fish by enhancing habitat diversity and riverine productivity in the main channel

The steepest section of the line between flow and area in Figure 6 can be seen to occur be between 55 000 ML/d and 80 000 ML/d. For flows in this band, the percentage increase in total vegetated area inundated is approximately five times the corresponding percentage increase in flow. For example, 80 000 ML/d is a 45% increase in flow compared to 55 000 ML/d, however the total vegetated area inundated by these flows increases from 11 000 ha to 38 100 ha (right axis of Figure 6), an increase of 247%. As such, relatively small increases in flow rates at target frequencies at durations in this flow band can support relatively large vegetated areas.

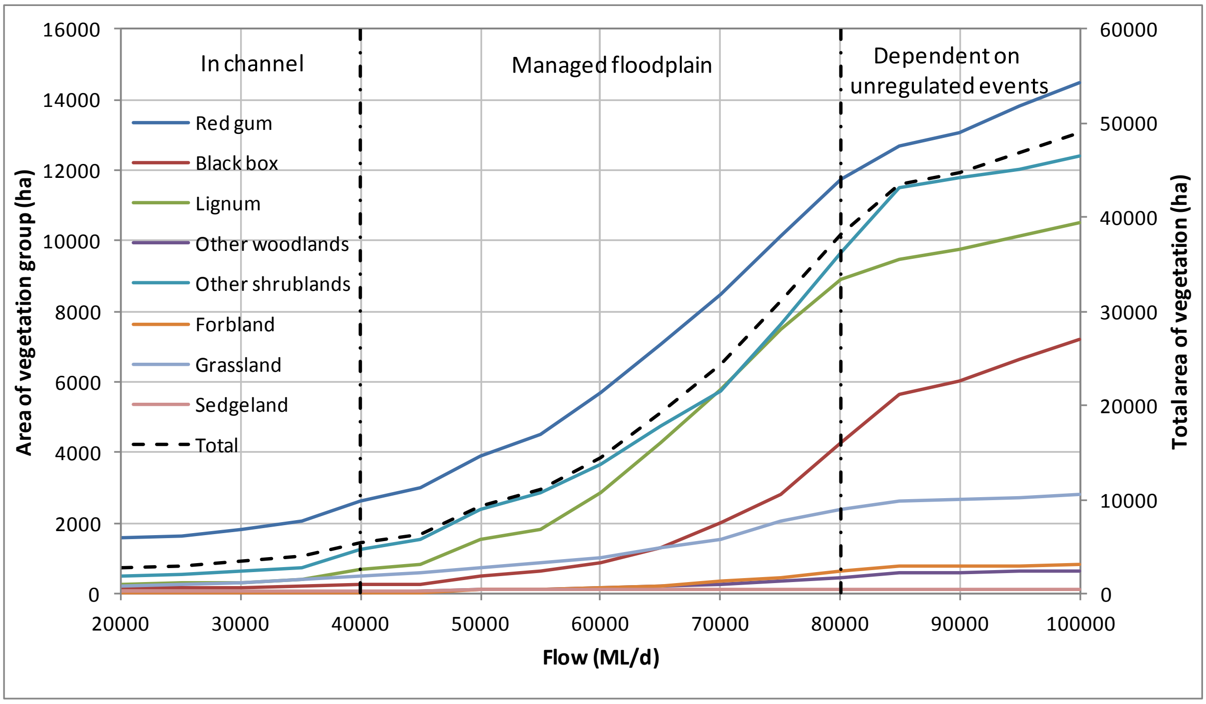



**Figure 6. Area of vegetation communities targeted by SA EWRs inundated as a function of flow**

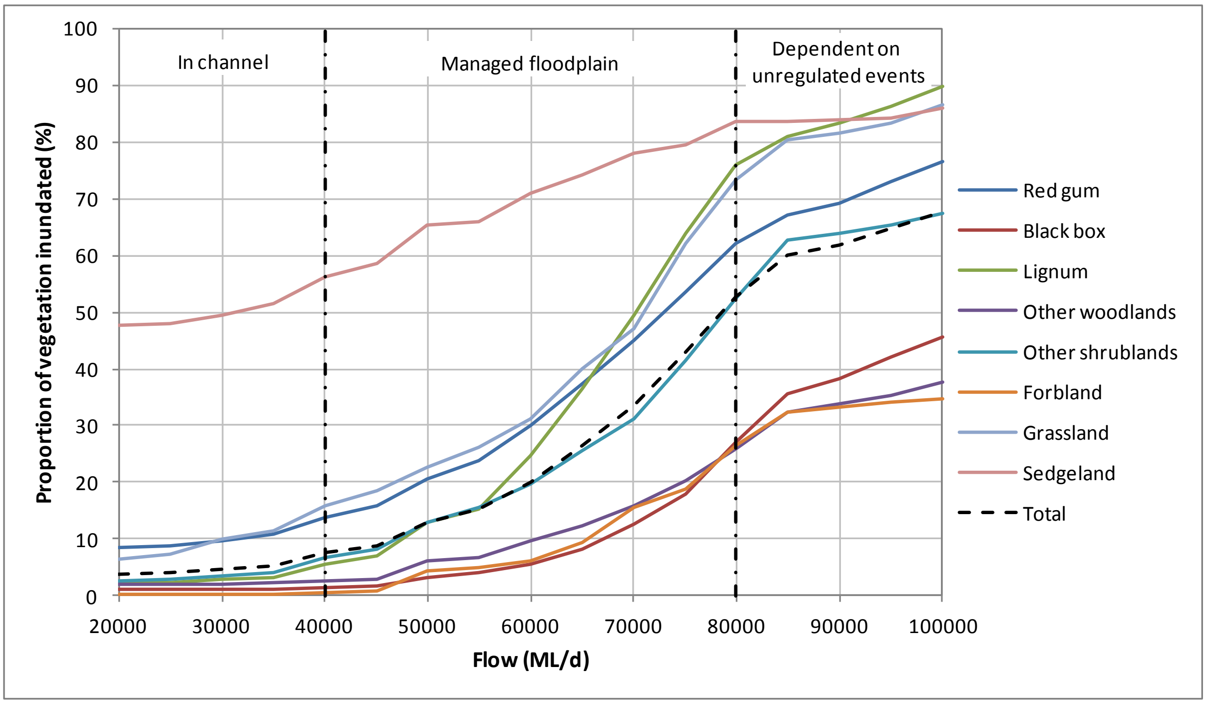



**Figure 7.** **Proportion of vegetation communities targeted by SA EWRs inundated as a function of flow**

## *4.4. APPROACH FOR ASSESSMENT OF HYDROLOGICAL AND ECOLOGICAL OUTCOMES RELATIVE TO SOUTH AUSTRALIAN EWRS*

A 'multiple lines of evidence approach' has been used to assess the differences between the four scenarios to explore the potential benefits of higher water volume recovery and/or the relaxation of constraints. This builds on previous hydrological and ecological approaches used in Bloss *et al.* (2012), supplemented with further analysis to more fully explore the differences between scenarios and associated ecological benefits.

These analyses assessed different elements of the SA EWRs by holding some components of the EWR steady and assessing changes in others. They have not been undertaken in order to assess the degree to which targets were met but rather to enable potential improvement in each of the components under the different water recovery scenarios to be assessed.

The first set of analyses identified how often over the 114 year time period events of the desired duration occurred at the target flow rate. This was done in two ways, one by assessing the average frequency of events as defined within a water year and second by determining the number of events occurring overall using the strict ecological definitions defined by the EWR. The first was used to be consistent with a more traditional method of identifying years containing successful watering events (e.g. Bloss *et al.* (2012) and MDBA (2012)). The second was used to enable further analysis using ecological response curves.

For the SA EWR targets which were not met at the target flow rate, it was considered important to quantify potential improvements between scenarios. This was assessed by determining the flow rate at which average frequency or maximum interval metrics and duration were met. This was expressed as area of the relevant vegetation community on the floodplain to demonstrate where benefits could be realised. Changes in flow rate were observed while holding other EWR components constant.

An analysis exploring events of all durations at the target flow rate was undertaken for the key vegetation species of red gum and lignum using Murray Flows Assessment Tool (MFAT) ecological response curves. This classed flows of various durations into habitat suitability categories. This analysis held the flow rate steady and observed improvements which could be made to the duration of events between the four scenarios.

Finally, an analysis of specific flow peaks delivered within the model was undertaken. This analysis also used the MFAT tool for key vegetation communities (red gum and lignum) but assesses the habitat suitability associated with a particular flow peak at a given point in time and does not relate to habitat suitability over the 114 year time period. A summary of the flow statistics for South Australia is provided as a precursor to these analyses.

It should be noted that all these assessments infer ecological habitat suitability based on meeting hydrological metrics. Some of these relationships have not been validated in the South Australian floodplain and therefore ecological outcomes may not eventuate as these analyses predict. It should also be noted that the SA EWRs are predicated on the assumption that the floodplain assets are currently in good condition and are therefore able to respond to flow in the manner predicted. It is recognised that this may not be the case (Lamontagne *et al.* 2012) and that higher frequency of flows is likely to be required to reinstate resilience in those areas that are heavily degraded. However, the EWRs have been used as a means to compare between the water-recovery scenarios, not to determine absolute outcomes for the floodplain.

The analyses represent the habitat suitability for the floodplain as determined by flow only, and do not account for other risks including water quality issues such as blackwater, salinity or impacts associated with extended periods of drought. This analysis is a comparative assessment and describes habitat suitably based on hydrological metrics. Therefore it describes the potential to support floodplain communities rather than commenting directly on the resulting condition or 'health' of existing communities or ecosystems on the floodplain. To draw inference from this analysis to a broader assessment of floodplain condition relies on the assumption that a reduced or contracted floodplain, where habitat suitability is more limited and perhaps spatially different to 'natural' conditions, is sustainable. This assumption has not been assessed and therefore no comment on the long-term sustainability under the four water recovery scenarios can be made.

In summary the lines of evidence used in the analyses included:

1. comparison of flow statistics for annual and daily flow to South Australia (Section 4.5.1, 4.6.1)
2. analysis of improved delivery of unsuccessful environmental watering events (Section 4.5.2, 4.6.2)
3. frequency of meeting target flow rates for all SA EWRs (Section 4.5.3, 4.6.3)
4. number of events meeting all metrics of SA EWRs (Section 4.5.4, 4.6.4)
5. floodplain area (i.e. flow rate) at which key EWR metrics are maintained (Section 4.5.5, 4.6.5)
    a. flow rate at which average frequency and duration metrics are met
    b. flow rate at which maximum interval and duration metrics are met
6. number of events of all durations that achieved the flow target for red gum and lignum (Section 4.5.6, 4.6.6)
7. analysis of specific requested flow peaks (Section 4.5.7, 4.6.7)

## *4.5. METHODS*

### 4.5.1. COMPARISON OF FLOW STATISTICS FOR ANNUAL AND DAILY FLOW TO SOUTH AUSTRALIA

A comparison of flow statistics for annual and daily flow was undertaken using the model output *Flow to SA*, which is the modelled River Murray flow at the South Australia–New South Wales–Victoria border. *Flow to SA* is considered representative of the total water available for environmental flow and diversions within South Australia since contribution from tributaries is relatively minor compared to mainstream River Murray flow.

### 4.5.2. ANALYSIS OF IMPROVED DELIVERY OF UNSUCCESSFUL ENVIRONMENTAL WATERING EVENTS

This analysis has been undertaken to investigate if the delivery of environmental watering events was improved by the relaxation of constraints. This analysis was expected to demonstrate how the relaxation of constraints influenced active watering events, in contrast to considering average frequencies over the whole 114 year record, which has the potential to mask benefits from a small number of watering events.

The requested watering events that did not meet the indicator are of interest for this analysis, as these are cases where it is possible that further water recovery or relaxation of constraints may change this status and meet the desired outcome. All of the events that were requested in the same year for each of the four scenarios for the 60 000 ML/d for 60 days target at Riverland-Chowilla were successfully delivered using the MDBA's assessment framework.

However, there were three years where events were requested in all four scenarios for the 80 000 ML/d for 30 days target at Riverland-Chowilla that were not successfully delivered under the BP2800 scenario, and as such provide useful case studies for how increasing water recovery and/or relaxing constraints can improve the delivery of these environmental watering events. For these three years where the requested events were not successful for the BP2800 scenario, the flow that did meet the specified duration of inundation for the relevant target has been identified. For the 80 000 ML/d indicator, this is the flow that was met or exceeded for 30 days.

Comparing the same watering event in the same year was used to attempt to compare the changes in model runs. However, there are other factors, such as the storage volumes and changes to the watering of other events, which will also influence the flow simulated in a given year. While storage reliability is aimed to be the same across model runs, there is likely to be annual variability that is different between the scenarios, and as such will influence the results presented.

### 4.5.3. NUMBER OF YEARS MEETING SA EWRS

To assess the frequency at which the EWR is met, the same approach used by Bloss *et al.* (2012) has been adopted. That is, days where the specified flow rate was exceeded were identified, subject to a seven day minimum event duration, under the assumption that some time will be required for the area corresponding to that flow rate to be inundated. No minimum event duration was applied for EWRs specifying 100 000 ML/d or more. The number of days exceeding the specified flow rate (subject to the minimum event duration), were totalled each water year (June–May) to determine if the event duration specified by the EWR had been met. As such, two events exceeding the target flow rate could be combined that occurred in different months, subject to the minimum event duration and seasonality. A manual post processing was undertaken to determine if the event occurred outside the seasonality specified by the EWR, as some leniency was applied (for example, the end of summer could have extended longer than the end of February). The number of successful events over the 114-year period were then totalled to calculated the frequency meeting the EWR.

### 4.5.4. NUMBER OF EVENTS MEETING SA EWRS

As a precursor to the more detailed analysis using ecological response curves, the number of events reaching the target flow rate, timing and duration for important ecological taxa and communities (Murray cod, red gum, lignum, black box and mosaic of habitats) were determined for each of the modelled scenarios, based on the strict timing of the EWR for flow rates between 40 000 and 85 000 ML/d. EWRs relating to vegetation were examined at all times of the year. Given the vegetation communities represented in the EWR are generally perennial species it was considered that flow would provide ecological benefits at all times of year (Ian Overton (CSIRO) 2012 pers. comm. 24 August). Events were defined by the duration specified in the EWR. Where the flow rate dropped below that specified in the target by less than 10% and by less than 30 days for vegetation and 10 days for other EWRs, the event was deemed continuous. As such, this analysis is different to the hydrological assessment of EWRs described above as only continuous events are considered. More than one event could be counted for in a single year, with the minimum time between events for vegetation EWR being 30 days and 10 days for all other EWRs. The number of events was compared between each water recovery scenario. This analysis was a necessary precursor to that outlined in Section 4.5.6.

### 4.5.5. FLOODPLAIN AREA AT WHICH KEY EWR METRICS ARE MAINTAINED

Two separate analyses were undertaken to assess the partial meeting of EWRs in terms of reduced flow rates, i.e. the flow that was delivered to the frequency, interval and duration specified by the EWRs. For the first analysis, the average frequency and duration metrics of the EWRs were held steady while, for the second, the maximum interval and duration metrics were held steady. The flow rate that maintained these metrics was determined and then related to the area of key floodplain habitats that would be inundated at these flow rates. Area of inundation was estimated using RiM-FIM model outputs (Overton *et al.* 2006). Methods are described in more detail in Bloss *et al.* (2012). These methods were refined slightly as follows:

- flow rates were not rounded down to the nearest 5000 ML/d
- RiM-FIM outputs that estimated areas of floodplain habitats inundated at 5000 ML/d increments were interpolated.

The flow rate meeting the average frequency and duration requirements was determined by identifying the flow rate that met the duration requirement each year. A seven-day minimum event duration was included in the analysis, to provide time for a simulated flow rate to inundate the area expected. From the flow that met the target duration each year, the flow rate that met the desired average frequency over the 114-year record was then identified. An example is presented in Figure 8, where the flow rate that was exceeded for 30 days each year in the BP3200RC scenario can be seen. These average frequencies and a duration of 30 days corresponded to a number of EWRs, such as FP, Lig1, Lig2, Mos1, Mos2, RG and TW1. The same process also has been undertaken for event durations of 20, 60 and 90 days, to identify the flow rates that met the targeted average frequency and duration metrics for all SA EWRs.

An analytical approach was not possible to determine the flow rate that meets the maximum interval specified by EWRs, as the successful events first had to be identified based on a certain flow rate. As such, the maximum interval between events of each duration (20, 30, 60 and 90 days) specified by EWRs was calculated for all flow rates at increments of 1000 ML/d. From this information, the highest flow rate that still met the maximum interval between events specified by each EWR was determined.

The analysis of maximum interval meeting could not be undertaken for the two targets relating to recruitment by large-bodied native fish (FSr and MCr), as their EWRs relate to a required flow velocity rather than inundation of floodplain vegetation communities.

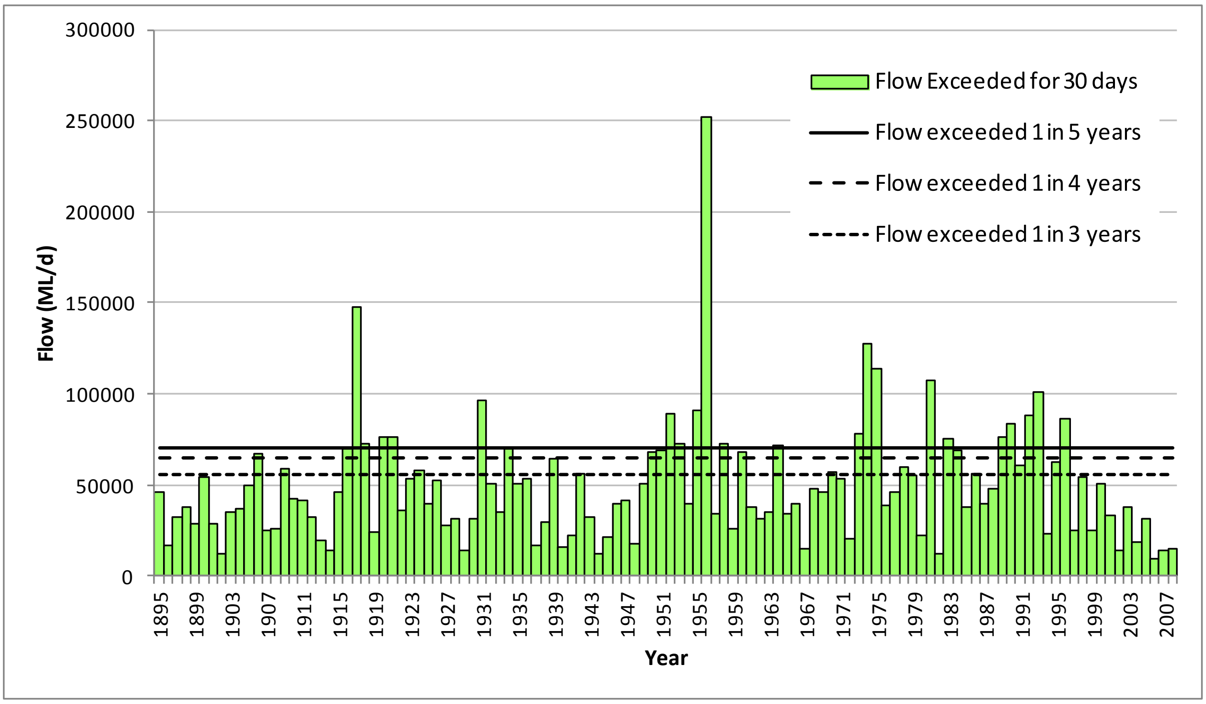



**Figure 8. Flow rate for 30 days duration each year for the BP3200RC scenario**

### 4.5.6. NUMBER AND QUALITY OF EVENTS THAT ACHIEVE THE TARGET FLOW RATE FOR RED GUM AND LIGNUM

Flow events that exceeded threshold values of the relevant EWR were examined to determine their likely impact on habitat quality for adult red gums and lignum. Specifically, the duration of each event meeting the target flow rate was compared to the appropriate ecological response curve and assigned a rating of poor, moderate, good or optimal according to the duration of days in Table 5. In this way events which did not meet the target duration of the EWR specified were examined and their ability to improve habitat condition between the scenarios determined.

MFAT is a decision support system that uses ecological response curves to describe the ecological implications of modifying flows within the River Murray (Young *et al.* 2003). The MFAT curves for the Lower River Murray were revised for the Riverine Recovery Project and documented in Overton *et al.* (2010). MFAT provides ecological response curves for most species or communities of interest for the floodplain. The analyses outlined in Section 4.5.5 examined the flow rate which meets the average frequency and duration metrics of the EWR (holding duration and average frequency steady). These analyses have not explored the consequences when the duration of the EWR is relaxed. The two key species used for this analysis, adult red gum and lignum are considered the dominant species on the managed floodplain. These communities were selected as they are key taxa on the managed floodplain, and the MFAT curves had a high confidence rating, which is not the case for other communities with EWRs specified. Improvements in duration of flows between the scenarios were examined in this way. Habitat suitability was measured on a scale of 0–1 (1, 'optimum'; 0, 'poor'). A score of >0.7 represented a 'good' year and <0.2 a 'poor' year (Young *et al.* 2010). These values were adopted when assessing the 'quality' of all flow events. Each relevant ecological response curve (e.g. Figure 9, Figure 10) was examined to determine the hydrological values associated with the duration of flows relating to each habitat suitability category.

The ecological response curves were assessed against the different modelled flow scenarios used for two purposes:

- to assess against all the events which were extracted for each flow rate relating to red gum and lignum EWRs
- against specific flow peaks where water was specifically called for at Riverland-Chowilla, see section below.

## 4.5.7. SPECIFIC FLOW PEAK ANALYSIS OF REQUESTED EVENTS

There were six specific flow peaks relating to six particular years where environmental water was deliberately released for the purpose of delivering a 80 000 ML/d event for 30 days at Riverland-Chowilla common to the four scenarios. Of these six flow peaks three were not successfully delivered. These provide a useful comparison for the benefits that may be achieved through the relaxation of constraints. A fourth event has also been considered that was requested in the BP3200RC event only, to investigate the benefit from having a larger water recovery volume. These peaks have also been analysed for improvements in habitat condition associated with the ecological response curves. Potential ecological differences were also identified by applying MFAT ecological response curves to the flow pattern associated with that demand sequence in the model for each of the four flow peaks of the four scenarios.

For all four of these specific years the duration of each or peak identified through the flow rules, was assigned an MFAT score (according to Table 5). In the case that more than one peak was scored, the most ideal (highest score category) was captured for each scenario across the range of flow rates achieved by the modelled event.

**Table 5. Revised MFAT curve threshold values for inundation duration in days (upper and lower threshold presented)**

| MFAT habitat condition score | MFAT category | Adult red gum | Adult lignum |
|---|---|---|---|
| 0 | | >720 | NA |
| <0.2 | Poor | <6; >596 | <6; >360 |
| 0.2-0.7 | Moderate | 6-27; 283-596 | 6-28; 184-360 |
| 0.7-1 | Good | 27-39; 96-283 | 28-41; 81-184 |
| 1 | Optimal | 39-96 | 41-81 |

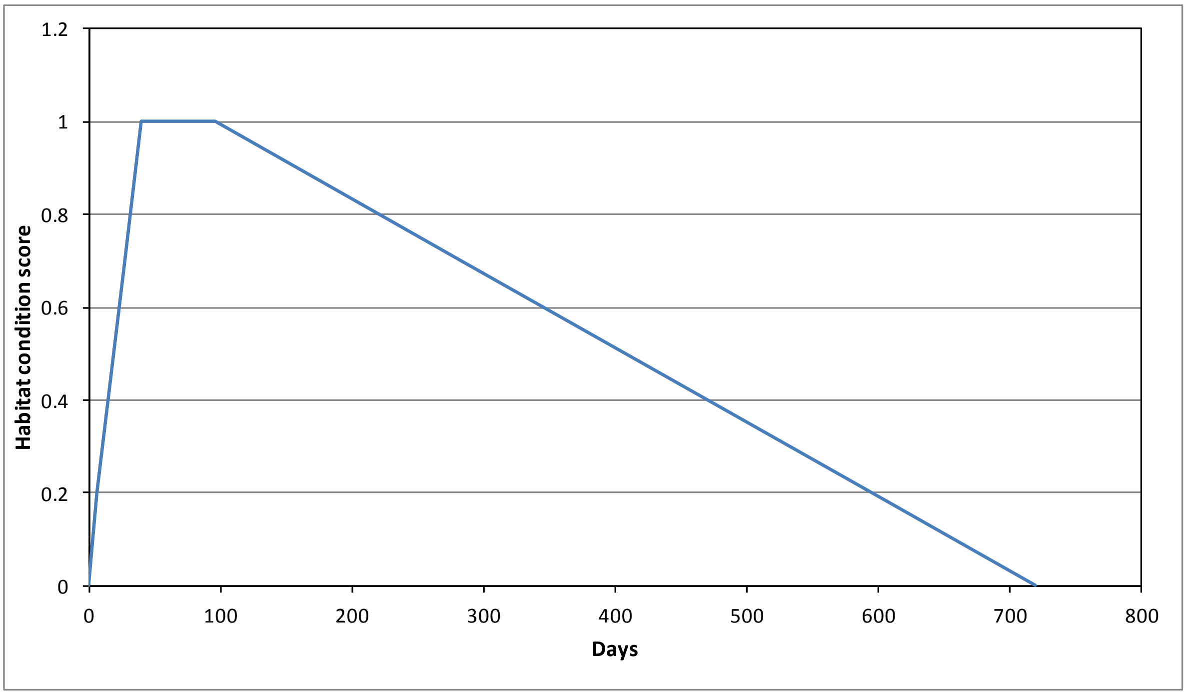



**Figure 9. MFAT ecological response curve for adult red gum inundation duration**

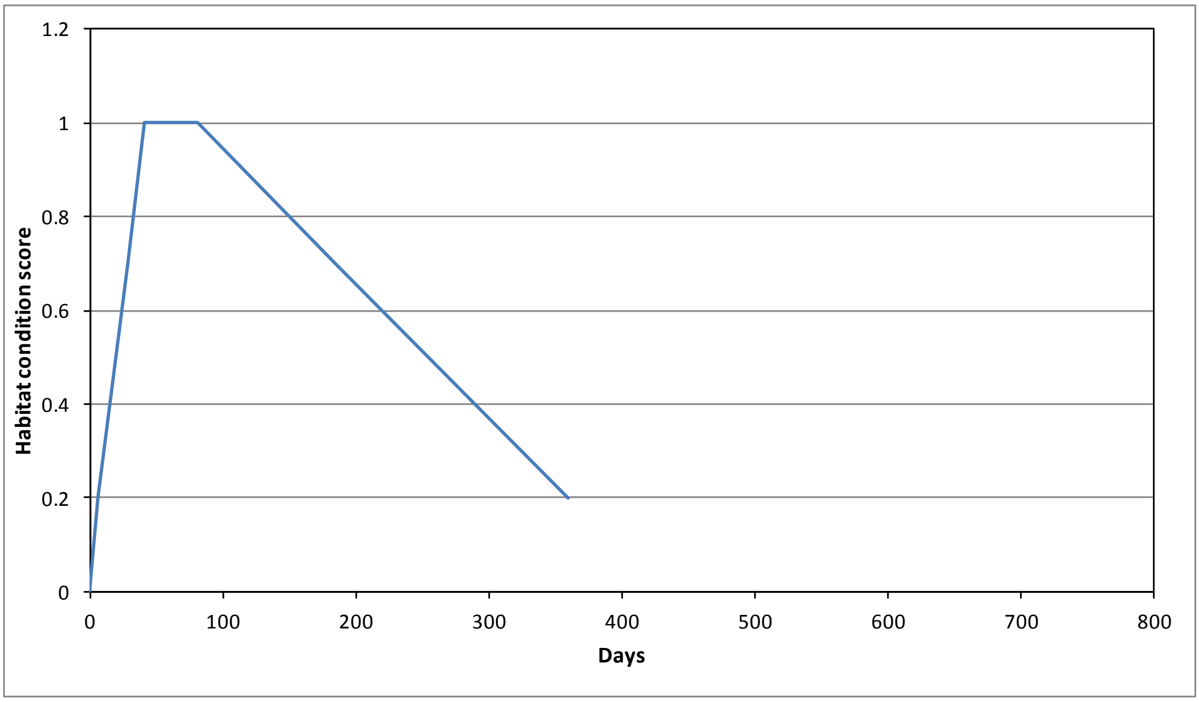



**Figure 10. MFAT ecological response curve for adult lignum inundation duration**

## *4.6. RESULTS FOR HYDRO-ECOLOGICAL ANALYSIS OF THE SOUTH AUSTRALIAN RIVER MURRAY FLOODPLAIN AND CHANNEL*

### 4.6.1. COMPARISON OF FLOW STATISTICS FOR ANNUAL AND DAILY FLOW

Statistics for the flow to South Australia for the water recovery scenarios, as well as Baseline and Without Development conditions, are presented in Table 6 for annual volumes and Table 7 for daily flows. The increase in mean annual volume from BP2800/BP2800RC to BP3200/BP3200RC is approximately 300 GL. All flow statistics, apart from minimum daily flow, which is the same, and maximum daily flow when comparing BP3200RC and BP2800RC, increased when comparing increased water recovery volumes (i.e. BP3200 to BP2800 or BP3200RC to BP2800RC).

The mean annual volumes can be seen to decrease slightly (15 GL) for the same water recovery volume when comparing scenarios with and without constraints relaxed. This is likely due to targeting environmental watering events that inundate larger areas of floodplain in the constraints relaxed scenarios, and as such slightly increased losses in evaporation and return flows to the main channel.

**Table 6. Annual volume (GL/y) of *Flow to SA* statistics**

| Statistics | Baseline | BP2800 | BP2800RC | BP3200 | BP3200RC | Without Development |
|---|---|---|---|---|---|---|
| Mean | 6592 | 8415 | 8399 | 8711 | 8696 | 12 796 |
| Median | 4762 | 7169 | 7127 | 7374 | 7466 | 11 624 |
| Minimum | 1027 | 2080 | 2005 | 2122 | 2198 | 1531 |
| Maximum | 40 897 | 42 236 | 42 266 | 42 432 | 42 453 | 46 195 |
| 10th percentile | 2382 | 3372 | 3319 | 3551 | 3438 | 6126 |
| 90th percentile | 11 298 | 13 387 | 13 442 | 13 746 | 14 170 | 19 294 |

**Table 7. Daily *Flow to SA* (ML/d) statistics**

| Statistics | Baseline | BP2800 | BP2800RC | BP3200 | BP3200RC | Without Development |
|---|---|---|---|---|---|---|
| Mean | 18 048 | 23 038 | 22 995 | 23 848 | 23 809 | 35 035 |
| Median | 9490 | 13 407 | 13 433 | 14 399 | 14 116 | 25 600 |
| Minimum | 724 | 765 | 765 | 765 | 765 | 7 |
| Maximum | 270 459 | 276 551 | 274 901 | 277 184 | 274 337 | 287 864 |
| 10th percentile | 3975 | 5177 | 5201 | 5353 | 5541 | 6368 |
| 90th percentile | 44 093 | 53 583 | 54 441 | 55 443 | 55 592 | 73 690 |

The frequency distributions of annual volume and daily flow to South Australia are shown in Figure 11 and Figure 12, respectively. While it is difficult to distinguish from the figures, as noted above and from Table 6, the annual volume and daily flow values generally increase with water recovery volume. Also from Table 7, both the 10th and 90th daily flows also increase when comparing relaxed to original constraints for the same water recovery volume. However, the difference is small (less than 5%).

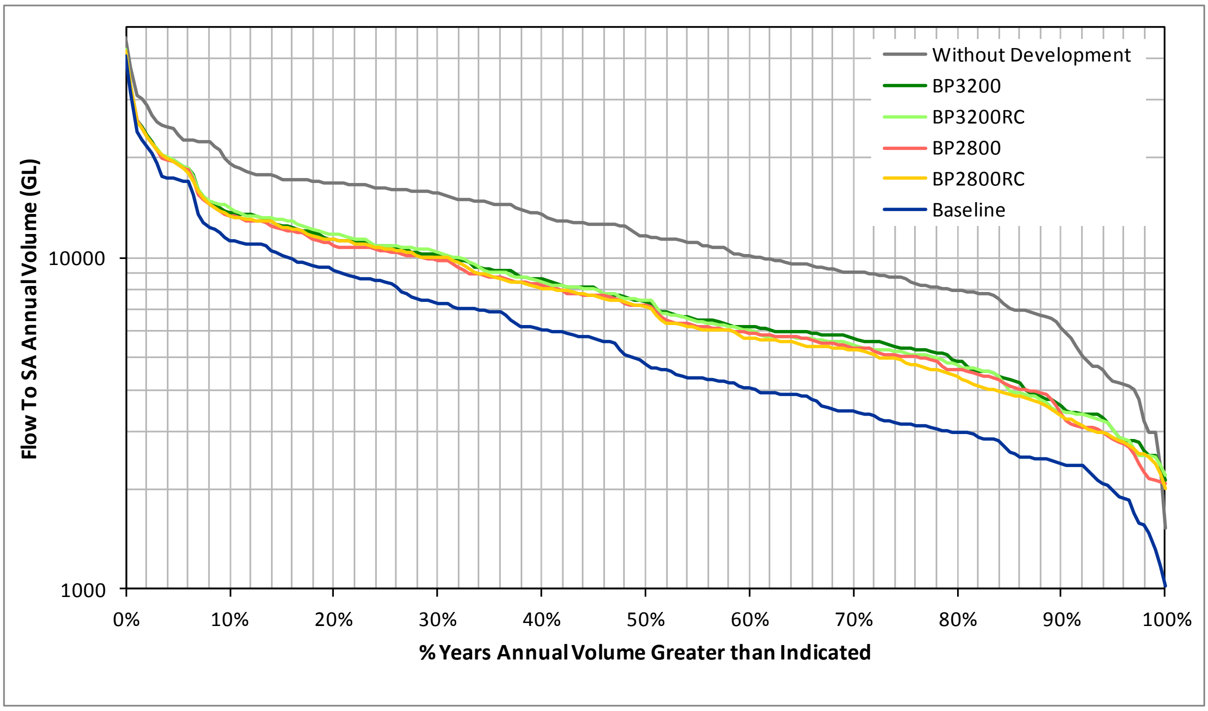



**Figure 11. Frequency distribution of annual volume to South Australia (1895–96 to 2008–09)**

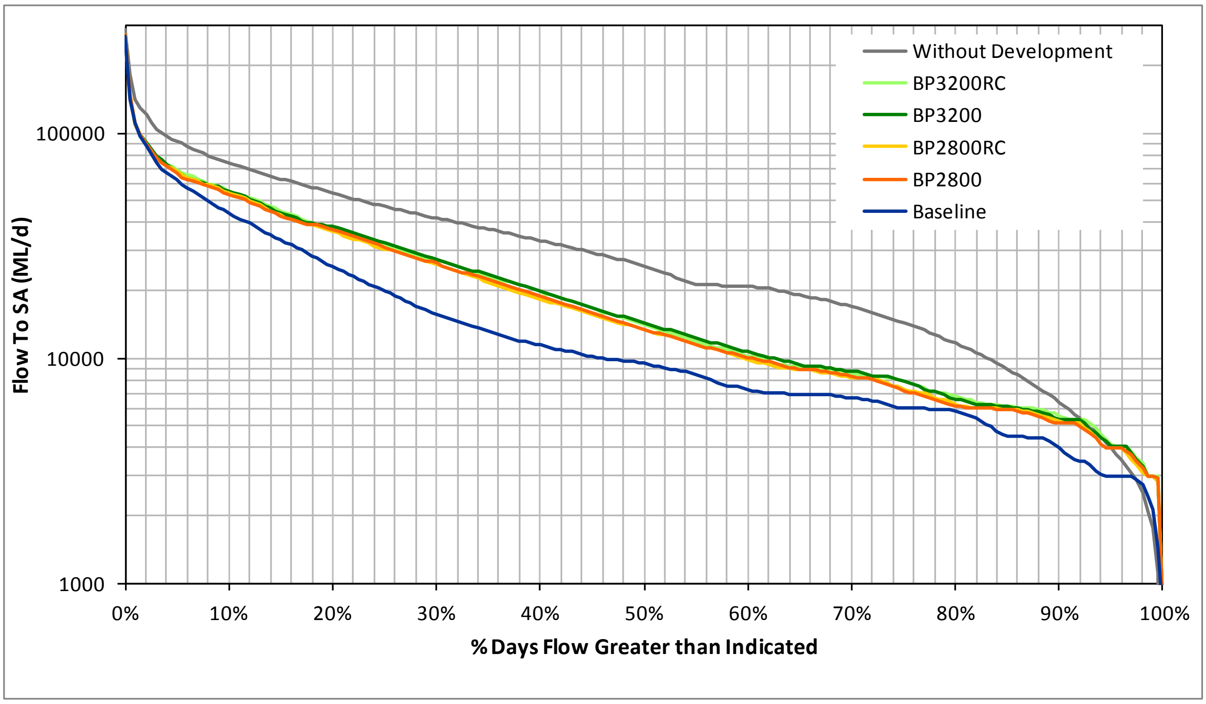



**Figure 12. Frequency distribution of daily flow to South Australia (1895–96 to 2008–09)**

The flow statistics and distributions presented above provide an overview of the changes in *Flow to SA* simulated for the different scenarios considered. To also investigate the annual variations in flows across the scenarios, the difference between annual volumes for scenarios of interest have been plotted in Figures 13–15. When comparing the relaxation of constraints for the same water recovery volume, (Figure 13 for 2800 GL and Figure 14 for 3200 GL) it can be seen that there are large differences in the annual volume in the same year between the different scenarios. However, this is generally compensated for in the following year, and from Table 6 it can be seen that the annual average volumes are similar for both of the 2800 GL scenarios (Figure 13) and both of the 3200 GL scenarios (Figure 14)). These differences in the annual volumes are expected to be due to different environmental watering decisions, redistributing flow from one year to the next. Even when comparing BP3200RC to BP2800, there were 21 years (18%) where BP2800 had a higher annual volume to South Australia. This highlights the influence that watering decisions and inter-annual variability in the storage volumes can have on the flows simulated between the modelled scenarios.

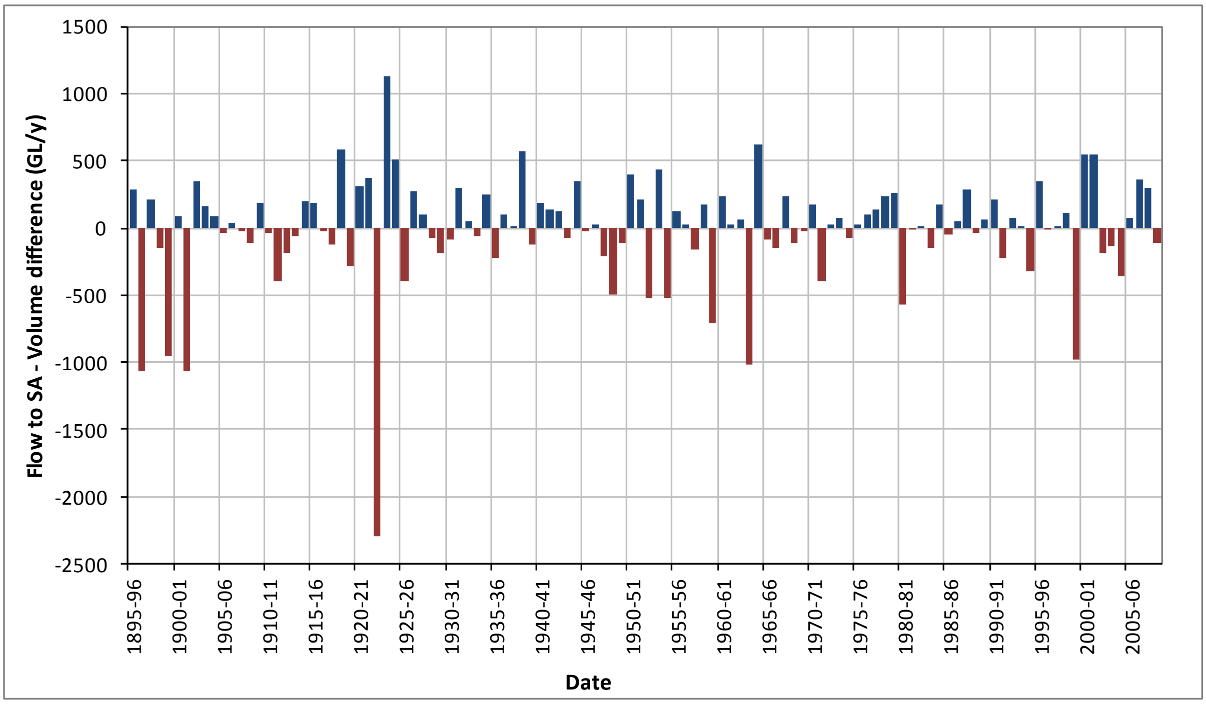



**Figure 13.** ***Flow to SA*** **differences in annual volume between BP2800 and BP2800RC scenarios (blue – BP2800RC greater, red – BP2800 greater)**

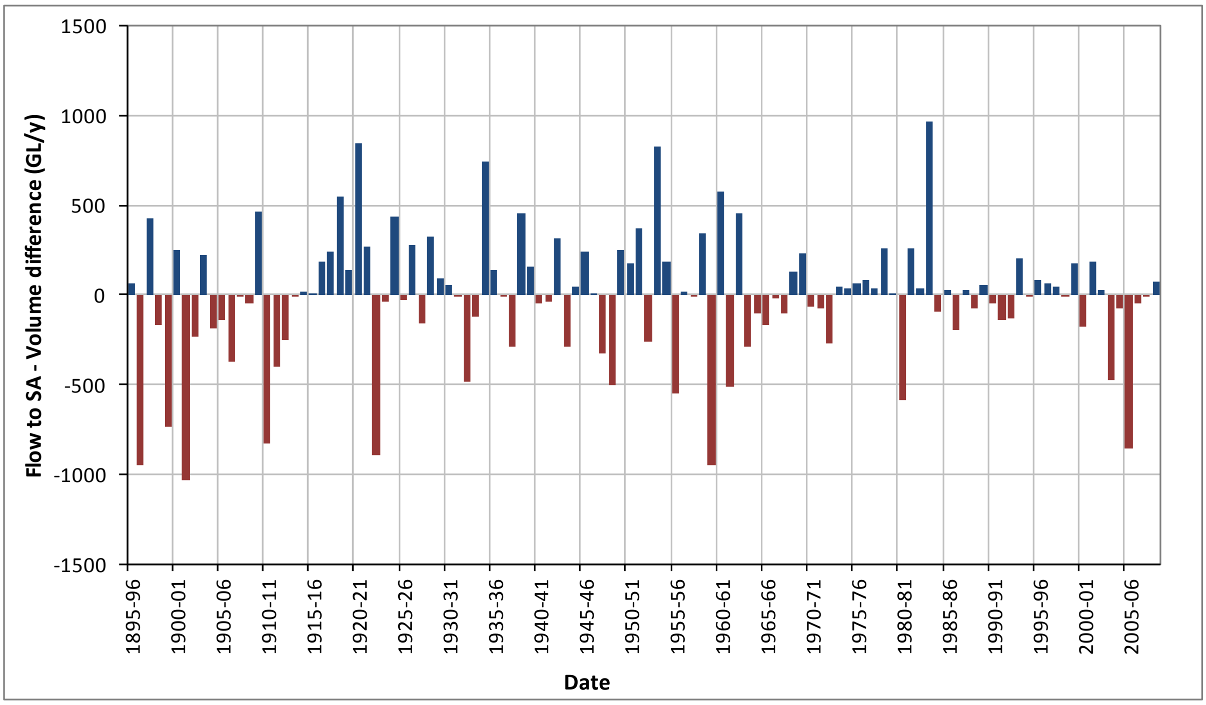



**Figure 14.** ***Flow to SA*** **differences in annual volume between BP3200RC and B3200 scenarios (blue – BP3200RC greater, red – BP3200 greater)**

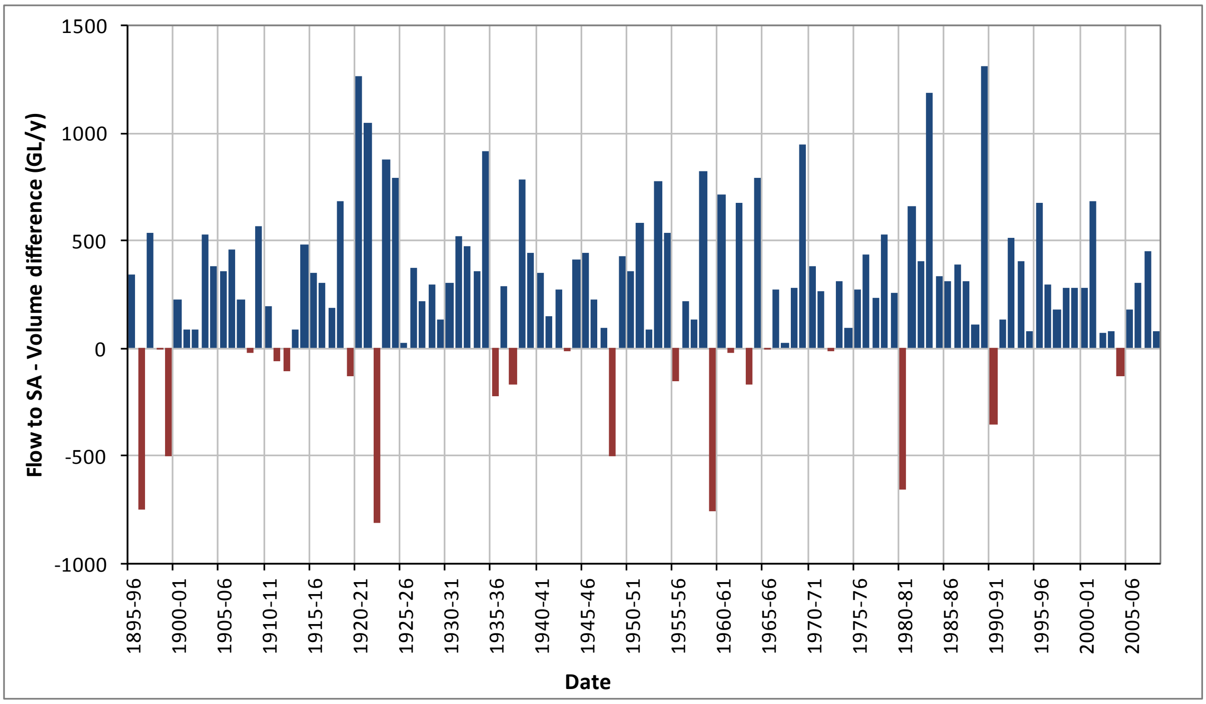



**Figure 15.** ***Flow to SA*** **differences in annual volume between BP3200RC and BP2800 scenarios (blue – BP3200RC greater, red – BP2800 greater)**

#### 4.6.1.1. Summary of flow statistics

- All flow statistics, apart from minimum daily flow, which is the same, and maximum daily flow when comparing BP3200RC and BP2800RC, increased when comparing increased water recovery volumes with or without constraints relaxed.
- Annual volume statistics are similar between BP2800 and BP2800RC, and between BP3200 and BP3200RC. Nonetheless, there is large inter-annual variability for some periods due to differences in the environmental watering sequence between scenarios.
- Small differences were observed in the comparison of daily flow statistics.

### 4.6.2. ANALYSIS OF IMPROVED DELIVERY OF UNSUCCESSFUL ENVIRONMENTAL WATERING EVENTS

The modelled environmental watering plan was interrogated to identify years where the same events were requested for the 80 000 ML/d for 30 day indicator at Riverland-Chowilla but not successfully delivered in the BP2800 scenario. These years were identified to be 1950, 1951 and 1960. The hydrograph for each of these years is analysed in this section.

*1950*

1950 was the first year where an environmental water event was requested for the 80 000 ML/d for 30 days target at Riverland-Chowilla in all four scenarios considered that was not successfully delivered in the BP2800 scenario. The hydrograph for the event requested at Riverland-Chowilla can be seen in Figure 16. Very high unregulated flows occurred in the Darling in this year, and high flows in the order of 80 000 – 100 000 ML/d were simulated in all scenarios (see Appendix A). Constraints can be seen to be limiting the release of water from Hume Dam, where the releases increased from the original constraint of 25 000 ML/d to the relaxed constraint of 40 000 ML/d for part of the year. However, this increase of 15 000 ML/d was small in comparison to the unregulated flows from Menindee

Lakes, and as such the improvements in the flow meeting the target duration of 30 days simulated at Riverland-Chowilla were relatively small (Figure 16).

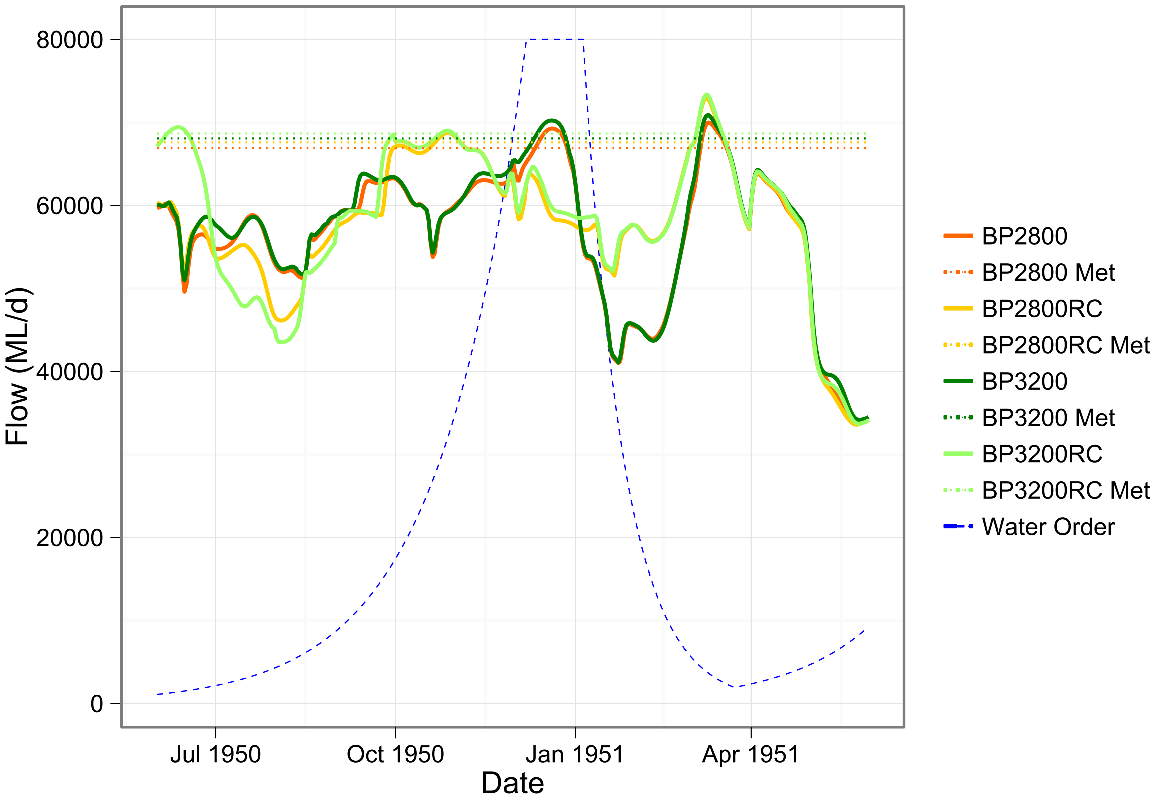



**Figure 16. Hydrograph of flows delivered to Riverland-Chowilla in 1950. For each scenario, the horizontal dotted line (e.g. BP2800 Met) represents the flow exceeded for 30 days.**

*1951*

The impact of the relaxation of constraints for the flow event ordered for Riverland-Chowilla in 1951 for all four modelled scenarios was presented in Figure 3. It can be seen that the relaxed constraints scenarios increase the peak flows, with the highest flows extended for longer periods of time in the relaxed constraints scenarios compared to the two scenarios with constraints active. Both the BP2800RC and BP3200RC scenarios increase the flow rate that was met for 30 days duration. The flow that was exceeded for 30 days is 59 738 ML/d for BP2800, increasing to 64 099 ML/d for BP2800RC. The flow that exceeds 30 days for BP3200 is 61 049 ML/d, increasing to 66 655 ML/d after relaxing constraints. The higher flow in BP3200RC compared to BP2800RC occurred even though an extra event was requested for the bird breeding target at Gunbower - Koondrook - Perricoota in the BP3200RC scenario in 1951, which was not requested in the BP2800RC scenario.

*1960*

The final year that can be used for comparison is 1960. From Figure 17, it can be seen that the relaxation of constraints provided a greater increase in the flow that exceeded the 30 day target duration compared to that from just an increase in volume of water recovered. In this year there were high unregulated flows occurring in all scenarios in the Murrumbidgee and Goulburn Rivers (see Appendix A). As the constraints were not active for much of the year for these two rivers, the additional benefit from further relaxing constraints was minimal.

The BP2800RC scenario resulted in a slightly higher flow meeting the target duration compared to BP3200RC. This is expected to be due to also targeting a higher volume target in the BP3200RC scenario compared to the BP2800RC scenario, where in the same year a 70 000 ML/d for 42 days event was targeted in BP3200RC, compared to a 35 000 ML/d for 30 day event at Barmah in the BP2800RC scenario. This highlights an advantage of further water recovery volume, where a number of high flow targets could be requested with 3200 GL available, however it is assumed that this was not possible for the 2800 GL water recovery scenario, and instead a lower flow and duration target had to be attempted.

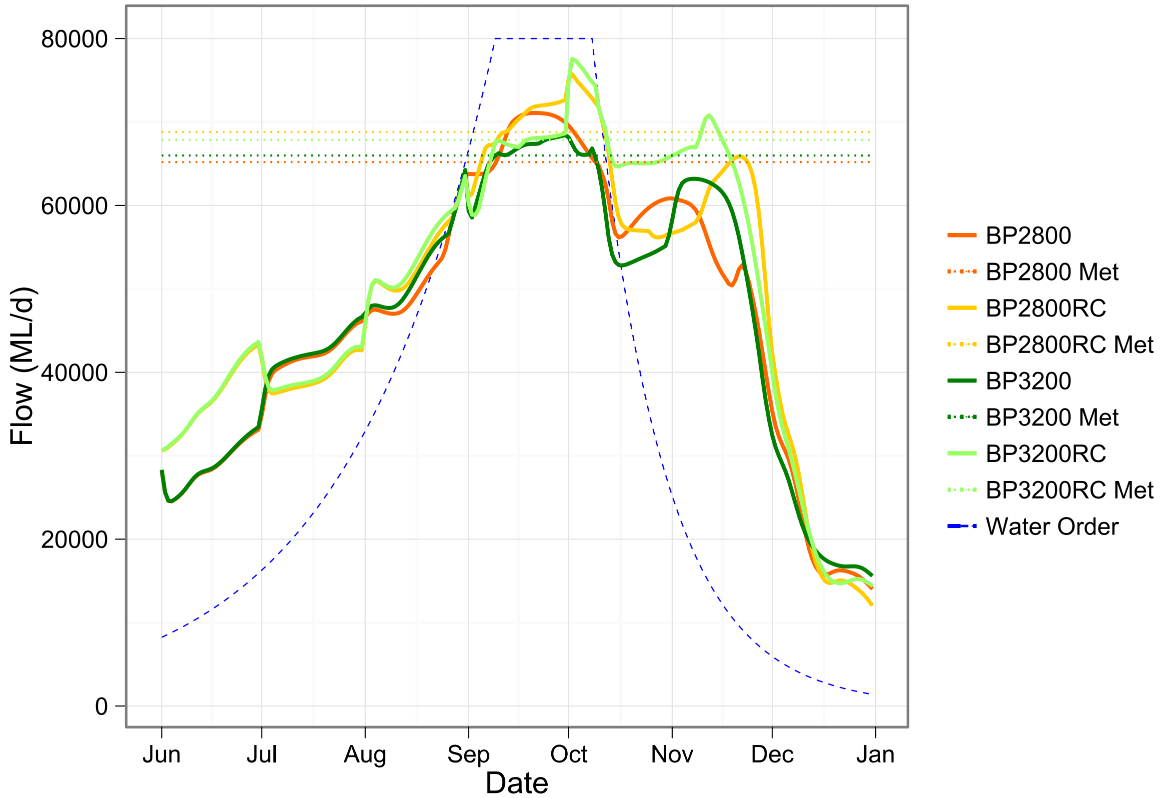



**Figure 17. Hydrograph of flows delivered to Riverland-Chowilla in 1960. For each scenario, the horizontal dotted line (e.g. BP2800 Met) represents the flow exceeded for 30 days.**

#### 4.6.2.1. Summary of improvements to unsuccessful watering events

- The increased water recovered and the relaxation of constraints results in improved ability to deliver the highest watering events targeted in the watering plan.
- This was particularly the case when constraints are limiting the delivery of flow (i.e. in the absence of unregulated flow events upstream).

### 4.6.3. NUMBER OF YEARS MEETING SA EWRS

An assessment of the SA EWRs is shown in Table 8. In this section, each EWR has been coloured to denote whether the target has been met in the following manner:

| |
|---|
| EWR target is met under scenario |
| EWR target is not met under scenario, but occurs at an increased frequency compared to BP2800 conditions |
| EWR target is not met under scenario, but occurs at an increased frequency compared to Baseline conditions |
| EWR target is not met under scenario, with a frequency that is less than or the same as under Baseline conditions |

**Table 8. Hydrological assessment of the average frequency of events at the target flow rate for SA EWRs. Modelled scenario average frequency must be less than target to be met.**

| Label | Target | Flow (ML/d) | Duration (days) | Average Frequency (1 in … years) | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Target | Base-line | BP2800 | BP2800RC | BP3200 | BP3200RC | Without Develop-ment |
| BB1 | Maintain and improve the health of 80% of the black box woodlands | >100 000 | 20 | 6 | 16.3 | 19 | 16.3 | 14.3 | 14.3 | 5 |
| BB2 | Maintain and improve the health of ~60% of the black box woodlands | 100 000 | 20 | 5 | 16.3 | 19 | 16.3 | 14.3 | 14.3 | 5 |
| BB3 | Maintain and improve the health of ~50% of the black box woodlands | 85 000 | 30 | 5 | 11.4 | 9.5 | 9.5 | 10.4 | 10.4 | 3.5 |
| BBr1 | Successful recruitment of cohorts of black box at lower elevations | 85 000 | 20 | 10 | 9.5 | 8.8 | 8.8 | 8.1 | 9.5 | 2.9 |
| BBr2 | Successful recruitment of cohorts of black box at higher elevations | >100 000 | 20 | 10 | 16.3 | 19 | 16.3 | 14.3 | 14.3 | 5 |
| FSr | Support spawning and recruitment by native fish that are characterised as flow-cued spawners (i.e. golden perch and silver perch) | 15 000 | 60 | 2 | 3.1 | 1.8 | 1.8 | 1.7 | 1.7 | 1.2 |
| FP | Stimulate spawning, provide access to the floodplain and provide nutrients and resources | 80 000 | >30 | 4 | 10.4 | 9.5 | 9.5 | 8.8 | 9.5 | 2.9 |
| Lig1 | Maintain and improve the health of ~50% of the lignum shrubland | 70 000 | 30 | 3 | 8.1 | 6 | 6.3 | 5.4 | 5.0 | 2.4 |
| Lig2 | Maintain and improve the health of 80% of the lignum shrubland | 80 000 | 30 | 5 | 10.4 | 9.5 | 9.5 | 8.8 | 9.5 | 2.9 |

| Label | Target | Flow (ML/d) | Duration (days) | Average Frequency (1 in … years) | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Target | Base-line | BP2800 | BP2800RC | BP3200 | BP3200RC | Without Develop-ment |
| MCr | Support spawning and recruitment by Murray cod | 40 000 | 60 | 4 | 6 | 3.8 | 3.7 | 3.6 | 3.2 | 1.7 |
| Mos1 | Provide mosaic of habitats (i.e. larger proportions of various habitat types are inundated) | 90 000 | 30 | 5 | 14.3 | 12.7 | 12.7 | 12.7 | 14.3 | 4.2 |
| Mos2 | Provide mosaic of habitats (i.e. larger proportions of various habitat types are inundated) | 80 000 | >30 | 4 | 10.4 | 9.5 | 9.5 | 8.8 | 9.5 | 2.9 |
| Mos3 | Provide mosaic of habitats (i.e. larger proportions of various habitat types are inundated) | 70 000 | 60 | 4 | 14.3 | 12.7 | 12.7 | 9.5 | 11.4 | 3 |
| Mos4 | Provide mosaic of habitats (i.e. larger proportions of various habitat types are inundated) | 60 000 | 60 | 3 | 8.1 | 5.2 | 4.8 | 4.8 | 4.4 | 2.4 |
| RG | Maintain and improve the health of 80% of the red gum woodlands and forests (adult tree survival) | 80 000 to 90 000 | >30 | 4 | 10.4 | 9.5 | 9.5 | 8.8 | 9.5 | 2.9 |
| RGr | Successful recruitment of cohorts of red gums | 80 000 | 60 | 5 | 16.3 | 16.3 | 19 | 16.3 | 16.3 | 5 |
| TW1 | Inundation of (~80%) temporary wetlands for large scale bird and fish breeding events | 80 000 | >30 | 4 | 10.4 | 9.5 | 9.5 | 8.8 | 9.5 | 2.9 |
| TW2 | Maintain and improve majority of lower elevation (~20%) temporary wetlands in healthy condition; and Inundation of lower elevation temporary wetlands for small scale bird and fish breeding events, and microbial decay/export of organic matter | 40 000 | 90 | 2 | 4.4 | 3 | 3.1 | 2.9 | 2.9 | 1.7 |
| WB1 | Maintain lignum inundation for waterbird breeding events | 70 000 | 60 | 4 | 14.3 | 12.7 | 12.7 | 9.5 | 11.4 | 3 |

| Label | Target | Flow (ML/d) | Duration (days) | Average Frequency (1 in … years) | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Target | Base-line | BP2800 | BP2800RC | BP3200 | BP3200RC | Without Develop-ment |
| WB2 | Provide habitat (red gum communities) for waterbird breeding events | 70 000 | 60 | 4 | 14.3 | 12.7 | 12.7 | 9.5 | 11.4 | 3 |

Three of the targets can be seen to be met for all four water-recovery scenarios; the two metrics for recruitment by large-bodied native fish and one of the black box recruitment EWRs. The desired frequency was not achieved for the remaining 17 EWRs for any of the water recovery scenarios. However, it can be seen that frequency of events did generally improve between water recovery scenarios comparing volumes of 2800 GL to 3200 GL (Table 8). The relaxation of constraints had some effect on the frequency of events at the target flow rate (with a duration as defined by the particular EWR), where four of the EWRs increased in frequency when comparing BP2800 to BP2800RC (BB1, BB2 BBr1 and Mos4), and two of the EWRs increased when comparing BP3200 to BP3200RC (Mos4 and Lig1).

As noted in Appendix B, only one of the events requested for the MDBA's 80 000 ML/d for 30 day indicator of Riverland-Chowilla was delivered in full (in the BP3200 scenario). As such, the results from requesting these events are more likely to be seen in a slightly lower flow target, the 70 000 ML/d for 30 day Lig1, EWR for example. Therefore, the two EWRs that increased in frequency when comparing BP3200 to BP3200RC, Lig1 and Mos4, correspond to MDBA indicators, and as such targeted events in the modelled environmental watering decisions. A number of the SA EWRs that were beyond the MDBAs modelled environmental watering plan, those targeting a flow above 80 000 ML/d for 30 days, or above 60 000 ML/d for 60 days can be seen to decrease, most likely due to decisions made in the modelling to enable more efficient delivery of flows to the intended targets.

It is recognised that the objectives of the modelling and watering decisions by the MDBA to meet their own Riverland-Chowilla floodplain indicators influences the differences (or lack thereof) observed in SA EWRs. There are differences between the frequency of meeting SA EWRs presented in Table 8 to the frequency of meeting MDBA indicators for the same flow and duration as reported by the MDBA (MDBA, 2012). The differences in the assessment methods are explained in Appendix B. Ecological analysis has determined that improvements and trends between scenarios are better demonstrated by comparing the area of habitat supported by frequency and duration metrics for each EWR (as discussed later in this document and shown in Table 11), rather than comparing average frequencies of EWRs (Table 8).

#### 4.6.3.1. Summary of years meeting SA EWRs

- The analysis of frequency of meeting target flow rates in water years for all SA EWRs over the 114 year period indicated that the environmental water requirements were met at the target flow rate for three out of 20 of South Australia's floodplain/channel targets under all water recovery scenarios, with two of these being channel targets to support fish breeding and the other EWR being for Black Box recruitment.
- The desired frequency was not achieved for the remaining 17 of the 20 EWRs for any of the water recovery scenarios. However, the frequency of events did generally improve between 2800 GL and 3200 GL water recovery scenarios.
- The relaxation of constraints had some effect on the frequency of events at the target flow rate (with a duration as defined by the particular EWR), where four of the EWRs increased in frequency when comparing BP2800 to BP2800RC (BB1, BB2 BBr1 and Mos4), and two of the EWRs increased when comparing BP3200 to BP3200RC (Mos4 and Lig1).
- There was also no worsening of the average frequency of flows above 100 000 ML/d (generally unregulated events) under the BP3200RC scenario.

### 4.6.4. NUMBER OF EVENTS MEETING SA EWRS

The majority of EWR targets between 40 000 ML/d and 80 000 ML/d had the highest number of events meeting their target requirements under the BP3200 or BP3200RC scenarios (Table 9). For events relating to Murray cod recruitment with a target flow rate of 40 000 ML/d (MCr) there were 37 events received under the BP2800 scenario compared to 41 under BP3200RC. For events associated with filling and sustaining processes within lower elevation temporary wetlands (TW2) there were 31 events under BP2800RC compared to 37 under BP3200RC. For events associated with sustaining a mosaic of habitats at 60 000 ML/d flow rate, 22 events were received under the BP2800 scenario compared to 29 under the BP3200RC scenario. Seventeen events meeting the requirements for sustaining healthy lignum populations occurred under the BP2800 recovery scenario compared to 22 under the BP3200RC scenario.

Several targets had the highest number of events delivered under the BP3200 scenario. Waterbird breeding targets (WB1 and WB2) recorded 10 events under the BP3200 scenario compared to nine for all other recovery scenarios including Baseline. This compared to 36 events under Without Development conditions. For targets associated with the 80 000 ML/d flow band (Mos2, FP, RG) there were 12 events delivered under the BP3200 scenario compared to 11 for all other recovery scenarios and Baseline. This compares to 37 under Without Development conditions (Table 9).

The target for Black box (BB3) had the highest number of events delivered under the BP2800 and BP2800RC scenarios (Table 9).

The EWRs that had the most events recorded for the BP3200 and BP2800 GL scenarios were generally beyond the indicators targeted for Riverland-Chowilla in the MDBA's watering plan. For example, there was no indicator requesting flow as high as 70 000 ML/d for as long as 60 days (WB1, WB2 and Mos3), and no events greater than 80 000 ML/d (i.e. BB3). While events were requested for the 80 000 ML/d for 30 day MDBA indicator, only one event was delivered in full, in the BP3200 scenario (Appendix B). As such, this scenario recorded one more event for these EWRs (TW1, Mos2, FP and RG).

A number of the events requested for the 80 000 ML/d for 30 day MDBA indicator were delivered within 10% of this target (Appendix B). As such, these targeted watering events can be observed for the 70 000 ML/d for 30 day EWR (Lig1) target. 60 000 ML/d for 60 days (Mos4) was also targeted in the MDBA's watering plan. For these two EWRs, the relaxation of constraints can be seen to have a benefit with the number of events increasing when comparing BP2800 to BP2800RC, and also BP3200 and BP3200RC. The number of events also increased with the increased water recovery volume, and as such BP3200RC delivered the most events for these two EWRs.

**Table 9. Number of events meeting EWR targets between 40 000 ML/d and 85 000 ML/d for each flow recovery scenario**

| | Baseline | BP2800 | BP2800RC | BP3200 | BP3200RC | Without Development |
|---|---|---|---|---|---|---|
| MCr (40 000 ML/d) | 26 | 37 | 36 | 39 | 41 | 74 |
| TW2(40 000 ML/d) | 23 | 31 | 32 | 33 | 37 | 64 |
| Mos4 (60 000 ML/d) | 14 | 22 | 24 | 24 | 29 | 50 |
| WB1 & WB2(70 000 ML/d) | 9 | 9 | 9 | 10 | 9 | 36 |
| Lig1 (70 000 ML/d) | 15 | 17 | 18 | 19 | 22 | 51 |
| Mos 3 (70 000 ML/d) | 8 | 9 | 9 | 10 | 9 | 33 |
| TW1 (80 000 ML/d) | 11 | 11 | 11 | 12 | 11 | 37 |
| Mos2, FP, RG (80 000 ML/d) | 11 | 11 | 11 | 12 | 11 | 37 |
| BB3 (85 000 ML/d) | 10 | 11 | 11 | 10 | 10 | 30 |

#### 4.6.4.1. Summary of number of events meeting SA EWRs

- In general, the greatest number of events for EWRs between 40 000 and 80 000 ML/d flow bands was observed under the BP3200 or BP3200RC scenarios.
- Several of the EWR targets had the greatest number of events for the BP3200RC scenario. These were Murray Cod (MCr), Mosaic of habitats at 60 000 ML/d (Mos4), Lignum (Lig1) at 70 000 ML/d and lower elevation temporary wetlands (TW2).
- The EWR targets for water bird breeding (WB1 and WB2), Mosaic of habitats (Mos2), floodplain access (FP) and red gum (RG) had the highest number of events recorded under the BP3200 scenario.
- For flow bands where the MDBA targeted improvements, the relaxation of constraints provided the highest number of events. This was particularly observed for Lignum (Lig1) and Mosaic of habitats (Mos 4).

### 4.6.5. FLOODPLAIN AREA AT WHICH KEY EWR METRICS ARE MAINTAINED

#### 4.6.5.1. Flow rate at which average frequency and duration metrics are met

For three of the floodplain/channel EWRs (BBr2, FSr, MCr), the flow rate that met the average frequency and duration metrics exceeded the target flow rate under all of the water recovery scenarios (Table 10). The target flow rate was also exceeded under Baseline for two of these EWRs (BBr2, FSr).

Despite target flow rates not being met, the results indicate that the flow rate that did meet the average frequency and duration metrics increased for all 20 EWRs under BP2800 when compared to Baseline. This increase ranged from 4081 ML/d for BBr1 and BBr2 to 13 065ML/d for FSr, Mos3, WB1 and WB2. For 18 of the 20 EWRs, there were further improvements under BP3200RC ranging from 198 ML/d for TW2 to 3794 ML/d for RGr compared to BP2800.

For all but three of the targets (BBr1, BBr2, TW2), the highest flow rate that met the specified average frequency and duration metrics occurred in the BP3200RC scenario and ranged from being within 8810 ML/d (TW2) to within 27 200 ML/d (BB2) of the targeted flow rate (Table 10).

For two of the remaining targets (BBr1 and BBr2), the highest flow rate that met the specified average frequency and duration metrics occurred in the BP2800 scenario. However, the flow rates that met the specified average frequency and duration metrics were above 85 000 ML/d in all scenarios, including Baseline, and therefore unlikely to be influenced by environmental water releases. For the remaining EWR (TW2), the highest flow was delivered by the BP3200 scenario. Flow rates that met the specified average frequency and duration metrics for TW2 were below 40 000 ML/d in all scenarios. Flow events in these lower flow bands may have decreased in magnitude or duration under the scenarios with relaxed constraints to enable the delivery of the higher flow events (as noted in Section 3).

Results indicate that the frequency and duration requirements were met for both of the new in-channel EWRs relating to recruitment by large-bodied native fish. However, the results presented in this section did not take into account the timing of flows, which is a critical aspect for fish recruitment as it influences water temperature. The results therefore show an improvement for in-channel flows under the water recovery scenarios, however they are only an indication of potential ecological outcomes for large-bodied native fish recruitment. Timing is also important for waterbird breeding and small-scale fish breeding within temporary wetlands (WB1, WB2, TW1 and TW2).

When the area of floodplain habitat that is inundated at the flow rates that met the average frequency and duration metrics was determined, the results showed an increase in area for 18 of the targets under BP2800 when compared to Baseline. In general, between 40–60% of the managed floodplain is supported with the average frequency and duration metrics for 10 floodplain/channel EWRs falling in this range. The increase ranged from 320 ha (BBr1 and BBr2) to 6130ha (FP). For 16 of the 18 targets, there were further improvements under BP3200RC, ranging from 10 ha (TW2) to 3280 ha (Mos1). For all but three of the targets (BBr1, BBr2, TW2), the maximum area inundated at the required frequency and duration, as specified by the relevant EWR, occurred in the BP3200RC scenario (Table 11).

**Table 10. Flow rate that meets the average frequency and duration metrics of the SA floodplain/channel EWRs under each modelled scenario compared to target flow rate**

| Label | Frequency (years) | Duration (days) | Target flow rate (ML/d) | Flow rate that meets average frequency and duration metrics (ML/d) | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | Baseline | BP2800 | BP2800RC | BP3200 | BP3200RC | WoD |
| BB1 | 1-in-6 | 20 | >100 000 | 67 287 | 73 189 | 73 291 | 75 651 | 76 052 | 110 625 |
| BB2 | 1-in-5 | 20 | 100 000 | 64 391 | 71 400 | 71 733 | 72 676 | 72 800 | 100 542 |
| BB3 | 1-in-5 | 30 | 90 000 | 61 379 | 66 595 | 69 200 | 68 774 | 69 833 | 96 200 |
| BBr1 | 1-in-10 | 20 | >100 000 | 85 119 | 89 200 | 89 042 | 88 338 | 86 573 | 119 246 |
| BBr2 | 1-in-10 | 20 | 85 000 | 85 119 | 89 200 | 89 042 | 88 338 | 86 573 | 119 246 |
| FP | 1-in-4 | 30 | 80 000 | 56 000 | 63 257 | 62 000 | 62 000 | 64 752 | 88 565 |
| FSr | 1-in-4 | 60 | 15 000 | 43 600 | 56 665 | 56 600 | 57 800 | 58 517 | 77 605 |
| Lig1 | 1-in-3 | 30 | 70 000 | 47 201 | 54 000 | 54 000 | 54 800 | 55 200 | 80 200 |
| Lig2 | 1-in-5 | 30 | 90 000 | 61 379 | 66 595 | 69 200 | 68 774 | 69 833 | 96 200 |
| MCr | 1-in-3 | 60 | 40 000 | 37 725 | 47 655 | 48 542 | 49 600 | 49 771 | 70 358 |
| Mos1 | 1-in-5 | 30 | 90 000 | 61 379 | 66 595 | 69 200 | 68 774 | 69 833 | 96 200 |
| Mos2 | 1-in-4 | 30 | 80 000 | 56 000 | 63 257 | 62 000 | 62 000 | 64 752 | 88 565 |
| Mos3 | 1-in-4 | 60 | 70 000 | 43 600 | 56 665 | 56 600 | 57 800 | 58 517 | 77 605 |
| Mos4 | 1-in-3 | 60 | 60 000 | 37 725 | 47 655 | 48 542 | 49 600 | 49 771 | 70 358 |
| RG | 1-in-4 | 30 | 80 000 | 56 000 | 63 257 | 62 000 | 62 000 | 64 752 | 88 565 |
| RGr | 1-in-5 | 60 | 80 000 | 49 759 | 60 078 | 62 493 | 60 464 | 63 872 | 80 486 |
| TW1 | 1-in-4 | 30 | 80 000 | 56 000 | 63 257 | 62 000 | 62 000 | 64 752 | 88 565 |
| TW2 | 1-in-2 | 90 | 40 000 | 18 164 | 30 992 | 30 000 | 31 500 | 31 190 | 47 600 |
| WB1 | 1-in-4 | 60 | 70 000 | 43 600 | 56 665 | 56 600 | 57 800 | 58 517 | 77 605 |
| WB2 | 1-in-4 | 60 | 70 000 | 43 600 | 56 665 | 56 600 | 57 800 | 58 517 | 77 605 |

Maximum flow rate for scenarios (excluding WoD)

**Table 11.** **Area (rounded down to nearest 10 ha) of target habitat on the South Australian River Murray floodplain that is inundated at flow rates that meet the average frequency and duration metrics of the EWR under each modelled scenario. Highlighted cells indicate the maximum result obtained for each target (excluding WoD)**

| Target/EWR | | Reference areas (ha) | | Area inundated under modelled scenario (ha) | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Label** | **Taxa/Function** | **total floodplain** | **managed floodplain** | **Baseline** | **BP2800** | **BP2800RC** | **BP3200** | **BP3200RC** | **WoD** |
| BB1 | Black box woodlands | 15 800 | 4260 | 1610 | 2510 | 2530 | 3000 | 3120 | 7210 |
| BB2 | Black box woodlands | 15 800 | 4260 | 1250 | 2220 | 2270 | 2430 | 2450 | 7210 |
| BB3 | Black box woodlands | 15 800 | 4260 | 980 | 1520 | 1870 | 1820 | 1960 | 6780 |
| BBr1 | Black box (recruitment – lower elevations) | 15 800 | 4260 | 5650 | 5970 | 5960 | 5900 | 5760 | 7210 |
| BBr2 | Black box (recruitment – higher elevations) | 15 800 | 4260 | 5650 | 5970 | 5960 | 5900 | 5760 | 7210 |
| FP | Spawning/floodplain access | 80 040 | 41 840 | 14 540 | 20 670 | 19 450 | 19 450 | 22 120 | 48 340 |
| Lig1 | Lignum shrubland | 11 700 | 8890 | 1110 | 1740 | 1740 | 1790 | 1840 | 8920 |
| Lig2 | Lignum shrubland | 11 700 | 8890 | 3260 | 4750 | 5530 | 5400 | 5720 | 10 210 |
| Mos1 | Mosaic of habitats | 72 340 | 38 150 | 15 820 | 20 870 | 23 510 | 23 070 | 24 150 | 47 410 |
| Mos2 | Mosaic of habitats | 72 340 | 38 150 | 11 700 | 17 600 | 16 410 | 16 410 | 19 020 | 44 430 |
| Mos3 | Mosaic of habitats | 72 340 | 38 150 | 6080 | 12 170 | 12 130 | 12 970 | 13 470 | 34 740 |
| Mos4 | Mosaic of habitats | 72 340 | 38 150 | 4710 | 7940 | 8470 | 9100 | 9200 | 24 800 |
| RG | Red gum woodlands and forests | 18 910 | 11 720 | 4750 | 6600 | 6250 | 6250 | 7010 | 12 970 |
| RGr | Red gums (recruitment) | 18 910 | 11 720 | 3860 | 5720 | 6390 | 5820 | 6770 | 11 820 |

| Target/EWR | | Reference areas (ha) | | Area inundated under modelled scenario (ha) | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Label | Taxa/Function | total floodplain | managed floodplain | Baseline | BP2800 | BP2800RC | BP3200 | BP3200RC | WoD |
| TW1 | Temporary wetlands (higher elevations) | 6380 | 5600 | 3920 | 4380 | 4310 | 4310 | 4470 | 5770 |
| TW2 | Temporary wetlands (lower elevations) | 6380 | 5600 | 2260 | 2810 | 2790 | 2830 | 2820 | 3530 |
| WB1 | Waterbird breeding (lignum) | 11 700 | 8890 | 760 | 2150 | 2140 | 2400 | 2550 | 8220 |
| WB2 | Waterbird breeding (red gum) | 18 910 | 11 720 | 2880 | 4900 | 4890 | 5170 | 5340 | 10 950 |

Maximum result obtained for each target (excluding WoD)

#### 4.6.5.2. Flow rate at which maximum interval and duration metrics are met

The flow rate that met the duration and maximum interval metrics of the EWRs was well below the target flow rate for 16 of the floodplain/channel targets (Table 12). The flow rate that met the specified maximum interval and duration for recruitment by flow-cued spawners (FSr) was greater than the target flow rate, indicating that this EWR was met. However, the maximum interval analysis did not consider continuous flow events, which is critical for successful recruitment by large-bodied native fish. Similarly, the flow rates meeting maximum interval for MCr may be an over-estimate, as events that were not continuous may be included in the assessment of flows meeting the maximum interval (Table 8 only included continuous events for the two channel metrics). This analysis could not be undertaken for three of the floodplain targets, which relate to black box and red gum recruitment (BBr1, BBr2, RGr), as their EWRs do not specify a maximum interval.

Despite target flow rates not being met, the results indicate that the flow rate that did meet duration and maximum interval metrics increased for all 17 EWRs under BP2800 when compared to Baseline. This increase ranged from 8000 ML/d for BB1 and BB2 to 18 000 ML/d for FP, Lig1, Mos1, Mos2, RG, TW1. For nine of the 17 EWRs, the flows were the same or greater for BP3200RC compared to BP2800, up to a 4000 ML/d increase for Mos4. Eight of the 17 EWRs showed no difference between three of the scenarios.

There was an increase in the area of floodplain habitats inundated at the required maximum interval and duration for all of the 15 floodplain/channel targets assessed under BP2800 when compared to Baseline (Table 13). This increase ranged from 10 ha (WB1) to 2450 ha (FP). For six of the 15 targets, there were further but small improvements under BP3200RC, ranging from 20 ha (WB1) to 270 ha (Mos3). These results indicate an increase in the area of habitat that may be inundated at the appropriate flood frequency, duration and maximum interval as per the relevant SA EWR. This information was not generated for the two targets relating to recruitment by large-bodied native fish (FSr and MCr), as their EWRs relate to a required flow velocity rather than inundation of floodplain vegetation communities.

The water recovery scenario that inundated the greatest area at the required maximum interval and duration, as specified by the relevant EWR, varied between targets. However, in terms of addressing maximum interval, the best results were achieved under the BP3200 scenario, where the maximum area was obtained for 12 of the 15 targets (Table 13).

Habitat areas were again translated into proportions of the total area of each habitat type found targeted by each EWR. For all but two of the targets, less than 50% of the targeted area is supported under any of the water recovery scenarios in terms of meeting the maximum interval and duration requirements specified by the SA floodplain/channel EWRs.

Analysis of maximum interval and duration metrics over the 114-year period showed subtle differences. Consistent differences between scenarios were not able to be observed. However, as maximum interval metrics were not targeted in the MDBA modelling it was not expected that major differences would be observed between scenarios.

Maximum interval is considered to reflect an important ecological threshold. The analysis undertaken here may not be the most suitable for assessing differences in dry spell longevity between modelled scenarios. This could be explored further in the future.

**Table 12. Maximum flow rates that meet duration and maximum interval metrics of SA floodplain/channel EWRs under each modelled scenario. Highlighted cell indicates maximum flow rate (excluding WoD)**

| Label | Maximum Interval (years) | Duration (days) | Target flow rate (ML/d) | Flow rate that meets average frequency and duration metrics (ML/d) | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | BSL | BP2800 | BP2800RC | BP3200 | BP3200RC | WoD |
| BB1 | 8 | 20 | >100 000 | 43 000 | 51 000 | 57 000 | 56 000 | 52 000 | 63 000 |
| BB2 | 8 | 20 | 100 000 | 43 000 | 51 000 | 57 000 | 56 000 | 52 000 | 63 000 |
| BB3 | 8 | 30 | 90 000 | 37 000 | 50 000 | 48 000 | 50 000 | 50 000 | 78 000 |
| FP | 5 | 30 | 80 000 | 20 000 | 38 000 | 37 000 | 38 000 | 38 000 | 53 000 |
| FSr | 5 | 60 | 15 000 | 15 000 | 25 000 | 27 000 | 33 000 | 28 000 | 47 000 |
| Lig1 | 5 | 30 | 70 000 | 20 000 | 38 000 | 37 000 | 38 000 | 38 000 | 53 000 |
| Lig2 | 8 | 30 | 90 000 | 37 000 | 50 000 | 48 000 | 50 000 | 50 000 | 78 000 |
| MCr | 5 | 60 | 60 000 | 15 000 | 25 000 | 27 000 | 33 000 | 28 000 | 47 000 |
| Mos1 | 6 | 30 | 90 000 | 20 000 | 38 000 | 37 000 | 38 000 | 38 000 | 60 000 |
| Mos2 | 5 | 30 | 80 000 | 20 000 | 38 000 | 37 000 | 38 000 | 38 000 | 53 000 |
| Mos3 | 6 | 60 | 70 000 | 15 000 | 25 000 | 27 000 | 34 000 | 28 000 | 51 000 |
| Mos4 | 4 | 60 | 60 000 | 13 000 | 23 000 | 25 000 | 26 000 | 27 000 | 43 000 |
| RG | 5 | 30 | 80 000 | 20 000 | 38 000 | 37 000 | 38 000 | 38 000 | 53 000 |
| TW1 | 5 | 30 | 80 000 | 20 000 | 38 000 | 37 000 | 38 000 | 38 000 | 53 000 |
| TW2 | 3 | 90 | 40 000 | 6000 | 15 000 | 13 000 | 20 000 | 15 000 | 36 000 |
| WB1 | 6 | 60 | 70 000 | 15 000 | 25 000 | 27 000 | 34 000 | 28 000 | 51 000 |
| WB2 | 6 | 60 | 70 000 | 15 000 | 25 000 | 27 000 | 34 000 | 28 000 | 51 000 |

Maximum flow rate (excluding WoD)

**Table 13. Area (rounded down to nearest 10 ha) of target habitat on the South Australian River Murray floodplain that is inundated at flow rates that meet the maximum interval and duration metrics of the EWR under each modelled scenario. Highlighted cells indicate the maximum result obtained for each target (excluding WoD)**

| Target/EWR | | Reference areas (ha) | | Area inundated under modelled scenario (ha) | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Label | Taxa/Function | Total floodplain | Managed floodplain | Baseline | BP2800 | BP2800RC | BP3200 | BP3200RC | WoD |
| BB1 | Black box woodlands | 15 800 | 4260 | 260 | 520 | 720 | 680 | 550 | 1120 |
| BB2 | Black box woodlands | 15 800 | 4260 | 260 | 520 | 720 | 680 | 550 | 1120 |
| BB3 | Black box woodlands | 15 800 | 4260 | 210 | 500 | 410 | 500 | 500 | 3680 |
| FP | Spawning/floodplain access | 80 040 | 41 840 | 4900 | 7350 | 7030 | 7350 | 7350 | 13 110 |
| Lig1 | Lignum shrubland | 11 700 | 8890 | 270 | 540 | 490 | 540 | 540 | 1680 |
| Lig2 | Lignum shrubland | 11 700 | 8890 | 490 | 1510 | 1220 | 1510 | 1510 | 8330 |
| Mos1 | Mosaic of habitats | 72 340 | 38 150 | 2810 | 4800 | 4490 | 4800 | 4800 | 14 520 |
| Mos2 | Mosaic of habitats | 72 340 | 38 150 | 2810 | 4800 | 4490 | 4800 | 4800 | 10 340 |
| Mos3 | Mosaic of habitats | 72 340 | 38 150 | 2810 | 2960 | 3140 | 3790 | 3230 | 9670 |
| Mos4 | Mosaic of habitats | 72 340 | 38 150 | 2810 | 2900 | 2960 | 3050 | 3140 | 5970 |
| RG | Red gum woodlands and forests | 18 910 | 11 720 | 1580 | 2390 | 2280 | 2390 | 2390 | 4270 |
| TW1 | Temporary wetlands (higher elevations) | 6380 | 5600 | 2280 | 3090 | 3030 | 3090 | 3090 | 3800 |
| TW2 | Temporary wetlands (lower elevations) | 6380 | 5600 | 2020 | 2220 | 2170 | 2280 | 2220 | 2980 |
| WB1 | Waterbird breeding (lignum) | 11 700 | 8890 | 270 | 280 | 290 | 360 | 300 | 1560 |
| WB2 | Waterbird breeding (red gum) | 18 910 | 11 720 | 1580 | 1640 | 1710 | 2020 | 1750 | 4030 |

#### 4.6.5.3. Interpretation of floodplain area at which key EWR metrics are maintained for key habitats

The results for average frequency and maximum interval for key floodplain habitats have been combined in order to determine the areas of each of these habitats that are supported on the managed floodplain and the broader 1956 floodplain.

*Red gums*

Under the BP2800 scenario, the flow rate that meets the average frequency and duration requirements for adult red gums (as per the SA EWR - RG) is 63 257 ML/d. At this flow rate approximately 6600 ha of existing red gum woodlands and forests will be inundated for the desired frequency and duration. This equates to 56% of red gums found on the managed floodplain or 35% of red gums found on the 1956 floodplain. Under the BP3200RC these results increase to approximately 7010 ha of existing red gum woodlands and forests, which represents 60% of red gums on the managed floodplain or 37% of red gums on the 1956 floodplain.

The EWR for adult red gum survival also specifies a maximum interval between events of five years. These events must be a minimum of 30 day duration to meet the red gum water requirements. The maximum flow at which this five-year interval is not exceeded (for 30 day duration events) is 38 000 ML/d under three out of four of the water recovery scenarios (BP2800, BP3200 and BP3200RC). At flows of 38 000 ML/d, approximately 2390 ha of existing red gum woodlands and forests on the SA River Murray floodplain will be inundated, which represents 20% of red gums found on the managed floodplain or 13% of red gums found on the 1956 floodplain.

The maximum area of red gum woodlands and forests receiving the appropriate flow regime to maintain and/or improve condition is 13% of the current extent on the SA River Murray floodplain. While the maximum interval will be supported by three of the water recovery scenarios (BP2800, BP3200 and BP3200RC), the average frequency and duration analysis indicates that the BP3200RC scenario provides the best flow regime for red gums (Table 10 and Table 11).

*Black box*

There are three SA targets and EWRs relating to adult tree survival for black box woodlands (BB1, BB2 and BB3). These targets vary in terms of the proportion of black box to be improved and/or maintained and hence the flow rate of the EWR also changes as it relates directly to area of inundation. Event frequency and duration also varies between the black box EWRs as a representation of the different water requirements of trees located at different elevations and hence their history of inundation.

The maximum flow at which the frequency and duration metrics of any of the adult black box targets are satisfied is 75 651 ML/d for target BB1 under the BP3200RC scenario. However, BB1 provides EWR metrics for the black box trees located at higher elevations (>100 000 ML/d), which specify a shorter event duration and lower frequency, and trees at lower elevations may require water for longer or more frequently to survive (as implied by the EWR for BB3). The flow rate that meets the inundation frequency and duration requirements for adult black box trees at lower elevations is 69 833 ML/d for target BB3 under the BP3200RC scenario. At flows of 69 833 ML/d, approximately 1960 ha of existing black box woodlands on the SA River Murray floodplain are inundated, which represents 46% of black box on the managed floodplain or 12% of black box on the 1956 floodplain.

All three of the black box adult tree survival targets specify a maximum event-interval of eight years, with an event duration of 20 or 30 days (depending on the target). The maximum flow at which this eight-year interval is not exceeded is 57 000 ML/d for 20 day events (BP2800RC) and 50 000 ML/d for 30 day events (BP2800, BP3200 and BP3200RC). At flows of 50 000 ML/d, 1510 ha of existing black box woodlands on the SA River Murray floodplain are inundated, which represents 12% of black box on the managed floodplain or 3% of black box on the 1956 floodplain.

The maximum area of black box woodlands receiving the appropriate flow regime to maintain and/or improve condition is 3% of the current extent on the SA River Murray floodplain. While the maximum interval will be supported by three of the water recovery scenarios (BP2800, BP3200 and BP3200RC), the average frequency and duration analysis indicates that the BP3200RC scenario provides the best flow regime for black box (Table 10 and Table 11).

### *Lignum*

There are two targets and EWRs relating to the maintenance and/or improvement of lignum shrublands. Lig1 target is for a lesser proportion of lignum on the floodplain and has a lower flow rate but also a higher frequency than Lig2, implying a need for more frequent floods for lignum located at lower elevations.

The flow rate that meets the frequency and duration metrics of Lig2 (high elevation lignum) under the BP2800 and BP3200RC scenarios is 61 379 ML/d and 69 833 ML/d, respectively. However, lignum located at elevations at or below 70 000 ML/d need to be inundated more frequently as indicated by the Lig1 EWR. The flow rate that meets the Lig1 frequency and duration metrics under the BP2800 and BP3200RC scenarios is 54 000 ML/d and 55 200 ML/d, respectively. At flows of 55 200 ML/d, approximately 1840 ha of existing lignum shrubland on the SA River Murray floodplain is inundated, which equates to 21% of lignum on the managed floodplain and 16% of lignum on the 1956 floodplain.

EWRs for SA targets Lig1 and Lig2 specify a maximum event interval of five and eight years, respectively. For both, the required event duration is 30 days. The flow rate at which these maximum intervals are not exceeded (for 30-day duration events) is 50 000 ML/d for eight years and 38 000 ML/d for five years under three of the water recovery scenarios (BP2800, BP3200, BP3200RC). Again, for lignum located at elevations below 70 000 ML/d, the metrics for Lig1 are appropriate (i.e. shorter maximum interval). At flows of 38 000 ML/d, approximately 540 ha of existing lignum shrubland on the SA River Murray floodplain is inundated, which equates to 6% of lignum on the managed floodplain and 5% of lignum on the 1956 floodplain.

The maximum area of lignum shrubland that will receive the appropriate flow regime to maintain and/or improve condition is 5% of the current extent on the SA River Murray floodplain. While the maximum interval will be supported by three of the water recovery scenarios (BP2800, BP3200 and BP3200RC), the average frequency and duration analysis indicates that the BP3200RC scenario provides the best flow regime for lignum (Table 10 and Table 11).

### *Temporary wetlands*

There are two targets for temporary wetlands. TW2 is for a lesser proportion of temporary wetlands compared to TW1 and has a lower flow rate, longer duration, higher frequency and shorter maximum interval, implying a need for longer, more frequent floods in wetlands located at lower elevations (below 40 000 ML/d).

The flow rate that meets the frequency and duration metrics of TW1 (higher elevation wetlands) is 63 257 ML/d under BP2800 and 64 752 ML/d under BP3200RC. The frequency and duration metrics of TW2 (lower elevation wetlands) are met by flows of 30 992 ML/d under the BP2800 scenario and 31 190 ML/d under BP3200RC. The highest flow rate of 31 500 ML/d occurred under the BP3200 scenario. The EWR for TW1 specifies a maximum interval metric of five years (for 30-day duration events), which is met at flows of 38 000 ML/d under BP2800, BP3200 and BP3200RC. However, wetlands located at elevations located below 40 000 ML/d require a shorter maximum interval and longer duration (three years interval and 90 day duration) as specified by the EWR for TW2. These requirements were met at flows of 15 000 ML/d under BP2800 and BP3200RC, with the best result of 20 000 ML/d occurring under the BP3200 scenario. At flows of 20 000 ML/d, approximately 2280 ha of existing mapped temporary wetlands are inundated, which equates to 41% of temporary wetlands on the managed floodplain and 36% of those found on the 1956 floodplain. In terms of meeting the average frequency, duration and maximum interval requirements, the best result for temporary wetlands is obtained under the BP3200 scenario.

*Mosaic of habitats*

There are four EWRs for the target 'provide mosaic of habitats' (Mos1, Mos2, Mos3 and Mos4), with targeted flow rates ranging from 60 000 ML/d for Mos4 to 90 000 ML/d for Mos1. The EWRs with a lower flow rate generally having a longer duration, higher frequency and shorter maximum interval. It is assumed that these EWRs take into account the potential for vegetation at higher elevations to have adapted to require water less often to survive, as well as the changes in the dominant species at different elevations.

The 'mosaic of habitats' targets represent a variety of floodplain vegetation communities and each of these communities differ in their individual water requirements. The targets do not directly represent the area of vegetation supported but rather the need for a diversity of habitats to be maintained, which is in turn supported by a variable flow regime. The above analysis has been based on maintaining the existing floodplain vegetation habitats in their current locations. However, there may be potential for the habitats to shift should an appropriate flow regime be provided at lower elevations. On this basis, the improvements in flow rates that meet the EWR metrics under the BP3200RC scenario for all of the mosaic of habitats targets indicate that greater areas of floodplain vegetation may be supported (Figure 18). For example, based on results for Mos3 an additional 3280 ha of floodplain vegetation would be supported under BP3200RC when compared to BP2800.

Within this mosaic of habitats, the two most dominant vegetation species on the managed floodplain are red gums and lignum. The ecological outcomes of the water recovery scenarios on these two particular species are investigated in more detail in later sections of this report.

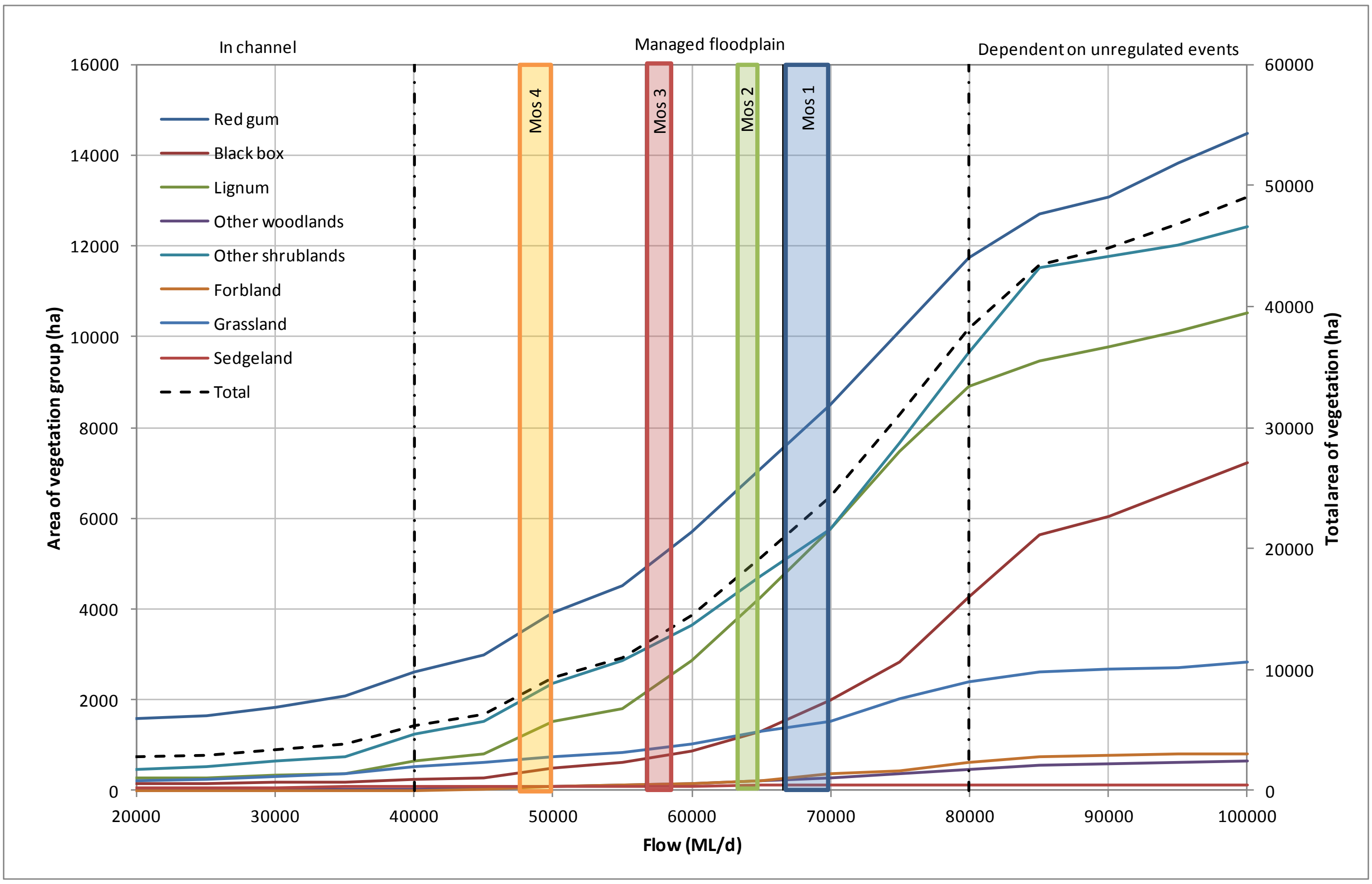



**Figure 18.** **Area of all floodplain vegetation types inundated at increasing flow rates. Areas within the shaded boxes indicate the potential zone of improved habitat suitability under BP3200RC compared to BP2800 based on results obtained for the analysis of the flow rate that meets average frequency and duration metrics of Mos1, Mos2, Mos3 and Mos4. The left side of each box indicates the results under BP2800 and the right side of each box indicates results under BP3200RC**

#### 4.6.5.4. Summary of floodplain area at which key EWR metrics are met – average frequency and maximum interval and duration

- The analysis of the flow rate that met the duration and average frequency metrics also showed that for 17 of the 20 SA EWR the highest flow rate occurred under the BP3200RC scenario.
- For 15 of the 18 floodplain/channel targets assessed, the maximum area inundated at the required frequency and duration, as specified by the relevant EWR was observed under the BP3200RC scenario.
- The improvements are most notable in the mid-level floodplain habitats which support red gum, lignum, water bird breeding, temporary wetlands, as well as sustaining a mosaic of habitats.
- In particular, an increase of 3280 ha was observed for the mosaic of habitats (Mos1) under the BP3200RC scenario compared to BP2800. This represents 63% of the vegetated areas of the active floodplain, which is an additional 9% compared to BP2800.
- Analysis of maximum interval and duration metrics over the 114 year period indicated that the flow rate that met these metrics was well below the target flow rate for 16 of the 17 floodplain/channel targets assessed. However there were increases in the flow rate that met the duration and maximum interval metrics for all 17 of the EWRs under the water recovery scenarios when compared to Baseline.
- Consistent differences between scenarios were not able to be observed using the analysis of duration and maximum interval with eight of the 17 EWRs showing similar outcomes between three of the scenarios, this was no unexpected as maximum interval metrics were not targeted in the MDBA. However, in terms of addressing maximum interval, the best results were achieved under the BP3200 scenario, where the maximum (or equal maximum) area was obtained for 12 of the 15 targets.

### 4.6.6. NUMBER AND QUALITY OF EVENTS THAT ACHIEVE THE TARGET FLOW RATE FOR RED GUM AND LIGNUM

This section explores the ecological benefits (using MFAT) of each water recovery scenario for red gum and lignum for all events exceeding the target flow rate, regardless of whether they meet the duration criteria of the EWR. For events exceeding the 80 000 ML/d target flow rate and applying the MFAT curve for adult red gums, the most events were delivered by the BP3200RC scenario, with 22 individual events compared to 21 for the three other water recovery scenarios for the 114 year period. In comparison, there were 15 events under Baseline and 65 events under Without Development conditions. Eight events which were likely to provide optimum habitat conditions occurred under the BP3200 compared to seven events provided by the other three recovery scenarios (Table 14, Figure 19). Six good events occurred under Baseline and BP3200 compared to five for all other recovery scenarios. Ten events were recorded as moderate under the BP3200RC scenario compared to seven, nine, and nine for BP3200, BP2800RC and BP2800 respectively.

As noted in the previous section, the only event that was requested for the 80 000 ML/d for 30 days MDBA indicator that was successfully delivered occurred in BP3200. As such, the 70 000 ML/d flow band has also been considered, to investigate the impact of the requested events that were not delivered in full. At the 70 000 ML/d flow rate, 34 events occurred under the BP2800 scenario compared to 37 for all other recovery scenarios. This compared to 24 events for Baseline and 64 for Without Development. Eleven flow events considered to provide optimal habitat conditions occurred under the BP3200RC scenario compared to 10, nine and nine for the BP3200, BP2800RC and BP2800 recovery scenarios, respectively. There were 10 events which provided 'good' habitat conditions for the BP2800 scenario compared to 14, 15, 13 for the BP3200RC, BP3200 and BP2800RC recovery scenarios, respectively. In general, the best habitat conditions for red gum occurred under the BP3200 and BP3200RC scenarios (Table 14, Figure 20).

The relaxation of constraints can be seen to have a positive effect on the quality of the events for red gums at the 70 000 ML/d flow band. For example, at the 2800 GL water recovery volume, 3 more good events occurred between

BP2800 and BP2800RC, with the same number of events for the other classifications. For the 3200 GL scenarios, one event can be seen to move up from a poor to moderate classification, and a good event moved to the optimum category, even though the total number of events is the same.

**Table 14. Number of events relating to optimum, good, moderate and poor habitat condition for red gum at 70 000 ML/d and 80 000 ML/d flow bands.**

| **80 000 ML/d** | **Baseline** | **BP2800** | **BP2800RC** | **BP3200** | **BP3200RC** | **Without Development** |
|---|---|---|---|---|---|---|
| Optimum | 5 | 7 | 7 | 8 | 7 | 19 |
| Good | 6 | 5 | 5 | 6 | 5 | 22 |
| Moderate | 4 | 9 | 9 | 7 | 10 | 22 |
| Poor | 0 | 0 | 0 | 0 | 0 | 2 |
| Total | 15 | 21 | 21 | 21 | 22 | 65 |
| **70 000 ML/d** | **Baseline** | **BP2800** | **BP2800RC** | **BP3200** | **BP3200RC** | **Without Development** |
| Optimum | 7 | 9 | 9 | 10 | 11 | 22 |
| Good | 7 | 10 | 13 | 15 | 14 | 31 |
| Moderate | 10 | 13 | 13 | 10 | 11 | 10 |
| Poor | 0 | 2 | 2 | 2 | 1 | 1 |
| Total | 24 | 34 | 37 | 37 | 37 | 64 |

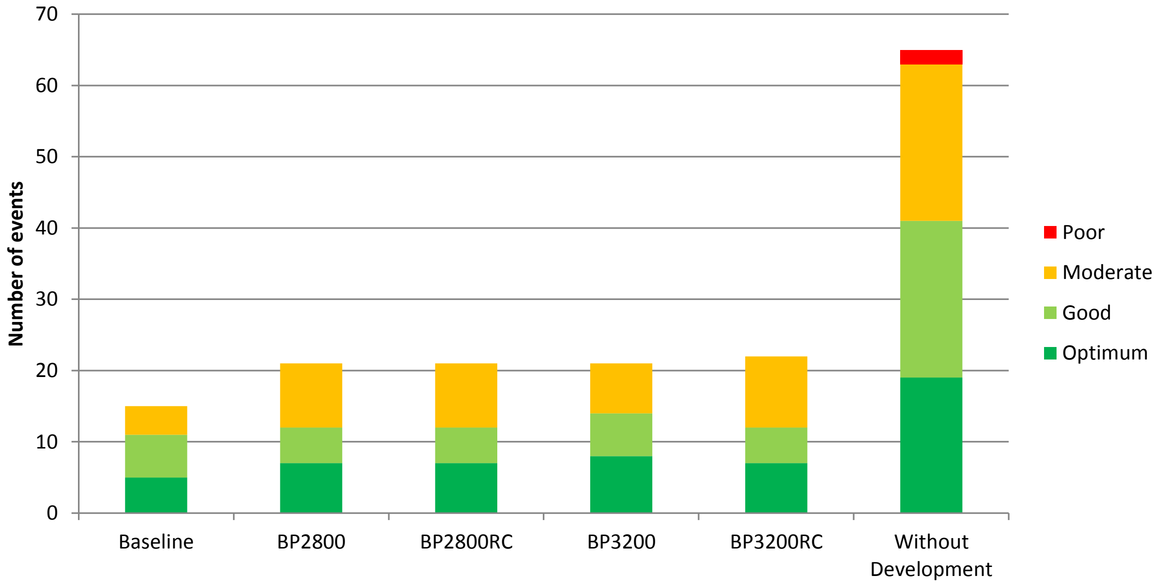



**Figure 19. Number of events reaching 80 000 ML/d target relating to MFAT preference scores for length of events in optimum, good, moderate and poor habitat condition**

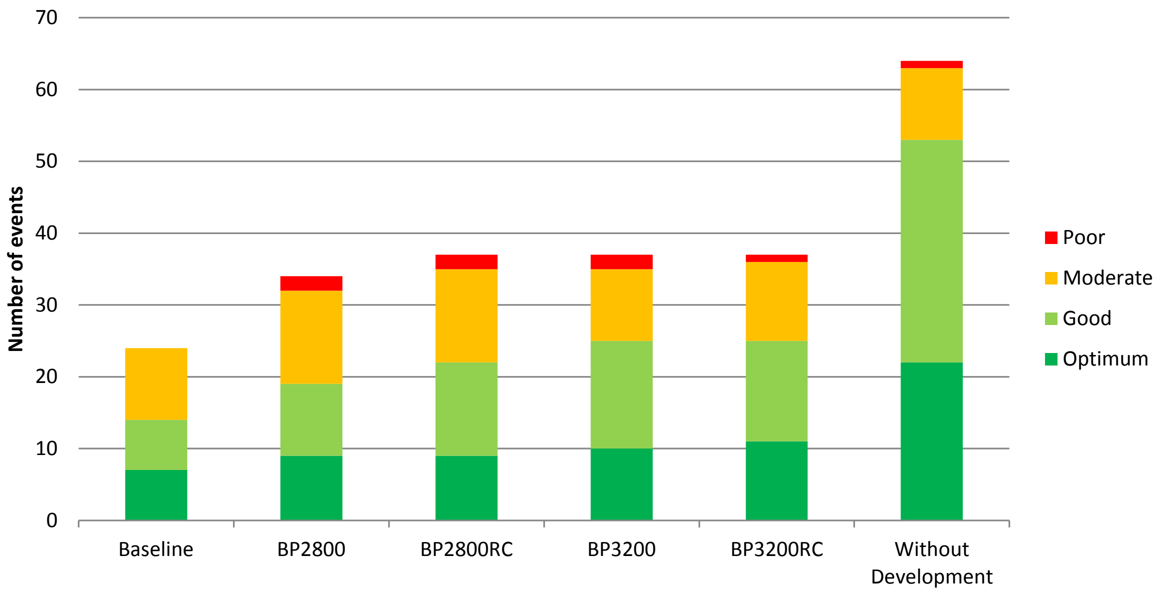



**Figure 20.** **Number of events at 70 000 ML/d flow rate relating to MFAT preference scores for length of events in optimum, good, moderate and poor habitat condition**

The MFAT curve for adult lignum has also been applied to the events that exceeded the 70 000 ML/d flow threshold. For this case, 34 events occurred under the BP2800 scenario compared to 37 for all other recovery scenarios. This compares to 24 events under Baseline conditions and 64 under Without Development conditions (Table 15, Figure 21). Of these events six were classed 'optimal' under BP2800 and BP2800RC compared to seven for the 3200 GL scenarios and Baseline. However, 11 events classed as 'good' occurred under BP2800 compared to 14, 16 and 17 under BP2800RC, BP3200 and BP3200RC respectively. Fifteen events of moderate duration occurred under the BP2800 and BP2800RC scenarios compare to 12 for BP3200 and BP3200RC (Table 15, Figure 21). One event classed as 'poor' occurred under the 3200RC scenario compared to 2 for the other recovery scenarios. Baseline recorded no poor events but had a lower number of events in total suggesting that shorter duration events did not exist under this scenario.

A similar change to the classification of events can be seen in Table 15 for Lignum that was seen for Red Gum. Again, there were three more events classified as good when comparing BP2800 to BP2800RC. Also, when comparing BP3200 to BP3200RC one event that provided poor habitat condition for adult lignum moved to the good classification after the relaxation of constraints.

**Table 15 .** **Number of events reaching 70 000 ML/d target relating to Lignum MFAT preference scores for length of events in optimum, good, moderate and poor habitat condition.**

| 70 000 ML/d | Baseline | BP2800 | BP2800RC | BP3200 | BP3200RC | Without Development |
|---|---|---|---|---|---|---|
| Optimum | 7 | 6 | 6 | 7 | 7 | 13 |
| Good | 6 | 11 | 14 | 16 | 17 | 35 |
| Moderate | 11 | 15 | 15 | 12 | 12 | 15 |
| Poor | 0 | 2 | 2 | 2 | 1 | 1 |
| Total | 24 | 34 | 37 | 37 | 37 | 64 |

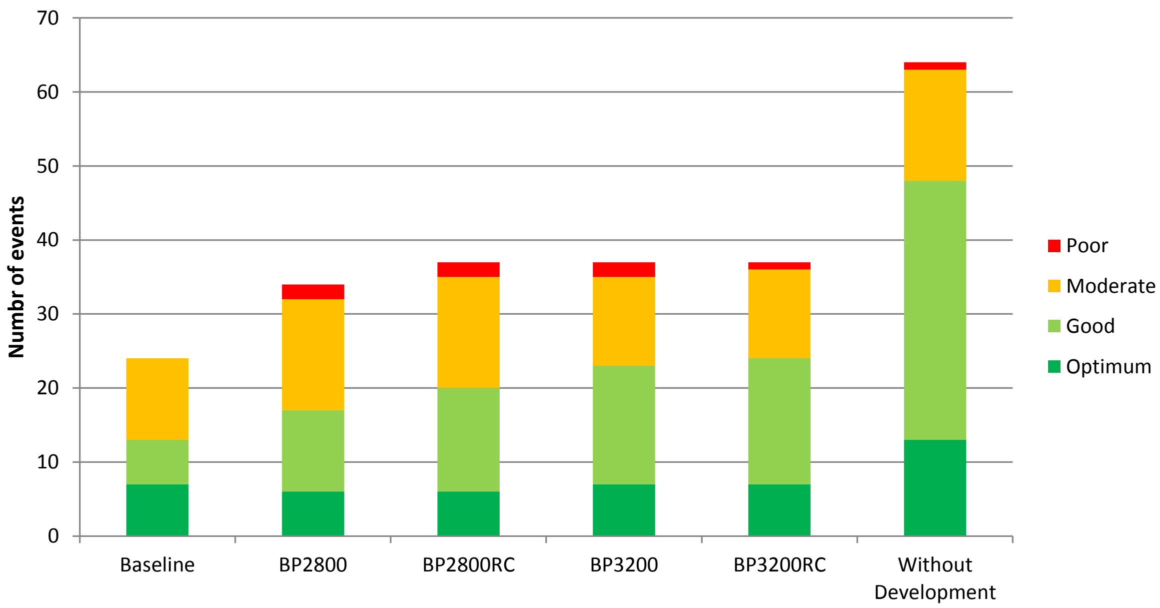



**Figure 21. Number of events reaching 70 000 ML/d target relating to MFAT preference scores for length of events in optimum, good, moderate and poor habitat condition**

### 4.6.6.1. Summary of total number of event analysis and ecological response

- When assessing the quality of events for lignum (target flow rate 70 000 ML/d) the highest quality habitat was likely to be delivered under the BP3200RC. 17 events providing good habitat conditions and seven providing optimal were delivered by BP3200RC. This compared to 11 providing good and six providing optimal for BP2800 scenario.
- For red gum the highest quality habitat was likely to be delivered under the BP3200 scenario at the target flow rate. There were eight events providing optimal habitat conditions for the BP3200 scenario compared to seven for the other recovery scenarios. However, at the 70 000 ML/d flow rate, corresponding to events delivered by the MDBA, the greatest number of optimal events was delivered by the 3200RC scenario.
- Relaxation of constraints was found to improve the quality of events for both red gum and lignum species. For example, three more good events were found when comparing BP2800 and BP2800RC for both species, and a number of events improved classifications when comparing BP3200 and BP3200RC. Therefore relaxation of constraints demonstrated the ability to provide better habitat conditions.

## 4.6.7. SPECIFIC FLOW PEAK ANALYSIS OF REQUESTED EVENTS

The three events identified in Section 4.6.2 have been considered in this section from an ecological perspective. An example of having the benefits achieved by having the ability to request extra watering events has also been undertaken by considering the year 1983, where there a water event for the 80 000 ML/d for 30 day indicator for the BP3200RC scenario, but not the other three scenarios (as described in Section 3).

MFAT habitat preference scores achieved for all events as defined by the ‘event rules’ under each of the four scenarios were also calculated. These results are presented as the maximum preference score achieved at flow bands between 50 000 ML/d and 80 000 ML/d (with 5000 ML/d increments) for the four scenarios as a means of articulating the potential habitat condition. The number of hectares of the relevant vegetation community (red gum or lignum) on the floodplain (as determined by the vegetation mapping see Appendix C) at each flow band has been included within the tables in this section. The full MFAT analysis undertaken for each event, which produced the following tables, can be seen in Appendix D.

### 4.6.7.1. Specific flow peaks requested in all four scenarios

*1950*

The hydrograph for the event requested at Riverland-Chowilla in 1950 can be seen in Figure 16.

The MFAT preference scores for red gums and lignum calculated from the flow event ordered for Riverland-Chowilla in 1950 are displayed in Table 16 and Table 17 respectively. All water recovery scenarios scored either good or optimum MFAT habitat preference scores (both red gum and lignum) in the 50 000 ML/d to 60 000 ML/d flow bands. The BP2800 scenario achieved a moderate habitat score for both red gum and lignum at the 65 000 ML/d flow band, whereas all other scenarios recorded an optimum rating. This translates to an additional 1380 ha of good or optimum habitat for red gum and an additional 1400 ha of good or optimum lignum in the three scenarios (BP2800RC, BP3200 and BP3200RC) compared to BP2800. No event was recorded at the 70 000 ML/d flow band for the BP2800 scenario whereas all other scenarios recorded a moderate habitat preference score for both red gum and lignum. The event did not reach the 75 000 ML/d flow band under any of the scenarios.

**Table 16. Maximum MFAT score achieved for red gums at flow rates between 50 000 ML/d and 80 000 ML/d under the four water recovery scenarios for the 1950 scenario Dark Green (1) Light Green (0.7–1) Orange (0.2–0.7) Red (0–0.2). The area of red gum represented at each flow rate is expressed in brackets.**

| Flow Rate ML/d (hectares of vegetation community at this flow band) | BP2800 | BP2800RC | BP3200 | BP3200RC |
|---|---|---|---|---|
| 50 000 ML/d (3913 ha) | | | | |
| 55 000 ML/d (4513 ha) | | | | |
| 60 000 ML/d (5701 ha) | | | | |
| 65 000 ML/d (7085 ha) | | | | |
| 70 000 ML/d (8501 ha) | No event | | | |
| 75 000 ML/d (10 120 ha) | No event | No event | No event | No event |
| 80 000 ML/d (11 727 ha) | No event | No event | No event | No event |

**Table 17. Maximum MFAT score achieved for lignum at flow rates between 50 000 ML/d and 80 000 ML/d under the four water recovery scenarios for the 1950 scenario Dark Green (1) Light Green (0.7–1) Orange (0.2–0.7) Red (0–0.2). The area of lignum represented at each flow rate is expressed in brackets**

| Flow Rate ML/d (hectares of vegetation community at this flow band) | BP2800 | BP2800RC | BP3200 | BP3200RC |
|---|---|---|---|---|
| 50 000 ML/d (1512 ha) | | | | |
| 55 000 ML/d (1802 ha) | | | | |
| 60 000 ML/d (2873 ha) | | | | |
| 65 000 ML/d (4277 ha) | | | | |
| 70 000 ML/d (5773 ha) | No event | | | |
| 75 000 ML/d (7485 ha) | No event | No event | No event | No event |
| 80 000 ML/d (8898 ha) | No event | No event | No event | No event |

*1951*

The hydrograph of the flow event ordered for Riverland-Chowilla in 1951 for all four modelled scenarios can be seen in Figure 3. It can be seen that the relaxed constraints scenarios increase the peak flows, with the elevated flows extended for longer periods of time, compared to the two scenarios with constraints active.

The MFAT preference scores for red gums and lignum calculated from the flow event ordered for Riverland-Chowilla in 1951 are displayed in Table 18 and Table 19 respectively. All water recovery scenarios scored either good or optimum MFAT habitat preference scores (both red gum and lignum) in the 50 000 ML/d and 55 000 ML/d flow bands. The BP2800 scenario achieved a moderate habitat score for both red gum and lignum at the 60 000 ML/d flow band, whereas all other scenarios recorded an optimum rating. The scenarios with constraints relaxed (BP2800RC and BP3200RC) recorded optimum scores at the 65 000 ML/d flow band for both red gum and lignum, whereas the scenarios with constraints in place recorded a moderate score for red gum and lignum at the same flow band. This translates to an additional 2570 ha of good or optimum habitat for red gum and an additional 2470 ha of good or optimum lignum in the scenarios with relaxed constraints (BP2800RC and BP3200RC) compared to BP2800. Habitat preference for both red gum and lignum was moderate at the 70 000 ML/d flow band and poor at the 75 000 ML/d flow band for all four scenarios. No event was recorded at the 80 000 ML/d flow band for any scenario.

**Table 18. Maximum MFAT score achieved for red gums at flow rates between 50 000 ML/d and 80 000 ML/d under the four water recovery scenarios for the 1951 scenario Dark Green (1) Light Green (0.7–1) Orange (0.2–0.7) Red (0–0.2). The area of red gum represented at each flow rate is expressed in brackets.**

| Flow Rate ML/d (hectares of vegetation community at this flow band) | BP2800 | BP2800RC | BP3200 | BP3200RC |
|---|---|---|---|---|
| 50 000 ML/d (3913 ha) | Light Green | Light Green | Light Green | Light Green |
| 55 000 ML/d (4513 ha) | Dark Green | Dark Green | Dark Green | Dark Green |
| 60 000 ML/d (5701 ha) | Orange | Dark Green | Dark Green | Dark Green |
| 65 000 ML/d (7085 ha) | Orange | Dark Green | Orange | Dark Green |
| 70 000 ML/d (8501 ha) | Orange | Orange | Orange | Orange |
| 75 000 ML/d (10 120 ha) | Red | Red | Red | Red |
| 80 000 ML/d (11 727 ha) | No event | No event | No event | No event |

**Table 19. Maximum MFAT score achieved for lignum at flow rates between 50 000 ML/d and 80 000 ML/d under the four water recovery scenarios for the 1951 scenario Dark Green (1) Light Green (0.7–1) Orange (0.2–0.7) Red (0–0.2). The area of lignum represented at each flow rate is expressed in brackets.**

| Flow Rate ML/d (hectares of vegetation community at this flow band) | BP2800 | BP2800RC | BP3200 | BP3200RC |
|---|---|---|---|---|
| 50 000 ML/d (1512 ha) | Light Green | Light Green | Light Green | Light Green |
| 55 000 ML/d (1802 ha) | Light Green | Light Green | Light Green | Light Green |
| 60 000 ML/d (2873 ha) | Orange | Dark Green | Dark Green | Dark Green |
| 65 000 ML/d (4277 ha) | Orange | Dark Green | Orange | Dark Green |
| 70 000 ML/d (5773 ha) | Orange | Orange | Orange | Orange |
| 75 000 ML/d (7485 ha) | Red | Red | Red | Red |
| 80 000 ML/d (8898 ha) | No event | No event | No event | No event |

*1960*

The final year that can be used for comparison of the events requested for the 80 000 ML/d for 30 day events in the same year is 1960. It can be seen from Figure 17 that the relaxation of constraints provided a greater increase in the flow that exceeded the 30-day target duration compared to that from just an increase in volume of water recovered.

The MFAT preference scores for red gums and lignum calculated from the flow event ordered for Riverland-Chowilla in 1960 are displayed in Table 20 and Table 21, respectively. All water recovery scenarios scored either good or optimum MFAT habitat preference scores (both red gum and lignum) in the 50 000 ML/d and 65 000 ML/d flow bands. At the 70 000 ML/d flow band all scenario scored moderate habitat preference for both red gum and lignum, except the BP3200 scenario for which no event was recorded. No event was recorded at the 75 000 ML/d flow band for the scenarios with constraints in place (BP2800 and BP3200), whereas a poor event was recorded in the scenarios with constraints relaxed (BP2800RC and BP3200RC). No event was recorded at the 80 000 ML/d flow band for any scenario.

**Table 20. Maximum MFAT score achieved for red gums at flow rates between 50 000 ML/d and 80 000 ML/d under the four water recovery scenarios for the 1960 Dark Green (1) Light Green scenario (0.7–1) Orange (0.2–0.7) Red (0–0.2). The area of red gum represented at each flow rate is expressed in brackets.**

| Flow Rate ML/d (hectares of vegetation community at this flow band) | BP2800 | BP2800RC | BP3200 | BP3200RC |
|---|---|---|---|---|
| 50 000 ML/d (3913 ha) | | | | |
| 55 000 ML/d (4513 ha) | | | | |
| 60 000 ML/d (5701 ha) | | | | |
| 65 000 ML/d (7085 ha) | | | | |
| 70 000 ML/d (8501 ha) | | | No event | |
| 75 000 ML/d (10 120 ha) | No event | | No event | |
| 80 000 ML/d (11 727 ha) | | | | |

**Table 21. Maximum MFAT score achieved for lignum at flow rates between 50 000 ML/d and 80 000 ML/d under the four water recovery scenarios for the 1960 scenario Dark Green (1) Light Green (0.7–1) Orange (0.2–0.7) Red (0–0.2). The area of lignum represented at each flow rate is expressed in brackets.**

| Flow Rate ML/d (hectares of vegetation community at this flow band) | BP2800 | BP2800RC | BP3200 | BP3200RC |
|---|---|---|---|---|
| 50 000 ML/d (1512 ha) | | | | |
| 55 000 ML/d (1802 ha) | | | | |
| 60 000 ML/d (2873 ha) | | | | |
| 65 000 ML/d (4277 ha) | | | | |
| 70 000 ML/d (5773 ha) | | | No event | |
| 75 000 ML/d (7485 ha) | No event | | No event | |
| 80 000 ML/d (8898 ha) | | | | |

### 4.6.7.2. Specific flow peaks requested in BP3200RC only

*1983*

An example of having the ability to request extra watering events has been undertaken by considering the year 1983, where there was a water event requested for the 80 000 ML/d for 30 day indicator for the BP3200RC scenario, but not the other three scenarios (see Section 3).

The MFAT preference scores for red gums and lignum calculated from the flow event ordered for Riverland-Chowilla in 1983 are displayed in Table 22 and Table 23 respectively. All water recovery scenarios scored either good or optimum MFAT habitat preference scores (both red gum and lignum) in the 50 000 ML/d and 65 000 ML/d flow bands. At the 70 000 ML/d flow band all scenario scored a good habitat preference for both red gum and lignum, except the BP2800 scenario for which a moderate habitat score was recorded. At the 75 000 ML/d flow band the only scenario to achieve a good habitat preference score was BP3200RC with all other scenarios achieving a moderate score. This translates to an additional 3040 ha of good or optimum habitat for red gum and an additional

3210 ha of good or optimum lignum in the BP3200RC scenario compared to BP2800. At the 80 000 ML/d flow band no event was achieved for the scenarios with constraints in place (BP2800 and BP3200), whereas a moderate event was recorded in the scenarios with constraints relaxed (BP2800RC and BP3200RC).

**Table 22. Maximum MFAT score achieved for red gum at flow rates between 50 000 ML/d and 80 000 ML/d under the four water recovery scenarios for the 1983 scenario Dark Green (1) Light Green (0.7–1) Orange (0.2–0.7) Red (0–0.2). The area of red gum represented at each flow rate is expressed in brackets.**

| Flow Rate ML/d (hectares of vegetation community at this flow band) | BP2800 | BP2800RC | BP3200 | BP3200RC |
|---|---|---|---|---|
| 50 000 ML/d (3913 ha) | | | | |
| 55 000 ML/d (4513 ha) | | | | |
| 60 000 ML/d (5701 ha) | | | | |
| 65 000 ML/d (7085 ha) | | | | |
| 70 000 ML/d (8501 ha) | | | | |
| 75 000 ML/d (10 120 ha) | | | | |
| 80 000 ML/d (11 727 ha) | No event | | No event | |

**Table 23. Maximum MFAT score achieved for lignum at flow rates between 50 000 ML/d and 80 000 ML/d under the four water recovery scenarios for the 1983 scenario Dark Green (1) Light Green (0.7–1) Orange (0.2–0.7) Red (0–0.2). The area of lignum represented at each flow rate is expressed in brackets.**

| Flow Rate ML/d (hectares of vegetation community at this flow band) | BP2800 | BP2800RC | BP3200 | BP3200RC |
|---|---|---|---|---|
| 50 000 ML/d (1512 ha) | | | | |
| 55 000 ML/d (1802 ha) | | | | |
| 60 000 ML/d (2873 ha) | | | | |
| 65 000 ML/d (4277 ha) | | | | |
| 70 000 ML/d (5773 ha) | | | | |
| 75 000 ML/d (7485 ha) | | | | |
| 80 000 ML/d (8898 ha) | No event | | No event | |

In order to summarise the results presented in this section, a summary table is provided below (Table 24). It can be seen that overall BP3200RC was the scenario that most consistently showed the best ecological outcomes for the floodplain of the four scenarios analysed.

**Table 24. Summary table of MFAT duration analysis for specific event analysis for the water recovery scenarios considered to achieve the best overall ecological outcomes for red gum and lignum for each of the four specific requested flow events inferred by 1) the area of good to optimum habitat and 2) the extent of inundation created by the event**

| Year | BP2800 | BP2800RC | BP3200 | BP3200RC |
|---|---|---|---|---|
| 1950 | | ✓ | ✓ | ✓ |
| 1951 | | ✓ | | ✓ |
| 1960 | | ✓ | | ✓ |
| 1983* | | | | ✓ |

*A watering event for this year was only requested in BP3200RC

### 4.6.7.3. Summary of specific requested flow peaks

- The majority of the flow peaks assessed for the BP3200RC scenario supported a greater area of floodplain in a good to optimum habitat condition than the BP2800 scenario. For example the 1951 flow peak shows a 2570 ha improvement in the area of red gums with an optimum habitat rating for the BP3200RC scenario compared to BP2800.
- The ecological response analysis of the four specific requested watering events showed that in general there was little difference in the habitat condition supported between scenarios for the portion of the floodplain inundated between 40 000 ML/d and 55 000 ML/d, as the habitat at this flow band was rated as either good or optimum. Differences were observed between scenarios in the flow bands of 60 000 ML/d and 80 000 ML/d. This suggests that ecological outcomes within the targeted floodplain (i.e. the floodplain inundated between the 40 000 ML/d and 80 000 ML/d flow bands) would most likely differ between the four scenarios for these given flow events.
- In general the smallest area of good or optimum habitat was supported by BP2800 and the greatest area was supported by some combination of the other three scenarios, with BP3200RC the only scenario that was consistently one of the scenarios with the greatest area.
- There was some evidence that that the relaxation of constraints (both BP2800RC and BP3200RC) improved outcomes with either greater area of good or optimum habitat (1951) or extension of the particular event out further onto the floodplains (i.e. 1960 and 1983), even though the duration of the event was short and therefore habitat condition in this portion of the floodplain would be considered moderate or poor.

# 5.LOWER LAKES

Water level and salinity are critical parameters in the assessment of changes to ecological conditions in the Lower Lakes. Heneker (2010) demonstrated that water level and salinity outcomes are responsive to annual lake inflows and barrage discharge volumes over a three year timeframe.

The freshwater environment of the Lower Lakes supports a variety of freshwater plant and animal species and is an important pathway/habitat for diadromous fish species including Congolli, Common galaxias and Lamprey (Bice and Ye 2009; Zampatti *et al*. 2010). These diadromous fish are dependent on access to both freshwater and marine environments. Fish passage is impeded by extended periods with no barrage outflow.

The cycling of water levels within the target water level range for the Lower Lakes support a rich zone of riparian vegetation around the lake margins (Phillips and Muller, 2006). This zone of vegetation (both aquatic and terrestrial) provides high habitat quality for many organisms, including bird, macroinvertebrates and fish (Phillips and Muller, 2006; Muller, 2010). Extreme low water levels also increase the risk of exposing acid-producing sulfidic soils, resulting in either localised or potentially, broad-scale acidification of the Lakes (DEH, 2010, DENR 2010).

It is important to recognise that the modelling approach used by the MDBA does not explicitly include demands for Coorong, Lower Lakes and Murray Mouth (CLLMM) EWRs, meaning that environmental water is not specifically directed to meet water level, salinity or barrage outflow targets for the CLLMM. Instead, the approach assumes that CLLMM EWRs are largely met by baseflows and return flows from upstream sites. The iterative approach adopted by the MDBA does allow water to be provided to the CLLMM if available, which was generally only in drier years where the volume available was insufficient to supply other upstream environmental water demands (MDBA 2012).

As discussed in Heneker and Higham (2012), model outputs of water level, salinity and barrage outflow is dependent on assumptions in the modelling, including the lake operating strategy (i.e. variation of water levels and timing of barrage releases) and the ability to reproduce the volume and salinity of river inflow. Given the sensitivity of the modelling results to these assumptions, absolute values should be interpreted with caution. Nonetheless, the results allow the identification of periods where the site is likely to be at risk for each water recovery scenario. The differences between model results are as important as the absolute values and provide a robust measure of the impact of changes due to each model scenario, since model errors would be present and correlated in all sets of results and therefore expected to allow for consistent comparisons.

The methodology and assessment of parameters has generally replicated that of Heneker and Higham (2012), with the analysis focussing on comparison of the key parameters of water level, salinity and barrage outflow between the modelled Basin Plan scenarios BP2800, BP2800RC, BP3200 and BP3200RC.

## *5.1. BARRAGE OUTFLOWS*

Current understanding of the long term behaviour of water levels and salinity in the Lower Lakes indicates that these parameters are largely driven by annual volumes of barrage outflows and lake inflows. The relaxation of constraints is expected to have the greatest influence on the ability to increase and extend the duration of peak flows within an event. Prior to undertaking the assessment, it is expected that only minor differences are to be observed in annual average volumes, however differences in ecological outcomes in the Lower Lakes may result because changes to the flow distribution, both intra- and inter-year, may affect water levels and the flushing of salt from the lakes.

### 5.1.1. ANNUAL BARRAGE OUTFLOW

The frequency of annual barrage outflows between the different modelled scenarios is shown in Figure 22. Previous analysis by Heneker (2010) indicates that periods of relatively low flow are important in determining salinity and water level and as such Barrage outflows less than 5000 GL/y are shown in Figure 23 to demonstrate the effect that the different recovery volumes have on the provision of low barrage outflows. Summary statistics for the annual barrage outflows simulated for each scenario considered are shown in Table 25. As observed in the previous section in the annual average flow to SA, the relaxed constraints scenarios resulted in slightly lower average annual barrage outflows. This is understood to be due to targeting environmental watering events that inundate larger areas of floodplain in the constraints-relaxed scenarios, and as such slightly increased losses. The increase in barrage outflow can be seen to be approximately 70% of the increase in the water recovery volume when comparing between the relevant scenarios.

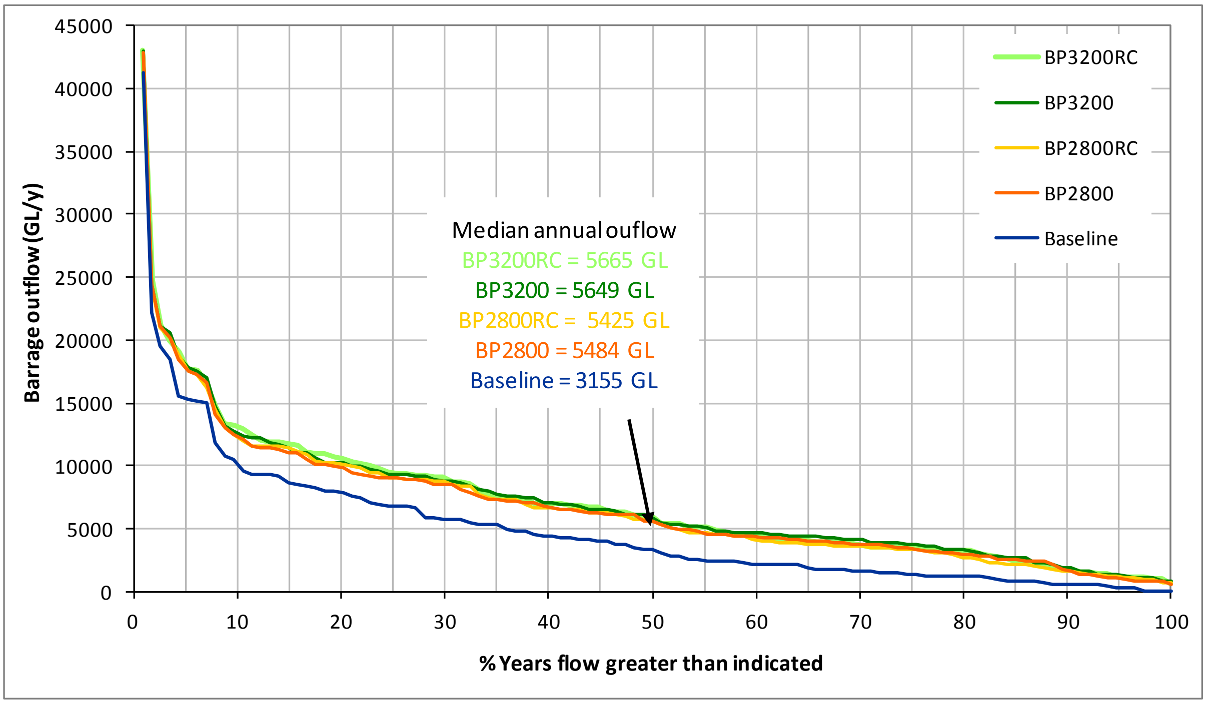



**Figure 22. Barrage outflow frequency curve (1895–96 to 2008–09)**

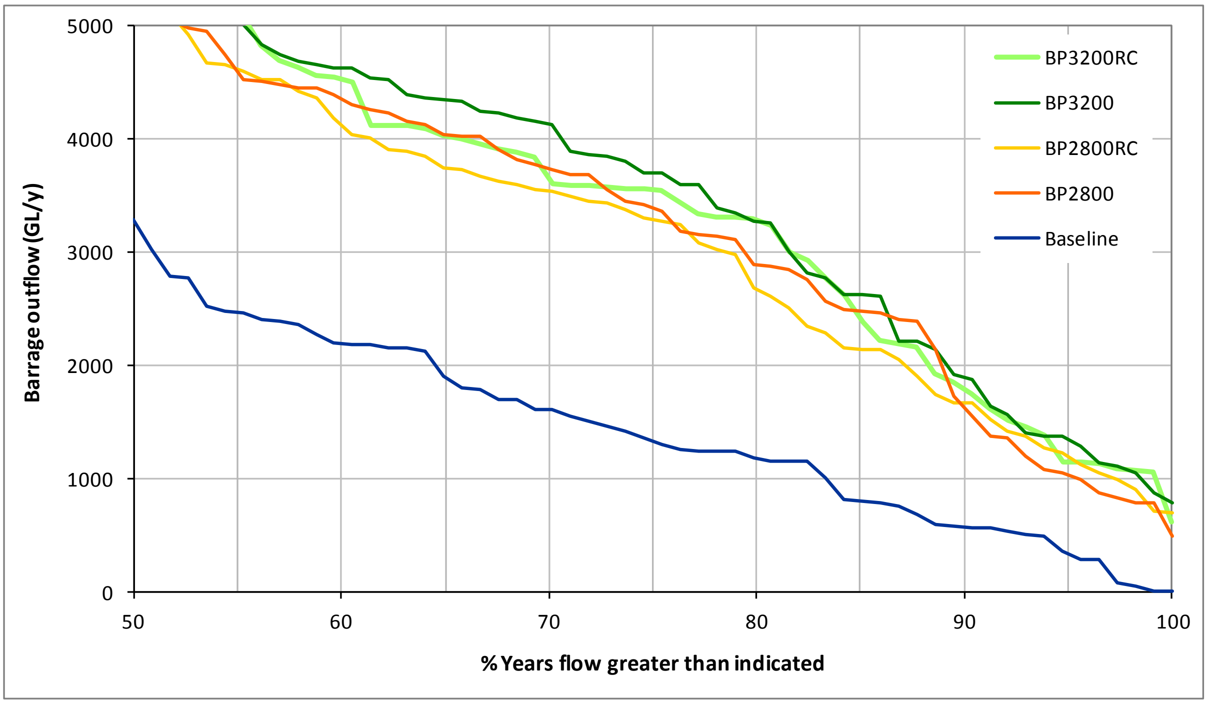



**Figure 23. Barrage outflow frequency curve limited to outflow less than 5000 GL/y (1895–96 to 2008–09)**

**Table 25. Summary statistics for annual barrage flows**

| Statistic | Barrage Outflow (GL) | | | | |
|---|---|---|---|---|---|
| | Baseline | BP2800 | BP2800RC | BP3200 | BP3200RC |
| Minimum | 0 | 490 | 701 | 787 | 609 |
| 10th Percentile | 569 | 1605 | 1672 | 1890 | 1781 |
| Mean | 4862 | 6838 | 6823 | 7140 | 7127 |
| Median | 3154 | 5484 | 5426 | 5649 | 5665 |
| 90th Percentile | 9518 | 11 881 | 11 802 | 12 290 | 12 764 |
| Maximum | 41 214 | 42 839 | 42 897 | 43 043 | 43 088 |

From Figure 23 it can be seen that there are small differences between the frequencies of barrage outflows between scenarios, where the relaxed constraint scenarios resulted in slightly increased frequency of outflows above approximately 5000 GL/y, and slightly decreased frequencies below. However, as demonstrated in Figure 24, which compared the annual outflows between the BP2800 and BP2800RC scenarios, there can be considerable inter-year difference in volumes reaching the Lower Lakes and discharged through the barrages, with annual variability between the 2800 GL scenarios exceeding 1000 GL/y in several years, most likely due to differences in the scheduling of environmental watering events.

It can be seen in Figure 25 and Figure 26 that even when comparing the higher water recovery volumes of BP3200 and BP3200RC to BP2800, there are some years where the lower volume scenario simulated a greater annual average barrage outflow. However, the average increase is in the order of 300 GL/y over the 114 years modelled, or 70% of the difference in water recovery volume of 400 GL between 2800 GL and 3200 GL.

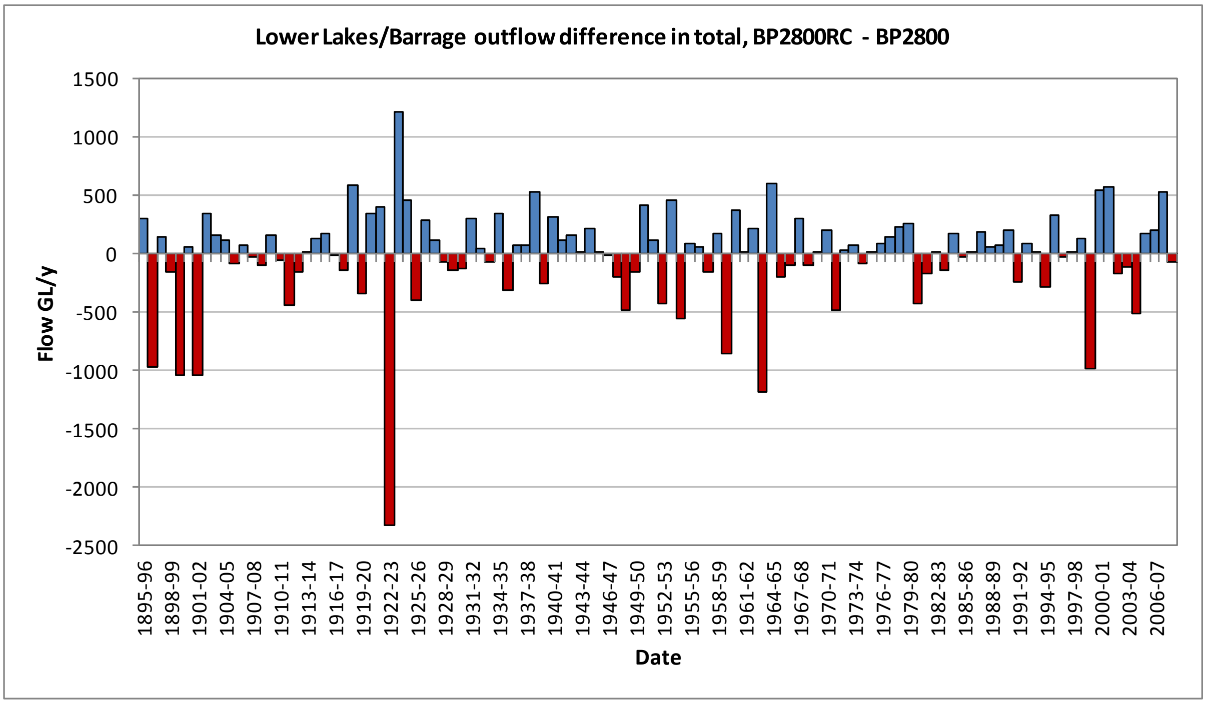



**Figure 24. Difference in barrage outflows between BP2800 and BP2800RC scenarios (blue – BP2800RC greater, red – BP2800 greater)**

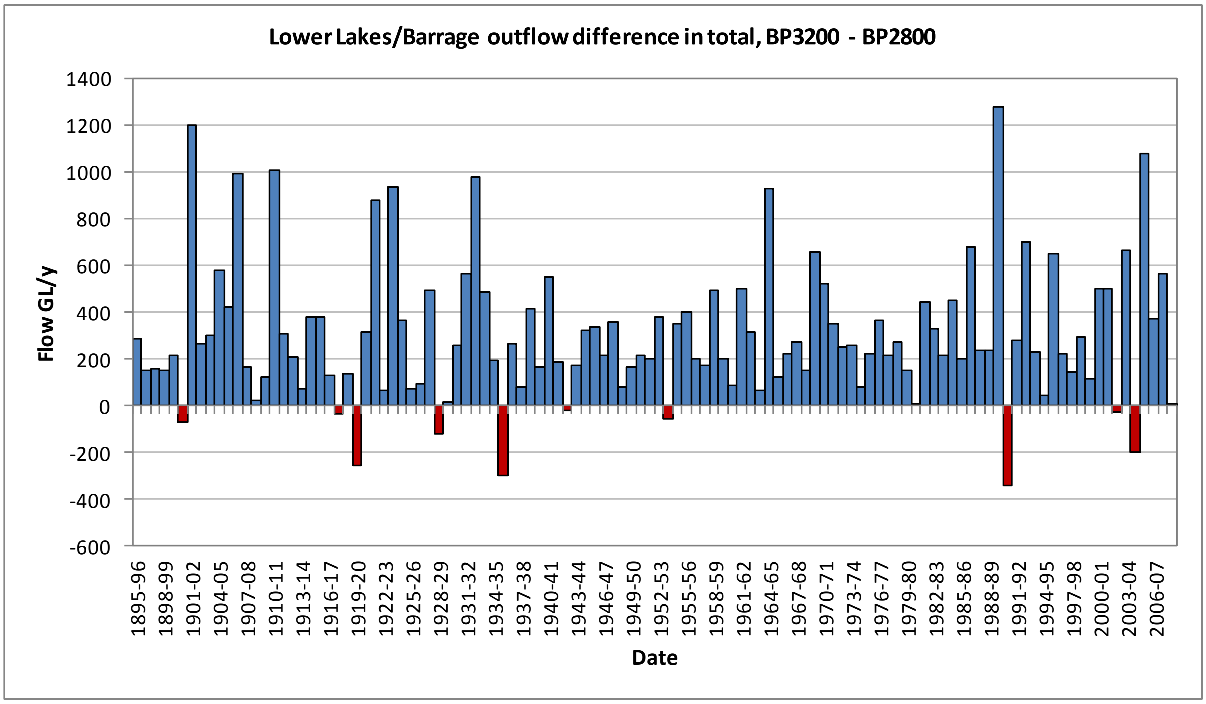



**Figure 25. Differences in barrage outflows between BP2800 and BP3200 scenarios (blue-BP3200 greater, red-BP2800 greater)**

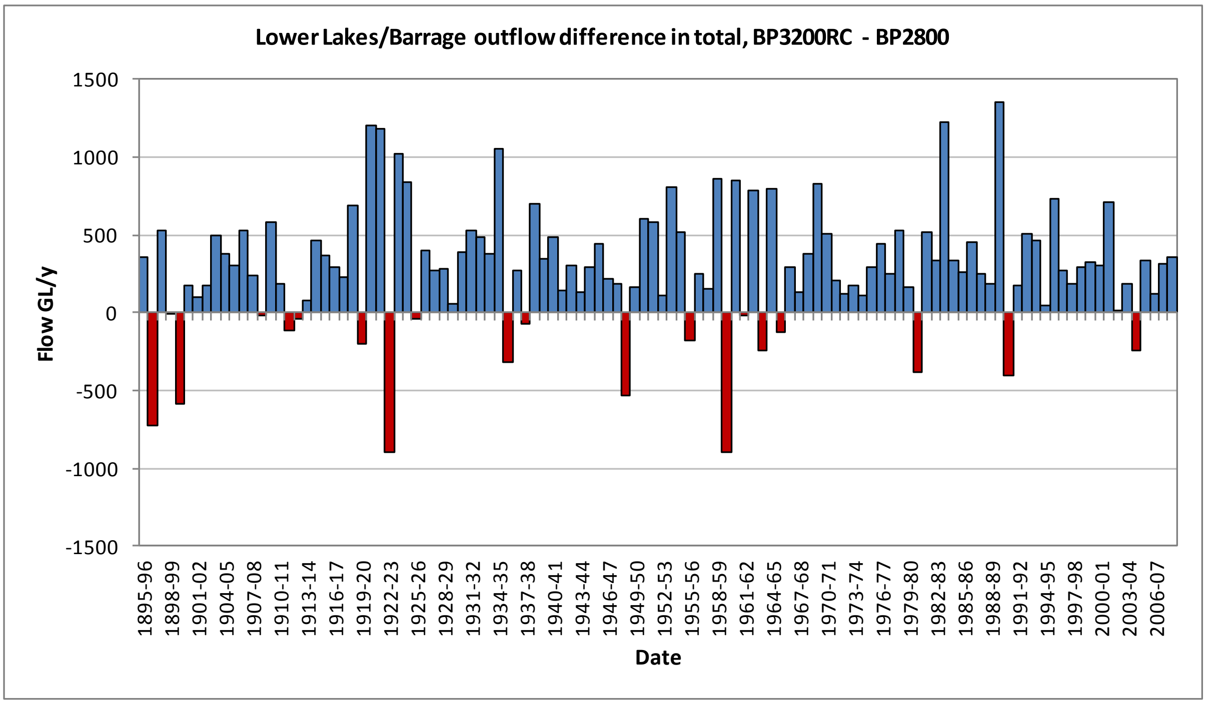



**Figure 26. Differences in barrage outflows between BP2800 and BP2800RC scenarios (blue-BP3200RC greater, red-BP2800 greater)**

### 5.1.2. PERIODS OF BARRAGE CLOSURE

Periods of 30 days or more with no barrage outflow may have an impact on the downstream environment of the Coorong, with periods of no outflow between June and January being particularly critical for fish migration (Lester *et al.* 2011). The specific timing of events less than 30 days in duration has not been considered, the assumption is that short periods of no barrage outflow in the modelled results are unlikely to be ecologically significant and as such, these short periods have not been included in the calculation of summary statistics (Heneker and Higham, 2012). The periods of no barrage flow longer than 30 days are outlined in Table 26, and all periods in decreasing order of length for each scenario provided in Figure 27. It can be seen that only the BP3200RC scenario avoids periods of no barrage flow (greater than 30 days) in consecutive years regardless of the timing they occur.

It can be seen from Table 26 and Figure 27 that increases in water recovery volume for both with constraints and constraints-relaxed scenarios reduces the number of periods of no barrage outflow. Considering periods longer than 30 days only, the number of no outflow periods reduces by close to half, reducing from 11 to five from BP3200 to BP2800, and from five to three from BP3200RC to BP2800RC. Also, the maximum length of those periods reduces considerably, from 125 to 59 days in the BP2800 and BP3200 scenarios, and from 172 to 50 days for the BP2800RC and BP3200 RC (relaxed constraints) scenarios.

When comparing scenarios with the same water recovery volume, relaxing constraints also reduced the number of periods exceeding thirty days by approximately half (reducing from 11 to five from BP2800 to BP2800RC, and from five to three for BP3200RC to BP3200). There was not a consistent trend in maximum period of no barrage outflow when comparing scenarios with and without constraints relaxed. However, there were only 24 days of flow less than or equal to 2000 ML/d between the two no-outflow periods in May 2008 in the BP2800 scenario. If this event is excluded, the maximum period of no-barrage flow between the BP2800 and BP2800RC scenarios are very similar. From Figure 27, to can be seen that the mean and median durations of periods of no-barrage outflow are reduced between these scenarios, even though the one longest event was worse when comparing BP2800 to BP2800RC.

An analysis of the distribution of periods of no-barrage outflow is shown in Figure 28. From Figure 28 it can be seen periods of no-barrage outflow occur irregularly throughout the time series, and for all scenarios there are multiple periods of no barrage outflow that occur within a 10-year period. All periods of no barrage flow seen in Figure 27 are presented in Figure 28 which allows the distribution of no-barrage flows to be observed. However, Figure 28 should also be interpreted along with the periods of no-barrage outflow longer than 30 days presented in Table 26, as for example only in BP2800 did the period of no barrage outflow in 1945 exceed the 30 day duration. Based on the number of periods of no barrage outflow, the length of these events and the distribution over the 114-year period, the BP3200RC scenario demonstrates improved outcomes, particularly over the last 10-year dry period, with reduced incidence of no outflow periods in adjacent years.

The intra-annual distribution of periods with no barrage outflow from Table 26 is shown in Figure 29. The critical period of July to January for connection between Lake Alexandrina and the Coorong to permit the passage of diadromous species is highlighted in grey. It is noted that periods of closure outside this timing have no or negligible ecological consequences on outcomes in the Coorong but these will be assessed elsewhere in this report. The BP3200RC scenario shows the least risk of having no-barrage outflows during the critical July to January period, with only one month of the three periods in this critical range. This is followed by the BP3200 and BP2800RC scenarios, with three periods beginning or ending within a month of this critical period, and one period that extended longer than a month into the July to January period. It should be noted that the one occurrence in this period for the BP3200RC scenario only commenced a few days inside the critical period, simulated to start on 24 January 24 2007. However, the last period is continuing to the end of the simulation period, 30 June 2009, and as such is likely to continue into the critical July period (this is also the case for the other scenarios).

For all Basin Plan scenarios analysed, none of the periods of barrage closure extend for the entire duration of the June to January period that corresponds to high risk to migratory fish communities. Those events that occur in June–August are likely to have impacts on the downstream migration of congolli as well as the upstream migration of lampreys, whilst events in the December and January period are expected to impact on upstream migration of juvenile common galaxiids (Bice and Ye, 2009). As the periods of no barrage flow occur in years separated by years with barrage flows during the critical period, permitting connectivity during the period of concern, the model results indicate the impacts are likely to be minor relative to the Baseline scenario.

**Table 26. Periods of no barrage outflow (>30 days)**

| BP2800 | | BP2800RC | | BP3200 | | BP3200RC | |
|---|---|---|---|---|---|---|---|
| **Period** | **Length (days)** | **Period** | **Length (days)** | **Period** | **Length (days)** | **Period** | **Length (days)** |
| 01/1900 – 3/1900 | 62 | | | 01/1900 - 03/1900 | 54 | | |
| 06/1901 – 07/1901 | 43 | | | | | | |
| 01/1903 – 03/1903 | 55 | | | | | | |
| 01/1915 - 05/1915 | 101 | 01/1915 - 04/1915 | 70 | | | | |
| | | 01/1920 - 05/1920 | 104 | 01/1920 - 03/1920 | 59 | 02/1920 - 03/1920 | 38 |
| 06/1920 - 07/1920 | 33 | | | 06/1920 - 07/1920 | 34 | | |
| 01/1945 - 05/1945 | 119 | | | | | | |
| 02/1983 - 03/1983 | 38 | 02/1983 - 03/1983 | 36 | | | | |
| 12/2006 - 04/2007 | 125 | | | | | 01/2007 - 03/2007 | 50 |
| 01/2008 - 05/2008 | 104 | | | | | | |
| 06/2008 - 08/2008 | 66 | 06/2008 - 08/2008 | 64 | 06/2008 - 08/2008 | 70 | | |
| 06/2009 - 06/2009 | 30 | 01/2009 - 06/2009 | 172 | 06/2009 - 06/2009 | 30 | 06/2009 - 06/2009 | 30 |
| **Number** | **11** | **Number** | **5** | **Number** | **5** | **Number** | **3** |
| **Maximum** | **125** | **Maximum** | **172** | **Maximum** | **59** | **Maximum** | **50** |

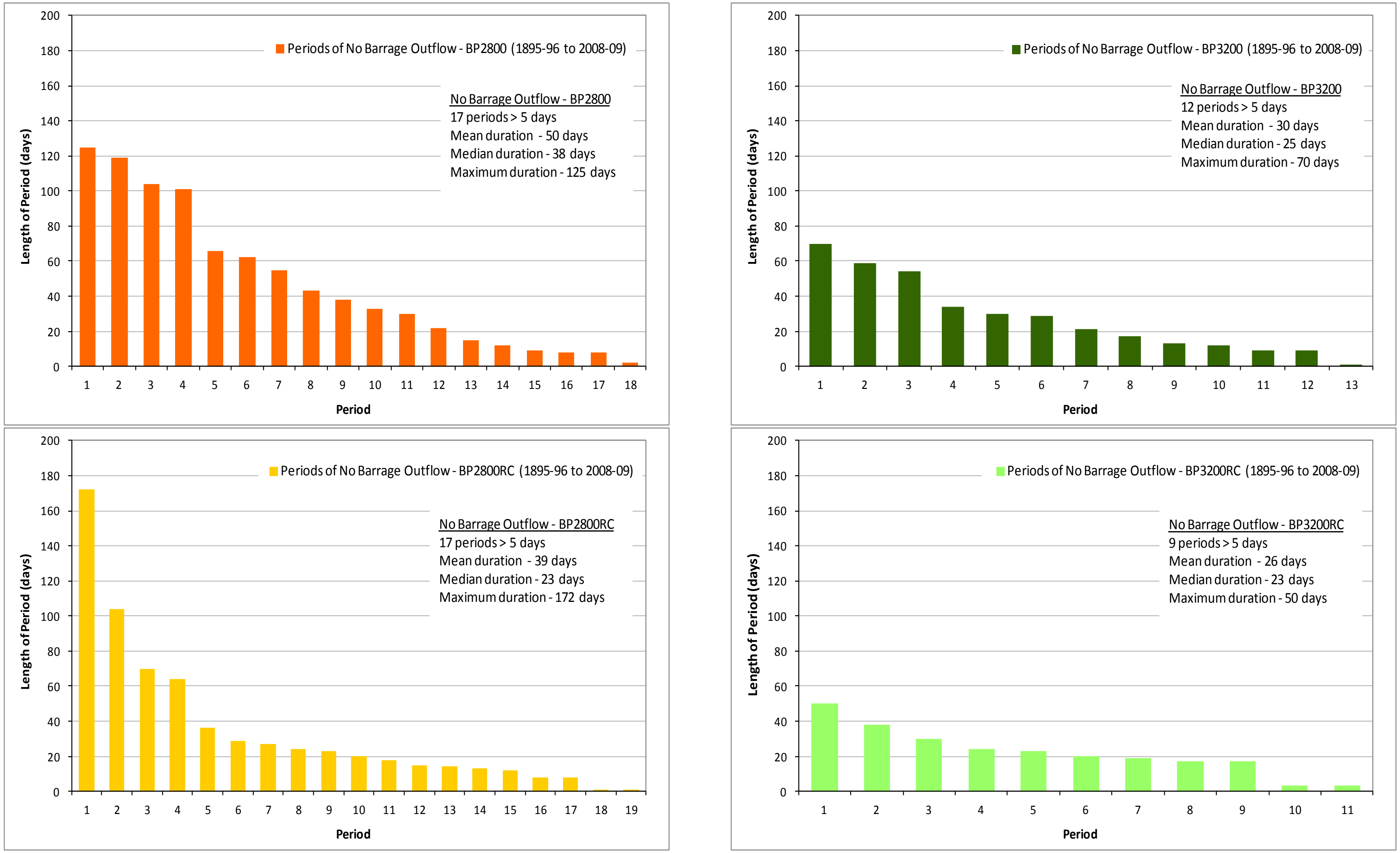



**Figure 27. Length of periods of no barrage flow**

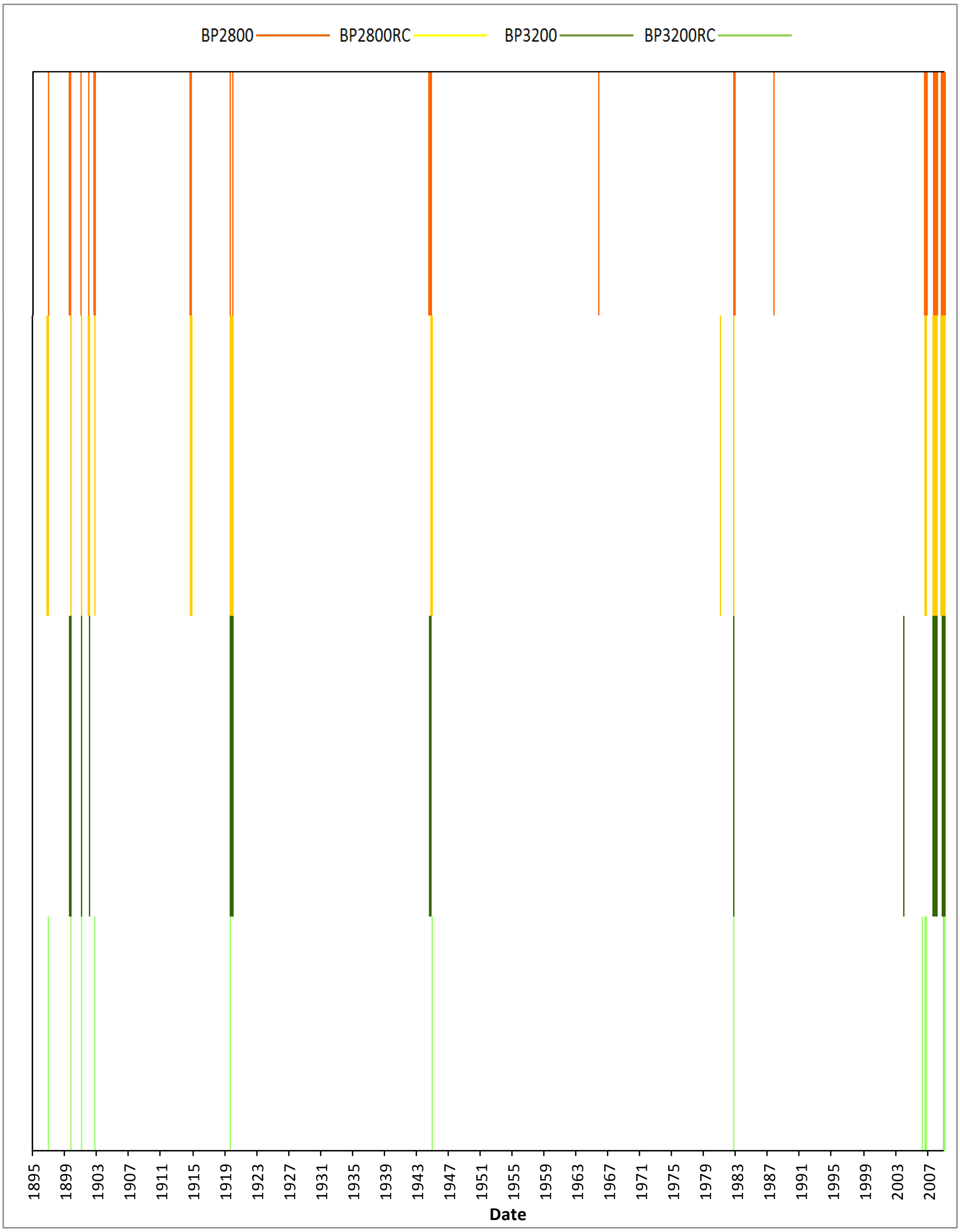



**Figure 28. Periods of no barrage flow for each scenario considered**

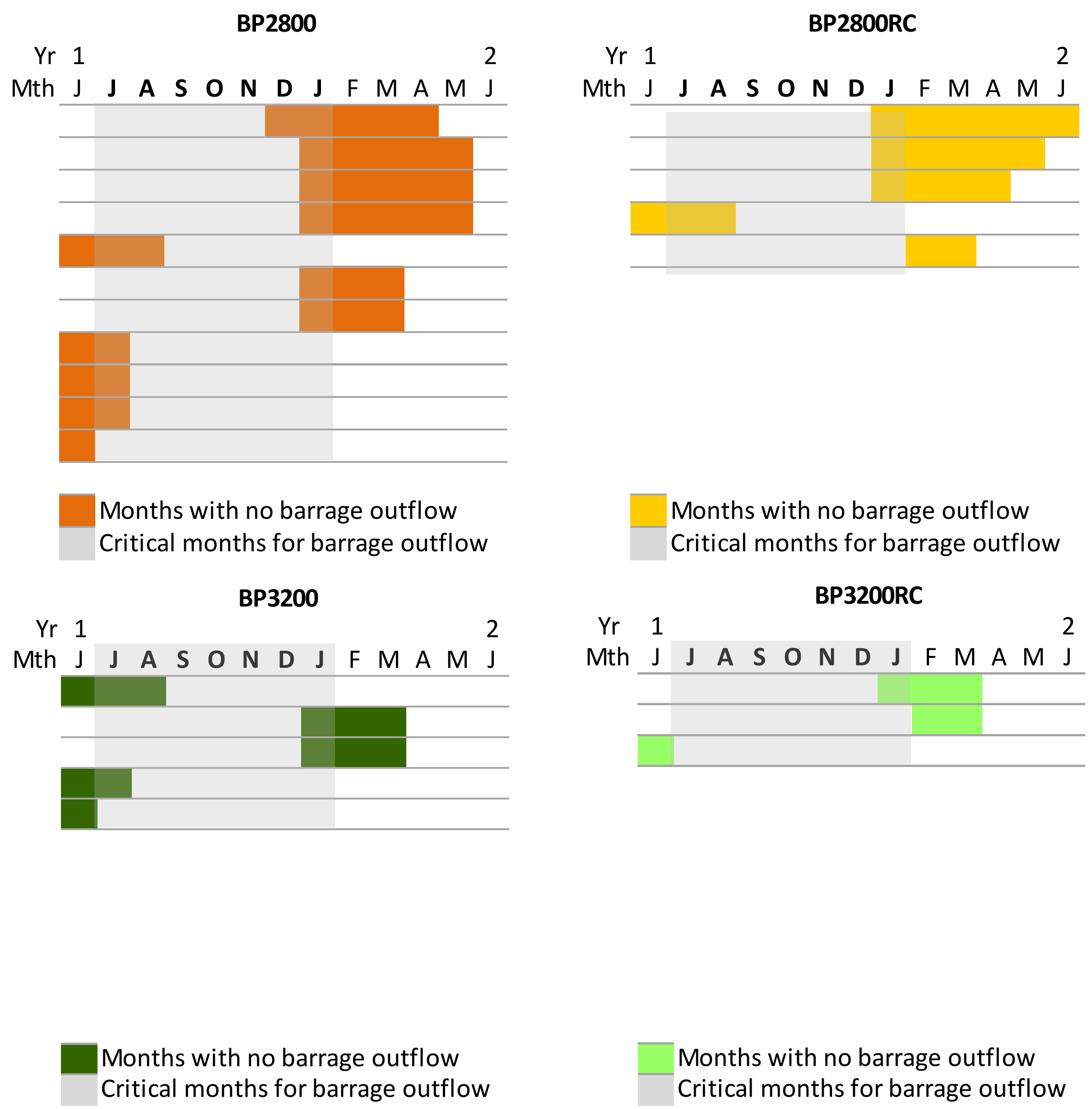



**Figure 29.** **Seasonality of periods of no barrage flows, where reach row represents a year with no barrage flow (in descending order of length)**

## *5.2. LOWER LAKES WATER LEVELS*

Heneker and Higham (2012) reported that the modelled representation of the Lake Alexandrina water level regime under Baseline Conditions resulted in lower water levels in some non-drought years than would be expected to occur in reality. For example, during the low flow period of 2003 to 2005, modelled water levels dropped to approximately 0.15 m AHD in Lake Alexandrina in the Baseline scenario due to barrage releases, despite a minimum water level of 0.35 m AHD being specified by the variable water level regime. Advice received from the MDBA (31 August 2012) acknowledges that the model currently allows water levels to fall below the notional operating range during non-drought years through barrage releases, and that rectification of this matter is proposed to be undertaken as part of a larger suite of model improvements in the future. In the interim, the MDBA have undertaken an analysis of minimum water levels for the BP3200RC scenario and confirmed that a lake level of 0.4 m AHD or above in Lake Alexandrina can be achieved for 96% of the time. Advice had not been provided for the other scenarios considered at the time of writing.

While there the uncertainties in absolute values of the modelled outputs, the comparison of differences between scenarios is still valid, as the modelling approach was consistent across the scenarios. However, it is acknowledged that the underestimation of water levels in some years may have effects on lake salinity and barrage outflow analysis presented here.

The daily water level frequency curve for Lake Alexandrina is shown in Figure 30, with the same data shown in Figure 31 focusing on the water levels of most interest, 0.4 m AHD and below. It can be seen that the increase in water recovery volume results in a given water level being maintained for a greater percentage of time (line shifts to the right).

The effect of relaxing constraints is unclear, as around the water level of 0.35–0.4 m AHD BP2800RC maintained these levels for slightly more of the simulation period compared to BP2800, however the reverse was true for the 3200 GL scenarios. This is likely to be due to changes in upstream floodplain watering decisions between scenarios, and the fact that CLLMM is not a targeted demand in the model.

The water level variability between scenarios over the drought years of 2004 to 2009 can be seen in Figure 32. There is some variability between scenarios, particularly in 2006–07, which again is likely to be due to different environmental watering decisions in the scenarios. It can be seen that in the worst year (2008–09) that the BP3200 and BP3200RC scenarios provide greater security for maintaining water levels. Note that for modelling purposes, the water level of Lake Albert is assumed to be the same as Lake Alexandrina.

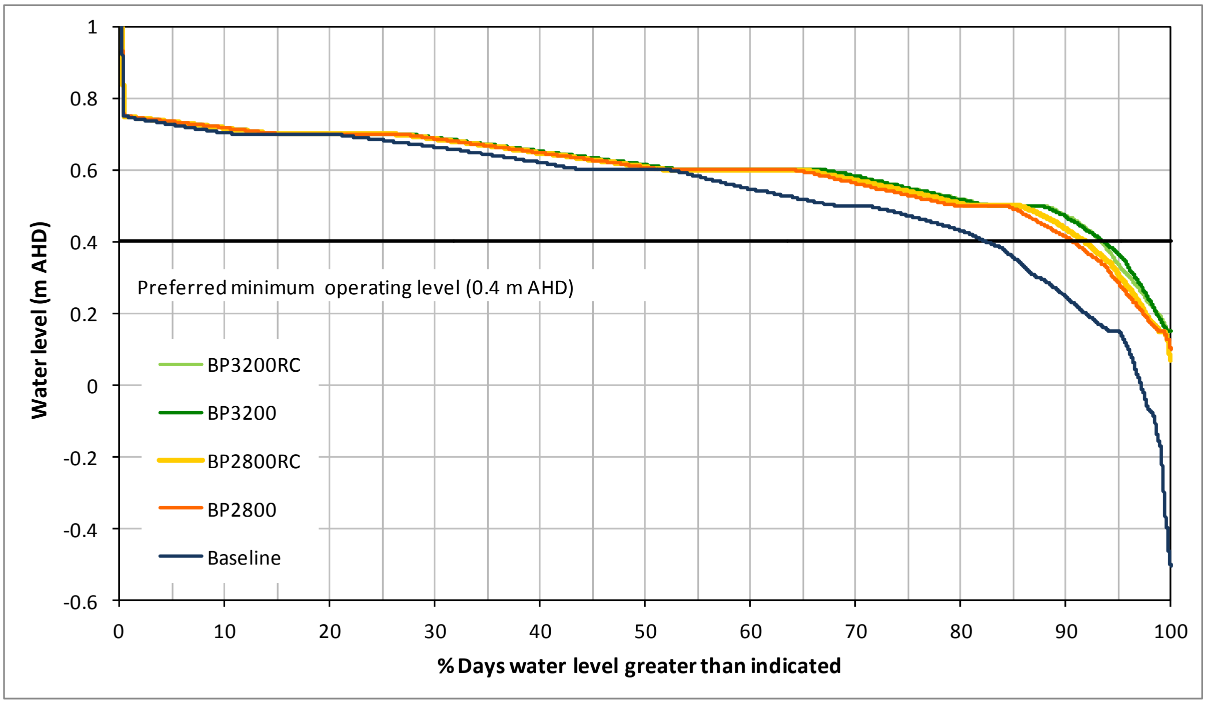



**Figure 30. Daily water level frequency curve**

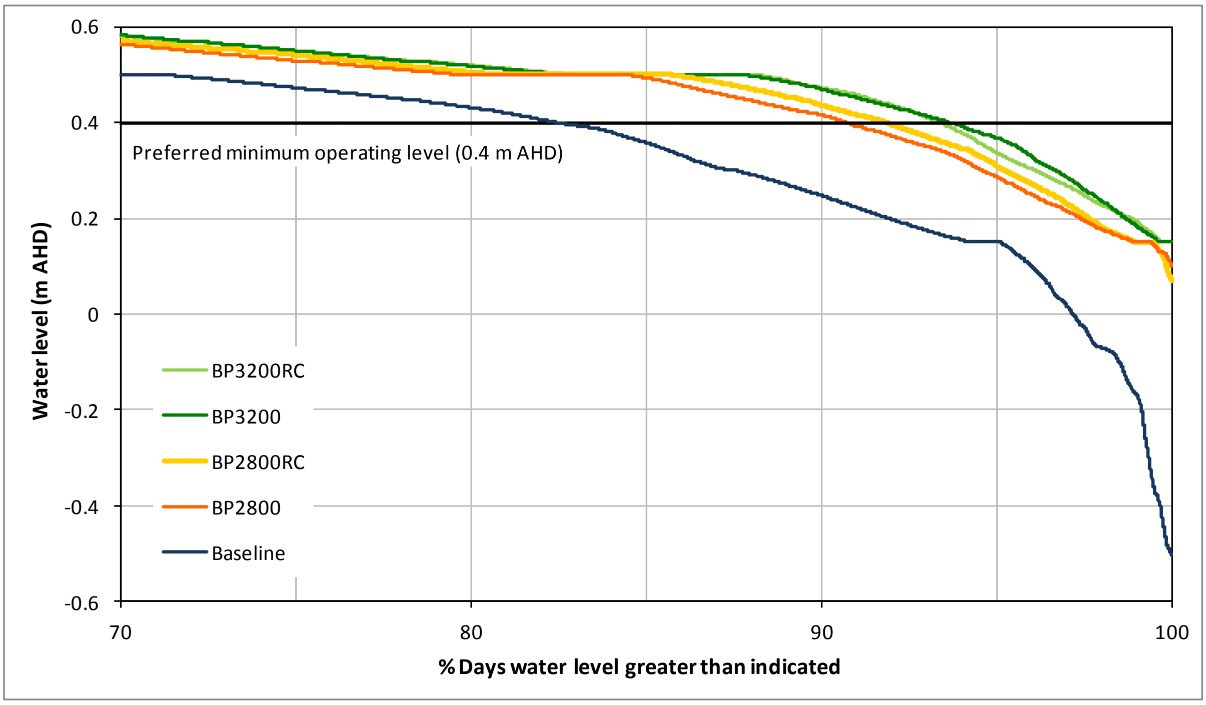



**Figure 31. Daily water level frequency curve (greater than 70% Frequency)**

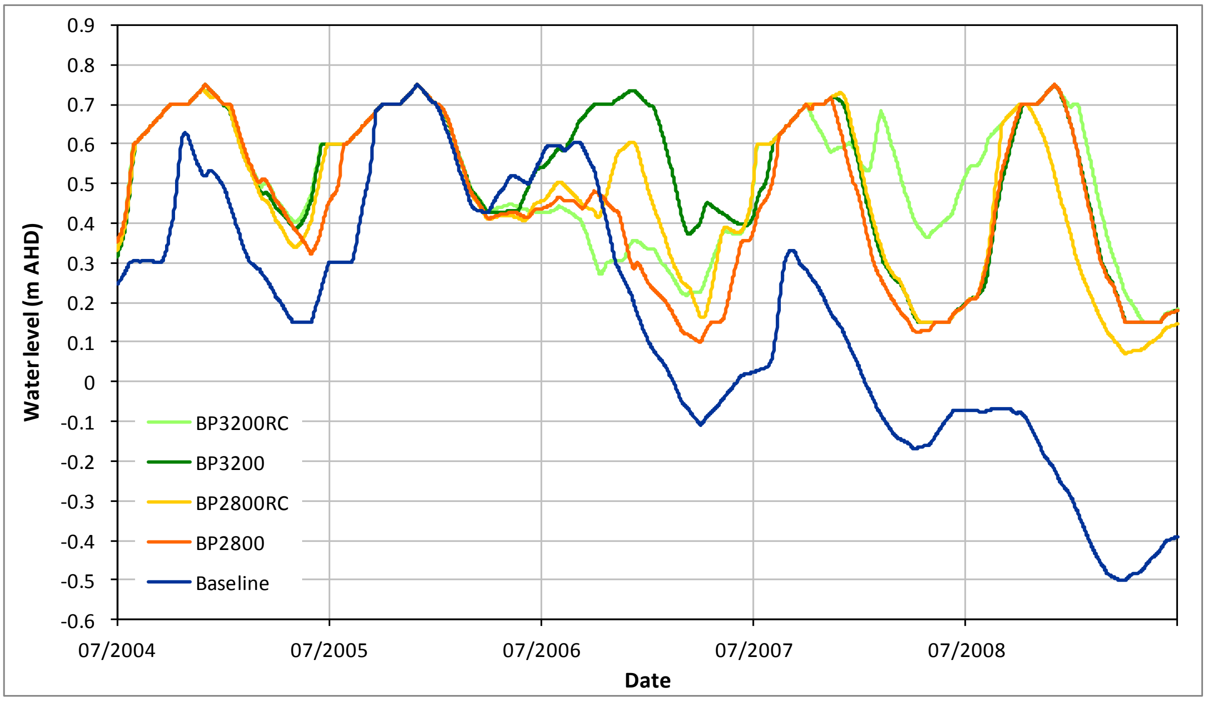



**Figure 32. Water level variation (2004–05 to 2008–09)**

## 5.3. SALINITY

An analysis of salinity in Lake Alexandrina and Lake Albert is described below. The results presented are based on salinity outputs from MSM-BIGMOD for the period 1 January 1975 to 30 June 2009. Therefore, it must be assumed that the maximum salinities, which in practice are believed to have occurred in the most recent 'millennium drought' and are of most interest in ensuring environmental outcomes and the specified environmental water requirements for the site outlined in Lester et al (2011) are met. Previous analysis by Heneker and Higham (2012) used regression relationships developed by Heneker (2010) to model Lake Alexandrina and Lake Albert salinities for the whole modelled period of 1895–96 to 2008–09. This salinity modelling and analysis for the 1895–96 to 2008–09 period has not been undertaken for this review. This difference in the source of modelled salinity time series is the main reason for different statistics presented in this report compared to Heneker and Higham (2012) for the same or similar scenarios (i.e. BP3200 and BP2750 compared to BP2800).

### 5.3.1. LAKE ALEXANDRINA

Descriptive statistics of salinity in Lake Alexandrina as modelled by the MDBA from 1975 are provided in Table 27. In terms of salinities, the following should occur in Lake Alexandrina (Lester *et al.*, 2011):

- a maximum salinity of 1000 EC should be maintained in 95% of years
- 1500 EC should not be exceeded
- a mean annual salinity of 700 EC is recommended as the long term average and should be the target for most years.

Table 27 highlights that modelled salinity for all four water recovery scenarios meet the average salinity of 700 EC target, and 1500 EC was not exceeded in the modelled period. As the median is less than the mean for all scenarios, it can be deduced that there are a number of higher salinity events that skew the mean to be higher than the median (the salinity that is exceeded for 50% of the time). From Table 27 it can be seen that increasing the water recovery volume from 2800 GL to 3200 GL reduces each salinity statistic, therefore reduces the likelihood of undesirable water quality events.

**Table 27. Lake Alexandrina salinity statistics (1975 to 2008–09)**

| Statistic | Salinity (EC) | | | | |
|---|---|---|---|---|---|
| | Baseline | BP2800 | BP2800RC | BP3200 | BP3200RC |
| Minimum | 222 | 217 | 217 | 216 | 216 |
| 10th Percentile | 456 | 378 | 366 | 365 | 363 |
| Mean | 735 | 539 | 531 | 511 | 516 |
| Median | 659 | 513 | 525 | 487 | 485 |
| 90th Percentile | 1036 | 771 | 736 | 698 | 720 |
| Maximum | 2460 | 1119 | 1105 | 1043 | 1086 |

The percentage of the time period the modelled salinity data were in different ranges is presented in Table 28 and the time in days and maximum duration exceeding 1000 EC in Table 29. From these tables it can be seen that the final metric, to maintain the modelled salinity in Lake Alexandria below 1000 EC 95% of the time is met for all water recovery scenarios. It can be seen from Table 28 that the modelled salinity was less than the target average salinity of 700 EC 85% of the time in BP2800, which increased up to 90% of the time for BP3200RC.

Table 29 indicates that as the total duration and maximum duration of modelled salinity over 1000 EC is the same for BP2800RC, BP3200 and BP3200RC, there was only one period over 1000 EC in these three scenarios, with the period reducing duration by over a month when comparing BP2800RC to BP3200, and reduced by more than another month when comparing BP3200 to BP3200RC. The time series of modelled Lake Alexandrina salinities are shown in Figure 33, where the peak salinities for each event can be seen to reduce as the water recovery volume increases.

However the effect of relaxing constraints is variable. In some cases the peak salinities are lower with relaxed constraints, but slightly higher in other years. This difference is likely due to the different decisions made in the delivery of watering events upstream and indicates that salinity outcomes can be affected by alterations in upstream watering actions.

**Table 28. Daily Lake Alexandrina salinity within critical ranges**

| Salinity Range | Time within the Salinity Range (%) (1975 to 2008–09) | | | | |
|---|---|---|---|---|---|
| | Baseline | BP2800 | BP2800RC | BP3200 | BP3200RC |
| < 700 EC | 56 | 85 | 87 | 88 | 90 |
| 7000 - 1000 EC | 33 | 14 | 12 | 11 | 10 |
| 1000 - 1500 EC | 7 | 1 | 1 | 1 | <0.5 |
| > 1500 EC | 4 | 0 | 0 | 0 | 0 |

**Table 29. Duration of Lake Alexandrina salinity above threshold values**

| Threshold | Duration of Salinity above Threshold Value (1975 to 2008–09) (days) | | | | |
|---|---|---|---|---|---|
| | Baseline | BP2800 | BP2800RC | BP3200 | BP3200RC |
| Days over 1000 EC | 1391 | 162 | 121 | 89 | 43 |
| Longest Period over 1000 EC | 888 | 115 | 121 | 89 | 43 |

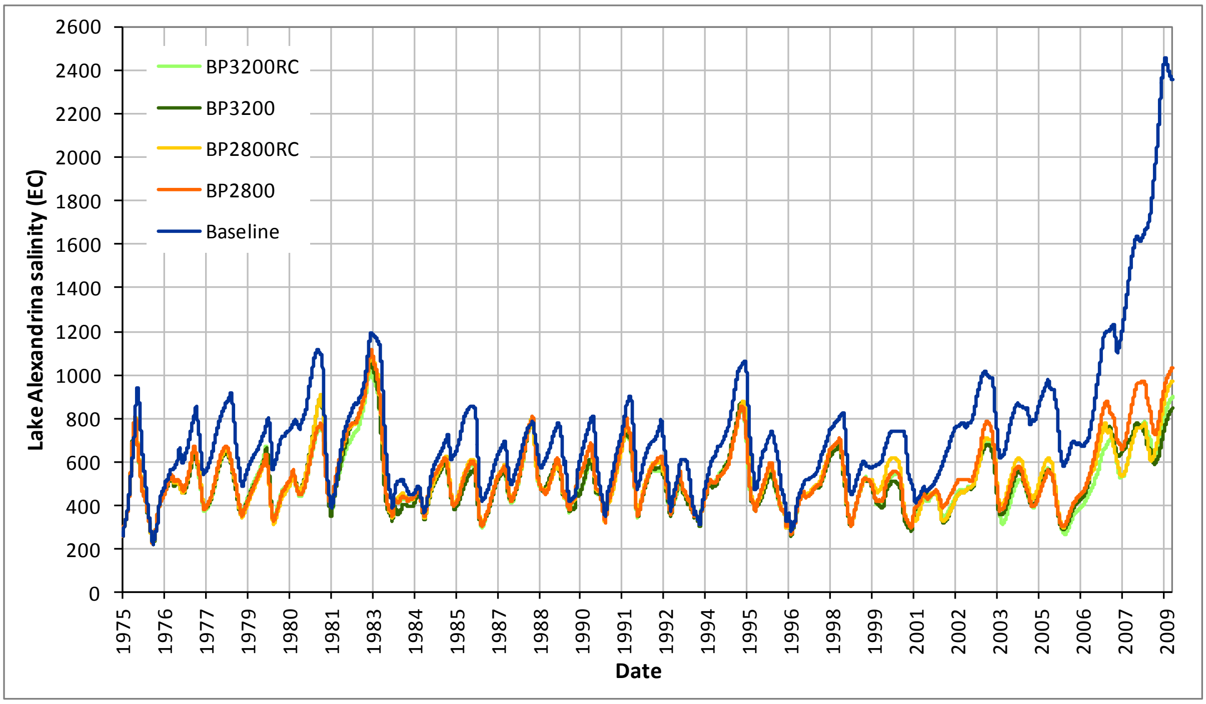



**Figure 33. Lake Alexandrina salinity (1975 to 2008–09)**

## 5.3.2. LAKE ALBERT

The descriptive statistics for salinity in Lake Albert during the benchmark period (1975 to 2008–09) are presented in Table 30 for Lake Albert. Generally salinity decreases with the increased water recovery volume; however the maximum salinity is reduced by a large amount when comparing Baseline conditions to the four water-recovery scenarios. As was the case in Table 27 for Lake Alexandrina, all statistics reduce in salinity as the water recovery volume increases, and the impact of relaxing constraints was variable between the scenarios but changes were small in magnitude.

**Table 30. Lake Albert salinity (1975 to 2008–09)**

| Statistic | Salinity (EC) | | | | |
|---|---|---|---|---|---|
| | Baseline | BP2800 | BP2800RC | BP3200 | BP3200RC |
| Minimum | 1024 | 955 | 962 | 893 | 946 |
| 10th Percentile | 1170 | 1039 | 1045 | 1011 | 1019 |
| Mean | 1507 | 1200 | 1191 | 1158 | 1167 |
| Median | 1360 | 1167 | 1166 | 1142 | 1137 |
| 90th Percentile | 1821 | 1389 | 1368 | 1322 | 1354 |
| Maximum | 6964 | 2130 | 1931 | 1853 | 1851 |

The percentage of time the modelled salinity data were in different ranges during the benchmark period is presented in Table 31, and the time in days and maximum duration exceeding 1500 EC in Table 32. From Table 30 and Table 31 it can be seen that the BP2800 scenario did exceed 2000 EC for 1% of the 1975–2009 period, which does not occur for the three other water recovery scenarios.

The total time and maximum period simulated over 1500 EC is presented in Table 32, where the total time over 1500 EC can be seen to reduce when comparing the 2800 GL scenarios to the 3200 GL scenarios, however the effect of relaxing constraints varied across the two scenarios for comparison. The maximum period over 1500 EC can be seen in the order of seven to eight months for the four water recovery scenarios. The time series of modelled Lake Albert salinities are shown Figure 34, where the reduced salinities in the water recovery scenarios compared to Baseline is very clear. Given the magnitude of this difference it is difficult to identify any other differences between the water recovery scenarios over most of the 1975–2009 period presented, however the reduced salinity produced by increasing the water recovery volume from 2800 GL to 3200 GL in the last three to six years can be seen in Figure 34.

**Table 31. Daily Lake Albert salinity within critical ranges**

| Salinity Range | Time within Salinity Range (%) (1975 to 2008-09) | | | | |
|---|---|---|---|---|---|
| | Baseline | BP2800 | BP2800RC | BP3200 | BP3200RC |
| 700 - 1000 EC | 0 | 3 | 3 | 6 | 8 |
| 1000 - 1500 EC | 73 | 91 | 92 | 90 | 88 |
| 1500 - 2000 EC | 21 | 5 | 5 | 4 | 4 |
| > 2000 EC | 6 | 1 | 0 | 0 | 0 |

**Table 32. Duration of Lake Albert salinity above threshold values**

| Threshold | Duration of Salinity above Threshold Value (days) (1975 to 2008-09) | | | | |
|---|---|---|---|---|---|
| | Baseline | BP2800 | BP2800RC | BP3200 | BP3200RC |
| Days over 1500 EC | 3365 | 726 | 609 | 497 | 511 |
| Longest Period over 1500 EC | 975 | 255 | 253 | 243 | 212 |

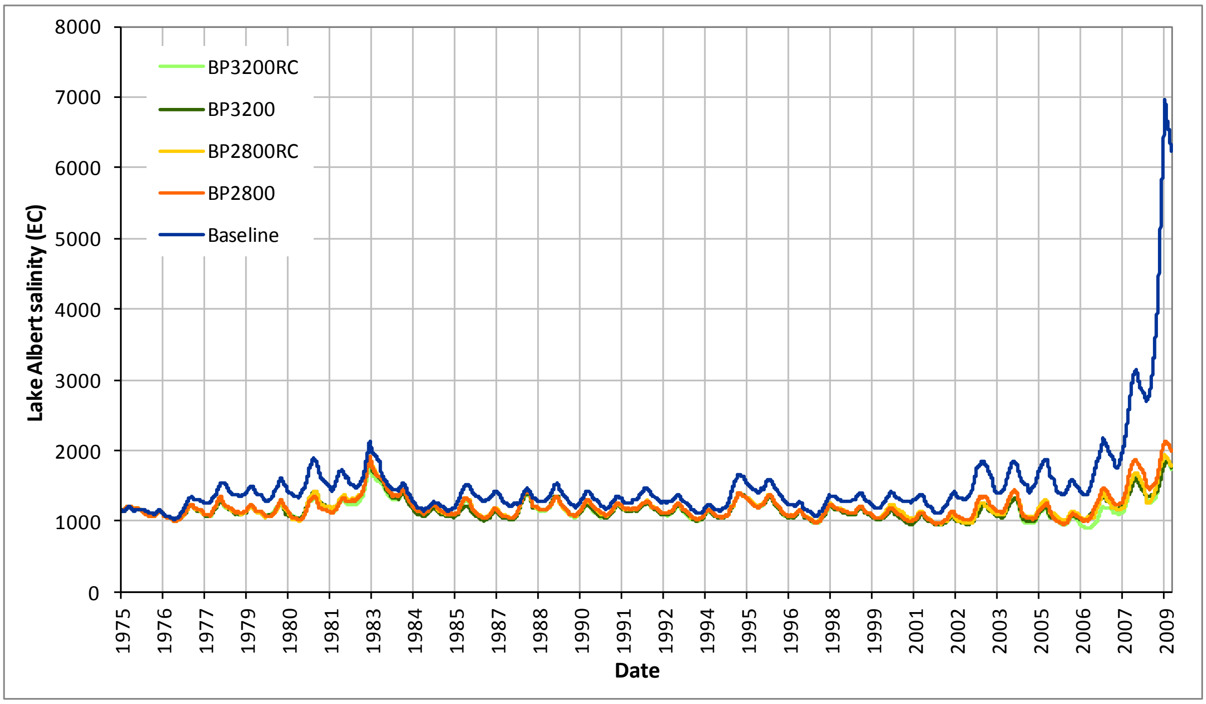



**Figure 34. Lake Albert salinity (1975 to 2008-2009)**

### 5.3.3. SALT EXPORT

Section 8.09 of the Altered Proposed Basin Plan states that the salt-load objective is the discharge of a minimum of two million tonnes (t) of salt from the River Murray System into the Southern Ocean each water-accounting period (financial year). It is also stated that the Authority must assess, on an annual basis, achievement of the salt-load objective against the number of tonnes of salt per year averaged over the preceding 10 years.

MDBA (2012) reported salt export as a long term average, as opposed to the 10-year rolling average stated in the Basin Plan. MDBA (2012) stated that the long-term average salt export for BP2800 was 1.96 million t/y and 2.00 million t/y for BP3200. The long term average salt export for the relaxed constraints scenarios are similar to that in the original scenarios, with 1.95 million t/y for BP2800RC, and 2.00 million t/y for BP3200RC. In comparison, 3.83 million t/y of salt was exported on average for the Without Development scenario and 1.66 million t/y for the Baseline scenario (MDBA, 2012).

South Australia has specified a salt export target of two million t/y over a three year rolling average rather than ten, informed by analysis by Heneker (2010) which demonstrated that lake salinity and associated ecological outcomes were sensitive to barrage outflow and salt export over a three-year time period. A comparison of the three year rolling average salt export for the four water recovery scenarios considered can be seen in Figure 35.

To demonstrate the difference between the long-term average salt export and the 10-year rolling average objective stated in the Basin Plan, the salt export for the modelled period for the BP3200RC scenario is presented in Figure 36.

The three year and 10-year rolling averages are also presented, with the value corresponding to a year on Figure 36 derived from the middle of the period, for example the value for the 10-year rolling average for 1980 was calculated over the period 1 July 1975–30 June 1985.

It can be seen from Figure 36 that the salt export on an annual, three year rolling, or ten-year rolling period is below the objective 2 million t/y for the majority of the time (52% of the periods for a 10-year rolling average, and 65% of the periods for a three year rolling average). The average salt export over the modelled period for the BP3200RC scenario, presented in Figure 36, was 1.73 million t/y. As the annual barrage outflow for the period where salinity was modelled was 6477 GL/y, compared to 7470 GL/y for the whole 114-year period, the average salt export for the whole periods was scaled up to 2.00 million t/y to represent the long-term average salt export over the 114 years.

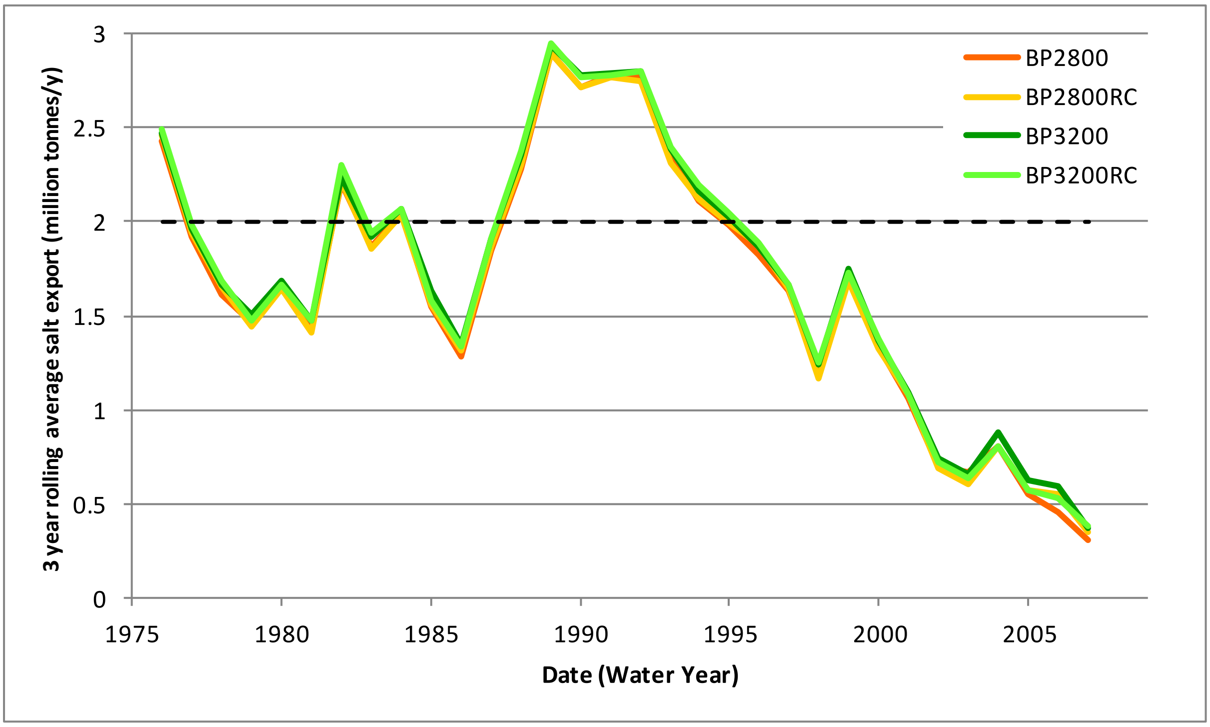



**Figure 35. Three year rolling average salt export for the water recovery scenarios for the period with modelled salinities**

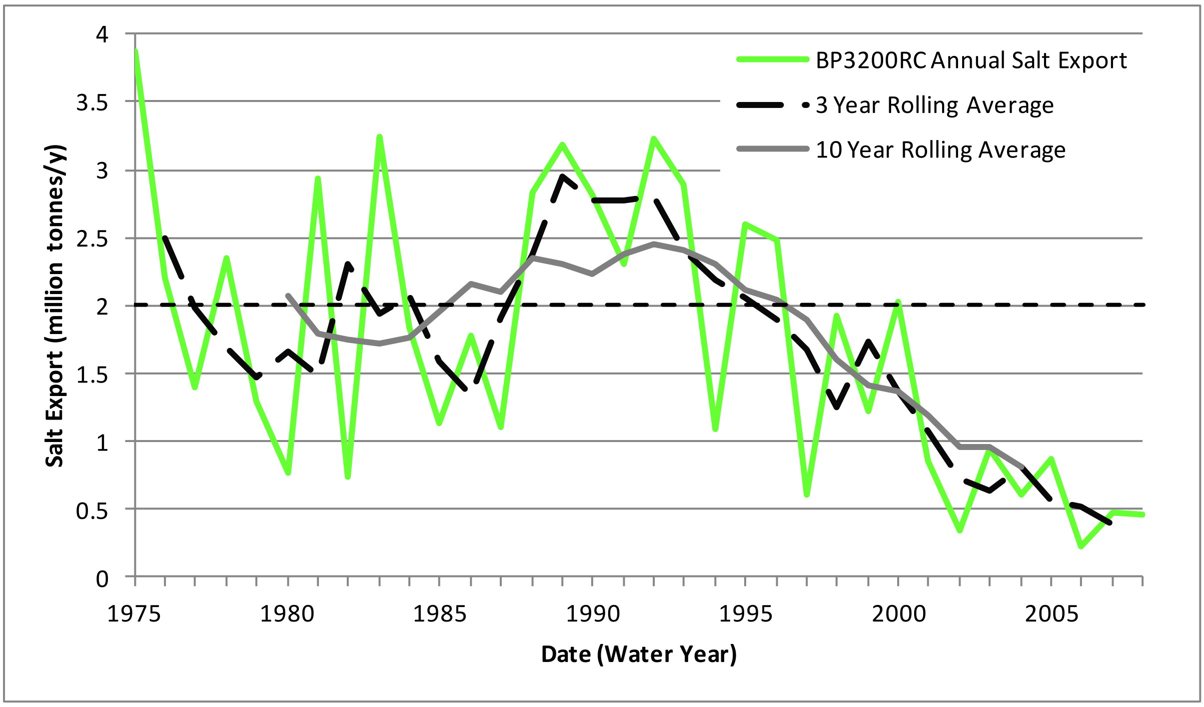



**Figure 36. Salt export for BP3200RC for the period with modelled salinities**

## *5.4. ASSESSMENT OF SOUTH AUSTRALIAN EWRS FOR LOWER LAKES*

A summary of the ability to meet each of South Australian defined EWRs for the Lower Lakes for each scenario considered is provided in Table 33. With the exception of except BP2800RC, all water recovery scenarios meet the barrage outflow rules required to maintain salinity in Lake Alexandrina from not exceeding 1000 EC 95% of the time, based on the relationship developed by Heneker (2010). For the BP2800RC scenario the 1000 EC flow relationship is achieved in 94% of years over the 114-year modelled period.

The final threshold outlined in Lester *et al.* (2011) is the flow required to ensure salinity in Lake Alexandrina does not exceed 1500 EC in all years, assessed based on the regression relationships with barrage outflow (Heneker, 2010). The four water recovery scenarios can be seen to be close meeting the 100% target, however in most cases there is a risk that 1500 EC may be exceeded. This is in contrast to the analysis of modelled salinities in Section 5.3.1, which found none of the water recovery scenarios exceeded 1500 EC in the period since 1975.

The years where the minimum barrage outflow relationships were not met occurred only in the 2007–08 and 2008–09 water years for the BP2800, BP2800RC and BP3200RC scenarios. The volume necessary to meet flow relationships representing the 1500 EC threshold for the BP2800 scenario was more than the barrage outflow for the BP2800 scenario in 2008–09. As such there is an increased risk of exceeding 1500 EC for this scenario, even though the maximum salinity simulated by BIGMOD in this year was 1033 EC (the maximum of 1119 EC occurred in 1983, as seen in Figure 33). While there was also a deficit for BP2800RC and BP3200RC (as the percentage meeting the target was 99 and 98% respectively in Table 33), the volume required to meet the target was much smaller than BP2800, thus providing increased security in terms of reducing the risk of peak salinities exceeding 1500 EC.

**Table 33. Assessment of South Australia EWRs for Lower Lakes**

| Target | EWRs | Requirement Definition | Baseline | Target | BP2800 | BP2800RC | BP3200 | BP3200RC |
|---|---|---|---|---|---|---|---|---|
| Lower Lakes | Lake Alexandrina salinity <1000 EC for 95% of all years | Barrage outflow, greater of three targets | 70% | 95% | 95% | 94% | 96% | 96% |
| | Lake Alexandrina salinity <1500 EC for all years | Barrage outflow, greater of three targets | 88% | 100% | 98% | 99% | 100% | 98% |

Target met

## *5.5. SUMMARY OF OUTCOMES FOR LOWER LAKES*

### 5.5.1. BARRAGE OUTFLOWS

- Changes to the distribution of flow within the year through the relaxation of constraints did reduce the number and length of periods of no barrage outflow longer than 30 days.
- Increasing the water recovery volume also reduced the number and length of periods of no barrage outflow. As such, the combination of increased water recovery and relaxation of constraints reduced the number of periods of no-barrage flow longer than 30 days from 11 events in BP2800 to three events in BP3200RC, and the length of the longest period of no-barrage flow reduced from 125 days in BP2800 to 50 days in BP3200RC.
- The EWRs for the frequency of high barrage outflows greater than 6000 GL/y and 10 000 GL/y were met by all four water recovery scenarios.

### 5.5.2. WATER LEVELS

- Heneker and Higham (2012) identified that modelled water levels dropped below the minimum operating water levels specified in the variable water level regime, even in non-drought years. The MDBA have acknowledged this model limitation, and rectification of this matter has been identified as a technical improvement to be undertaken as part of a larger suite of model improvements in the future.
- In the interim, the MDBA have undertaken an analysis of minimum water levels for the BP3200RC scenario and confirmed that the preferred minimum operating lake level of 0.4 m AHD or above in Lake Alexandrina can be achieved for 96% of the time, exceeding the target 95% of the time. This analysis was not available for the other scenarios considered at the time of writing.
- Even with the uncertainty in modelled water levels, the four water recovery scenarios all maintain water levels above 0.0 m AHD 100% of the time.

### 5.5.3. LAKES SALINITY

- Modelled salinity time-series provided by MDBA, commencing in 1975, indicated that the salinity in Lake Alexandrina for all four scenarios was: maintained below an average annual salinity 700 EC, maintained below 1000 EC 95% of the time and maintained below 1500 EC 100% of the time.
- The relationship based on the previous three years of barrage outflows suggests that three of the scenarios may exceed 1500 EC in Lake Alexandrina for the last two water years of the modelled time series.
- For Lake Albert, the four water recovery scenarios all maintained salinity below 1500 EC 95% of the time. The maximum salinity threshold of 2000 EC was exceeded for a short period in the BP2800 scenario only.

### 5.5.4. SALT EXPORT

- A long-term average salt export of 2.00 million t/y is delivered for both 3200 GL scenarios. By comparison, the long term average salt export for BP2800 was calculated to be 1.96 million t/y and 1.95 million t/y for BP2800RC.
- However, an assessment of salt export as a three or 10-year rolling average both demonstrated that there were extended periods where the desired salt export target is unlikely to be met for all scenarios considered, predominantly during drought when barrage outflows continue to be low.

# 6. COORONG AND MURRAY MOUTH

The Coorong and Murray Mouth, together with the Lower Lakes, is the terminal hydrological indicator site for the Murray-Darling Basin Plan. The Coorong and Lower Lakes (Alexandrina and Albert) are highly valued for their environmental significance, tourism, and fisheries, and are the traditional home of the Ngarrindjeri Nation (Higham, 2012). A Ramsar-listed site, it supports some threatened ecological communities and species, as well as extensive and diverse waterbird, fish and plant assemblages (Phillips and Muller, 2006). For example at least 85 bird species have been recorded in the site, 25 of which are listed under international migratory bird conservation agreements (Higham 2012).

A description of how the Coorong and Murray Mouth is targeted in the modelled watering plan was provided at the start of Section 5. The analysis undertaken below largely reflects an assessment of the implications that two different watering priorities have on the site, at two different water recovery volumes (2800 GL and 3200 GL). The different priorities are enabled as a result of the relaxation of constraints upstream which permits the provision of higher water releases from storage and facilitates larger flows that primarily target higher elevations of the floodplain.

## *6.1. SUMMARY OF HYDROLOGICAL METRICS TO BE USED IN ANALYSIS*

The hydrological metrics used in this analysis are those used in the previous Science Review in Higham (2012). A summary of the metrics is provided below and further information on the derivation of the metrics and how they are related to environmental outcomes is provided in Higham (2012).

### 6.1.1. MURRAY MOUTH 'OPENNESS'

To indicate Murray Mouth openness, average annual Murray Mouth (Mouth) depth will be analysed as the following classes based on Higham (2012):

- greater that 2 m (unconstricted)
- less than 2 m but greater than 1 m (constricted)
- less than 1 m (severely constricted).

An additional surrogate indicator for Murray Mouth openness is based on the MDBA indicator for an 'Open' Murray Mouth, which is the number of years in which total barrage flow is greater than 2000 GL/y (MDBA 2011a). An analysis of sequence of years where flow is less than 2000 GL/y is expected to also provide some indication of sequences where increased risk is posed to Mouth constriction that may require dredging. None of these analyses are expected to be definitive in regards to the decision to implement dredging (see Higham 2012).

### 6.1.2. COORONG SALINITY

Assessing the salinity regimes of the Coorong Lagoons seeks to provide indication of the relative effects of the recovery volume and application of water at upstream sites on one aspect of habitat availability. To provide an assessment of suitability of habitat for key species for both the North and South Lagoons, Higham (2012) outlined rationale for separate thresholds for these environments.

These thresholds were then assessed separately, focussing primarily on maximum salinity, analysing the duration and the number of events that average daily salinity exceeds the identified thresholds:

North Lagoon:

- should be to not exceed 45 g/L so as to avoid sub-lethal effects on mudflat macroinvertebrate biota
- lethal salinities for target species (*Ruppia megacarpa*) begin to manifest at salinities greater than 50 g/L

South Lagoon:

- should be to not exceed 90 g/L so as to avoid sub-lethal effects on Chironomids and other target biota
- lethal salinities for Chironomids begin to manifest at salinities greater than 100 g/L.

Maximum salinities of 108 g/L and 120 g/L will also be assessed to examine the ability to avoid extreme salinities expected to impact on Small-mouthed hardyhead (*Atherinosoma microstoma)* and *Ruppia tuberosa* populations, respectively in the South Lagoon as outlined in Higham (2012).

### 6.1.3. WATER LEVEL IN THE SOUTH LAGOON

A target average annual water level in the South Lagoon to support *Ruppia tuberosa* populations of greater than 0.27 m AHD based on Overton *et al.* (2009) has been adopted as a metric for comparative analyses as outlined in Higham (2012).

## *6.2. ASSESSMENT OF SCENARIOS*

Given the indicative nature of the modelling undertaken by the MDBA and the range of untested assumptions used, the focus of this analysis is seeking to assess the percent of years where modelled values exceed target threshold values (e.g. maximum salinity in the Coorong South Lagoon) and comparison of relative exceedences (both absolute value and duration).

As this analysis is comparative between scenarios, it is also important to examine the events in the time series where thresholds are exceeded. Such occurrences are indicative of events that could reasonably be expected in the future, and how watering decisions have accommodated mitigating these risks as a component of climate variability (as opposed to climate change).

Events where thresholds are exceeded (being indicative of climate variability) require an analysis of their occurrence to fully understand the implications of the various water recovery options. This is undertaken while acknowledging that watering-actions upstream do not directly target Coorong salinity outcomes.

The assessment of the absolute outcomes, specifically maximum salinities and duration of exceeding a given threshold in the Coorong, despite the uncertainty inherent in the modelled outcomes, provides valuable insights into the ecological impacts that could manifest under the proposed recovery volume if delivered as modelled. These outcomes could be further affected by local climatic conditions both positively and negatively, as outlined in Higham (2012).

By selecting appropriate threshold values for ecological drivers (primarily salinity and water level), it is expected that an assessment of whether the flow-recovery scenarios will avoid events that are likely to affect biota can be identified. Thereby screening the flow scenarios and permitting a comparison of relative benefits or a simplistic assessment of risk of adverse impact occurring to the ecology of the Coorong (Higham 2012).

## 6.3. MOUTH OPENNESS

### 6.3.1. TOTAL ANNUAL AVERAGE FLOW LESS THAN 2000 GL

Table 34 summarises the analysis of total annual flow through the barrages for the MDBA modelling scenarios. This analysis indicates that for the Baseline scenario, total annual flow through the barrages is less than 2000 GL in approximately one-third of all years (36%). In comparison, the 2800 GL and 3200 GL scenarios show considerable improvement compared to the Baseline, with 11% of years having total annual barrage flow less than 2000 GL (Table 34).

**Table 34. Number of years and percent of years in the series where total annual barrage flow is less than 2000 GL**

| | Without Development | Baseline | BP2800 | BP2800RC | BP3200 | BP3200RC |
|---|---|---|---|---|---|---|
| # of years | 3 | 41 | 13 | 15 | 13 | 14 |
| % of years | 3% | 36% | 11% | 13% | 11% | 12% |

An examination of the sequence of years where flows are less than 2000 GL (Figure 37) indicates that under the Baseline scenario, there are nine sequences where two or more years are concurrent while under Without Development there are no concurrent sequences. Several of the sequences under Baseline are for four years or more with one sequence up to eight years in duration (2001–02 to 2008–09).

In contrast, under both the 2800 GL and 3200 GL scenarios, one sequence (2006–09) results in three concurrent years where flows are less than 2000 GL remaining (Figure 37). The occurrence of this sequence of two or more years poses an increased risk of severe constriction occurring.

Relaxing constraints shows no improvement when compared to BP2800, with BP2800RC having 13% of years that flow is less than 2000 GL compared to 11% of years (Table 34).

The analysis of the sequence of years where flows are less than 2000 GL under the BP2800RC scenario indicates flows are greater than 2000 GL in two additional years (2004–05) relative to the BP2800 scenario, but that these do not increase the sequences of consecutive years.

Similarly, the relaxation of constraints at 3200 GL shows no improvement between scenarios, as BP3200RC had 12% of years with barrage flow less than 2000 GL compared to 11% of years for BP3200 (Table 34). The additional volume included in the 3200 GL scenarios is thought to be the reason for BP3200RC having one less year where flows are less than 2000 GL relative to the BP2800RC scenario.

The analysis of the sequence of years where flows are less than 2000 GL indicates that despite an additional year occurring where flows are less than 2000 GL for the relaxing of constraints scenario, there is no difference in the number of consecutive years where total barrage flow is less than 2000 GL for the 2800 GL scenarios relative to the 3200 GL scenarios, as seen in Figure 37.

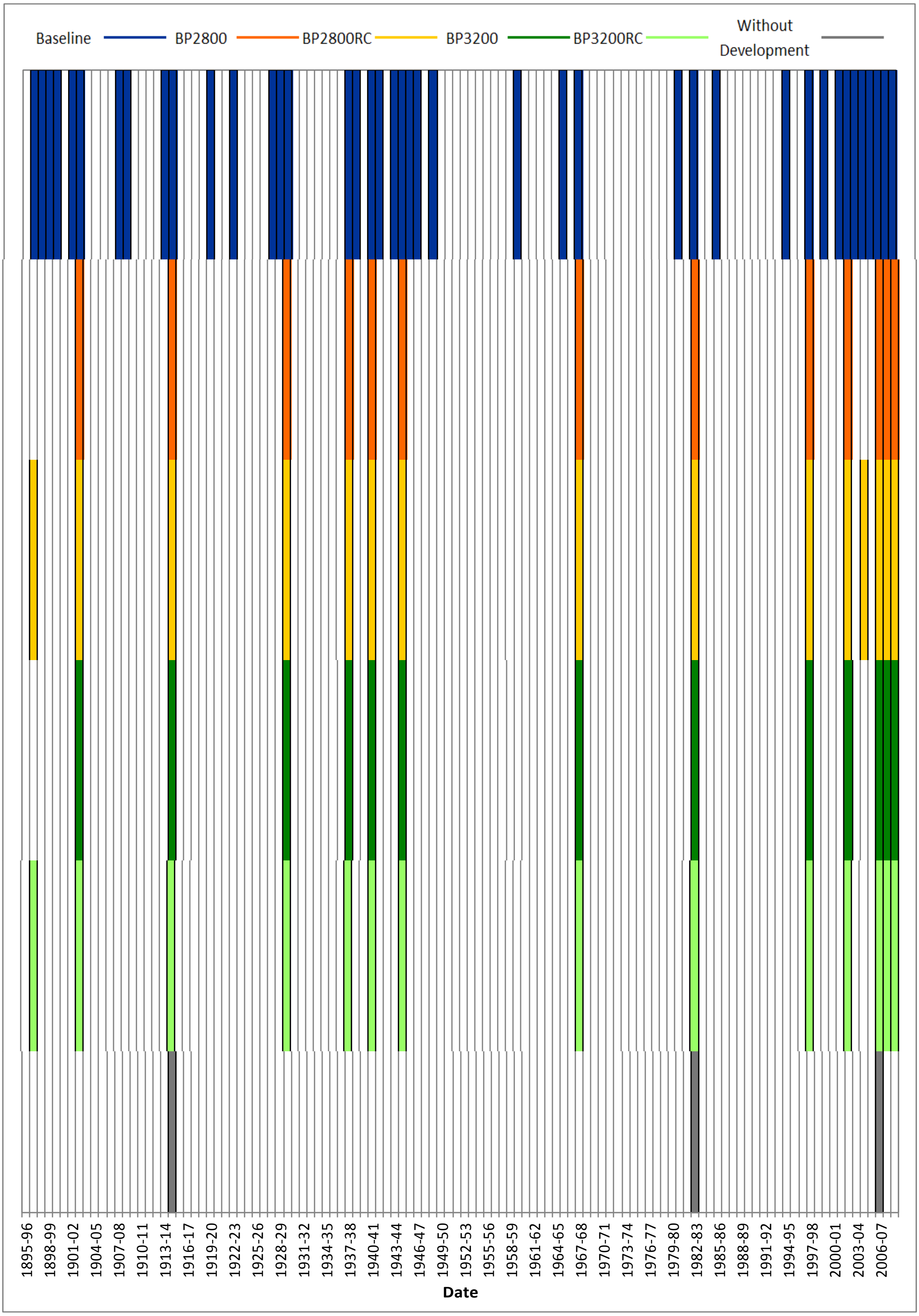



**Figure 37. Sequence of years where total modelled barrage flow is less than 2000 GL in that year**

### 6.3.2. ANALYSIS OF ANNUAL AVERAGE MURRAY MOUTH DEPTH

The analysis of annual average effective Mouth depth compares the average annual effective Mouth depth (relative to the water's surface) as calculated from the hydrodynamic model outputs, for the various water recovery scenarios. The analysis reveals a substantial improvement between the BP2800 and BP3200 scenarios relative to the Baseline scenario (Figure 38).

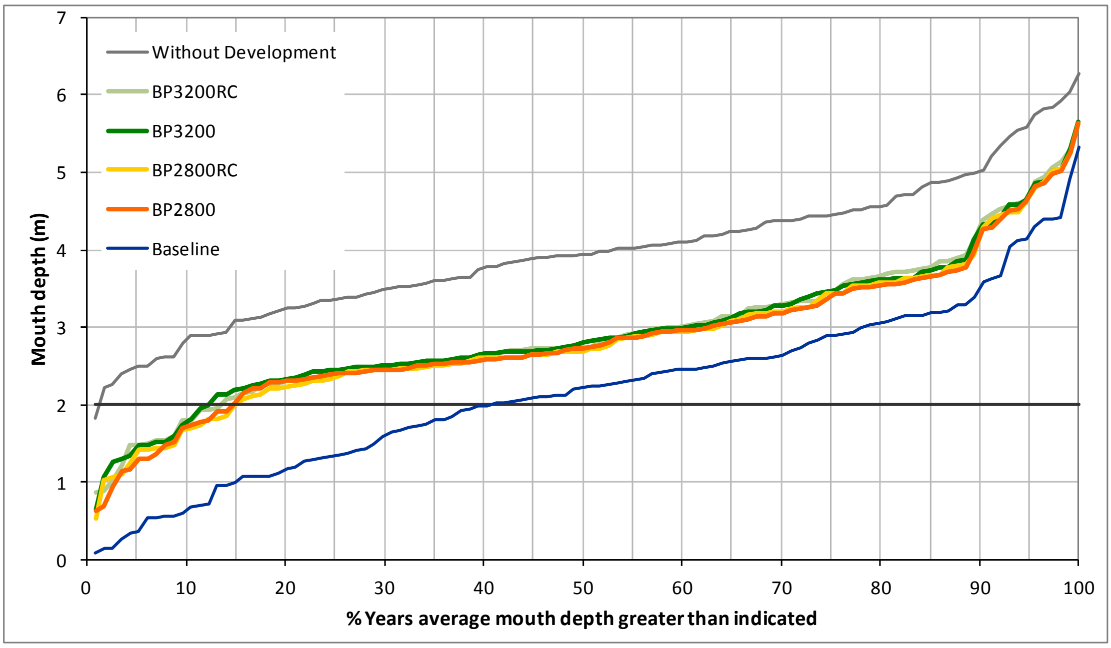



**Figure 38. Frequency distribution plot of Mouth depth averaged for each water year over the time series with a depth of 2 m indicated by the black line**

The analysis of effective Mouth depth during the full time-series on an average annual basis indicates that the Murray Mouth is constricted approximately 40% of years for the Baseline scenario (using the 2 m average annual depth criterion). Relative to the Baseline scenario, all water recovery scenarios show a large amount of relative improvement, with the 2800 GL and 3200 GL scenarios indicating constriction occurring in approximately 12% and 14% of years respectively (Figure 38). The frequency distribution analysis reveals some variation of Mouth depths between years for the water recovery scenarios, assumed to be as a result of altered water delivery made possible due to the additional volume represented by 3200 GL scenarios relative to the 2800 GL scenarios.

The frequency distribution analysis (Figure 38) reveals some variation of Mouth depths between years that are comparatively minor with improvements in some years offset by reductions in other years. This is assumed to be as a result of altered upstream water delivery made possible due to the relaxation of constraints that alters the timing and distribution of flow within and between years relative to the BP2800 scenario. This outcome is to be expected in that there is no increase in the rolling average volume between scenarios that might affect the volume released and therefore maintain any improvement in mouth depth that would differentiate the scenarios.

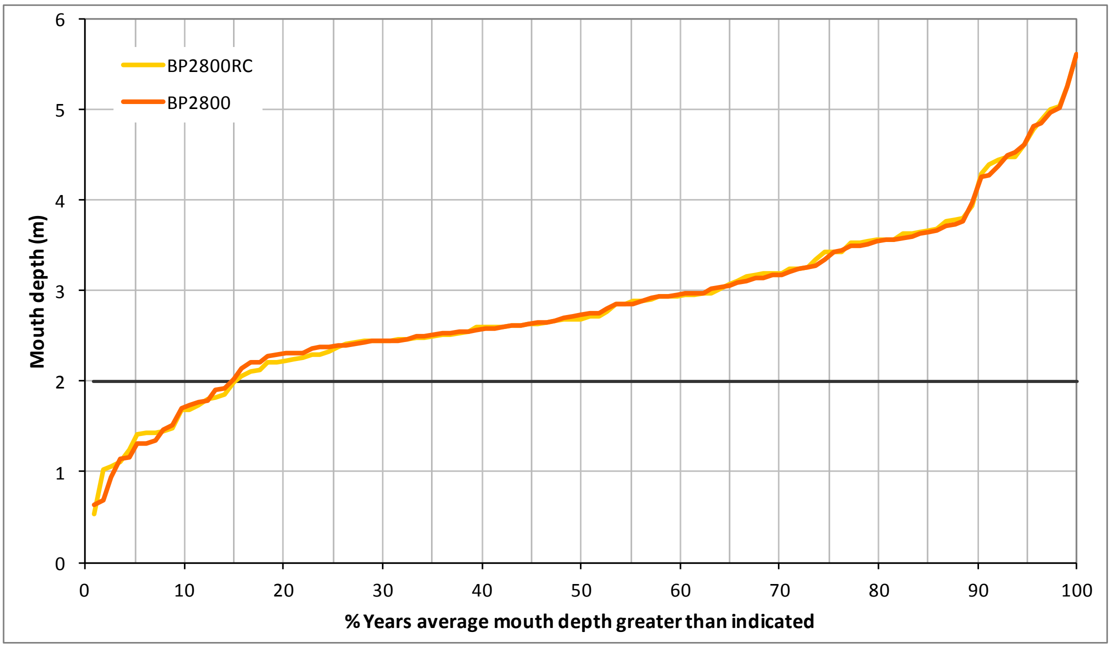



**Figure 39. Frequency distribution on plot of Mouth depth averaged for each water year over the time series with a depth of 2 m indicated by dark grey line (1895–96 to 2008–09)**

Similarly to the relaxation of constraints at 2800 GL, the frequency distribution analysis (Figure 40) reveals some variation of Mouth depths between years, assumed to be as a result of altered water delivery between the two scenarios in response to the relaxation of constraints which alters the timing and distribution of flow within and between years relative to the BP3200 scenario.

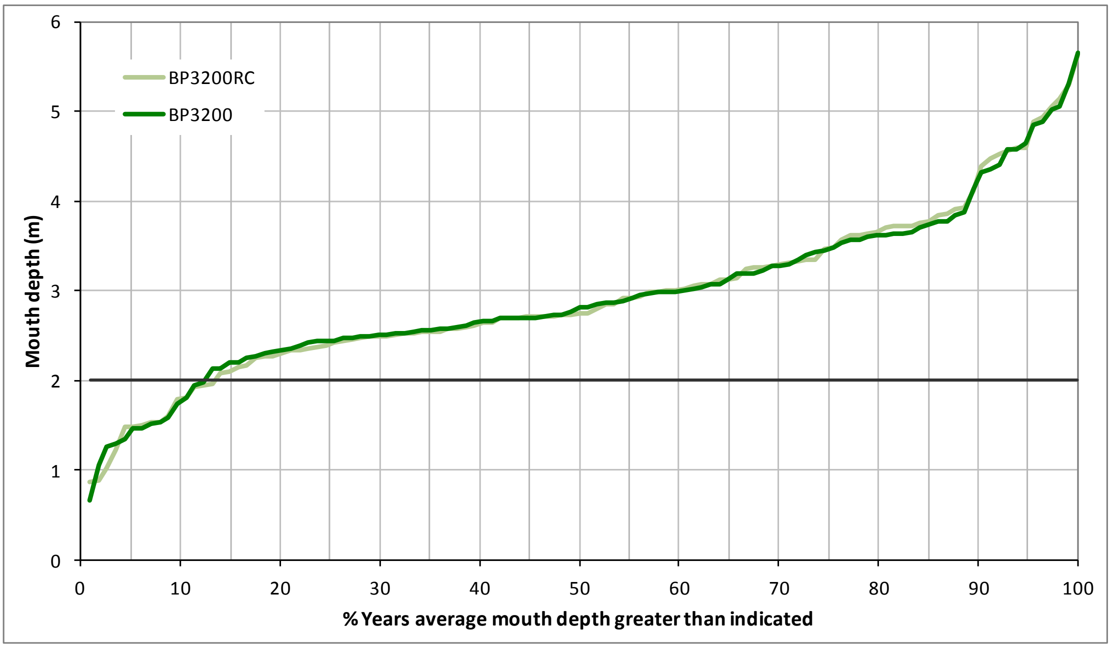



**Figure 40. Frequency distribution plot of Mouth depth averaged for each water year over the time series with a depth of 2 m indicated by the dark grey line (1895–96 to 2008–09)**

### 6.3.3. ANNUAL AVERAGE MOUTH DEPTH STATISTICS

An analysis of annual Mouth depth greater or less than 2 m was undertaken for each available scenario. Table 35 shows that the water recovery scenarios proposed result in the Mouth being 'unconstricted' (average annual depth greater than 2 m) between 85% and 88% of years, which is a considerable improvement relative to the Baseline where the Mouth is 'unconstricted' in approximately 60% of years.

Relative to the Baseline, there is improvement in the annual Mouth depth for both the BP2800 and BP3200 water recovery scenarios. The number of years where the Mouth is classified as unconstricted is improved as the recovery-volume increases with BP3200 improving relative to BP2800 (Table 35).

**Table 35. Summary of percentage years where the Murray Mouth is classified as constricted or unconstricted (1895–96 to 2008–09)**

| | Without Development | Baseline | BP2800 | BP2800RC | BP3200 | BP3200RC |
|---|---|---|---|---|---|---|
| Unconstricted | 99.1 | 59.6 | 86.0 | 85.1 | 87.7 | 86.8 |
| Constricted | 0.9 | 40..4 | 14.0 | 14.9 | 12.3 | 13.2 |

The results summarised in Table 36 indicate that the water recovery scenarios represent a substantive improvement in the achievement of outcome of maintaining an open Mouth with a low risk of dredging compared to those currently experienced under the Baseline scenario. The number of years where the Mouth, on average, is classified as severely constricted reduces as the volume provided to the environment increases. The variation in results between scenarios with and without constraints relaxed demonstrates that the outcomes are affected by upstream watering actions as well as recovery volume.

**Table 36. Summary of number of years where Murray Mouth is constricted under each water recovery scenario (1895–96 to 2008–09)**

| | Without Development | Baseline | BP2800 | BP2800RC | BP3200 | BP3200RC |
|---|---|---|---|---|---|---|
| Unconstricted | 113 | 68 | 98 | 97 | 100 | 99 |
| Constricted | 1 | 29 | 13 | 16 | 13 | 13 |
| Severely constricted | 0 | 17 | 3 | 1 | 1 | 2 |

Comparison of the annual average Mouth depth in the four most-constricted events illustrates the improvement between the water recovery volumes. The four most constricted years were chosen to illustrate the same four years in the sequence where the average annual Mouth depth is most constricted and approaching less than 1.0 m average depth. An improvement can be seen in all years examined as flow volume increases (Table 37).

**Table 37. Minimum depth (m) of the Murray Mouth for the worst four years of the time series**

| BP2800 | | BP3200 | | BP2800RC | | BP3200RC | |
|---|---|---|---|---|---|---|---|
| Year | Minimum depth (m) | Year | Minimum depth (m) | Year | Minimum depth (m) | Year | Minimum depth (m) |
| 2008–09 | 0.63 | 2008–09 | 0.66 | 2008–09 | 0.53 | 2008–09 | 0.89 |
| 2007–08 | 0.68 | 2007–08 | 1.05 | 2007–08 | 1.02 | 2007–08 | 0.87 |
| 2006–07 | 0.94 | 2006–07 | 1.27 | 2006–07 | 1.06 | 2006–07 | 1.02 |
| 1902–03 | 1.14 | 1902–03 | 1.3 | 1902–03 | 1.11 | 1902–03 | 1.22 |

An examination of Mouth depth classification indicates that the BP2800RC scenario performed marginally worse than the BP2800 scenario (Table 35) with approximately 1% more years being constricted.

When examining the years where the Mouth is constricted, the 2800 GL scenarios result in an apparent improvement, as the relaxation of constraints resulted in less years being severely constricted (two less years). The Mouth was also classified as unconstricted in one year less when comparing BP2800RC to BP2800 (Table 36).

With the relaxation of constraints at 2800 GL, the relative performance by examining annual average mouth depth in these years (Table 37) indicates that the depth of some years is improved but also in some years is worsened. This is most likely a result of the total-flow changing between years in the adjoining years that correspond to the years examined here, as a result of watering choices at upstream sites.

An examination of Mouth depth classification indicates that similarly to the 2800 GL scenarios, the BP3200RC scenario performs marginally poorer than the BP3200 scenario (Table 35) with approximately 1% more years being classified as constricted.

When examining the years where the Mouth is constricted for the BP3200RC scenario, an additional year is classified as severely constricted and one additional year is classified as constricted (Table 36).

With the relaxation of constraints at 3200 GL, the same outcome observed for the 2800 GL scenarios occurred with the Mouth depth of some years being improved but in some years also worsened (for the reasons populated above).

## *6.4. AVERAGE ANNUAL WATER LEVELS IN THE SOUTH LAGOON*

### 6.4.1. NUMBER OF YEARS WATER LEVELS SUPPORT RUPPIA TUBEROSA IN THE SOUTH LAGOON

Annual average water levels were analysed for each of the scenarios on a financial year basis. Table 38 indicates that under the Baseline scenario, average annual water levels are less than 0.27m AHD (ie would not support *Ruppia tuberosa* in the South Lagoon) in 43% of years. Under the 2800 GL and 3200 GL scenarios, there is some improvement with an additional 5% and 8% of years respectively where water levels support the distribution of *R. tuberosa* in the South Lagoon (Table 38).

**Table 38. Years average annual water depth is lower than 0.27 m AHD (1895–96—2008–09)**

| | Without Development | Baseline | BP2800 | BP2800RC | BP3200 | BP3200RC |
|---|---|---|---|---|---|---|
| # of years | 14 | 49 | 43 | 32 | 40 | 40 |
| % of years | 12% | 43% | 38% | 28% | 35% | 35% |
| Improvement relative to Baseline | NA | 0 | 5% | 15% | 8% | 8% |

With the relaxation of constraints (BP2800RC), the number of years that average annual water levels support *R. tuberosa* substantially improves relative to the BP2800 scenario, with a 10% increase in the number of years where average annual water levels support *R. tuberosa* in the South Lagoon (Table 38).

Figure 41 shows the time series of average annual South Lagoon water levels for the 2800 GL scenarios. In many years, water levels in the Coorong are better under the constraints relaxed scenario, however there are exceptions where some years indicated a poorer performance on average annual water level basis. This is likely as a result of changes in flow volume and timing between years and within years interacting with local climate and sea levels altering average annual water levels in the Coorong.

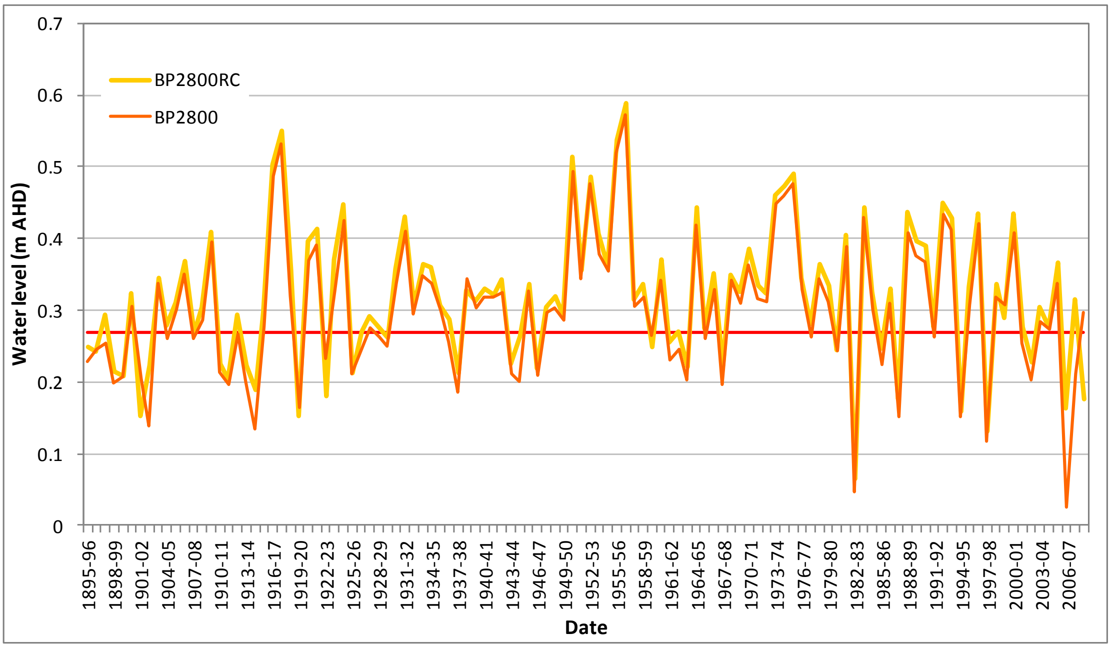



**Figure 41. Time series of annual average water levels in the South Lagoon for 2800 GL scenarios (1895–96 to 2008–09). Target annual average water level in the South Lagoon is indicated in red.**

Under the BP3200 scenario (Table 38; Figure 42), average annual water level shows comparatively limited improvement with the relaxation of constraints with one year worse and one year improved relative to the threshold. This is likely as a result of changes in upstream watering events impacting on delivery to the Coorong (i.e. of flow volume and timing between years). In addition, there are within-year interactions with local climate and sea levels altering average annual water levels in the Coorong.

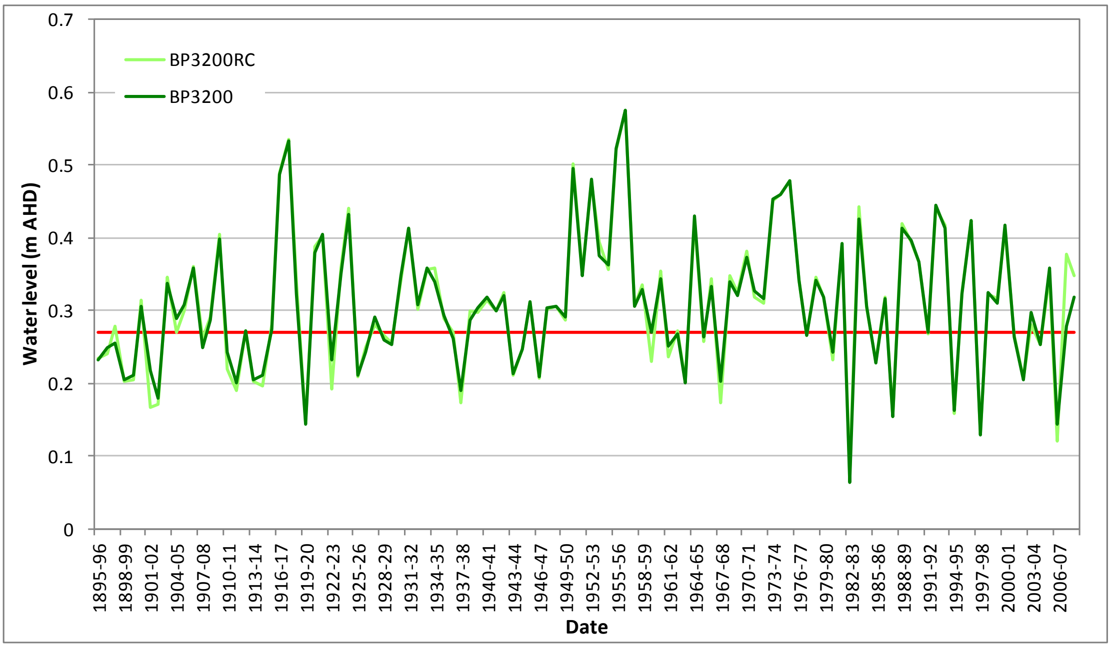



**Figure 42.** **Time series of annual average water levels in the South Lagoon for 3200 GL scenarios (1895–96 to 2008–09). Target annual average water level in the South Lagoon is indicated in red.**

### 6.4.2. SEQUENCE OF YEARS WATER LEVELS SUPPORT RUPPIA TUBEROSA IN THE SOUTH LAGOON

An analysis of years indicates that there are three sequences where average annual average daily water levels are less than 0.27 m AHD in concurrent years (of three or more years in a row). In comparison, under the Without-Development scenario there are no sequences of three years or more in a row where average annual water levels are less than 0.27 m AHD.

For the 2800 GL scenarios, the number of years where annual average daily average water levels are less than 0.27m AHD decreases, but the number of sequences where water levels are less than 0.27 m AHD for three or more consecutive years does not change. Conversely, with the provision of 3200 GL, both the number of years and the number of sequences where water levels are less than 0.27 m AHD reduces by one (1912–13), altering a sequence of five consecutive years that occurred under the 2800 GL scenarios. The remaining sequences that occur under Baseline remain unaffected (Figure 43).

With the relaxation of constraints and the provision of 2800 GL, further improvement in the number of years and the sequences where water levels are less than 0.27 m AHD for three or more consecutive years changes, such that these are eliminated from the time series (Figure 43).

With the relaxation of constraints and the provision of 3200 GL, similarly to 2800 GL, the sequences where water levels are less than 0.27 m AHD for three or more consecutive years changes such that these are eliminated from the time series (Figure 43). However, the number of years where water levels are less than 0.27 m AHD shows no changes.

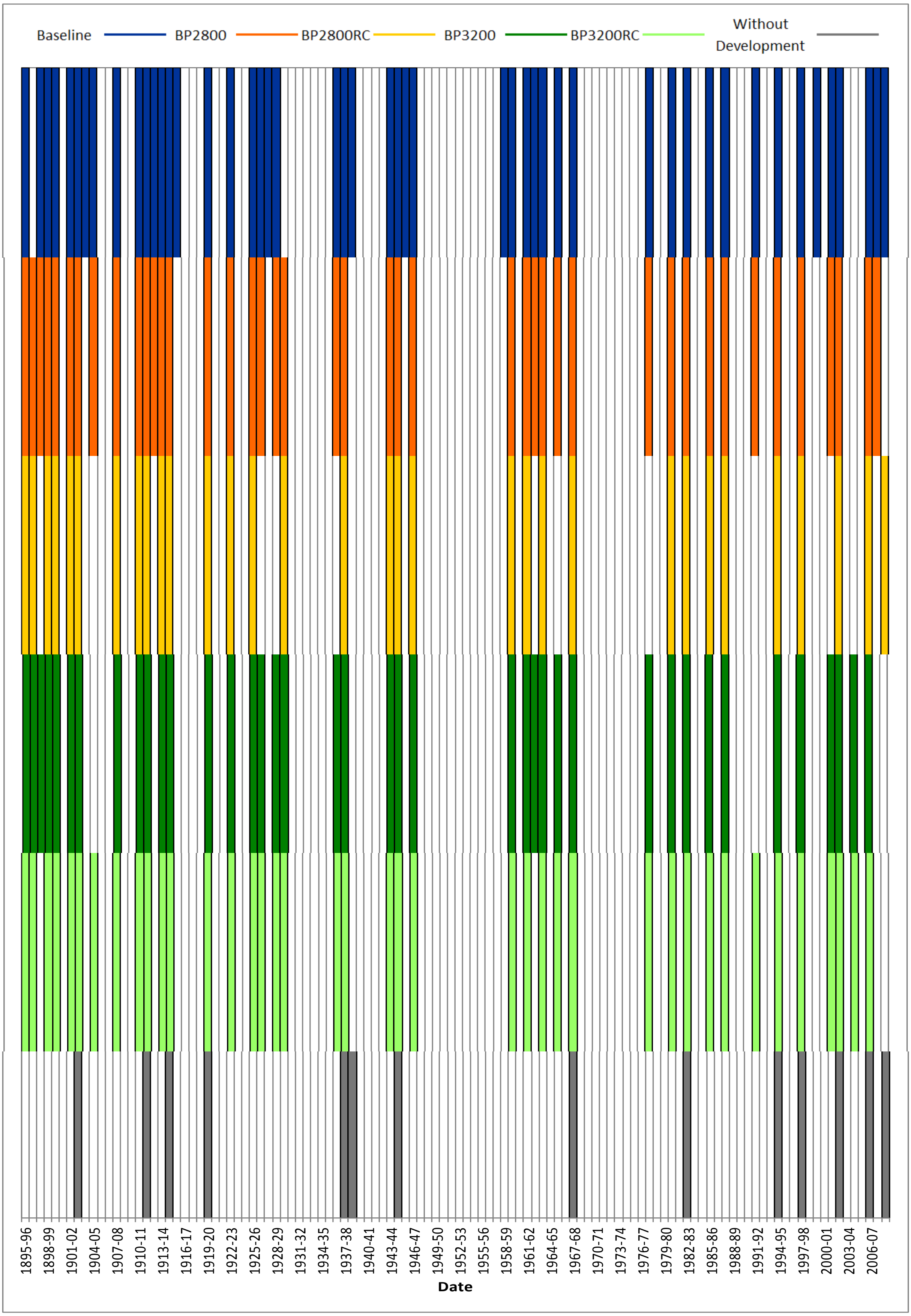



**Figure 43. Sequences of years where annual average of daily South Lagoon water levels are less than 0.27 m AHD**

# 6.5. COORONG SALINITIES

## 6.5.1. COORONG NORTH LAGOON AVERAGE ANNUAL SALINITIES

Table 39 summarises the modelled average annual salinity in the North Lagoon for the 114 years modelled by the MDBA (1895–96 to 2008–09). The Baseline scenario indicates an average annual salinity for the North Lagoon ranging between approximately 3.5 g/L and 49.5 g/L. The Without Development scenario has a substantially smaller salinity range relative to the Baseline scenario. Maximum average annual salinity in the North Lagoon under the Baseline scenario is much greater relative to the Without Development scenario at over 148 g/L, although 95% of average annual North Lagoon salinities are less than approximately 51 g/L. In addition, the average and median salinities are considerably greater for the Baseline scenario relative to the Without Development scenario.

The 2800 GL scenarios indicates the potential for a considerable improvement relative to the Baseline scenario, with average annual salinities ranging between 2.4 g/L and 55.8 g/L, effectively half of that observed under Baseline conditions. With constraints relaxed, BP2800RC also shows a considerable improvement compared to the Baseline scenario, with average annual salinities ranging between 2.4 g/L and 60.7 g/L (Table 30). Of the BP2800 and BP2800RC scenarios, BP2800 showed the greatest improvement, with the maximum salinity (55.8 g/L) closer to that seen under Without Development conditions.

Average annual salinities observed under the BP3200 scenario showed further improvements (from the BP2800 and BP2800RC scenarios) compared to the Baseline scenario, with average annual salinities ranging from 2.3 g/L and 47.2 g/L (Table 30). Relaxing of constraints for the 3200 GL scenarios represented the greatest improvement in average minimum and maximum annual salinities in the North Lagoon when compared to the Baseline scenario, at 2.2 g/L and 43 g/L, respectively. Average annual salinity improved under all water recovery scenarios compared to the Baseline scenario.

Of the scenarios examined, BP3200RC showed the greatest improvement with the average maximum salinity lower, at 43.0 g/L, compared to 148.4 g/L for the Baseline scenario.

When comparing the BP2800 and BP2800RC scenarios, the range in average annual salinity for the North Lagoon is similar, with only a slightly higher maximum average salinity observed under BP2800RC (60.7 g/L) compared to BP2800 (55.8 g/L) (Table 39). Average annual salinity in the North Lagoon is similar under both BP2800 and BP2800RC scenarios, at 20.8 g/L and 20.5 g/L, respectively.

The range in average annual salinity for the North Lagoon is similar under BP3200 and BP3200RC scenarios, with the most notable difference observed in the average maximum salinity (i.e. a reduction of 4.2 g/L with the relaxation of constraints at 3200 GL; Table 39). Relaxing constraints for the 3200 GL scenarios had no effect on the average annual salinity.

**Table 39. Statistics of average annual salinity (g/L) for the North Lagoon under the different scenarios modelled by the MDBA**

| | Without Development | Baseline | BP2800 | BP2800RC | BP3200 | BP3200RC |
|---|---|---|---|---|---|---|
| MINIMUM | 1.8 | 3.5 | 2.4 | 2.4 | 2.3 | 2.2 |
| 5th percentile | 4.0 | 11.1 | 7.8 | 7.7 | 7.5 | 7.3 |
| 10th percentile | 4.8 | 14.0 | 9.6 | 9.4 | 9.0 | 8.9 |
| AVERAGE | 11.6 | 28.9 | 20.8 | 20.5 | 19.6 | 19.6 |
| MEDIAN | 9.6 | 27.7 | 20.6 | 20.5 | 19.4 | 19.6 |
| 90th percentile | 21.4 | 42.4 | 31.4 | 30.8 | 30.1 | 30.0 |
| 95th percentile | 27.5 | 51.2 | 34.5 | 33.1 | 32.0 | 32.0 |
| MAXIMUM | 49.5 | 148.4 | 55.8 | 60.7 | 47.2 | 43.0 |

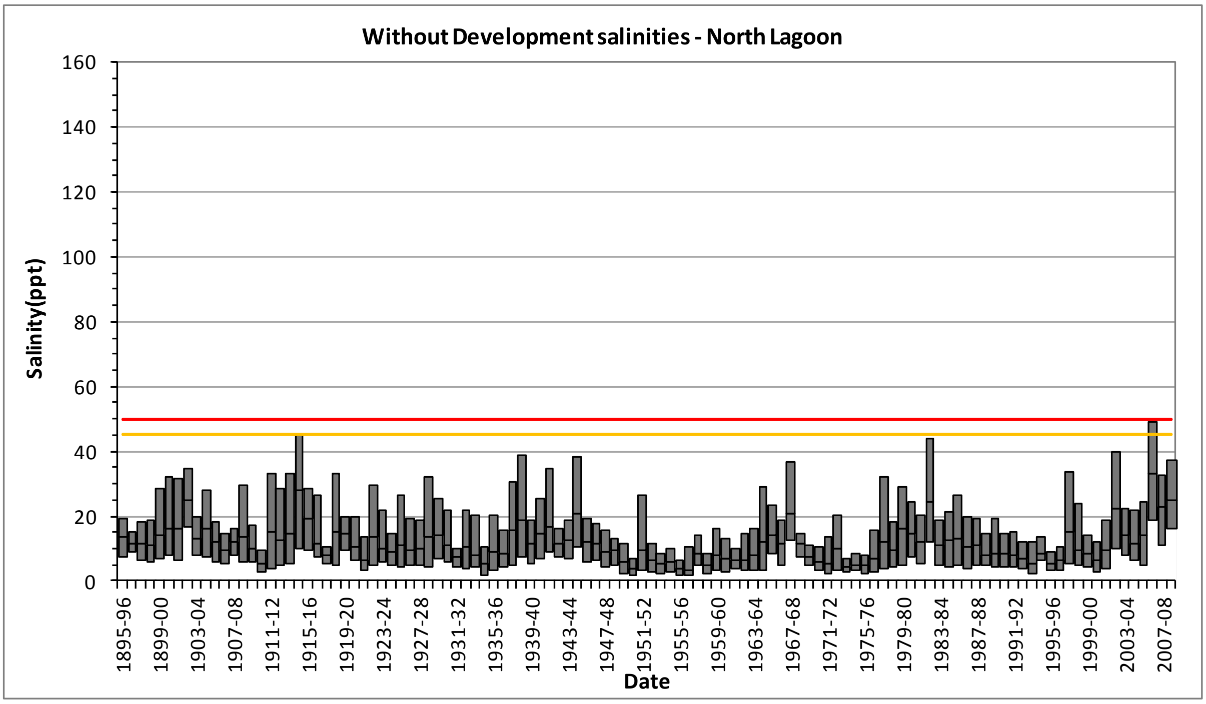
## 6.5.2. COORONG NORTH LAGOON AVERAGE DAILY SALINITIES

Figure 44 a-f illustrates the range of average daily North Lagoon salinities modelled as delineated by the MDBA (Higham, 2012) for each year from 1895–96—2008–09, resulting from the Baseline, BP2800, BP2800RC, BP3200, and BP3200RC scenarios.

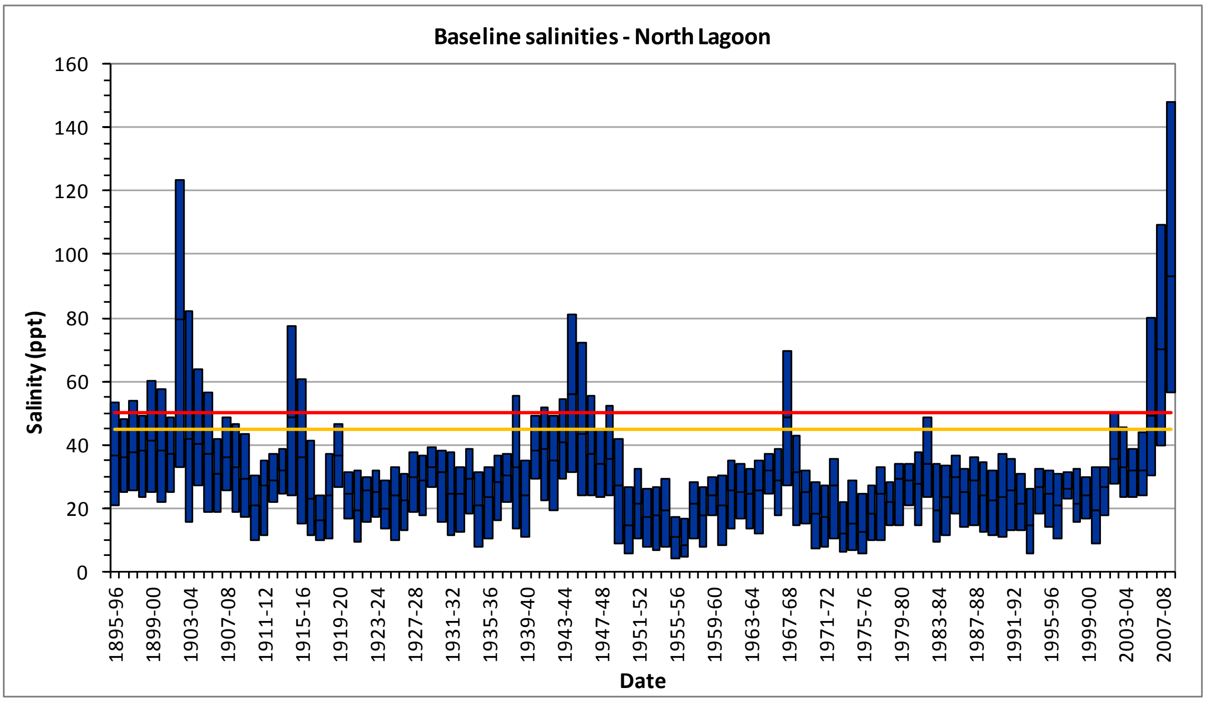
In comparison to the Baseline scenario all scenarios show a reduced range of average salinities in each year; minimum average and maximum average salinities in the North Lagoon in all years are lower with a sizeable reduction in the range of average salinities experienced in each year. The BP3200RC scenario shows the greatest improvement compared to the Baseline and Without Development scenarios, with an improvement in peak salinities and neither threshold being exceeded.

In comparison to the BP2800 scenario, peak salinities under the BP2800RC scenario are generally lower (with the exception of 2008–09; Figure 44 c and d). Despite this, the average North Lagoon salinity exceeded the sub-lethal salinity thresholds for target biota and *R. megacarpa* under both scenarios, but relaxing constraints did reduce the number of years where both thresholds were exceeded.

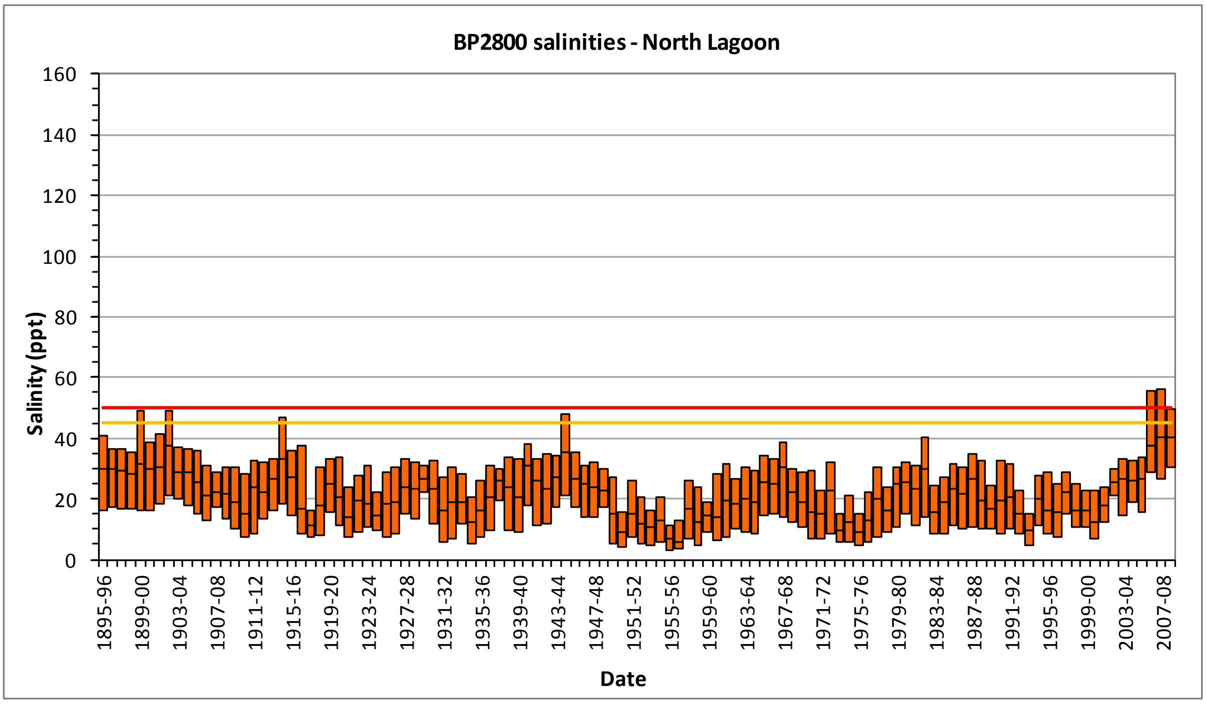
Peak salinities under the BP3200RC scenario are lower than those seen under the BP3200 scenario (Figure 44 e and f). The average North Lagoon salinity exceeded the sub-lethal threshold for target biota under the BP3200 scenario (exceeded in 1899–1900), but the threshold for *R. megacarpa* was not exceeded in any years. When constraints were relaxed under 3200 GL no years exceeded either of the target thresholds.


Without Development salinities - North Lagoon
Salinity(ppt)
160
140
120
100
80
60
40
20
0
1895-96
1899-00
1903-04
1907-08
1911-12
1915-16
1919-20
1923-24
1927-28
1931-32
1935-36
1939-40
1943-44
1947-48
1951-52
1955-56
1959-60
1963-64
1967-68
1971-72
1975-76
1979-80
1983-84
1987-88
1991-92
1995-96
1999-00
2003-04
2007-08
Date

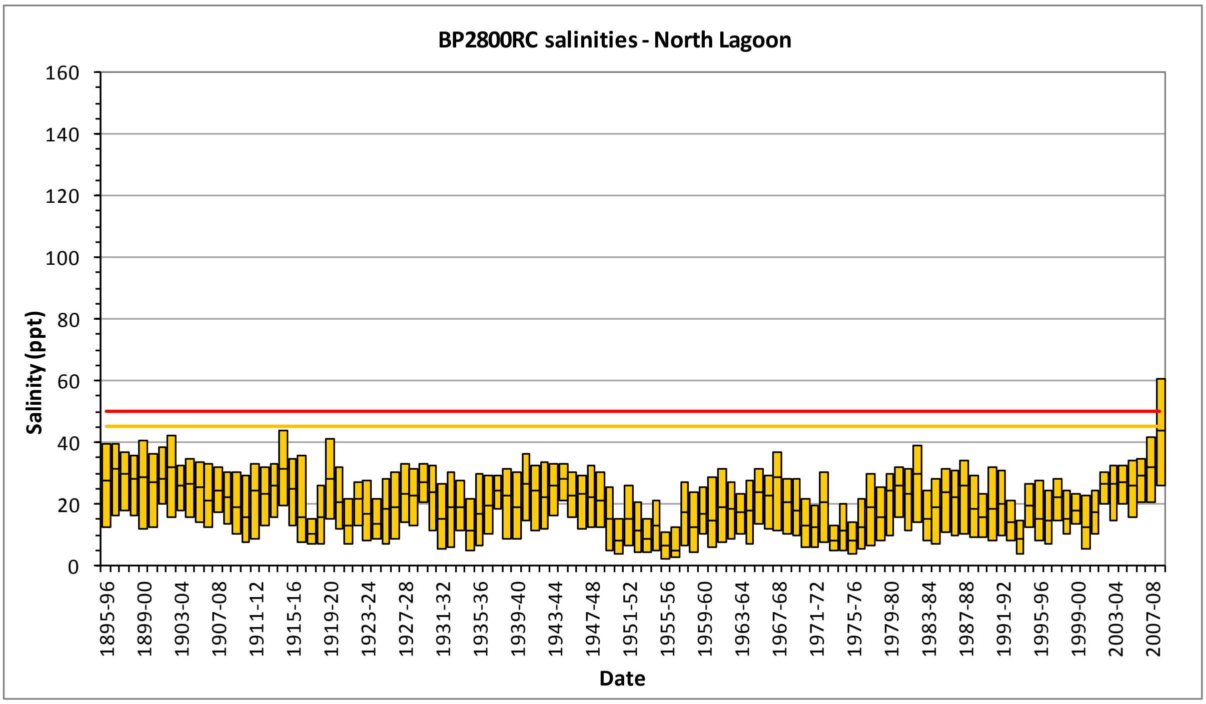
(a)


Baseline salinities - North Lagoon
Salinity (ppt)
160
140
120
100
80
60
40
20
0
1895-96
1899-00
1903-04
1907-08
1911-12
1915-16
1919-20
1923-24
1927-28
1931-32
1935-36
1939-40
1943-44
1947-48
1951-52
1955-56
1959-60
1963-64
1967-68
1971-72
1975-76
1979-80
1983-84
1987-88
1991-92
1995-96
1999-00
2003-04
2007-08
Date

(b)


BP2800 salinities - North Lagoon
Salinity (ppt)
0
20
40
60
80
100
120
140
160
1895-96
1899-00
1903-04
1907-08
1911-12
1915-16
1919-20
1923-24
1927-28
1931-32
1935-36
1939-40
1943-44
1947-48
1951-52
1955-56
1959-60
1963-64
1967-68
1971-72
1975-76
1979-80
1983-84
1987-88
1991-92
1995-96
1999-00
2003-04
2007-08
Date

(c)


BP2800RC salinities - North Lagoon
Salinity (ppt)
0
20
40
60
80
100
120
140
160
1895-96
1899-00
1903-04
1907-08
1911-12
1915-16
1919-20
1923-24
1927-28
1931-32
1935-36
1939-40
1943-44
1947-48
1951-52
1955-56
1959-60
1963-64
1967-68
1971-72
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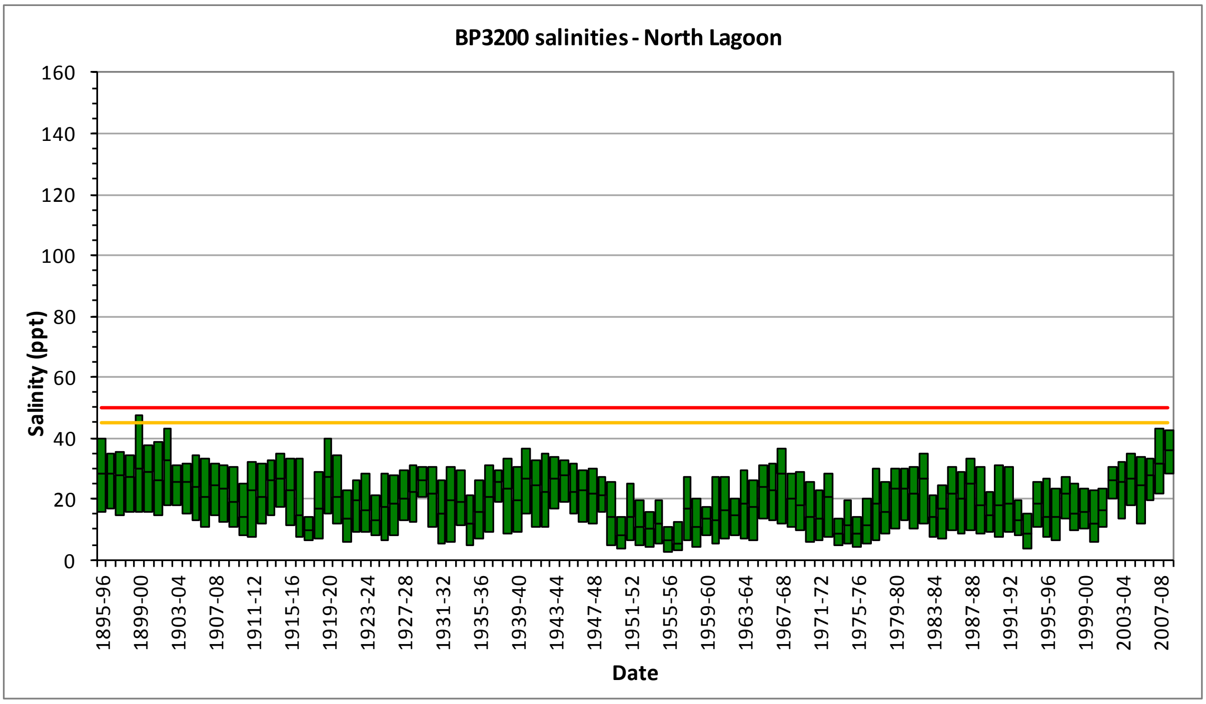
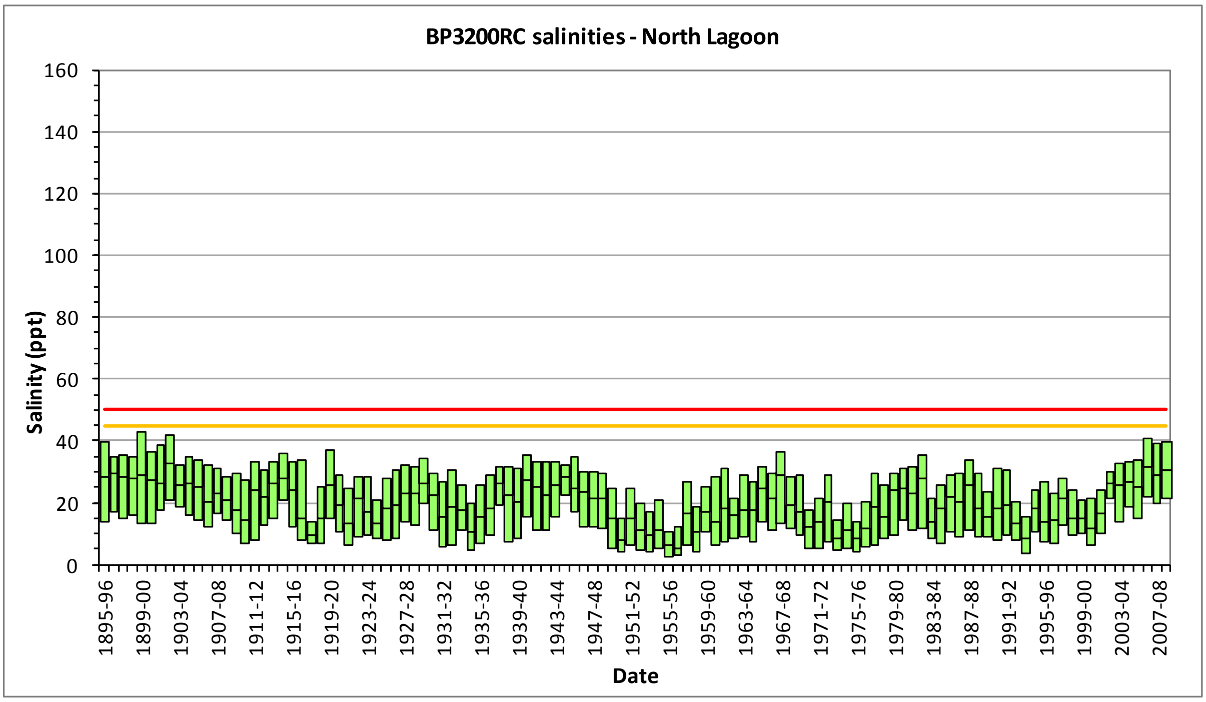
1979-80
1983-84
1987-88
1991-92
1995-96
1999-00
2003-04
2007-08
Date

(d)




(e)




(f)

**Figure 44 a-f. Comparison of annual average daily salinity and average daily salinity ranges (modelled by the MDBA) in the North Lagoon for the Baseline, BP2800 GL, BP2800RC, BP3200, and BP3200RC scenarios. Sub-lethal maxima for target biota of 45 g/L indicated in orange and upper lethal tolerance for *Ruppia megacarpa* in red (50 g/L).**

### 6.5.3. COORONG NORTH LAGOON SALINITY THRESHOLD EXCEEDENCES – TARGET BIOTA 45 g/L THRESHOLD

Daily average salinities within a year indicate that average salinities in the North Lagoon under the Baseline scenario exceed the sub-lethal threshold for target biota 42 times. In comparison to the Baseline scenario all of the other scenarios show an improvement in the number of times the threshold (i.e. 45 g/L) for target biota is exceeded. The average and maximum duration of the exceedences of the sub-lethal threshold is generally improved compared to the Baseline, except for the average duration seen under the BP2800RC scenario (which is a result of a single event of exceedence longer than five days, in comparison to 42 events longer than five days under the Baseline scenario; Table 40).

Only the BP3200 scenario shows an improvement within the single event, with the duration lower at 18 days, compared to 77 days under the Without Development scenario. The BP3200RC scenario shows the greatest improvement though, with the threshold for target biota in the North Lagoon never exceeded.

**Table 40. Average daily salinity (modelled by the MDBA) exceeding the 45 g/L threshold for sub-lethal impacts on target biota in the North Lagoon**

| | Without Development | Baseline | BP2800 | BP2800RC | BP3200 | BP3200RC |
|---|---|---|---|---|---|---|
| # events longer than 5 days | 1 | 42 | 9 | 1 | 1 | 0 |
| Mean duration | 77 | 79 | 48 | 146 | 18 | 0 |
| Median duration | 77 | 30 | 50 | 146 | 18 | 0 |
| Maximum duration | 77 | 624 | 102 | 146 | 18 | 0 |

When comparing the BP2800 and BP2800RC scenarios, relaxing constraints improves the number of times the threshold for target biota is exceeded, with the threshold exceeded 12 times under the BP2800 scenario and a single event under the BP2800RC scenario. The average and maximum duration of these exceedences of the sub-lethal threshold is much greater under the BP2800RC scenario when compared to the BP2800 scenario (Table 40). Despite the greater durations, with constraints relaxed there is only a single event longer than five days compared to the nine events observed under the BP2800 scenario.

Daily average salinities within a year indicate that average salinities in the North Lagoon under the BP3200 scenario exceed the sub-lethal threshold for target biota once. When constraints are relaxed under 3200 GL, the threshold is never exceeded (Table 40). As a result, the average and maximum duration is greater under the BP3200 scenario compared to the BP3200RC scenario.

### 6.5.4. COORONG NORTH LAGOON SALINITY THRESHOLD EXCEEDENCES – RUPPIA MEGACARPA 50 g/L THRESHOLD

Daily average salinities within a year indicate that average salinities in the North Lagoon under the Baseline scenario exceed the sub-lethal threshold for *R. megacarpa* 29 times. In comparison to the Baseline scenario all of the other scenarios show an improvement in the number of times the threshold (i.e. 50 g/L) for *R. megacarpa*, with BP3200 and BP3200RC showing the greatest improvement with the threshold never exceeded (Table 41). The maximum duration of exceedence and the number of events of exceedence longer than five days, is improved across all scenarios compared to the Baseline, with the average duration also generally improved. Compared to the Without

Development scenario, only the BP3200 and BP3200RC are equivalent, with the threshold for *R. megacarpa* in the North Lagoon never exceeded (Table 41).

**Table 41. Average daily salinity (modelled by the MDBA) exceeding the 50g/L threshold for sub-lethal impacts on *R. megacarpa* in the North Lagoon**

| | Without Development | Baseline | BP2800 | BP2800RC | BP3200 | BP3200RC |
|---|---|---|---|---|---|---|
| # events longer than 5 days | 0 | 29 | 2 | 1 | 0 | 0 |
| Mean duration | 0 | 77 | 66 | 114 | 0 | 0 |
| Median duration | 0 | 16 | 66 | 114 | 0 | 0 |
| Maximum duration | 0 | 604 | 75 | 114 | 0 | 0 |

Average salinities in the North Lagoon under the BP2800 scenario exceed the sub-lethal threshold for *R. megacarpa* twice, compared to five times under the BP2800RC scenario. On average, relaxing constraints with 2800 GL extended the duration of threshold exceedence but was restricted to a single even longer than five days (with 2800 GL having two events longer than five days; Table 41).

Daily average salinities within a year indicate that average salinities in the North Lagoon under the BP3200 and BP3200RC scenarios never exceed the sub-lethal threshold (i.e. 50 g/L) for *R. megacarpa* (Table 41).

### 6.5.5. COORONG SOUTH LAGOON AVERAGE ANNUAL SALINITIES

The South Australian delineation of the South Lagoon has been used in this section. This delineation adopts a smaller subset of the hydrodynamic model outputs compared to that used by the MDBA to provide a more conservative estimate of average salinity. For more information on the differences between delineations, see Higham (2012).

Table 42 summarises the modelled average annual salinity in the South Lagoon for the 114 years (1895–96—2008–09). The Baseline scenario indicates an average annual salinity for the South Lagoon ranging between 18.3 g/L and 298.1 g/L (Table 42). The BP2800 scenario represents a considerable improvement compared to the Baseline scenario, with average annual salinities ranging between 11.9 g/Land 121.4 g/L. With constraints relaxed in BP2800RC, average annual salinity ranges showed slightly more improvement than BP2800. Average annual salinities observed under the BP3200 scenario showed the greatest improvement compared to the Baseline (when comparing the BP2800, BP2800RC, BP3200, and BP3200RC scenarios). When comparing maximum average annual salinities in the South Lagoon, the greatest improvement is seen under the BP3200 scenario.

**Table 42. Statistics of average annual salinity (g/L) for the South Lagoon under the different scenarios for SA delineation of the South Lagoon**

| | Without Development | Baseline | BP2800 | BP2800RC | BP3200 | BP3200RC |
|---|---|---|---|---|---|---|
| MINIMUM | 7.2 | 18.3 | 11.9 | 11.8 | 11.5 | 11.0 |
| 5th percentile | 12.2 | 33.5 | 23.2 | 23.7 | 22.3 | 22.4 |
| 10th percentile | 13.2 | 38.6 | 27.2 | 26.9 | 25.7 | 25.5 |
| AVERAGE | 24.1 | 62.7 | 44.6 | 43.7 | 41.8 | 41.9 |
| MEDIAN | 23.0 | 55.8 | 42.0 | 42.0 | 40.2 | 40.0 |
| 90th percentile | 36.3 | 94.8 | 65.5 | 63.0 | 60.5 | 61.1 |
| 95th percentile | 43.1 | 108.5 | 74.2 | 69.5 | 66.9 | 67.2 |
| MAXIMUM | 68.5 | 298.1 | 121.4 | 113.1 | 99.7 | 100.1 |

When comparing the BP2800 and BP2800RC scenarios, the ranges in average annual salinity are similar (Table 42). Relaxing constraints under 2800 GL does improve the average and slightly more notably the maximum salinity when compared to the BP2800 scenario.

When comparing the BP3200 and BP3200RC scenarios, very little difference in the average annual salinity statistics is observed (Table 42). Only minimal differences are seen in the maximum salinity, where minimum salinity is lower under the BP3200 and BP3200RC scenarios.

Further analysis of Coorong salinities was undertaken to understand the implications of assessing average annual and average daily salinities to identify periods of risk to the ecology of the Coorong, specifically the South Lagoon (Appendix E).

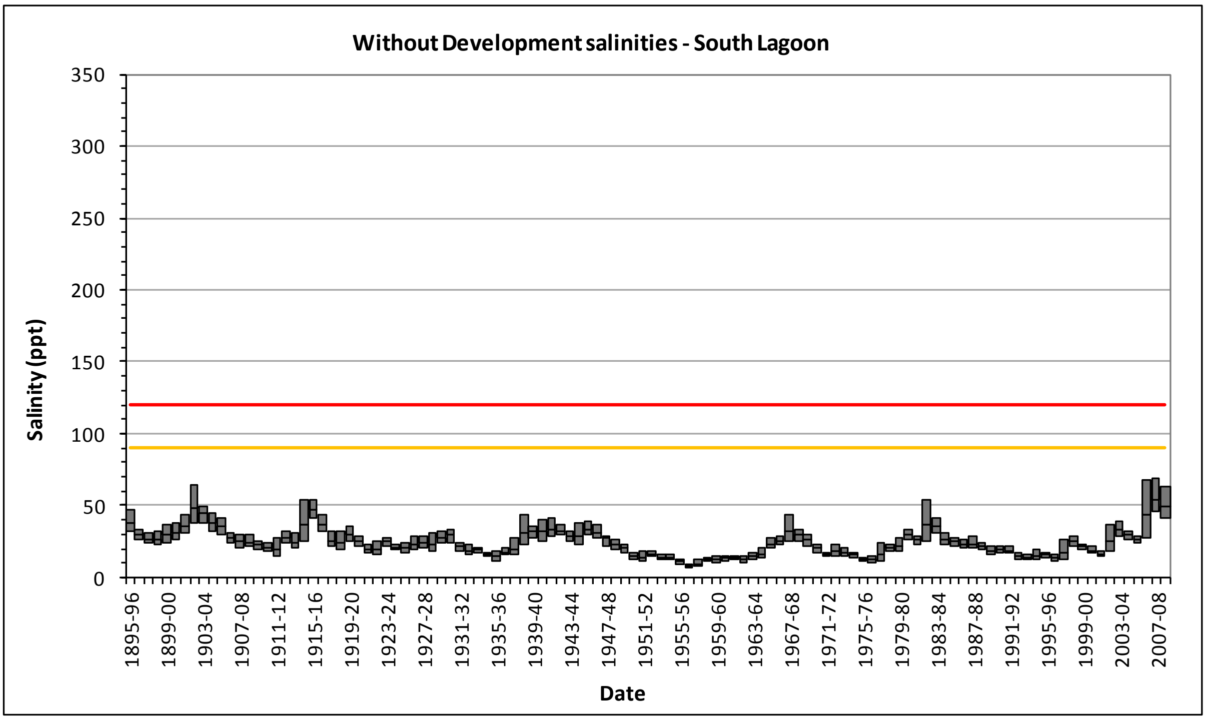
### 6.5.6. COORONG SOUTH LAGOON AVERAGE DAILY SALINITIES

Figure 45 a-f illustrates the range of average South Lagoon salinities for each year from 1895–96 to 2008–09, resulting from the Baseline, BP2800, BP2800RC, BP3200, and BP3200RC scenarios. The Without Development scenario has a smaller salinity range relative to the Baseline scenario, with maximum average salinity less than the average salinity experienced under Baseline conditions. Maximum annual average salinity in the Baseline scenario is extreme at over 298 g/L, although in 95% of years the average South Lagoon salinities are less than 109 g/L.

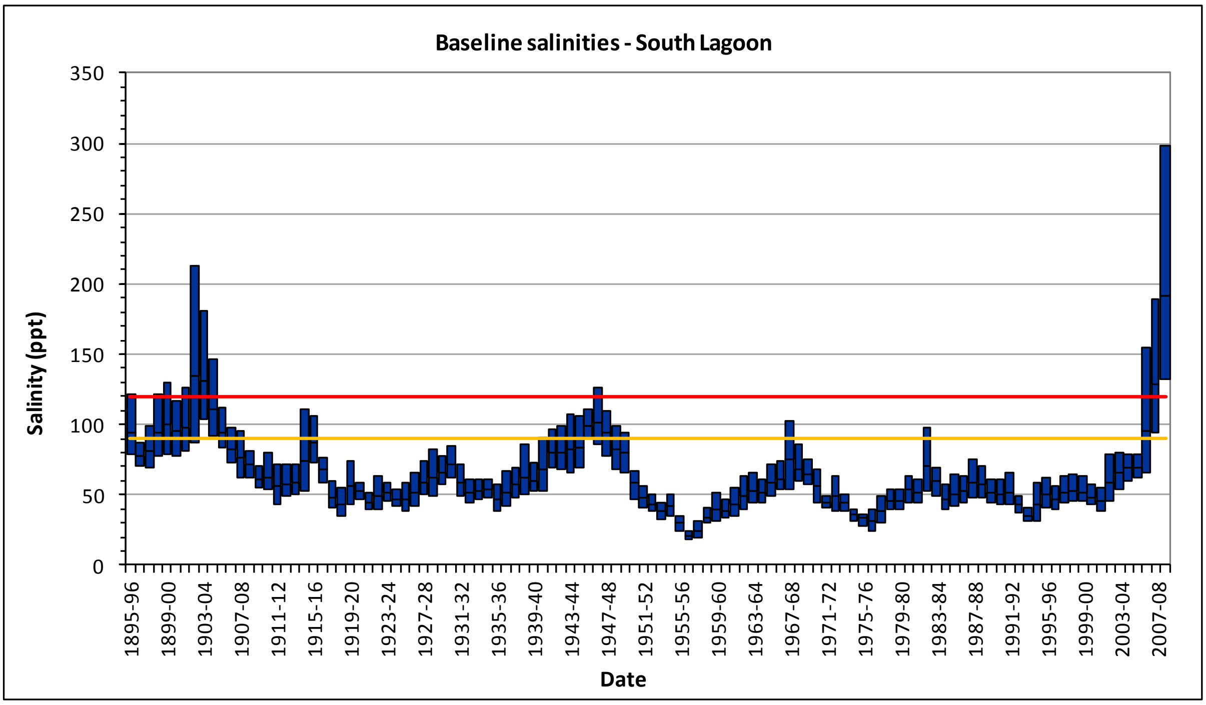
In comparison to the Baseline scenario, all scenarios show a reduction in peak salinities in corresponding years and the range of salinities are also substantially reduced. Hence, average South Lagoon salinity exceeded the sub-lethal thresholds for target biota (i.e. 90 g/L) and *R. tuberosa* (i.e. 120 g/L) the most under the Baseline scenario, with the BP3200RC scenario showing the greatest improvement, where the threshold for target biota is exceeded only once.

In comparison to the BP2800 scenario, peak salinities under the BP2800RC were generally lower. Average South Lagoon salinity exceeds the sub-lethal salinity thresholds for target biota under both scenarios, but relaxing constraints reduced the number of years where both thresholds were exceeded (Figure 45 c and d). The threshold for *R. tuberosa* is not exceeded under either the BP2800 GL or BP2800RC scenarios, although the threshold is very close to being crossed in 2008–09 under the BP2800 scenario.

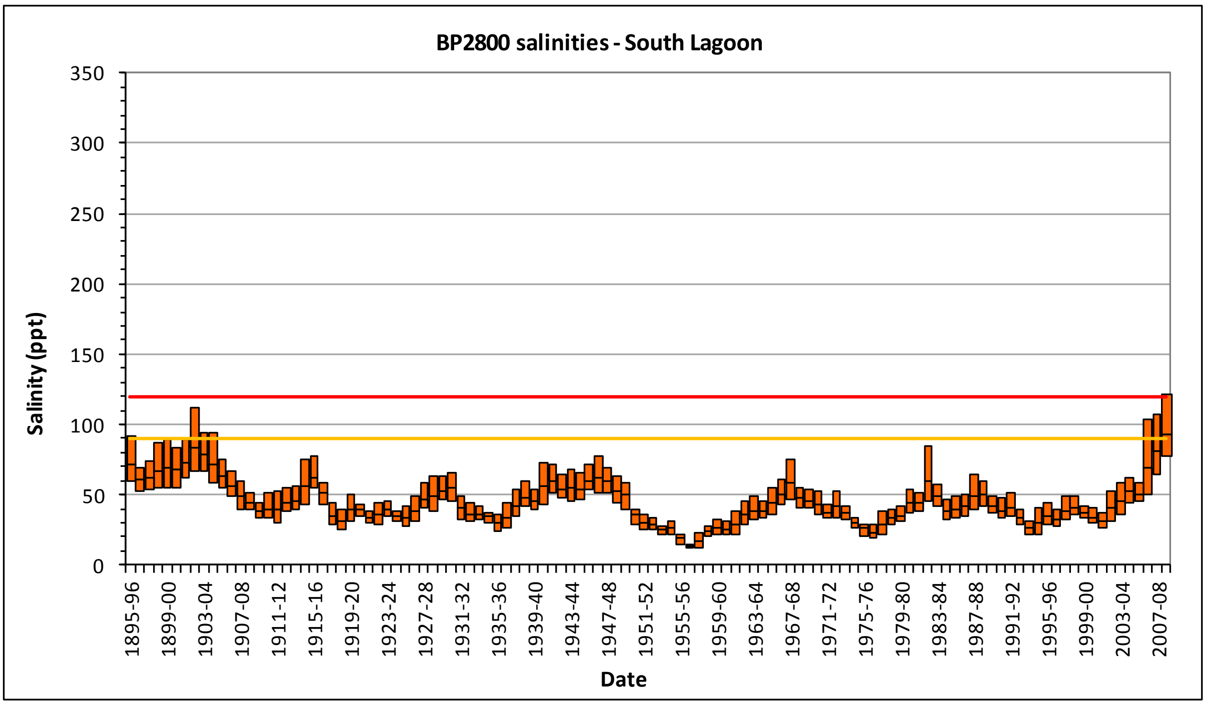
Peak salinities under the BP3200RC scenario were generally lower than those seen under the BP3200 scenario. Despite this, the threshold for target biota is exceeded under both scenarios, although relaxing constraints reduces this to a single year (Figure 45 e and f). The threshold for *R. tuberosa* is not exceeded under either the BP3200 BP3200RC scenarios.




(a)

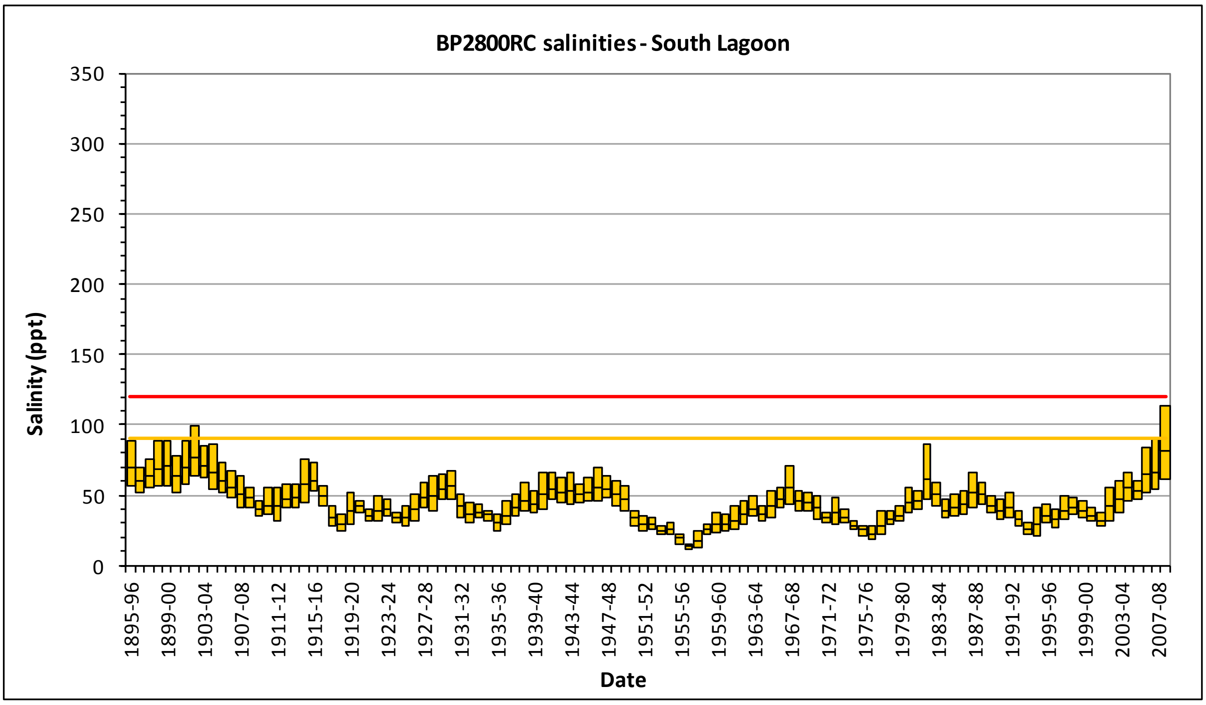



(b)



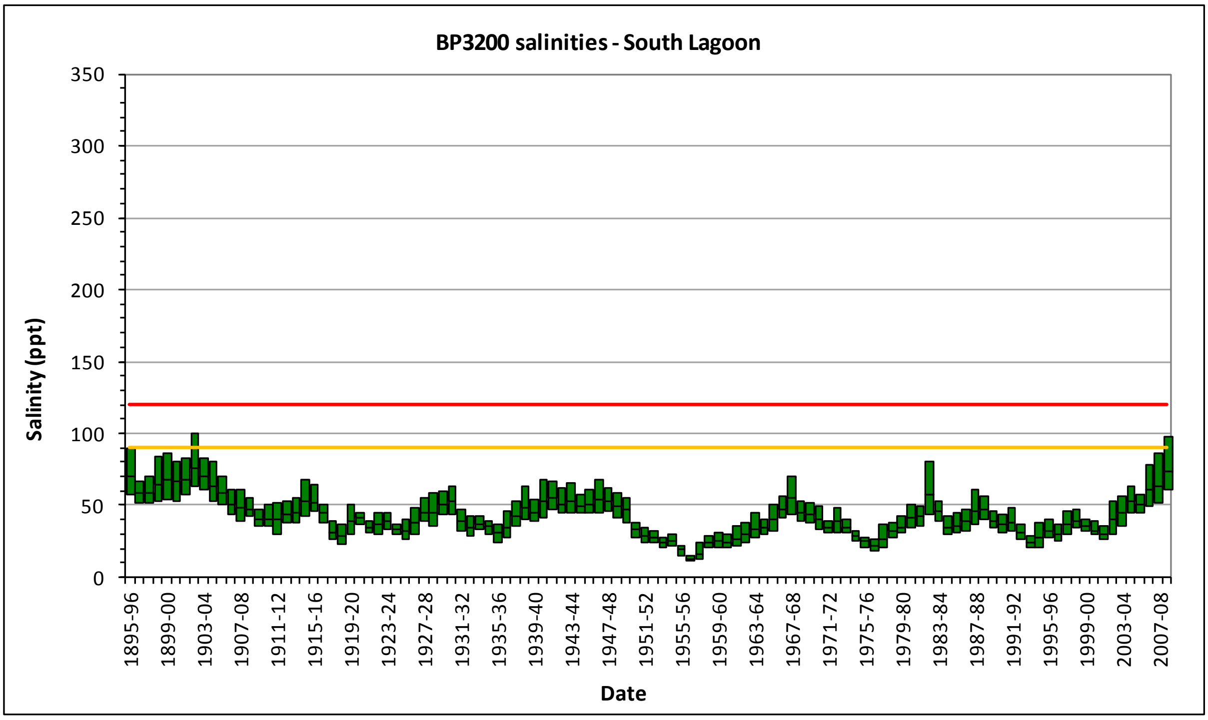
BP2800 salinities - South Lagoon
Salinity (ppt)
350
300
250
200
150
100
50
0
1895-96
1899-00
1903-04
1907-08
1911-12
1915-16
1919-20
1923-24
1927-28
1931-32
1935-36
1939-40
1943-44
1947-48
1951-52
1955-56
1959-60
1963-64
1967-68
1971-72
1975-76
1979-80
1983-84
1987-88
1991-92
1995-96
1999-00
2003-04
2007-08
Date


(c)

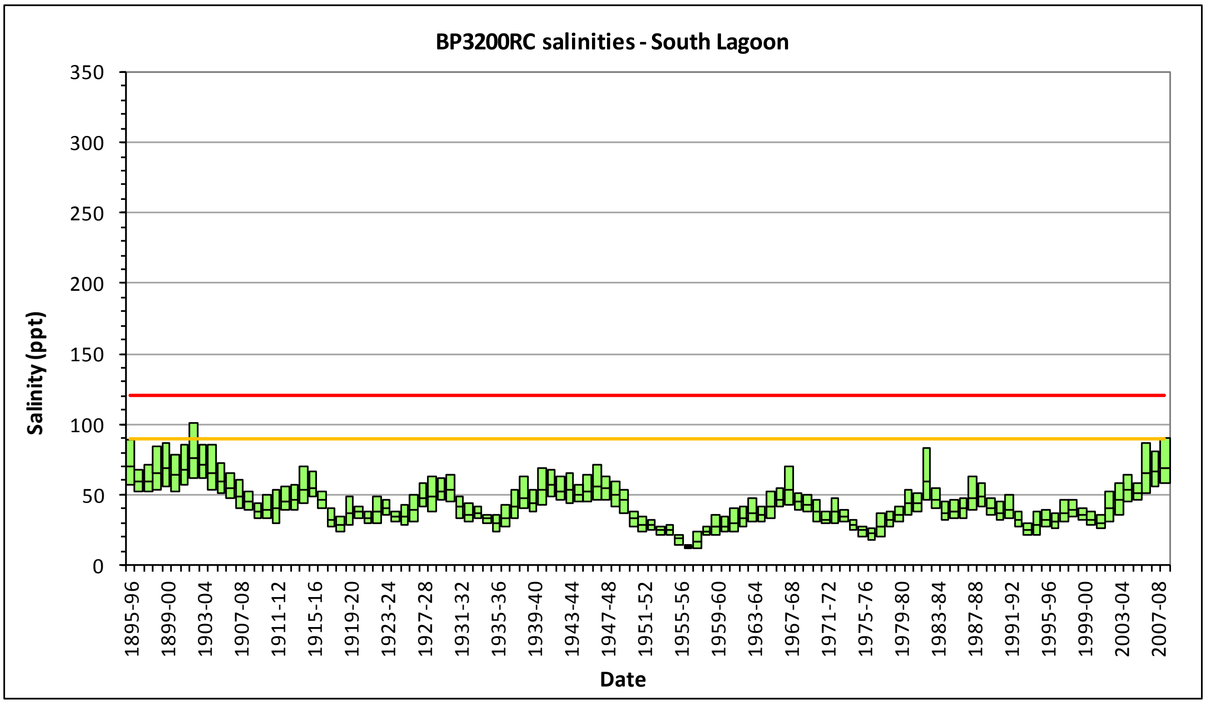


BP2800RC salinities - South Lagoon
Salinity (ppt)
350
300
250
200
150
100
50
0
1895-96
1899-00
1903-04
1907-08
1911-12
1915-16
1919-20
1923-24
1927-28
1931-32
1935-36
1939-40
1943-44
1947-48
1951-52
1955-56
1959-60
1963-64
1967-68
1971-72
1975-76
1979-80
1983-84
1987-88
1991-92
1995-96
1999-00
2003-04
2007-08
Date


(d)




(e)




(f)

**Figure 45 a-f. Comparison of annual average daily salinity and average daily salinity ranges (SA delineation) in the South Lagoon for the Without Development, Baseline, BP2800, BP2800RC, BP3200, and BP3200RC scenarios. Sub-lethal maxima for target biota of 90 g/L indicated in orange and upper lethal tolerance for *Ruppia tuberosa* in red (120 g/L).**

### 6.5.7. COORONG SOUTH LAGOON SALINITY THRESHOLD EXCEEDENCES – TARGET BIOTA 90 g/L THRESHOLD

Compared to the Baseline scenario there is considerable improvement seen in the number of events of exceedences longer than five days, the average, and maximum durations of these exceedences across the BP2800, BP2800RC, BP3200, and BP3200RC scenarios (Table 43). Of those scenarios the greatest improvement, when compared to the Baseline, is seen in the BP3200 and BP3200RC scenarios, with reduced number of exceedence events longer than five days and maximum durations. The BP3200RC scenario showed the greatest improvement compared to Baseline, however it should be noted that under Without Development the threshold for target biota in the South Lagoon was never exceeded.

**Table 43. Average daily salinity (modelled by SA) exceeding the 90 g/L threshold for sub-lethal impacts on target biota in the South Lagoon**

| | Without Development | Baseline | BP2800 | BP2800RC | BP3200 | BP3200RC |
|---|---|---|---|---|---|---|
| # events longer than 5 days | 0 | 25 | 8 | 2 | 2 | 1 |
| Mean duration | 0 | 211 | 70 | 107 | 57 | 80 |
| Median duration | 0 | 123 | 41 | 107 | 57 | 80 |
| Maximum duration | 0 | 1030 | 182 | 135 | 78 | 80 |

Daily average salinities within a year indicate that average salinities in the South Lagoon exceed the sub-lethal threshold for target biota nine times under the BP2800 scenario, as opposed to twice under the BP2800RC scenario. The average duration of these exceedences of the sub-lethal threshold for target biota was greater under BP2800RC compared to BP2800 scenario (Table 43). The maximum duration of exceedence and the number of events greater than five days was lower for BP2800RC.

Relaxing constraints for BP3200RC reduced the number of events of threshold exceedence to a single event, compared to two events seen under the BP3200 scenario (Table 43). Because of this single event, the average duration and maximum duration of these threshold exceedences appear to be greater under the BP3200RC scenario.

### 6.5.8. COORONG SOUTH LAGOON SALINITY THRESHOLD EXCEEDENCES – CHIRONOMID 100 g/L THRESHOLD

The sub-lethal threshold for Chironomid in the South Lagoon is exceeded more times under the Baseline scenario (21 times) compared to BP2800 (four times), BP2800RC (once), BP3200, and BP3200RC (never exceeded). There is also considerable improvement seen in the number of events of exceedences longer than five days, the average and maximum durations of these exceedences across the BP2800, BP2800RC, BP3200, and BP3200RC scenarios compared to the Baseline scenario (Table 44). The greatest improvement, when compared to the Baseline, is seen in the BP3200 and BP3200RC scenarios, which are the same as the Without Development scenario, where the threshold is never exceeded.

**Table 44. Coorong South Lagoon salinity threshold exceedences – Chironomids 100 g/L exceedence**

| | Without Development | Baseline | BP2800 | BP2800RC | BP3200 | BP3200RC |
|---|---|---|---|---|---|---|
| # events longer than 5 days | 0 | 19 | 4 | 1 | 0 | 0 |
| Mean duration | 0 | 160 | 71 | 89 | 0 | 0 |
| Median duration | 0 | 118 | 79 | 89 | 0 | 0 |
| Maximum duration | 0 | 599 | 111 | 89 | 0 | 0 |

The exceedence of the higher sub-lethal salinity threshold (100 g/L) for Chironomids in the South Lagoon is more frequent under the BP2800 scenario compared to the BP2800RC scenario, exceeded four times and once, respectively (Table 44). The maximum duration of exceedence, with the number of events longer than five days, is also greater under the BP2800 scenario compared to the BP2800RC scenario.

When comparing the BP3200 and BP3200RC scenarios for exceedence of the threshold for Chironomids in the South Lagoon, daily average salinities indicate that both scenarios have no times where the threshold is crossed (Table 44).

### 6.5.9. COORONG SOUTH LAGOON SALINITY THRESHOLD EXCEEDENCES – SMALL-MOUTHED HARDYHEAD 108 g/L THRESHOLD

Daily average salinities within a year indicate that average salinities in the South Lagoon exceed the sub-lethal threshold for target biota considerably more under the Baseline scenario (15 times) compared to BP2800 (four times), BP2800RC (once), BP3200, and BP3200RC (never exceeded). Compared to the Baseline scenario there is also considerable improvement seen in the number of events of exceedences longer than five days, the average and maximum durations of these exceedence across the BP2800, BP2800RC, BP3200, and BP3200RC scenarios (Table 45). The greatest improvement, when compared to the Baseline, is seen in the 3200 GL scenarios, which are the same as the Without Development scenario, where the threshold is never exceeded.

**Table 45. Coorong South Lagoon salinity threshold exceedences – Small-mouthed hardyhead 108 g/L exceedence**

| | Without Development | Baseline | BP2800 | BP2800RC | BP3200 | BP3200RC |
|---|---|---|---|---|---|---|
| # events longer than 5 days | 0 | 15 | 2 | 1 | 0 | 0 |
| Mean duration | 0 | 142 | 50 | 61 | 0 | 0 |
| Median duration | 0 | 86 | 50 | 61 | 0 | 0 |
| Maximum duration | 0 | 554 | 59 | 61 | 0 | 0 |

Average salinities in the South Lagoon exceed the sub-lethal threshold for small-mouthed hardyhead four times compared to one time for the BP2800RC scenario. Generally, relaxing constraints showed improvement compared to the BP2800 scenario, with lower average and maximum durations exceeding the salinity threshold (Table 45).

When comparing the BP3200 and BP3200RC scenarios for exceedence of the threshold for Small-mouthed hardyhead in the South Lagoon, daily average salinities indicate that both scenarios have no events longer than five days where the threshold is crossed (Table 45).

### 6.5.10. COORONG SOUTH LAGOON SALINITY THRESHOLD EXCEEDENCES – RUPPIA TUBEROSA GROWTH 120 g/L THRESHOLD

The sub-lethal threshold for *R. tuberosa* growth in the South Lagoon is exceeded more times under the Baseline scenario (26 times) compared to BP2800 (three times), BP2800RC, BP3200, and BP3200RC (never exceeded). Compared to the Baseline scenario there is also considerable improvement seen in the number of events of exceedences longer than five days, the average, and maximum durations of these exceedences across the BP2800, BP2800RC, BP3200, and BP3200RC scenarios (Table 46). The greatest improvement, when compared to the Baseline, is seen in the BP2800RC, BP3200, and BP3200RC scenarios, which are the same as the Without Development scenario, where the threshold is never exceeded.

**Table 46. Coorong South Lagoon salinity threshold exceedences – *Ruppia tuberosa* growth 120 g/L exceedence**

| | Without Development | Baseline | BP2800 | BP2800RC | BP3200 | BP3200RC |
|---|---|---|---|---|---|---|
| # events longer than 5 days | 0 | 11 | 1 | 0 | 0 | 0 |
| Mean duration | 0 | 100 | 9 | 0 | 0 | 0 |
| Median duration | 0 | 47 | 9 | 0 | 0 | 0 |
| Maximum duration | 0 | 534 | 9 | 0 | 0 | 0 |

Daily average salinities within a year indicate that average salinities indicate that average salinities in the South Lagoon exceed the sub-lethal threshold for *R. tuberosa* growth three times compared to once for the BP2800RC scenario. Relaxing constraints showed improvement compared to the BP2800 scenario, with no exceedence of the threshold seen under the BP2800RC scenario (Table 46).

When comparing the BP3200 and BP3200RC scenarios for exceedence of the threshold for *R. tuberosa* growth in the South Lagoon, daily average salinities indicate that both scenarios have no events where the threshold is crossed longer than five days (Table 46).

### 6.5.11. COORONG SOUTH LAGOON SALINITY THRESHOLD EXCEEDENCES – THE UPPER LIMIT OF THE SOUTH LAGOON 130 g/L THRESHOLD

The upper limit threshold in the South Lagoon is exceeded more times under the Baseline scenario (seven times) compared to the threshold never being exceeded under BP2800, BP2800RC, BP3200, and BP3200RC scenarios (comparable to what is seen under the Without Development scenario; Table 47).

Relaxing constraints therefore made no difference to the exceedence of the upper limit of the South Lagoon salinity threshold compared to the BP2800 and BP3200 scenarios.

**Table 47. Coorong South Lagoon salinity threshold exceedences – upper limit in the South Lagoon 130 g/L exceedence**

| | Without Development | Baseline | BP2800 | BP2800RC | BP3200 | BP3200RC |
|---|---|---|---|---|---|---|
| # events longer than 5 days | 0 | 5 | 0 | 0 | 0 | 0 |
| Mean duration | 0 | 189 | 0 | 0 | 0 | 0 |
| Median duration | 0 | 113 | 0 | 0 | 0 | 0 |
| Maximum duration | 0 | 516 | 0 | 0 | 0 | 0 |

# 6.6. SUMMARY OF OUTCOMES FOR THE COORONG AND MURRAY MOUTH

## 6.6.1. MOUTH OPENNESS

Total annual flow exceeding 2000 GL/annum and Mouth depth provide an indication of comparative risk of dredging being implemented to maintain an open Murray Mouth. Average annual Murray Mouth depth seeks to further quantify the risks of dredging being implemented but cannot provide a definitive assessment due to the complexity of the decision in reality.

**Total annual flow**

- The number of years where total annual flow is greater than 2000 GL is substantively greater for both BP2800 and BP3200 with 89% of years for both scenarios as opposed to only 64% of years under the Baseline scenario.
- Flows are less than 2000 GL in two additional years under BP2800RC compared to BP2800, (in 1896–97 and 2004–05), with one additional year (1896–97) under the BP3200RC relative to the BP3200 scenario.
- Examination of consecutive years where flow is less than 2000 GL indicates that one sequence of three concurrent years where flows are less than 2000 GL occurs under both the BP2800 and the BP3200 scenarios (2006-–07 to 2008–09)
- Relaxation of constraints sees no change in the occurrence of the sequence of consecutive years in the 2006–07 to 2008–09 period.

**Mouth depth**

- There is a substantial improvement in the annual average Murray Mouth depth and the number of years classified as unconstricted for the BP2800 and BP3200 scenario compared to the Baseline scenario.
- The number of years where the Mouth is classified as unconstricted improves as the recovered volume increases from 2800 GL to 3200 GL. The BP2800 scenario sees approximately 14 % of

years classified as constricted while the BP3200 scenario sees 12% of years classified as constricted.
- Relaxing of constraints results in small differences between the constraints-relaxed scenarios and the original scenarios for both the BP2800 and BP3200 scenarios, with an increase of approximately 1% of years where the Mouth is classified as constricted (less than 2m annual average depth).
- The number of years where Mouth is classified as severely constricted reduces with increasing volume. The relaxation of constraints sees two less years classified as severely reduced for the BP2800RC scenario relative to BP2800, whilst for the BP3200RC scenario, an additional year is classified as severely constricted relative to BP3200.

### 6.6.2. AVERAGE ANNUAL WATER LEVELS IN THE SOUTH LAGOON

Average annual South Lagoon water depth exceeding 0.27 m AHD acts as a comparative indicator of water levels supporting *Ruppia tuberosa* in the South Lagoon.

- An additional 5% and 8% of years where water levels would support *R. tuberosa* in the South Lagoon for BP2800 and BP3200, respectively, compared to the Baseline Scenario.
- Relaxing of constraints substantially improves average annual South Lagoon water levels under the BP2800RC scenario with an increase of 10% of years relative to the BP2800 scenario
- No improvement in the percent of years to support *R. tuberosa* occur under BP3200RC scenario.
- In many years water levels in the Coorong under the BP2800RC scenario is higher than BP2800 scenario, but not in all years. The years indicating poorer performance are offset by a larger number of years where average water levels exceeds the threshold.
- Importantly, there is improvement in the sequences of consecutive years not supporting *R. tuberosa* with the relaxation of constraints for both the 2800 GL and 3200 GL scenarios such that no sequence exceeds 2 consecutive years across the 114 years.

### 6.6.3. COORONG SALINITIES

Average daily salinities in the Coorong provide an assessment of the potential habitat suitability across time for target biota. The number of events and the duration they exceed the identified thresholds provides an indication of relative improvement and risk posed to the Coorong ecology.

**Salinity – North Lagoon**

- Maximum average salinity in the North Lagoon is improved as volume increases above 2800 GL with the number of events and duration of the events exceeding the thresholds lower compared to the Baseline scenarios.
- For the BP2800 scenario, average daily salinity in the north lagoon exceed the lower salinity threshold of 45 g/L that indicates potential impacts to mudflat macroinvertebrate species nine times, with a maximum duration of 102 days, while for the BP3200 scenario, this reduced to 1 event with a duration of 18 days.
- For the BP2800 scenario, average daily salinity exceeds the 50g/L threshold that indicates impacts to *Ruppia megacarpa* for two events with the maximum being 75 days, whereas BP3200 does not result in that threshold hold being exceeded at all.
- The relaxation of constraints for BP2800RC improved the number of events, reducing to one exceedence of 45g/L but the maximum duration of this event is much longer at 146 days.

Similarly, BP2800RC also sees the exceedence of the 50g/L threshold occur once but the maximum duration increases to 114 days

- The relaxation of constraints for BP3200RC sees average daily salinity not exceed either the lower salinity threshold of 45g/L or that of 50g/L
- Overall, the 3200 GL scenarios reduce the risk of average salinity exceeding the tolerance of key species in the Coorong.

**Salinity – South Lagoon**

- Maximum average salinity in the South Lagoon is improved as volume increases above 2800 GL with the number of events and duration of the events decreasing (improving) compared to the Baseline scenarios.
- For the BP 2800 scenario, maximum salinity exceeds all the identified thresholds, exceeding the 90g/L threshold eight times, and the 100g/L threshold four times indicating impacts to chironomids – an important food source in the South Lagoon. Additionally, BP2800 exceeds the 108 g/L threshold twice impacting on small mouthed hardheads that are important as a food source for piscivorous birds such as the Fair tern and 120g/L once impacting on *Ruppia tuberosa* growth. This compares to the BP3200 scenario where the 90g/L is exceeded twice over the modelled period, while none of the other thresholds were exceeded.
- With the relaxation of constraints at 2800, the number of events the 90g/L threshold is exceeded is reduced to two events and the maximum duration is reduced from 182 days under BP2800 to 135 days and exceedence of the 100g/L threshold has reduced to one event with the maximum duration reducing from 111 days to 89 days. Additionally the BP2800RC scenario results in a single occurrence of salinity exceeding 108g/L threshold with the duration increasing from 59 days to 61.
- Under the BP3200RC scenario, the 90 g/L threshold is exceeded only once with the maximum duration increasing from 78 days under BP3200 to 80 days
- Overall, the BP3200 and BP3200RC scenarios reduce the risk of average salinity exceeding the tolerance of key species in the Coorong.

# 7. SUMMARY OF KEY FINDINGS

A comparative analysis was undertaken for the four Basin Plan scenarios representing water recovery volumes of 2800 GL and 3200 GL, and with and without key constraints to flow delivery relaxed.

A key component of the analysis was examining the effect of relaxation of constraints on the ability to deliver managed flow events to mid-floodplain habitats on the South Australian River Murray and the potential ecological outcomes. In particular, this analysis has focused on outcomes for the floodplain inundated by flows ranging from 40 000 ML/d to 80 000 ML/d in line with Recommendation 4 from the South Australian Government submission on the proposed Basin Plan.

Ecological outcomes for the scenarios have also been assessed for the CLLMM site. While outcomes for the CLLMM site are understood to be primarily influenced by the volume received each year, changes to upstream watering events causing intra- and inter-annual variations in environmental water delivery have the potential to influence ecological outcomes.

## *7.1. SUMMARY OF FINDINGS FOR SOUTH AUSTRALIAN RIVER MURRAY FLOODPLAIN*

A series of hydrological and ecological analyses were undertaken to assess the potential ecological outcomes for a range of floodplain habitats from the four water recovery scenarios. These analyses used a variety of different methods and techniques, each investigating a different component of the EWR. They can be considered as multiple lines of evidence from which to draw overall conclusions. The analysis was consistent with previous methodologies (Bloss *et al.*, 2012) with additional ecological analysis (using the Murray Flow Assessment Tool) providing additional interpretation of the potential benefits of flow delivered within the model.

The multiple lines of evidence used in this report (Table 48) demonstrated the best potential to deliver ecological outcomes was provided by the higher water volume scenarios (BP3200 or BP3200RC). The higher volume coupled with the relaxation of constraints (BP3200RC) most consistently delivered the best ecological outcomes. Therefore of the four scenarios, BP3200RC was considered to achieve the best outcomes for the South Australian floodplain.

The benefits were most notable in the flow range 40 000 to 80 000 ML/d which is expected to support a mosaic of various habitats including key vegetation communities such as red gum and lignum, and support bird breeding habitat and temporary wetlands.

This is consistent with the MDBA analysis which demonstrated that the BP3200 RC scenario was the only scenario able to achieve all of the targeted Riverland-Chowilla indicators. The MDBA analysis also shows that 17 of 18 MDBA floodplain indicators are met for the Southern connected system compared with 11 of 18 for BP2800 and BP2800RC.

It can be concluded that although large areas of the South Australian floodplain remain at risk under all four water recovery scenarios, the BP3200RC scenario provides the best opportunity to improve outcomes for the mid level floodplain (40 000 ML/d to 80 000 ML/d). Outcomes for areas inundated up to 40 000 ML/d were achieved at similar levels for all scenarios.

**Table 48. Summary of water recovery scenario which delivered the best floodplain outcome for each line of evidence**

| Section | Analysis | BP2800 | BP2800RC | BP3200 | BP3200RC |
|---|---|---|---|---|---|
| 3.2 | MDBA hydrologic indicators | | | | |
| 4.6.3 | Best outcomes for frequency of years for SA EWRs | | | | |
| 4.6.4 | Best outcome for number of events for SA EWRs | | | | |
| 4.6.5 | Highest flows meeting average frequency (for all SA EWR) | | | | |
| 4.6.5 | Highest flows meeting maximum interval (for all SA EWR) | | | | |
| 4.6.6 | Good and optimum events delivered to 70 000 ML/d for red gum | | | | |
| 4.6.6 | Good and optimum events delivered to 70 000 ML/d for Lignum | | | | |
| 4.6.7 | Best outcome for specific flow peak analysis (red gum and lignum) | | | | |

shading represents order of scenarios (from lowest to highest)

The lines of evidence are discussed below relative to the three major components of the floodplain, the ‘In channel’, the ‘mid floodplain’ and habitats in the ‘high floodplain’.

## 7.1.1. IN CHANNEL HABITATS

Three of the SA EWRs relate to in (or near) channel outcomes. These were FSr, which supports spawning and recruitment by native fish that are characterised as flow-cued spawners (ie golden perch and silver perch), MCr, which supports spawning and recruitment of Murray cod, and TW2, which supports lower elevation temporary wetlands and in particular small scale bird and fish breeding events.

Both FSr and MCr were met (for average frequency and duration metrics of EWR) under all four scenarios. The low elevation wetlands EWR (TW2) was not met under any of the four scenarios however there was some minor improvement evident with the higher water recovery volumes with BP3200 and BP3200RC supporting 2830 ha and 2820 ha respectively compared to 2810 ha under BP2800.

It can be concluded therefore that there are only minimal differences between the four water recovery scenarios for habitats within and near the channel.

### 7.1.2. HABITATS IN THE MID FLOODPLAIN, REPRESENTED BY THE 40 000 ML/d TO 80 000 ML/d FLOW BAND

This is the portion of the floodplain considered most likely to be influenced by active watering decisions and is referred to within this report as the 'managed floodplain'. Many of the SA EWRs relate to this portion of the floodplain.

The improvements in ecological habitat observed between water recovery scenarios were most evident in this portion of the floodplain. The greatest number of events meeting SA EWRs between 40 000 and 80 000 ML/d flow bands was observed under the BP3200 or BP3200RC scenarios.

In terms of average frequency and duration, one out of 17 floodplain EWRs were met under all four scenarios.

Of the remaining 16 floodplain EWRs where the target flow rates were not met, improvements in area where average frequency and duration requirements were met were observed for 15 of the EWR between BP2800 and BP3200RC scenarios. In general, the BP3200RC scenario supported the greatest area of mid floodplain habitat at the appropriate frequency and duration.

#### 7.1.2.1. Mosaic of habitats

Given all the lines of evidence, it is considered that the higher volume (BP3200 and BP3200RC) scenarios had greatest potential to support a mosaic of habitats on the floodplain, with relaxation of constraints provided clear benefit when considering that area of floodplain inundated at the appropriate frequency and duration.

The greatest area supporting a mosaic of habitats (Mos1, Mos2, Mos3 and Mos4) was provided by the BP3200RC. For example, based on results for Mos1 an additional 3280 ha of floodplain vegetation would be supported under BP3200RC (24 150 ha) when compared to BP2800 (20 870 ha). This represents 63% of the vegetated areas of the managed floodplain compared to 55% for BP2800 (an additional 9% of the managed floodplain).

When considering all events which met the target flow rate, but not the duration criteria, the total number of events was higher in either the BP3200 (Mos2, Mos3) or the BP3200RC (Mos4) scenarios.

#### 7.1.2.2. Red gum

Given all the lines of evidence, it is considered that the higher volume (BP3200 and BP3200RC) scenarios had more potential to deliver outcomes for red gums on the floodplain (Table 48). The relaxation of constraints was also considered important, particularly for maximising outcomes from specific flow events as requested within the model. Therefore, of the four scenarios the BP3200RC provided the best potential to deliver outcomes for red gum within the managed floodplain.

Under the BP2800 scenario, the area of existing mapped red gum on the floodplain inundated at the required average frequency and duration to maintain or improve adult red gum condition was 6600 ha. This equates to 56% of red gums found on the managed floodplain or 35% of red gums found on the 1956 floodplain. Under the BP3200RC these results increase to approximately 7010 ha of existing river red gum woodlands and forests, which represents 60% of red gums on the managed floodplain.

When considering all events which met the target flow rate, but not the duration criteria, the total number of events as well as the habitat condition for red gum resulting from those events was generally the greatest under BP3200. Relaxation of constraints was found to improve the quality of habitat associated with these events for red gum based on ecological response curves. The analysis of the specific flow peaks provided an insight into the difference between scenarios for particular watering decisions. The BP3200RC scenario consistently gave the greatest area of habitat for red gum in good or optimum condition when targeted watering events were requested. This indicates greater potential for better outcomes but it must be recognised that the benefits of specific events will require that the time between events does not exceed critical thresholds.

#### 7.1.2.3. Lignum

Given all the lines of evidence the BP3200RC provided the best potential to deliver outcomes for lignum within the managed floodplain (Table 48).

Under the BP2800 scenario, approximately 1740 ha of existing lignum shrublands on the SA River Murray floodplain are inundated at the appropriate frequency and duration. This improves to 1840 ha (21% of total found on the managed floodplain) under the BP3200RC scenario, which was the greatest area supported of the four water recovery scenarios.

When examining the quality of events delivered at the target flow rate using MFAT ecological response curves the best habitat condition was likely to be delivered under the BP3200RC scenario. Seventeen events providing good habitat and seven providing optimum habitat occurred under BP3200RC compared to 11 providing good and six proving optimum habitat for the BP2800 scenario.

The BP3200RC scenario consistently gave the greatest area of habitat in good or optimum condition for lignum when targeted watering events were requested. This indicates greater potential for better outcomes but it must be recognised that the benefits of specific events will require that the time between events does not exceed critical thresholds.

### 7.1.3. HABITATS IN THE HIGH FLOODPLAIN, REPRESENTED BY THE FLOW BANDS GREATER THAN 80 000 ML/d

Given all the lines of evidence, it is considered that there is little influence of the higher volume and relaxation of constraints scenarios for the flow bands greater than 80 000 ML/d.

There are some indications that frequency of flows between 80 000 ML/d and 100 000 ML/d reduced when constraints were relaxed. There was no change in the average frequency of unregulated flow events (generally greater than 100 000 ML/d) under the BP3200RC scenario, indicating habitats located in the upper floodplain were not impacted by the relaxation of constraints.

As the MDBA was not targeting these within the model, the reduced frequency of meeting EWRs in the 80 000 ML/d -100 000 ML/d band is expected to be due to variations in the watering decisions and redistribution of flows, rather than a true reduction in high flows. However, further analysis is required to investigate this hypothesis.

## *7.2. SUMMARY OF FINDINGS FOR COORONG, LOWER LAKES AND MURRAY MOUTH*

Analysis for the Coorong, Lower Lakes and Murray Mouth site focussed on the assessment and comparison of metrics relating to water levels and salinity of Lake Alexandrina, Lake Albert, Coorong North and Coorong South Lagoons, as well as barrage outflow and Mouth openness. Consistent with the findings of the MDBA, Heneker and Higham (2012) and Higham (2012), it has been demonstrated that increasing the water recovery volume to 3200 GL maximises the benefits to the Coorong, Lakes Alexandrina and Albert together with the Murray Mouth.

The analysis undertaken here has shown that scenarios where constraints are relaxed (BP2800RC and BP3200RC) show some changes in outcomes achieved, which indicate that environmental watering decisions at upstream sites will have implications for the CLLMM site.

As such, although the CLLMM continues to remain at risk of impact during drought, the 3200 GL scenarios (BP3200 and BP3200RC) represent the lowest risk to maintaining the Coorong as healthy and resilient wetland of international importance.

## 7.2.1. LOWER LAKES

The Lower Lakes (Lakes Alexandrina and Albert) assessment focussed on three ecological drivers for the site. These included minimum lake water levels, periods of barrage closure and lake average salinity. It is assumed that the other parameters such as range of water levels and timing are supportive of the sites ecological character.

Relative to the BP2800, the 3200 GL scenarios showed improvement against all indicators assessed, demonstrating that an increase in recovered environmental water has the potential to provide improved security for the Lower Lakes. The relaxation of constraints indicates that Lakes outcomes are affected by the watering decisions made at upstream sites by altering the inter- and intra-annual inflow to the lakes.

### 7.2.1.1. Barrage Outflows

Increasing the water recovery volume reduced the number and length of periods of no barrage outflow. Changes to the distribution of flow (both within the year and between years) through the relaxation of constraints, also reduced the number and length of periods of no barrage outflow longer than 30 days.

The BP3200RC scenario reduced the number of periods of no-barrage flow longer than 30 days from 11 events in BP2800 to three events in BP3200RC, and the length of the longest period of no-barrage flow reduced from 125 days in BP2800 to 50 days in BP3200RC.

### 7.2.1.2. Water levels

Heneker and Higham (2012) identified that modelled water levels dropped below the minimum operating water levels specified in the variable water level regime, even in non-drought years. The MDBA have acknowledged this model limitation, and rectification of this matter has been identified as a ‘technical improvement’ to be undertaken as part of a larger suite of model improvements in the future.

In the interim, the MDBA have undertaken an analysis of minimum water levels for the BP3200RC scenario and confirmed that the preferred minimum operating lake level of 0.4 m AHD or above in Lake Alexandrina can be achieved for 96% of the time, exceeding the target of 95% of the time. This analysis was not available for the other scenarios considered at the time of writing.

The modelling limitation does not affect the finding that water levels can be maintained above 0.0 m AHD 100% of the time for all scenarios.

### 7.2.1.3. Lakes Salinity

The modelled salinity time-series provided by the MDBA, commencing in 1975, indicated that the salinity in Lake Alexandrina for all four scenarios could be maintained below 1000 EC 95% of the time and maintained below 1500 EC 100% of the time.

Using the flow-salinity relationship developed by Heneker (2010), analysis indicated that three of the scenarios (BP2800, BP2800RC and BP3200RC) may exceed 1500 EC in Lake Alexandrina for the last two water years of the modelled time series due to insufficient minimum barrage outflows, while the BP3200 scenario met the 1500 EC outflow threshold in all years.

For Lake Albert, the four water recovery scenarios all maintained salinity below 1500 EC 95% of the time. The maximum salinity threshold of 2000 EC was exceeded for a short period in the BP2800 scenario only.

#### 7.2.1.4. Salt Export

A long-term average salt export of 2.00 million t/y is delivered for both 3200 GL scenarios. By comparison, the long term average salt export for BP2800 was calculated to be 1.96 million t/y and 1.95 million t/y for BP2800RC.

An assessment of salt export as a three or 10-year rolling average both demonstrated that there were extended periods where the desired salt export target was not met for all scenarios considered, predominantly during drought when barrage outflows continue to be low.

### 7.2.2. COORONG AND MURRAY MOUTH

The Coorong and Murray Mouth assessment focussed on three ecological drivers for the site. These included Murray Mouth ‘openness’, Coorong water levels and Coorong salinity.

For the Coorong, the recovery of 3200 GL avoided some of the more severe consequences, including the occurrence of conditions that are likely to exceed the salinity tolerances of Coorong flora and fauna and result in a high risk of dredging being required.

#### 7.2.2.1. Mouth openness

Total annual flow provides a coarse assessment of Murray Mouth openness, indicating that with the provision of more flow the number of years the mouth is ‘closed’ or more correctly constricted decreases. Assessment using this measure indicates the mouth will be open approximately 89% of years for all water recovery scenarios assessed here.

The relaxation of constraints negatively alters this outcome by between one or two years depending on the recovery volume, likely as a result of redistributing flow between years resulting in flows declining to less than 2000 GL in those years by a small margin. The consequence is that this is unlikely to result in a significant increase in risk that these years will require dredging as flows in these years are still approaching 2000 GL. Overall the sequence of years where flow is less than 2000 GL remains largely unchanged, with a significant risk remaining in 2006–09.

Analysing the modelled Murray Mouth depth, the number of years where the Murray Mouth is classified as unconstricted improves as the water recovery volume increases from 2800 GL to 3200 GL. The 2800 GL scenarios sees approximately 14 % of years classified as constricted or severely constricted, while the 3200 GL scenarios sees 12% of years classified as constricted or severely constricted.

The provision of additional volume beyond 2800 GL appears to reduce the risk that dredging may be required by improving the annual average mouth depth (making it deeper), particularly relative to Baseline. Under all scenarios one period remains at a high risk of requiring dredging (2006–07-2008–09). Importantly with the recovery of additional water for the environment compared to BP2800 the average annual Murray Mouth depth during this period is improved. Relaxation of constraints shows variation in Murray Mouth depth during these years that differs from the standard scenarios, indicating that Murray Mouth depth is affected by the distribution of flow within the years as a consequence of altered upstream watering actions.

In combination, the analyses indicate that there remain a number of periods of constriction to the Murray Mouth that increase the risk that the implementation of dredging may be required. These occur primarily during periods of low barrage outflow (droughts).

The depth of the Murray Mouth is sensitive to both the water-recovery volume and the watering actions implemented. Therefore the risk of mouth constriction that could lead to the implementation of dredging can be ameliorated to some extent although not prevented.

The analysis undertaken here cannot be definitive about whether it will prevent dredging due to the complexity of the decision making to implement such an action but the analysis does indicate that the highest risk occurs in less than 5% of years across the whole 114 year modelling period.

Work undertaken by Webster *et al.* (2009) indicates that improved outcomes could be achieved by targeting water delivery to specifically maximise Murray Mouth depth under both the BP2800 and BP3200 scenarios when constricted to mitigate the risk that dredging may be required.

#### 7.2.2.2. Water levels in South Lagoon

When Coorong water levels fall below the desired annual average target of 0.27 m AHD this reduces the ability for the Coorong to ensure the key species *Ruppia tuberosa* remains inundated for sufficient duration to complete its lifecycle, in turn affecting macro-invertebrates, fish and waterbirds in the region. The provision of 3200 GL increases the number of years that average annual water levels support *Ruppia tuberosa* in the South Lagoon.

The relaxing of constraints substantially improved water levels under the BP2800RC scenario with an increase of 10% of years relative to the BP2800 scenario but did not increase the number of years achieved under the BP3200 scenario.

The relaxation of constraints changes the sequence of years where water levels were capable of supporting *Ruppia tuberosa*, removing sequences of three or more consecutive years that are likely to lead to decline of the population, potentially improving its resilience to years where salinity and or water levels do not support this species in the Coorong.

Increasing the recovery volume indicates that average annual water levels in the Coorong can be improved to support *Ruppia tuberosa* in the South Lagoon. It is not categorically demonstrated that this is due to increased recovery volume alone, given the altered upstream watering actions implicit in the relaxation of constraints at 2800 GL has a greater impact on average annual water levels than the other scenarios examined. This outcome is potentially due to a favourable distribution of flows between and within years that supports higher average annual water levels.

Importantly, there is improvement in the sequences of consecutive years not supporting *Ruppia tuberosa* with the relaxation of constraints, potentially because of changes in the distribution of flows in these scenarios biasing flows toward summer, retarding the reduction in water levels and favouring *Ruppia tuberosa.* This has the potential to improve the resilience of the population to years where salinity and or water levels do not support this species in the Coorong by permitting it to replenish its seedbank between unfavourable years.

This finding is supported by Webster *et. al.* (2009) who indicated that Coorong water level can be positively affected by the release-timing of flow additions.

#### 7.2.2.3. Coorong Salinities

Maximum average salinity in the North and South Lagoons reduced as the water recovery volume increases above 2800 GL, with the number of events and duration of the events decreasing (improving).

The 3200 GL scenarios reduce the risk of average salinity exceeding the threshold tolerances of different key species in the Coorong. in the South Lagoon, only the 90 g/L threshold is exceeded for the 3200 GL scenarios and as such the 100 g/L threshold is not exceeded by the 3200 GL scenarios, supporting important plant, macroinvertebrate and fish communities of the lagoon. This can be compared to the 2800 GL scenarios, where the 108 g/L threshold was exceeded for BP2800RC, and the 120 g/L threshold exceeded for BP2800.

Similarly for the North Lagoon, the 50 g/L threshold is exceeded for both 2800 GL scenarios, but not by the 3200 GL scenarios (also the 45 g/L threshold was not exceeded by the BP3200RC scenario).

Relaxation of constraints demonstrates that maximum salinity is affected by the volume recovered, and this can be further improved by how water is delivered through the barrages in a given year, not just the volume delivered between years. This finding is supported by Webster *et. al.* (2009) who indicated that Coorong maximum salinity can be positively affected by the release-timing of flow additions.

The BP3200 scenario reduces the risk of average salinity exceeding the tolerance of key species in the Coorong, even when using a more conservative assessment method than the MDBA.

## 7.3. OVERALL SUMMARY

When assessed against MDBA's flow indicators for environmental water requirements, the BP3200RC scenario resulted in achievement of 17 out of 18 flow indicators for the River Murray in the Southern System, compared to 11 for the current proposed Basin Plan scenario (BP2800) and BP2800RC scenarios and 13 for the BP3200 scenario. This demonstrates the benefits of additional water recovery and relaxation of constraints to key environmental sites throughout the Southern System of the Murray Darling Basin. The BP3200RC scenario was the only scenario able to achieve the 80,000 ML/d Riverland-Chowilla target relating to mid-floodplain habitats.

Analyses by South Australia supported MDBA's assessment that the BP3200RC scenario delivered the greatest benefit to the South Australian floodplain. The analyses has focused on improvements to the mid-level floodplain habitat inundated by flows of 40 000 ML/d to 80 000 ML/d. Improvement in this range is expected to benefit key vegetation communities such as red gum and lignum and support bird breeding habitat, temporary wetlands and support a mosaic of habitats. The scenario with the next-best level of improvement was the BP3200 scenario, demonstrating that recovery of additional water provides better outcomes compared with relaxing constraints with the level of proposed water recovery under the current proposed Basin Plan scenario.

There was little difference between the four scenarios for the habitat in the river channel (below 40 000 ML/d) or for the high-level floodplain (over 80 000 ML/d).

Overall, it is considered that the relaxation of constraints in combination with 3200 GL of water recovery provides the greatest opportunity and flexibility to deliver environmental watering events to South Australia's mid-level floodplain.

For the CLLMM site, the 3200 GL water recovery volume has the greatest impact on reducing the risks of ecological degradation. Water levels and salinity of Lake Alexandrina and Lake Albert, salinity of Coorong North and South Lagoons, water level in South Lagoon, as well as barrage outflows and Mouth openness were all improved compared to the recovery of 2800 GL. Changes to flow delivery sequences under the relaxed constraints scenarios have altered the timing of flow reaching the site in the model resulting in both positive and negative changes compared to scenarios with constraints. This demonstrates that outcomes at the site are sensitive to upstream watering decisions.

# APPENDIXES

## A. FLOWS AT LOCATIONS WITH CONSTRAINTS RELAXED

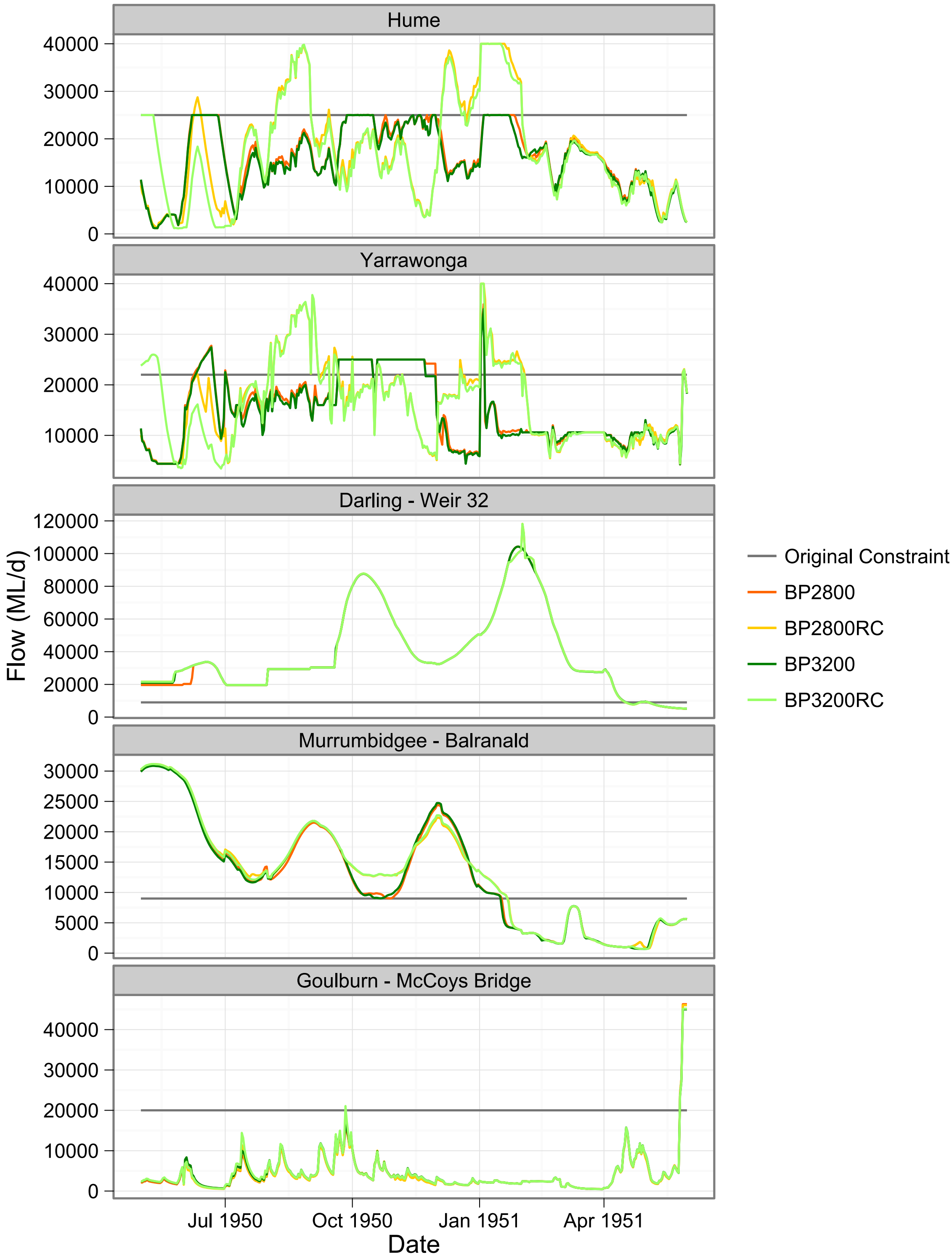



**Figure 46. Flows in 1950 for each scenario at locations impacted by constraints**

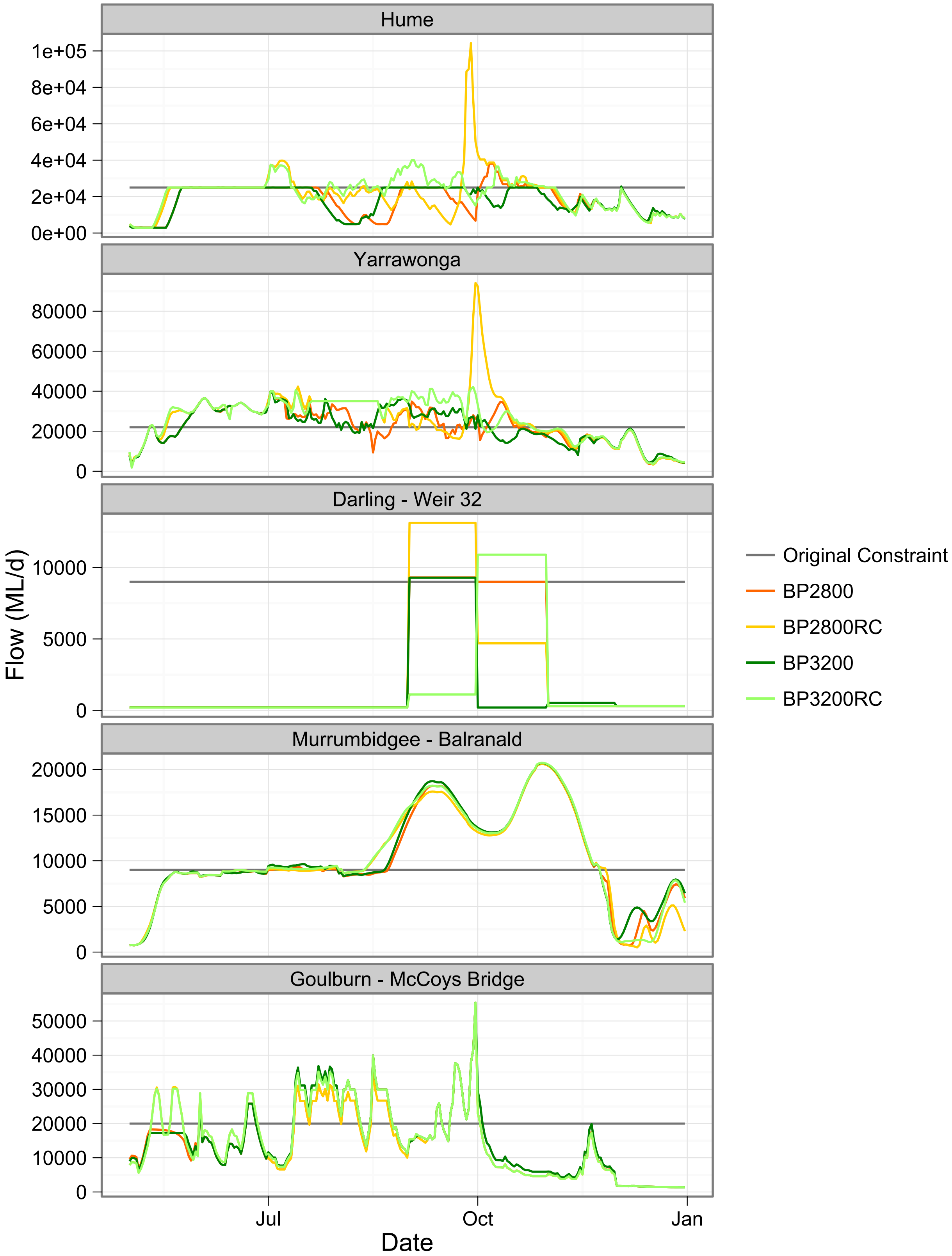



**Figure 47. Flows in 1960 for each scenario at locations impacted by constraints**

# B. DIFFERENCES BETWEEN SA AND MDBA EVENT ASSESSMENT METHODS

There are some differences between the frequencies of successful events assessed as meeting similar targets presented by the MDBA (Table 2) and in this report (Table 8). These differences can largely be explained by the MDBA assessment method, including a 10% leniency on both the duration and flow specified by the indicator in years where watering events were requested. To compare the effect of this 10% factor, the years identified as having a successful event by both methods are presented in Figure 48 for the 80 000 ML/d for 30 day target at Riverland-Chowilla in the BP3200RC scenario. Events assessed as successful by both approaches can be seen as the longer, darker green lines, where the extra events identified as successful using the MDBA assessment method, those within 10% of the target, are included in Figure 48 as lighter green lines.

The classification of the number of events occurring for the 80 000 ML/d for 30 day target in for all scenarios as undertaken by the MDBA is presented in Table 49. It can be seen that four and six more events were requested in the BP3200 and BP3200RC scenarios compared to the 2800 GL scenarios, respectively. However, only one of these events was successfully delivered, occurring in the BP3200 scenario. This event is the reason for the different average recurrence intervals presented in the SA analysis in Table 8, where the average frequency between events increased from 1 in 9.5 years for the BP2800, BP2800RC and BP3200RC scenarios, to 1 in 8.8 years for the BP3200 scenario.


**Figure 48. Assessment of successful events for the 80 000 ML/d for 30 day target and BP3200RC scenario, indicating years where events assessed as successful in both methods (successful events), and extra events identified as successful within 10% by the MDBA method (Successful within 10%).**

After including the events that were within 10% of the flow and duration specified for this indicator, the BP3200RC scenario delivered a further four (compared to BP2800RC and BP3200) or five (compared to BP2800) events. The total of eight events with 10% of the indicator for the BP3200RC scenario can be seen as the years with lighter green lines in Figure 48. These partial events increased frequency of successful events identified by the MDBA assessment framework to 18% of years for the BP3200RC scenario. This is more frequent than the MDBA high uncertainty target of 17%, and as such met the target according to the MDBA indicator and assessment method.

**Table 49. MDBA assessment of events for the 80 000 ML/d for 30 day indicator at Riverland-Chowilla**

| Scenario | BP2800 | BP2800RC | BP3200 | BP3200RC |
|---|---|---|---|---|
| Requested events | 6 | 6 | 10 | 12 |
| Delivered in full | 0 | 0 | 1 | 0 |
| Delivered within 10% | 4 | 3 | 3 | 8 |
| Occurred in Baseline scenario | 11 | 11 | 11 | 11 |
| Lost from Baseline scenario | 0 | 0 | 0 | 0 |
| Extra events delivered but not ordered | 1 | 1 | 1 | 1 |
| Number of fully successful events | 12 | 12 | 13 | 12 |
| Number of events within 10% | 16 | 15 | 16 | 20 |
| Successful events (% of years) | 11 | 11 | 11 | 11 |
| Successful events including within 10% (% of years) | 14 | 13 | 14 | 18 |
| Successful events (1 in … years) | 9.5 | 9.5 | 8.8 | 9.5 |
| Successful events including within 10% (1 in … years) | 7.1 | 7.6 | 7.1 | 5.7 |

The effect of relaxing constraints with further water recovery on the ability to deliver environmental watering events for the 80 000 ML/d for 30 day indicator can also be inferred from Table 49. For BP3200, less than half of the requested events could be delivered either in full or within 10% of the indicator. However, after relaxing constraints in BP3200RC, eight of the 12 requested events (75%) were delivered to within 10% of the target flow and duration, implying that relaxation of constraints improved the ability to deliver targeted watering events. However, this is only one comparison for one indicator, and further analysis would be required to determine if this is a generic result.

As an example of an event that produced the differences between the two assessment methods, the hydrograph for all scenarios for the year 1989 is presented in Figure 49. This can be seen as one of the years with a partially successful event in the BP3200RC scenario in Figure 48, and was also partially successful in BP3200. The peak flow simulated in the BP3200RC scenario for this year was 79 971 ML/d, and as such no days over the target flow rate of 80 000 ML/d were identified in the results presented in this work. The flow meeting the target 30 day duration can be seen as dashed lines in Figure 49, however the MDBA approach also allows a 10% leniency on the duration of the event (as this was an ordered event in the two 3200 GL scenarios). This event was identified as successful by the MDBA assessment framework, as the flow exceeded for 27 days is greater than 72 000 ML/d.

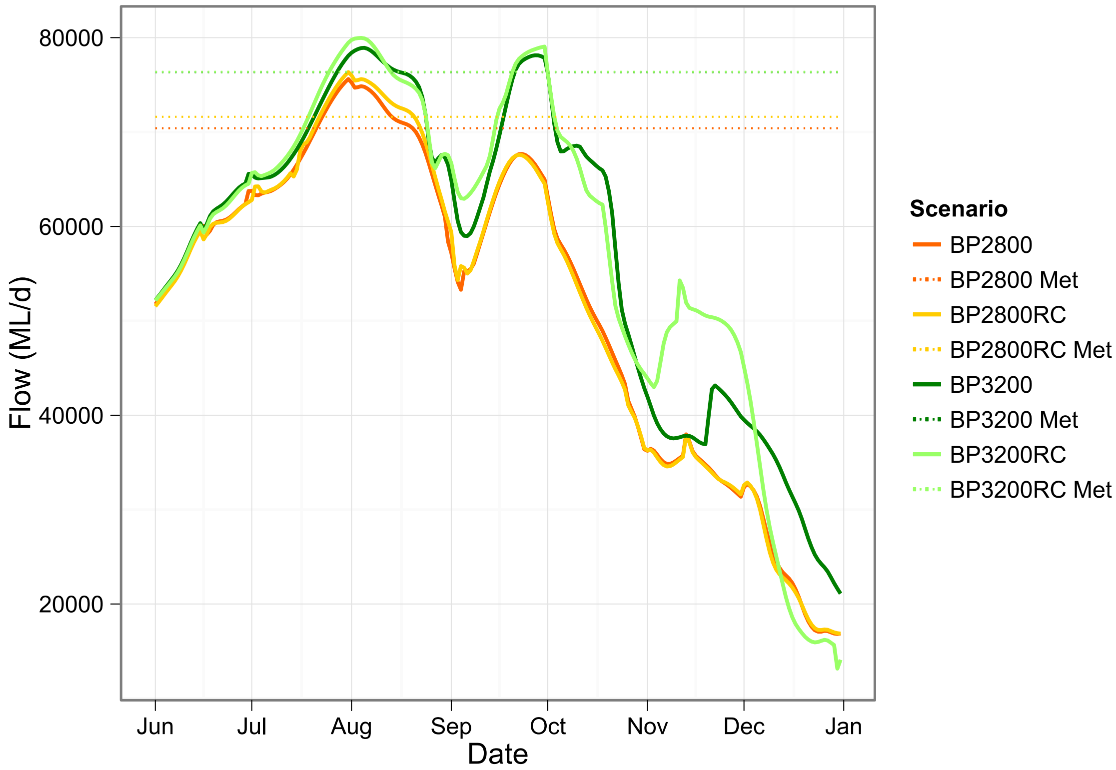



**Figure 49. Hydrograph for the 1989 event, assessed as successful within 10% of the 80 000 ML/d for 30 day target by the MDBA assessment framework.**

It is clear from Figure 49 that the ability to order this event in 1989 with further water recovery in 3200 scenarios provided a benefit by extending the period of high flows inundating the floodplain. By adopting the 10% allowance in the MDBA analysis this event contributes to the overall frequency of meeting the target of 80 000 ML/d for 30 days, even though it did not exceed 80 000 ML/d at all. This inclusion or exclusion of events is likely to be an issue with any threshold identifying successful events that is adopted, for example it is possible that there are events in other years where there is an improvement from one scenario to the next, however neither were included as successful in the frequency of meeting an indicator.

Given the general agreement between the results, the assessment undertaken by the MDBA can be considered alongside the stricter assessment of the EWR targets adopted in this work. This comparison is useful to provide an indication of the number of “near miss” events for the common indicators between the assessments, which may be able to be altered to become successful watering events through different river operating rules (as the 10% rule is only applied to ordered events). It is difficult to assess which approach is the most representative, as while it may be likely that ordered events can be modified to deliver the targeted event as intended, it is also likely that events in other years are delivered successfully in the modelling, even though in practice it may have been unlikely to be delivered. For example, this may occur for cases where perfect knowledge of the volume available was required, or when this volume was available early in the water year to be delivered for environmental purposes.

# C. AREA OF FLOODPLAIN HABITATS ON THE SOUTH AUSTRALIAN RIVER MURRAY FLOODPLAIN INUNDATED

The methods for determining vegetation and temporary wetland areas are described in Appendix A of Bloss *et al.* 2012

**Table 50. Area (ha) of vegetation communities on the SA River Murray floodplain inundated at 5000 ML/d increments**

Highlighted row indicates the maximum extent of the managed floodplain

| Flow band (ML/d) | Red gum | Black box | Lignum | Other woodlands | Other shrublands | Forbland | Grassland | Sedgeland | Unidentified vegetation | SUBTOTAL - VEGETATED | Unvegetated | TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 20 000 | 1581 | 154 | 271 | 35 | 478 | 8 | 214 | 70 | 5 | 2816 | 2088 | 4904 |
| 25 000 | 1643 | 157 | 283 | 35 | 530 | 8 | 234 | 71 | 5 | 2965 | 2119 | 5085 |
| 30 000 | 1831 | 176 | 325 | 36 | 639 | 8 | 323 | 73 | 5 | 3416 | 2405 | 5820 |
| 35 000 | 2073 | 192 | 379 | 38 | 747 | 8 | 377 | 76 | 5 | 3895 | 2493 | 6388 |
| 40 000 | 2614 | 241 | 663 | 43 | 1230 | 11 | 514 | 83 | 5 | 5404 | 2590 | 7994 |
| 45 000 | 2989 | 276 | 806 | 53 | 1512 | 19 | 604 | 87 | 6 | 6351 | 2633 | 8984 |
| 50 000 | 3913 | 502 | 1512 | 106 | 2371 | 100 | 737 | 97 | 6 | 9343 | 2744 | 12087 |
| 55 000 | 4513 | 635 | 1802 | 118 | 2866 | 118 | 849 | 97 | 7 | 11006 | 2797 | 13803 |
| 60 000 | 5701 | 862 | 2873 | 168 | 3641 | 145 | 1019 | 105 | 8 | 14522 | 2997 | 17519 |
| 65 000 | 7085 | 1305 | 4277 | 216 | 4729 | 216 | 1309 | 110 | 11 | 19258 | 3107 | 22365 |
| 70 000 | 8501 | 1989 | 5773 | 278 | 5748 | 366 | 1537 | 115 | 12 | 24320 | 3214 | 27534 |
| 75 000 | 10 120 | 2818 | 7485 | 355 | 7647 | 443 | 2030 | 118 | 16 | 31031 | 3423 | 34454 |
| 80 000 | 11 727 | 4261 | 8898 | 451 | 9666 | 617 | 2394 | 124 | 17 | 38155 | 3691 | 41846 |
| 85 000 | 12 706 | 5648 | 9477 | 567 | 11 521 | 760 | 2621 | 123 | 19 | 43442 | 3877 | 47319 |

| Flow band (ML/d) | Red gum | Black box | Lignum | Other woodlands | Other shrublands | Forbland | Grassland | Sedgeland | Unidentified vegetation | SUBTOTAL - VEGETATED | Unvegetated | TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 90 000 | 13 078 | 6036 | 9766 | 591 | 11 779 | 780 | 2664 | 124 | 20 | 44838 | 3916 | 48754 |
| 95 000 | 13 830 | 6646 | 10 116 | 615 | 12 017 | 797 | 2721 | 124 | 20 | 46886 | 4001 | 50887 |
| 100 000 | 14 475 | 7218 | 10 519 | 656 | 12 423 | 813 | 2825 | 127 | 21 | 49078 | 4093 | 53171 |
| >100 000 | 18 917 | 15 805 | 11 709 | 1746 | 18 410 | 2344 | 3265 | 148 | 65 | 72407 | 7634 | 80042 |

**Table 51. Area (ha) of temporary wetlands on the SA River Murray floodplain inundated at 5000 ML/d increments**

Highlighted row indicates the maximum extent of the managed floodplain

| Flow band (ML/d) | Area (ha) of temporary wetlands inundated |
|---|---|
| 5 000 | 2 006 |
| 10 000 | 2 099 |
| 15 000 | 2 229 |
| 20 000 | 2 285 |
| 25 000 | 2 381 |
| 30 000 | 2 791 |
| 35 000 | 2 936 |
| 40 000 | 3 194 |
| 45 000 | 3 314 |
| 50 000 | 3 731 |
| 55 000 | 3 851 |
| 60 000 | 4 204 |
| 65 000 | 4 486 |
| 70 000 | 4 812 |
| 75 000 | 5 285 |
| 80 000 | 5 603 |
| 85 000 | 5 745 |
| 90 000 | 5 788 |
| 95 000 | 5 867 |
| 100 000 | 5 947 |
| >100 000 | 6 386 |

# D. EVENT MFAT ANALYSIS

**Table 52. Number of 1950 sub peaks that fall within each of the four MFAT habitat categories for flows above 50 000 ML/d**

| | 0-0.2 | 0.2-0.7 | 0.7-1 | 1 |
|---|---|---|---|---|
| Red gum adults | | | | |
| BP2800 | | | 1 | 1 |
| BP2800RC | | | 1 | 1 |
| BP3200 | | | 1 | 1 |
| BP3200R | | | 1 | 1 |
| Lignum adults | | | | |
| BP2800 | | 1 | | 1 |
| BP2800RC | | 1 | | 1 |
| BP3200 | | 1 | | 1 |
| BP3200R | | 1 | 1 | |

**Table 53. Number of 1950 sub peaks that fall within each of the four MFAT habitat categories for flows above 55 000 ML/d**

| | 0-0.2 | 0.2-0.7 | 0.7-1 | 1 |
|---|---|---|---|---|
| Red gum adults | | | | |
| BP2800 | | 1 | 1 | |
| BP2800RC | | 1 | | 1 |
| BP3200 | | 1 | 1 | |
| BP3200R | | 2 | | 1 |
| Lignum adults | | | | |
| BP2800 | | 1 | 1 | |
| BP2800RC | | 1 | | 1 |
| BP3200 | | 1 | 1 | 1 |
| BP3200R | | 2 | | 1 |

**Table 54. Number of 1950 sub peaks that fall within each of the four MFAT habitat categories for flows above 60 000 ML/d**

| | 0-0.2 | 0.2-0.7 | 0.7-1 | 1 |
|---|---|---|---|---|
| Red gum adults | | | | |
| BP2800 | | | 1 | 2 |
| BP2800RC | | | 1 | 2 |
| BP3200 | | 1 | 1 | 2 |
| BP3200R | | | 1 | 2 |
| Lignum adults | | | | |
| BP2800 | | | 1 | 2 |
| BP2800RC | | | 1 | 1 |
| BP3200 | | 1 | 1 | 2 |
| BP3200R | | 1 | 1 | 1 |

**Table 55. Number of 1950 sub peaks that fall within each of the four MFAT habitat categories for flows above 65 000 ML/d**

| | 0-0.2 | 0.2-0.7 | 0.7-1 | 1 |
|---|---|---|---|---|
| Red gum adults | | | | |
| BP2800 | | 2 | | |
| BP2800RC | | 1 | | 1 |
| BP3200 | | 1 | 1 | |
| BP3200R | | 2 | | 1 |
| Lignum adults | | | | |
| BP2800 | | 2 | | |
| BP2800RC | | 1 | | 1 |
| BP3200 | | | | 2 |
| BP3200R | | 2 | | 1 |

**Table 56. Number of 1950 sub peaks that fall within each of the four MFAT habitat categories for flows above 70 000 ML/d**

| | 0-0.2 | 0.2-0.7 | 0.7-1 | 1 |
|---|---|---|---|---|
| Red gum adults | | | | |
| BP2800 | | | | |
| BP2800RC | | 1 | | |
| BP3200 | | 2 | | |
| BP3200R | | 1 | | |
| Lignum adults | | | | |
| BP2800 | | | | |
| BP2800RC | | 1 | | |
| BP3200 | | 2 | | |
| BP3200R | | 1 | | |

**Table 57. Number of 1951 sub peaks that fall within each of the four MFAT habitat categories for flows above 50 000 ML/d**

| | 0-0.2 | 0.2-0.7 | 0.7-1 | 1 |
|---|---|---|---|---|
| Red gum adults | | | | |
| BP2800 | | | 1 | |
| BP2800RC | | | 1 | |
| BP3200 | | | 1 | |
| BP3200RC | 1 | | 1 | |
| Lignum adults | | | | |
| BP2800 | | | 1 | |
| BP2800RC | | | 1 | |
| BP3200 | | | 1 | |
| BP3200R | 1 | | 1 | |

**Table 58. Number of 1951 sub peaks that fall within each of the four MFAT habitat categories for flows above 55 000 ML/d**

| | 0-0.2 | 0.2-0.7 | 0.7-1 | 1 |
|---|---|---|---|---|
| Red gum adults | | | | |
| BP2800 | | | | 1 |
| BP2800RC | | | | 1 |
| BP3200 | | | | 1 |
| BP3200R | | | | 1 |
| Lignum adults | | | | |
| BP2800 | | | 1 | |
| BP2800RC | | | 1 | |
| BP3200 | | | 1 | |
| BP3200R | | | 1 | |

**Table 59. Number of 1951 sub peaks that fall within each of the four MFAT habitat categories for flows above 60 000 ML/d**

| | 0-0.2 | 0.2-0.7 | 0.7-1 | 1 |
|---|---|---|---|---|
| Red gum adults | | | | |
| BP2800 | 1 | 2 | | |
| BP2800RC | 1 | | | 1 |
| BP3200 | 1 | | | 1 |
| BP3200R | 1 | | | 1 |
| Lignum adults | | | | |
| BP2800 | 1 | 2 | | |
| BP2800RC | 1 | | | 1 |
| BP3200 | 1 | | | 1 |
| BP3200R | 1 | | | 1 |

**Table 60. Number of 1951 sub peaks that fall within each of the four MFAT habitat categories for flows above 65 000 ML/d**

| | 0-0.2 | 0.2-0.7 | 0.7-1 | 1 |
|---|---|---|---|---|
| Red gum adults | | | | |
| BP2800 | 1 | 1 | | |
| BP2800RC | | | | 1 |
| BP3200 | | 2 | | |
| BP3200R | | | | 1 |
| Lignum adults | | | | |
| BP2800 | 1 | 1 | | |
| BP2800RC | | | | 1 |
| BP3200 | | 2 | | |
| BP3200R | | | | 1 |

**Table 61. Number of 1951 sub peaks that fall within each of the four MFAT habitat categories for flows above 70 000 ML/d**

| | 0-0.2 | 0.2-0.7 | 0.7-1 | 1 |
|---|---|---|---|---|
| Red gum adults | | | | |
| BP2800 | 2 | | | |
| BP2800RC | 1 | 1 | | |
| BP3200 | 2 | | | |
| BP3200R | 1 | 1 | | |
| Lignum adults | | | | |
| BP2800 | 2 | | | |
| BP2800RC | 1 | 1 | | |
| BP3200 | 2 | | | |
| BP3200R | 1 | 1 | | |

**Table 62. Number of 1951 sub peaks that fall within each of the four MFAT habitat categories for flows above 75 000 ML/d**

| | 0-0.2 | 0.2-0.7 | 0.7-1 | 1 |
|---|---|---|---|---|
| Red gum adults | | | | |
| BP2800 | | | | |
| BP2800RC | 1 | | | |
| BP3200 | | | | |
| BP3200RC | 1 | | | |
| Lignum adults | | | | |
| BP2800 | | | | |
| BP2800RC | 1 | | | |
| BP3200 | | | | |
| BP3200R | 1 | | | |

**Table 63. Number of 1960 sub peaks that fall within each of the four MFAT habitat categories for flows above 50 000 ML/d**

| | 0-0.2 | 0.2-0.7 | 0.7-1 | 1 |
|---|---|---|---|---|
| Red gum adults | | | | |
| BP2800 | | | 1 | |
| BP2800RC | | | 1 | |
| BP3200 | | | 1 | |
| BP3200R | | | | |
| Lignum adults | | | | |
| BP2800 | | | 1 | |
| BP2800RC | | | 1 | |
| BP3200 | | | 1 | |
| BP3200R | | | | |

**Table 64. Number of 1960 sub peaks that fall within each of the four MFAT habitat categories for flows above 55 000 ML/d**

| | **0-0.2** | **0.2-0.7** | **0.7-1** | **1** |
|---|---|---|---|---|
| Red gum adults | | | | |
| BP2800 | | | | 1 |
| BP2800RC | | | 1 | |
| BP3200 | | 1 | | 1 |
| BP3200R | | | 1 | |
| Lignum adults | | | | |
| BP2800 | | | | 1 |
| BP2800RC | | | 1 | |
| BP3200 | | 1 | | 1 |
| BP3200R | | | 1 | |

**Table 65. Number of 1960 sub peaks that fall within each of the four MFAT habitat categories for flows above 60 000 ML/d**

| | **0-0.2** | **0.2-0.7** | **0.7-1** | **1** |
|---|---|---|---|---|
| Red gum adults | | | | |
| BP2800 | | 1 | | 1 |
| BP2800RC | | 1 | | 1 |
| BP3200 | | 1 | | 1 |
| BP3200RC | | | | 1 |
| Lignum adults | | | | |
| BP2800 | | 1 | | 1 |
| BP2800RC | | 1 | | 1 |
| BP3200 | | 1 | | 1 |
| BP3200RC | | | 1 | |

**Table 66. Number of 1960 sub peaks that fall within each of the four MFAT habitat categories for flows above 65 000 ML/d**

| | 0-0.2 | 0.2-0.7 | 0.7-1 | 1 |
|---|---|---|---|---|
| Red gum adults | | | | |
| BP2800 | | | 1 | |
| BP2800RC | | 1 | | 1 |
| BP3200 | | 1 | 1 | |
| BP3200RC | | | | 1 |
| Lignum adults | | | | |
| BP2800 | | | 1 | |
| BP2800RC | | 1 | 1 | |
| BP3200 | | | 1 | |
| BP3200RC | | | | 1 |

**Table 67. Number of 1960 sub peaks that fall within each of the four MFAT habitat categories for flows above 70 000 ML/d**

| | 0-0.2 | 0.2-0.7 | 0.7-1 | 1 |
|---|---|---|---|---|
| Red gum adults | | | | |
| BP2800 | | 1 | | |
| BP2800RC | | 1 | | |
| BP3200 | | | | |
| BP3200RC | 1 | 1 | | |
| Lignum adults | | | | |
| BP2800 | | 1 | | |
| BP2800RC | | 1 | | |
| BP3200 | 1 | | | |
| BP3200RC | | 1 | | |

**Table 68. Number of 1960 sub peaks that fall within each of the four MFAT habitat categories for flows above 75 000 ML/d**

| | **0-0.2** | **0.2-0.7** | **0.7-1** | **1** |
|---|---|---|---|---|
| Red gum adults | | | | |
| BP2800 | | | | |
| BP2800RC | 1 | | | |
| BP3200 | | | | |
| BP3200RC | 1 | | | |
| Lignum adults | | | | |
| BP2800 | | | | |
| BP2800RC | 1 | | | |
| BP3200 | | | | |
| BP3200RC | | 1 | | |

**Table 69. Number of 1983 sub peaks that fall within each of the four MFAT habitat categories for flows above 50 000 ML/d**

| | **0-0.2** | **0.2-0.7** | **0.7-1** | **1** |
|---|---|---|---|---|
| Red gum adults | | | | |
| BP2800 | | | | 1 |
| BP2800RC | | | | 1 |
| BP3200 | | | | 1 |
| BP3200RC | | | 1 | |
| Lignum adults | | | | |
| BP2800 | | | 1 | |
| BP2800RC | | | 1 | |
| BP3200 | | | 1 | |
| BP3200RC | | | 1 | |

**Table 70. Number of 1983 sub peaks that fall within each of the four MFAT habitat categories for flows above 55 000 ML/d**

| | 0-0.2 | 0.2-0.7 | 0.7-1 | 1 |
|---|---|---|---|---|
| Red gum adults | | | | |
| BP2800 | | | | 1 |
| BP2800RC | | | | 1 |
| BP3200 | | | | 1 |
| BP3200RC | | | | 1 |
| Lignum adults | | | | |
| BP2800 | | | 1 | |
| BP2800RC | | | | 1 |
| BP3200 | | | 1 | |
| BP3200RC | | | 1 | |

**Table 71. Number of 1983 sub peaks that fall within each of the four MFAT habitat categories for flows above 60 000 ML/d**

| | 0-0.2 | 0.2-0.7 | 0.7-1 | 1 |
|---|---|---|---|---|
| Red gum adults | | | | |
| BP2800 | | | | 1 |
| BP2800RC | | | | 1 |
| BP3200 | | | | 1 |
| BP3200RC | | | | 1 |
| Lignum adults | | | | |
| BP2800 | | | | 1 |
| BP2800RC | | | | 1 |
| BP3200 | | | | 1 |
| BP3200RC | | | | 1 |

**Table 72. Number of 1983 sub peaks that fall within each of the four MFAT habitat categories for flows above 65 000 ML/d**

| | 0-0.2 | 0.2-0.7 | 0.7-1 | 1 |
|---|---|---|---|---|
| Red gum adults | | | | |
| BP2800 | | | 1 | |
| BP2800RC | | | 1 | |
| BP3200 | | | 1 | |
| BP3200RC | | | 1 | |
| Lignum adults | | | | |
| BP2800 | | | 1 | |
| BP2800RC | | | 1 | |
| BP3200 | | | 1 | |
| BP3200RC | | | | 1 |

**Table 73. Number of 1983 sub peaks that fall within each of the four MFAT habitat categories for flows above 70 000 ML/d**

| | 0-0.2 | 0.2-0.7 | 0.7-1 | 1 |
|---|---|---|---|---|
| Red gum adults | | | | |
| BP2800 | | 1 | | |
| BP2800RC | | | 1 | |
| BP3200 | | | 1 | |
| BP3200RC | | | 1 | |
| Lignum adults | | | | |
| BP2800 | | 1 | | |
| BP2800RC | | | 1 | |
| BP3200 | | | 1 | |
| BP3200RC | | | 1 | |

**Table 74. Number of 1983 sub peaks that fall within each of the four MFAT habitat categories for flows above 75 000 ML/d**

| | 0-0.2 | 0.2-0.7 | 0.7-1 | 1 |
|---|---|---|---|---|
| Red gum adults | | | | |
| BP2800 | | 1 | | |
| BP2800RC | | 1 | | |
| BP3200 | | 1 | | |
| BP3200R | | | 1 | |
| Lignum adults | | | | |
| BP2800 | | 1 | | |
| BP2800RC | | 1 | | |
| BP3200 | | 1 | | |
| BP3200R | | | 1 | |

**Table 75. Number of 1983 sub peaks that fall within each of the four MFAT habitat categories for flows above 80 000 ML/d**

| | 0-0.2 | 0.2-0.7 | 0.7-1 | 1 |
|---|---|---|---|---|
| Red gum adults | | | | |
| BP2800 | | | | |
| BP2800RC | | 1 | | |
| BP3200 | | | | |
| BP3200RC | | 1 | | |
| Lignum adults | | | | |
| BP2800 | | | | |
| BP2800RC | | 1 | | |
| BP3200 | | | | |
| BP3200RC | | 1 | | |

# E. SPATIAL SALINITY MAXIMUMS

Refer to Higham (2012) for a description of the results presented in this appendix.

## 1901 — 1904

| Year | month | 58 km | 64 km | 70 km | 76 km | 83 km | 90 km | 98 km |
|---|---|---|---|---|---|---|---|---|
| 1901-02 | July | 58.9 | 66.1 | 68.9 | 69.9 | 72.2 | 73.6 | 74.8 |
| | August | 55.3 | 64.8 | 68.5 | 69.7 | 71.6 | 72.3 | 72.8 |
| | September | 54.2 | 61.1 | 64.0 | 65.6 | 68.3 | 69.5 | 70.1 |
| | October | 52.1 | 60.0 | 62.7 | 64.0 | 66.3 | 67.0 | 67.2 |
| | November | 53.4 | 60.6 | 62.9 | 64.4 | 65.8 | 66.1 | 66.3 |
| | December | 50.0 | 60.2 | 64.4 | 66.2 | 69.3 | 70.2 | 71.1 |
| | January | 55.9 | 67.9 | 74.5 | 76.1 | 77.6 | 77.9 | 78.5 |
| | February | 50.3 | 69.7 | 79.6 | 82.5 | 86.6 | 88.8 | 92.4 |
| | March | 56.8 | 75.6 | 85.1 | 88.6 | 92.8 | 94.4 | 95.5 |
| | April | 46.7 | 68.4 | 83.3 | 87.3 | 93.1 | 94.9 | 96.1 |
| | May | 41.0 | 59.2 | 68.9 | 73.2 | 84.4 | 88.6 | 90.7 |
| | June | 51.8 | 62.9 | 69.8 | 72.6 | 78.7 | 81.3 | 82.9 |
| 1902-03 | July | 54.6 | 63.9 | 67.7 | 69.7 | 73.2 | 75.0 | 76.1 |
| | August | 58.1 | 64.9 | 66.8 | 67.6 | 69.9 | 71.3 | 72.0 |
| | September | 57.8 | 64.6 | 67.5 | 68.3 | 69.8 | 70.4 | 70.8 |
| | October | 55.5 | 64.6 | 67.1 | 68.2 | 69.9 | 70.3 | 70.7 |
| | November | 66.9 | 71.9 | 74.3 | 75.4 | 75.9 | 75.7 | 76.0 |
| | December | 63.1 | 73.6 | 79.6 | 82.1 | 84.4 | 84.9 | 85.7 |
| | January | 71.8 | 86.2 | 92.4 | 94.1 | 95.9 | 96.3 | 97.1 |
| | February | 79.5 | 96.0 | 105.1 | 107.3 | 109.6 | 110.1 | 111.7 |
| | March | 80.5 | 98.9 | 108.0 | 110.8 | 113.8 | 115.0 | 115.9 |
| | April | 62.0 | 84.3 | 103.2 | 108.4 | 113.7 | 115.2 | 116.6 |
| | May | 52.2 | 71.0 | 91.1 | 98.2 | 108.0 | 111.9 | 113.9 |
| | June | 41.0 | 59.9 | 71.4 | 77.1 | 91.2 | 97.5 | 101.1 |
| 1903-04 | July | 49.0 | 62.4 | 68.7 | 71.7 | 79.8 | 84.5 | 87.4 |
| | August | 57.3 | 67.5 | 71.1 | 72.3 | 75.7 | 77.8 | 79.2 |
| | September | 61.6 | 69.2 | 71.8 | 72.8 | 74.9 | 75.9 | 76.6 |
| | October | 61.3 | 70.1 | 73.3 | 74.3 | 75.6 | 75.7 | 76.1 |
| | November | 61.1 | 69.9 | 73.0 | 74.3 | 75.8 | 75.7 | 75.3 |
| | December | 65.5 | 75.6 | 79.1 | 79.9 | 80.9 | 81.3 | 81.9 |
| | January | 69.0 | 78.6 | 84.3 | 87.3 | 90.1 | 91.1 | 91.6 |
| | February | 57.8 | 76.0 | 88.1 | 92.4 | 97.4 | 98.8 | 101.1 |
| | March | 49.6 | 74.1 | 86.7 | 90.7 | 97.1 | 99.5 | 101.1 |
| | April | 47.2 | 66.3 | 77.6 | 85.2 | 94.2 | 97.5 | 99.3 |
| | May | 49.9 | 64.2 | 71.0 | 78.6 | 86.7 | 90.3 | 92.4 |
| | June | 53.9 | 65.0 | 69.0 | 71.3 | 77.9 | 81.0 | 82.8 |
| | | | | South Lagoon | | | | |

BP2800

| Year | month | 58 km | 64 km | 70 km | 76 km | 83 km | 90 km | 98 km |
|---|---|---|---|---|---|---|---|---|
| 1901-02 | July | 55.7 | 62.2 | 64.7 | 65.6 | 67.7 | 69.0 | 70.1 |
| | August | 51.5 | 60.8 | 64.2 | 65.3 | 67.1 | 67.7 | 68.2 |
| | September | 52.0 | 57.6 | 59.3 | 60.1 | 62.7 | 64.2 | 65.0 |
| | October | 48.9 | 56.0 | 59.7 | 60.9 | 62.0 | 61.9 | 62.1 |
| | November | 51.3 | 57.4 | 61.2 | 62.0 | 62.4 | 62.3 | 62.4 |
| | December | 48.0 | 58.5 | 63.8 | 65.2 | 67.2 | 67.7 | 68.4 |
| | January | 52.4 | 65.1 | 72.1 | 74.1 | 76.0 | 76.3 | 77.0 |
| | February | 47.8 | 67.7 | 77.6 | 80.8 | 85.3 | 87.6 | 91.5 |
| | March | 54.0 | 73.0 | 83.3 | 87.1 | 91.6 | 93.3 | 94.5 |
| | April | 44.4 | 68.1 | 81.5 | 85.7 | 91.9 | 93.7 | 95.0 |
| | May | 35.8 | 52.2 | 64.5 | 69.7 | 82.3 | 86.9 | 89.1 |
| | June | 48.4 | 59.1 | 64.8 | 68.1 | 75.1 | 78.2 | 80.1 |
| 1902-03 | July | 51.7 | 60.5 | 63.8 | 65.8 | 69.5 | 71.4 | 72.5 |
| | August | 55.3 | 61.6 | 63.4 | 64.2 | 66.4 | 67.7 | 68.4 |
| | September | 55.1 | 61.7 | 64.2 | 64.9 | 66.3 | 66.9 | 67.3 |
| | October | 52.8 | 61.4 | 63.9 | 64.9 | 66.5 | 66.9 | 67.2 |
| | November | 63.4 | 68.3 | 70.6 | 71.6 | 72.1 | 72.0 | 72.2 |
| | December | 60.0 | 70.1 | 75.4 | 77.8 | 80.0 | 80.5 | 81.2 |
| | January | 65.7 | 80.4 | 86.8 | 88.6 | 90.5 | 91.0 | 91.7 |
| | February | 65.8 | 81.7 | 92.9 | 96.0 | 100.0 | 101.5 | 103.4 |
| | March | 64.3 | 84.7 | 94.9 | 98.2 | 102.5 | 104.0 | 105.2 |
| | April | 44.6 | 65.1 | 85.0 | 91.8 | 100.1 | 102.7 | 104.3 |
| | May | 39.0 | 58.7 | 77.4 | 84.0 | 93.3 | 97.2 | 99.3 |
| | June | 42.1 | 55.1 | 61.7 | 68.8 | 79.9 | 85.1 | 88.1 |
| 1903-04 | July | 46.0 | 57.5 | 63.3 | 65.4 | 70.5 | 73.8 | 76.0 |
| | August | 51.6 | 60.6 | 64.0 | 65.1 | 67.8 | 69.4 | 70.4 |
| | September | 54.7 | 61.4 | 64.4 | 65.4 | 67.2 | 68.0 | 68.6 |
| | October | 54.4 | 62.6 | 65.3 | 66.3 | 67.6 | 67.7 | 68.2 |
| | November | 54.1 | 61.8 | 65.1 | 66.4 | 67.8 | 67.8 | 67.4 |
| | December | 59.3 | 67.9 | 71.0 | 71.6 | 72.5 | 72.7 | 73.3 |
| | January | 61.9 | 70.3 | 75.4 | 78.1 | 80.7 | 81.6 | 82.1 |
| | February | 52.0 | 68.2 | 79.5 | 83.2 | 87.4 | 88.8 | 90.9 |
| | March | 46.0 | 67.2 | 78.4 | 81.9 | 87.6 | 89.7 | 91.3 |
| | April | 44.2 | 60.8 | 70.7 | 77.3 | 85.2 | 88.1 | 89.7 |
| | May | 46.8 | 59.2 | 65.1 | 71.7 | 78.7 | 81.9 | 83.8 |
| | June | 50.2 | 59.7 | 62.9 | 65.0 | 70.8 | 73.7 | 75.3 |
| | | | | South Lagoon | | | | |

BP2800RC

| Year | month | 58 km | 64 km | 70 km | 76 km | 83 km | 90 km | 98 km |
|---|---|---|---|---|---|---|---|---|
| 1901-02 | July | 57.1 | 64.1 | 66.6 | 67.7 | 69.8 | 71.3 | 72.4 |
| | August | 45.0 | 55.1 | 60.3 | 64.0 | 68.1 | 69.4 | 70.1 |
| | September | 50.8 | 57.2 | 59.0 | 59.8 | 63.0 | 64.6 | 65.4 |
| | October | 48.2 | 56.1 | 59.3 | 60.5 | 61.8 | 62.1 | 62.3 |
| | November | 48.9 | 56.5 | 58.6 | 59.8 | 61.5 | 61.8 | 62.1 |
| | December | 44.8 | 55.4 | 59.6 | 61.0 | 64.3 | 65.4 | 66.3 |
| | January | 49.4 | 61.7 | 68.4 | 70.0 | 71.8 | 72.1 | 72.8 |
| | February | 45.9 | 63.9 | 73.3 | 76.1 | 80.2 | 82.4 | 86.2 |
| | March | 52.1 | 69.6 | 78.5 | 81.9 | 85.9 | 87.5 | 88.5 |
| | April | 43.8 | 63.6 | 77.2 | 80.9 | 86.2 | 87.9 | 89.0 |
| | May | 39.0 | 55.3 | 64.1 | 68.1 | 78.3 | 82.1 | 84.1 |
| | June | 48.4 | 58.6 | 65.1 | 67.7 | 73.1 | 75.5 | 77.0 |
| 1902-03 | July | 51.6 | 59.9 | 63.2 | 64.9 | 68.1 | 69.7 | 70.7 |
| | August | 54.8 | 60.8 | 62.5 | 63.2 | 65.2 | 66.4 | 67.1 |
| | September | 54.5 | 60.8 | 63.2 | 63.9 | 65.3 | 65.8 | 66.2 |
| | October | 52.9 | 60.9 | 63.1 | 64.1 | 65.6 | 65.8 | 66.1 |
| | November | 63.3 | 67.7 | 69.9 | 70.9 | 71.2 | 71.0 | 71.3 |
| | December | 60.1 | 69.8 | 75.2 | 77.5 | 79.5 | 79.9 | 80.6 |
| | January | 68.6 | 81.9 | 87.6 | 89.2 | 90.7 | 91.0 | 91.7 |
| | February | 68.3 | 82.7 | 93.3 | 97.0 | 101.2 | 102.6 | 104.6 |
| | March | 61.1 | 80.7 | 94.5 | 98.1 | 102.7 | 104.4 | 106.0 |
| | April | 42.3 | 63.5 | 83.5 | 90.6 | 99.5 | 102.5 | 104.2 |
| | May | 37.3 | 57.6 | 76.8 | 83.5 | 93.0 | 96.8 | 98.9 |
| | June | 38.4 | 55.3 | 63.8 | 68.4 | 78.8 | 84.1 | 87.2 |
| 1903-04 | July | 44.9 | 56.2 | 62.1 | 64.4 | 70.0 | 73.6 | 75.9 |
| | August | 51.0 | 60.1 | 63.2 | 64.3 | 67.0 | 68.7 | 69.8 |
| | September | 53.5 | 60.7 | 63.7 | 64.7 | 66.5 | 67.3 | 67.9 |
| | October | 53.1 | 61.5 | 64.4 | 65.4 | 66.8 | 67.0 | 67.4 |
| | November | 53.6 | 61.3 | 64.5 | 65.6 | 67.0 | 67.0 | 66.7 |
| | December | 57.6 | 66.5 | 69.6 | 70.3 | 71.2 | 71.6 | 72.2 |
| | January | 60.8 | 69.3 | 74.2 | 76.9 | 79.3 | 80.2 | 80.6 |
| | February | 50.9 | 66.9 | 77.4 | 81.2 | 85.7 | 87.1 | 89.3 |
| | March | 44.5 | 65.7 | 76.6 | 80.1 | 85.7 | 87.8 | 89.4 |
| | April | 43.6 | 59.8 | 69.2 | 75.5 | 83.3 | 86.2 | 87.8 |
| | May | 46.2 | 58.2 | 63.9 | 70.2 | 77.1 | 80.2 | 82.0 |
| | June | 49.5 | 58.9 | 62.2 | 64.1 | 69.7 | 72.3 | 73.9 |
| | | | | South Lagoon | | | | |

BP3200

| Year | month | 58 km | 64 km | 70 km | 76 km | 83 km | 90 km | 98 km |
|---|---|---|---|---|---|---|---|---|
| 1901-02 | July | 55.6 | 62.2 | 64.6 | 65.6 | 67.6 | 68.9 | 70.0 |
| | August | 43.8 | 53.7 | 59.4 | 62.8 | 66.2 | 67.4 | 67.9 |
| | September | 49.7 | 55.7 | 57.4 | 58.3 | 61.4 | 62.9 | 63.7 |
| | October | 47.4 | 55.0 | 58.1 | 59.2 | 60.4 | 60.4 | 60.6 |
| | November | 48.8 | 55.7 | 59.3 | 60.2 | 60.8 | 60.8 | 60.9 |
| | December | 46.1 | 56.6 | 61.2 | 62.8 | 65.3 | 65.9 | 66.6 |
| | January | 49.4 | 62.4 | 69.3 | 71.3 | 73.4 | 73.8 | 74.5 |
| | February | 45.4 | 64.8 | 74.6 | 77.7 | 82.2 | 84.6 | 88.5 |
| | March | 51.6 | 70.1 | 80.1 | 83.8 | 88.2 | 89.8 | 91.0 |
| | April | 43.0 | 63.8 | 78.5 | 82.5 | 88.4 | 90.2 | 91.5 |
| | May | 35.8 | 51.7 | 62.8 | 67.7 | 79.4 | 83.8 | 85.9 |
| | June | 48.8 | 57.3 | 63.3 | 66.3 | 72.8 | 75.7 | 77.4 |
| 1902-03 | July | 50.3 | 58.8 | 61.9 | 63.8 | 67.3 | 69.2 | 70.3 |
| | August | 52.1 | 58.7 | 60.6 | 61.5 | 64.4 | 65.6 | 66.3 |
| | September | 53.0 | 58.6 | 61.8 | 62.5 | 63.9 | 64.4 | 64.8 |
| | October | 51.5 | 58.5 | 61.8 | 62.7 | 64.2 | 64.5 | 64.8 |
| | November | 61.9 | 66.2 | 68.4 | 69.4 | 69.7 | 69.6 | 69.8 |
| | December | 58.6 | 68.2 | 73.5 | 75.8 | 77.8 | 78.2 | 78.8 |
| | January | 66.6 | 79.8 | 85.5 | 87.1 | 88.6 | 88.9 | 89.6 |
| | February | 68.4 | 83.6 | 93.8 | 96.5 | 99.6 | 100.6 | 102.4 |
| | March | 67.9 | 87.3 | 96.1 | 98.9 | 102.7 | 103.9 | 105.0 |
| | April | 47.8 | 67.0 | 86.4 | 92.9 | 100.7 | 103.1 | 104.5 |
| | May | 40.9 | 59.3 | 78.4 | 85.2 | 94.5 | 98.2 | 100.3 |
| | June | 39.4 | 56.3 | 64.9 | 69.2 | 79.9 | 85.3 | 88.5 |
| 1903-04 | July | 44.9 | 56.6 | 62.5 | 65.1 | 71.6 | 75.3 | 77.5 |
| | August | 51.7 | 60.9 | 64.0 | 65.1 | 68.1 | 69.9 | 71.1 |
| | September | 55.1 | 61.7 | 64.4 | 65.5 | 67.4 | 68.3 | 69.0 |
| | October | 52.9 | 61.9 | 65.3 | 66.3 | 67.8 | 68.0 | 68.4 |
| | November | 55.2 | 63.1 | 65.8 | 66.9 | 68.1 | 68.0 | 67.6 |
| | December | 58.4 | 67.6 | 70.9 | 71.6 | 72.6 | 72.9 | 73.5 |
| | January | 61.9 | 70.7 | 75.9 | 78.6 | 81.0 | 81.8 | 82.3 |
| | February | 52.8 | 66.8 | 79.2 | 83.2 | 87.7 | 89.0 | 91.2 |
| | March | 42.1 | 64.2 | 76.6 | 80.5 | 86.7 | 89.1 | 90.8 |
| | April | 42.8 | 59.8 | 69.4 | 75.7 | 84.0 | 87.2 | 88.9 |
| | May | 45.9 | 59.2 | 64.1 | 70.5 | 77.6 | 80.8 | 82.7 |
| | June | 49.6 | 59.9 | 62.1 | 64.1 | 69.9 | 72.7 | 74.3 |
| | | | | South Lagoon | | | | |

BP3200RC

## 2006–07 — 2008–09

| Year | month | 58 km | 64 km | 70 km | 76 km | 83 km | 90 km | 98 km |
|---|---|---|---|---|---|---|---|---|
| 2006-07 | July | 44.5 | 48.6 | 49.9 | 51.2 | 52.4 | 52.8 | 53.0 |
| | August | 40.3 | 46.7 | 49.6 | 50.3 | 51.5 | 52.0 | 52.4 |
| | September | 45.3 | 50.1 | 51.9 | 52.5 | 53.2 | 53.6 | 54.0 |
| | October | 47.7 | 53.6 | 55.7 | 56.2 | 56.9 | 57.2 | 57.6 |
| | November | 50.4 | 56.4 | 60.2 | 61.4 | 62.6 | 62.7 | 63.3 |
| | December | 55.8 | 63.9 | 68.7 | 69.8 | 70.6 | 70.8 | 71.3 |
| | January | 57.4 | 67.9 | 74.8 | 76.6 | 77.7 | 77.8 | 78.4 |
| | February | 68.9 | 80.9 | 86.0 | 86.6 | 87.2 | 87.0 | 87.8 |
| | March | 76.5 | 86.5 | 94.4 | 96.5 | 98.1 | 98.3 | 98.9 |
| | April | 73.5 | 92.4 | 100.6 | 102.8 | 104.9 | 105.4 | 106.0 |
| | May | 55.9 | 61.8 | 79.6 | 87.7 | 94.9 | 97.5 | 98.0 |
| | June | 48.8 | 62.0 | 67.9 | 70.1 | 78.4 | 83.5 | 86.6 |
| 2007-08 | July | 48.0 | 60.3 | 66.6 | 69.8 | 73.9 | 75.9 | 77.1 |
| | August | 46.1 | 56.5 | 63.1 | 66.3 | 69.5 | 71.0 | 72.0 |
| | September | 54.5 | 61.8 | 64.2 | 65.4 | 67.4 | 68.3 | 69.1 |
| | October | 54.5 | 62.8 | 65.8 | 66.9 | 68.6 | 69.3 | 69.9 |
| | November | 63.9 | 68.8 | 70.9 | 71.3 | 71.7 | 71.8 | 71.9 |
| | December | 63.5 | 69.8 | 73.2 | 74.8 | 76.4 | 76.4 | 76.6 |
| | January | 64.8 | 77.6 | 82.2 | 83.6 | 85.2 | 85.5 | 86.1 |
| | February | 78.1 | 86.3 | 93.4 | 94.4 | 95.0 | 94.9 | 95.4 |
| | March | 87.2 | 100.9 | 106.2 | 107.3 | 108.0 | 108.2 | 108.6 |
| | April | 78.9 | 94.7 | 103.9 | 106.5 | 110.2 | 111.2 | 112.1 |
| | May | 68.9 | 82.9 | 99.4 | 104.1 | 108.4 | 110.1 | 111.0 |
| | June | 59.1 | 75.2 | 82.6 | 86.8 | 96.8 | 101.7 | 104.5 |
| 2008-09 | July | 57.9 | 72.9 | 81.6 | 85.2 | 90.2 | 92.5 | 94.0 |
| | August | 60.3 | 72.2 | 78.3 | 81.7 | 85.5 | 87.2 | 88.2 |
| | September | 60.4 | 72.5 | 78.2 | 80.1 | 83.2 | 84.4 | 85.4 |
| | October | 60.2 | 72.3 | 77.0 | 79.0 | 82.5 | 84.0 | 85.2 |
| | November | 74.7 | 81.3 | 83.8 | 84.4 | 85.2 | 85.5 | 86.1 |
| | December | 74.7 | 83.0 | 87.6 | 89.7 | 92.0 | 92.5 | 93.4 |
| | January | 74.4 | 91.3 | 98.4 | 100.6 | 102.7 | 103.3 | 105.5 |
| | February | 86.9 | 98.8 | 107.3 | 110.4 | 113.2 | 114.2 | 115.5 |
| | March | 84.1 | 104.1 | 117.0 | 120.4 | 124.5 | 125.7 | 126.9 |
| | April | 57.6 | 78.5 | 104.3 | 113.3 | 122.0 | 124.6 | 126.2 |
| | May | 51.7 | 73.0 | 94.1 | 101.3 | 111.2 | 115.7 | 118.3 |
| | June | 67.2 | 83.2 | 89.5 | 91.9 | 99.4 | 104.0 | 106.8 |

South Lagoon

BP2800

| Year | month | 58 km | 64 km | 70 km | 76 km | 83 km | 90 km | 98 km |
|---|---|---|---|---|---|---|---|---|
| 2006-07 | July | 45.7 | 50.1 | 51.5 | 52.8 | 54.0 | 54.5 | 54.7 |
| | August | 41.3 | 48.0 | 51.0 | 51.8 | 53.1 | 53.6 | 54.0 |
| | September | 46.4 | 51.5 | 53.4 | 54.0 | 54.8 | 55.2 | 55.7 |
| | October | 46.7 | 55.0 | 57.2 | 57.8 | 58.6 | 58.8 | 59.2 |
| | November | 51.6 | 56.9 | 61.7 | 63.0 | 64.4 | 64.5 | 65.1 |
| | December | 52.7 | 62.0 | 68.2 | 70.1 | 71.7 | 72.2 | 72.8 |
| | January | 49.9 | 62.5 | 70.3 | 73.5 | 76.9 | 77.8 | 78.8 |
| | February | 51.7 | 66.6 | 75.5 | 77.6 | 80.3 | 81.0 | 82.1 |
| | March | 57.3 | 73.0 | 80.6 | 82.8 | 85.3 | 86.6 | 87.7 |
| | April | 41.2 | 56.2 | 72.5 | 78.7 | 84.8 | 86.8 | 88.6 |
| | May | 32.4 | 46.7 | 57.9 | 65.7 | 75.1 | 79.2 | 81.0 |
| | June | 47.2 | 55.8 | 59.1 | 60.3 | 64.3 | 67.9 | 70.2 |
| 2007-08 | July | 43.8 | 52.3 | 58.2 | 60.1 | 62.4 | 63.5 | 64.2 |
| | August | 45.2 | 51.8 | 54.1 | 56.2 | 59.0 | 60.2 | 60.9 |
| | September | 46.7 | 54.1 | 55.6 | 56.3 | 57.7 | 58.4 | 58.9 |
| | October | 49.3 | 54.7 | 56.2 | 56.9 | 58.0 | 58.7 | 59.3 |
| | November | 55.9 | 59.5 | 60.8 | 61.0 | 61.2 | 61.2 | 61.3 |
| | December | 55.9 | 60.0 | 63.0 | 64.4 | 65.6 | 65.6 | 65.8 |
| | January | 55.4 | 67.4 | 71.6 | 72.8 | 73.9 | 74.0 | 74.5 |
| | February | 65.4 | 76.2 | 80.2 | 81.5 | 82.4 | 82.4 | 82.9 |
| | March | 65.1 | 78.2 | 86.0 | 88.9 | 91.5 | 92.3 | 93.1 |
| | April | 46.1 | 56.5 | 74.7 | 81.8 | 88.8 | 91.3 | 92.6 |
| | May | 39.4 | 51.8 | 66.3 | 72.1 | 79.6 | 83.2 | 85.4 |
| | June | 53.0 | 61.8 | 64.9 | 66.1 | 70.2 | 73.8 | 75.9 |
| 2008-09 | July | 50.3 | 59.3 | 64.4 | 66.0 | 68.2 | 69.3 | 70.0 |
| | August | 51.8 | 58.8 | 62.0 | 64.0 | 66.0 | 66.9 | 67.4 |
| | September | 49.1 | 57.0 | 61.5 | 63.0 | 65.1 | 65.9 | 66.5 |
| | October | 58.5 | 62.9 | 64.1 | 64.6 | 65.5 | 66.0 | 66.6 |
| | November | 62.2 | 66.8 | 69.0 | 69.3 | 69.6 | 69.5 | 69.9 |
| | December | 61.7 | 67.8 | 71.2 | 73.1 | 75.2 | 75.7 | 76.5 |
| | January | 67.7 | 76.9 | 82.4 | 83.4 | 84.4 | 84.9 | 87.1 |
| | February | 78.8 | 89.4 | 94.1 | 94.9 | 95.8 | 96.1 | 97.3 |
| | March | 94.5 | 105.4 | 109.9 | 110.4 | 110.5 | 110.5 | 110.8 |
| | April | 89.1 | 102.1 | 109.8 | 112.3 | 114.8 | 115.4 | 116.1 |
| | May | 75.9 | 90.3 | 106.2 | 110.1 | 113.4 | 114.6 | 115.1 |
| | June | 65.9 | 81.1 | 93.1 | 98.8 | 105.7 | 108.9 | 110.7 |

South Lagoon

BP2800RC

| Year | month | 58 km | 64 km | 70 km | 76 km | 83 km | 90 km | 98 km |
|---|---|---|---|---|---|---|---|---|
| 2006-07 | July | 43.9 | 47.9 | 49.2 | 50.4 | 51.5 | 51.9 | 52.1 |
| | August | 40.0 | 46.2 | 48.9 | 49.6 | 50.7 | 51.2 | 51.6 |
| | September | 44.1 | 49.0 | 51.0 | 51.5 | 52.3 | 52.7 | 53.1 |
| | October | 44.7 | 51.5 | 54.3 | 54.9 | 55.7 | 56.0 | 56.4 |
| | November | 48.0 | 53.8 | 58.9 | 60.0 | 61.2 | 61.3 | 61.9 |
| | December | 50.8 | 59.5 | 65.6 | 67.2 | 68.5 | 68.8 | 69.4 |
| | January | 49.4 | 60.8 | 67.8 | 70.8 | 73.8 | 74.5 | 75.5 |
| | February | 52.6 | 63.3 | 71.7 | 74.6 | 77.7 | 78.4 | 79.5 |
| | March | 45.7 | 62.7 | 73.1 | 76.5 | 81.0 | 82.3 | 83.5 |
| | April | 34.3 | 50.5 | 65.8 | 71.9 | 79.2 | 81.6 | 83.1 |
| | May | 31.4 | 44.7 | 53.3 | 60.9 | 69.9 | 73.9 | 75.6 |
| | June | 45.9 | 52.8 | 55.4 | 56.4 | 59.7 | 63.1 | 65.3 |
| 2007-08 | July | 43.1 | 50.2 | 54.7 | 56.3 | 58.2 | 59.1 | 59.7 |
| | August | 41.2 | 47.6 | 51.7 | 53.8 | 55.7 | 56.6 | 57.1 |
| | September | 43.7 | 49.6 | 51.7 | 52.5 | 54.1 | 54.8 | 55.4 |
| | October | 47.7 | 52.2 | 53.4 | 53.9 | 54.8 | 55.3 | 55.8 |
| | November | 53.1 | 56.5 | 57.7 | 57.9 | 58.0 | 58.0 | 58.0 |
| | December | 53.1 | 56.9 | 59.8 | 61.1 | 62.3 | 62.2 | 62.5 |
| | January | 54.2 | 64.4 | 68.2 | 69.3 | 70.2 | 70.4 | 70.8 |
| | February | 63.9 | 72.7 | 77.1 | 78.1 | 78.6 | 78.6 | 79.0 |
| | March | 64.0 | 75.8 | 83.4 | 85.8 | 88.0 | 88.6 | 89.3 |
| | April | 47.0 | 56.1 | 72.8 | 79.3 | 85.6 | 87.8 | 88.9 |
| | May | 39.8 | 51.1 | 64.7 | 70.2 | 77.2 | 80.6 | 82.6 |
| | June | 52.1 | 60.3 | 63.2 | 64.4 | 68.2 | 71.6 | 73.6 |
| 2008-09 | July | 49.4 | 57.9 | 62.7 | 64.3 | 66.3 | 67.3 | 68.0 |
| | August | 51.3 | 57.9 | 60.6 | 62.4 | 64.3 | 65.1 | 65.6 |
| | September | 51.4 | 58.3 | 61.4 | 62.4 | 64.1 | 64.7 | 65.3 |
| | October | 50.5 | 58.4 | 61.5 | 62.8 | 64.9 | 65.7 | 66.4 |
| | November | 60.9 | 65.1 | 66.6 | 66.9 | 67.3 | 67.5 | 67.9 |
| | December | 61.0 | 66.9 | 70.3 | 71.7 | 73.2 | 73.4 | 74.1 |
| | January | 61.7 | 74.1 | 79.2 | 80.7 | 82.1 | 82.6 | 84.7 |
| | February | 71.2 | 79.9 | 86.4 | 88.9 | 91.3 | 92.1 | 93.4 |
| | March | 68.3 | 83.6 | 93.5 | 96.7 | 100.1 | 101.3 | 102.3 |
| | April | 47.5 | 64.9 | 83.6 | 90.8 | 98.0 | 100.2 | 101.6 |
| | May | 43.5 | 60.2 | 76.4 | 81.9 | 89.6 | 93.1 | 95.1 |
| | June | 56.6 | 68.6 | 73.3 | 75.0 | 80.7 | 84.2 | 86.4 |

South Lagoon

BP3200

| Year | month | 58 km | 64 km | 70 km | 76 km | 83 km | 90 km | 98 km |
|---|---|---|---|---|---|---|---|---|
| 2006-07 | July | 44.4 | 48.6 | 49.9 | 51.1 | 52.3 | 52.7 | 52.9 |
| | August | 40.3 | 46.7 | 49.5 | 50.3 | 51.5 | 51.9 | 52.3 |
| | September | 45.2 | 50.0 | 51.8 | 52.4 | 53.2 | 53.6 | 54.0 |
| | October | 48.8 | 54.2 | 56.3 | 56.7 | 57.2 | 57.4 | 57.7 |
| | November | 51.4 | 55.9 | 60.9 | 62.0 | 63.1 | 63.2 | 63.8 |
| | December | 53.0 | 61.8 | 67.4 | 69.2 | 70.7 | 71.1 | 71.7 |
| | January | 50.1 | 62.1 | 69.5 | 72.7 | 75.9 | 76.7 | 77.7 |
| | February | 57.0 | 71.2 | 78.1 | 79.4 | 81.1 | 81.4 | 82.3 |
| | March | 63.3 | 77.3 | 84.0 | 85.6 | 87.6 | 88.8 | 89.7 |
| | April | 46.5 | 60.6 | 76.5 | 82.3 | 87.5 | 89.8 | 91.4 |
| | May | 34.2 | 45.5 | 60.1 | 68.1 | 77.8 | 82.0 | 83.7 |
| | June | 47.2 | 56.4 | 60.0 | 61.3 | 65.7 | 69.7 | 72.2 |
| 2007-08 | July | 44.1 | 53.1 | 59.1 | 61.1 | 63.6 | 64.8 | 65.6 |
| | August | 46.7 | 52.8 | 55.0 | 57.1 | 60.1 | 61.3 | 62.1 |
| | September | 49.4 | 54.8 | 56.5 | 57.5 | 59.0 | 59.5 | 59.9 |
| | October | 52.0 | 57.2 | 58.8 | 59.4 | 60.3 | 60.7 | 61.2 |
| | November | 55.1 | 60.3 | 62.7 | 63.2 | 63.7 | 63.7 | 63.8 |
| | December | 54.5 | 61.4 | 64.5 | 65.9 | 67.5 | 67.6 | 67.9 |
| | January | 53.7 | 65.5 | 71.0 | 72.8 | 74.7 | 75.2 | 75.8 |
| | February | 58.2 | 68.4 | 73.4 | 76.2 | 79.5 | 80.6 | 81.5 |
| | March | 49.4 | 63.7 | 75.2 | 79.1 | 83.8 | 85.4 | 86.7 |
| | April | 37.4 | 54.3 | 66.8 | 73.6 | 81.0 | 83.8 | 85.4 |
| | May | 38.8 | 52.4 | 60.6 | 66.4 | 73.5 | 76.8 | 78.7 |
| | June | 49.0 | 57.8 | 61.1 | 62.2 | 66.2 | 69.1 | 70.9 |
| 2008-09 | July | 46.6 | 55.3 | 60.3 | 62.1 | 64.2 | 65.2 | 65.8 |
| | August | 45.5 | 53.2 | 57.2 | 59.5 | 61.6 | 62.5 | 63.1 |
| | September | 50.3 | 56.3 | 58.1 | 59.0 | 60.7 | 61.3 | 61.8 |
| | October | 48.3 | 55.7 | 58.5 | 59.5 | 61.4 | 62.2 | 62.8 |
| | November | 57.3 | 61.6 | 63.1 | 63.4 | 63.9 | 64.0 | 64.4 |
| | December | 57.4 | 62.7 | 66.2 | 67.7 | 69.3 | 69.6 | 70.3 |
| | January | 58.1 | 70.2 | 75.0 | 76.4 | 77.8 | 78.3 | 80.5 |
| | February | 67.7 | 78.5 | 82.3 | 84.5 | 86.9 | 87.8 | 89.1 |
| | March | 57.6 | 71.8 | 83.9 | 88.1 | 93.1 | 94.8 | 96.3 |
| | April | 38.7 | 54.1 | 74.3 | 81.8 | 90.2 | 93.1 | 94.8 |
| | May | 38.4 | 55.3 | 63.9 | 70.5 | 79.7 | 83.9 | 86.3 |
| | June | 52.7 | 62.3 | 65.7 | 66.9 | 71.1 | 74.4 | 76.4 |

South Lagoon

BP3200RC

# UNITS OF MEASUREMENT

## Units of measurement (SI and non-SI Australian legal)

| Name of unit | Symbol |
|---|---|
| day | d |
| gigalitre | GL |
| hectare | ha |
| kilometre | km |
| megalitre | ML |
| metre | m |
| microSiemens per centimetre | µS/cm |
| tonne | t |
| year | y |

## Shortened forms

| | |
|---|---|
| EC | electrical conductivity (µS/cm) |
| ppt | parts per trillion |

# GLOSSARY

**AHD –** Australian Height Datum

**Anabranch —** A branch of a river that leaves the main channel

**Aquatic community** — An association of interacting populations of aquatic organisms in a given water body or habitat

**Aquatic ecosystem** — The stream channel, lake or estuary bed, water and/or biotic communities and the habitat features that occur therein

**Aquatic habitat** — Environments characterised by the presence of standing or flowing water

**Aquatic macrophytes** — Any non-microscopic plant that requires the presence of water to grow and reproduce

**Barrage** — Specifically any of the five low weirs at the mouth of the River Murray constructed to exclude seawater from the Lower Lakes

**Baseflow** — The water in a stream that results from groundwater discharge to the stream; often maintains flows during seasonal dry periods and has important ecological functions

**Basin** — The area drained by a major river and its tributaries

**Blackwater** - oxygen-depleted water caused by the decay of organic matter

**Catchment** — That area of land determined by topographic features within which rainfall will contribute to run-off at a particular point

**CLLMM** – Coorong Lower Lakes and Murray Mouth

**CSIRO** — Commonwealth Scientific and Industrial Research Organisation

**Deflation basin** — A hollow formed by the removal of particles by wind

**DEH** — Department for Environment and Heritage (Government of South Australia)

**DENR** — Department of Environment and Natural Resources (Government of South Australia)

**DEWNR** — Department of Environment, Water and Natural Resources (Government of South Australia)

**DFW** — Department for Water (Government of South Australia)

**DWLBC** — Department of Water Land and Biodiversity Conservation (Government of South Australia)

**EC** — Electrical conductivity; 1 EC unit = 1 micro-Siemen per centimetre (µS/cm) measured at 25°C; commonly used as a measure of water salinity as it is quicker and easier than measurement by TDS

**Ecological indicators** — Plant or animal species communities or special habitats with a narrow range of ecological tolerance; for example in forest areas such indicators may be selected for emphasis and monitored during forest plan implementation because their presence and abundance serve as a barometer of ecological conditions within a management unit

**Ecological processes** — All biological physical or chemical processes that maintain an ecosystem

**Ecological values** — The habitats natural ecological processes and biodiversity of ecosystems

**Ecology** — The study of the relationships between living organisms and their environment

**Ecosystem** — Any system in which there is an interdependence upon and interaction between living organisms and their immediate physical chemical and biological environment

**Electrical Conductivity (EC)** – Electrical conductivity is a measure of the water's ability to conduct an electrical current. Electrical conductivity (measured at 25$^{o}$C in units of mS cm$^{-1}$ or µS cm$^{-1}$) can be used to estimate salinity because a relationship exists between the levels of dissolved salts in a water body and its conductivity.

**Entitlement flow** — Maximum monthly River Murray flow to South Australia agreed in to the Murray-Darling Basin Agreement 2008

**Environmental values** — The uses of the environment that are recognised as being of value to the community. This concept is used in setting water quality objectives under the Environment Protection (Water Quality) Policy which recognises five environmental values — protection of aquatic ecosystems recreational water use and aesthetics potable (drinking water) use agricultural and aquaculture use and industrial use. It is not the same as ecological values which are about the elements and functions of ecosystems.

**Environmental water requirements** — The water regimes needed to sustain the ecological values of aquatic ecosystems including their processes and biological diversity at a low level of risk

**Ephemeral streams or wetlands** — Those streams or wetlands that usually contain water only on an occasional basis after rainfall events. Many arid zone streams and wetlands are ephemeral.

**Estuaries** — Semi-enclosed water bodies at the lower end of a freshwater stream that are subject to marine freshwater and terrestrial influences and experience periodic fluctuations and gradients in salinity

**EWR** — Environmental Water Requirement

**Floodplain** — Of a watercourse means: (1) floodplain (if any) of the watercourse identified in a catchment water management plan or a local water management plan; adopted under the Act; or (2) where (1) does not apply — the floodplain (if any) of the watercourse identified in a development plan under the *Development (SA) Act 1993*; or (3) where neither (1) nor (2) applies — the land adjoining the watercourse that is periodically subject to flooding from the watercourse

**Flow bands** — Flows of different frequency volume and duration

**Flow regime** — The character of the timing and amount of flow in a stream

**Groundwater** — Water occurring naturally below ground level or water pumped diverted and released into a well for storage underground; see also 'underground water'

**HIS** – Hydrological Indicator Site

**Infrastructure** — Artificial lakes; dams or reservoirs; embankments walls channels or other works; buildings or structures; or pipes machinery or other equipment

**Irrigation** — Watering land by any means for the purpose of growing plants

**Irrigation season** — The period in which major irrigation diversions occur usually starting in August–September and ending in April–May

**Lake** — A natural lake pond lagoon wetland or spring (whether modified or not) that includes part of a lake and a body of water declared by regulation to be a lake. A reference to a lake is a reference to either the bed banks and shores of the lake or the water for the time being held by the bed banks and shores of the lake or both depending on the context.

**Land** — Whether under water or not and includes an interest in land and any building or structure fixed to the land

**Licence** — A licence to take water in accordance with the Act; see also 'water licence'

**Licensee** — A person who holds a water licence

**MDB** — Murray–Darling Basin

**MDBA** — Murray–Darling Basin Authority

**MDBC** — Murray–Darling Basin Commission

**MFAT** – Murray Flows Assessment Tool

**Model** — A conceptual or mathematical means of understanding elements of the real world that allows for predictions of outcomes given certain conditions. Examples include estimating storm run-off assessing the impacts of dams or predicting ecological response to environmental change

**Monitoring** — (1) The repeated measurement of parameters to assess the current status and changes over time of the parameters measured (2) Periodic or continuous surveillance or testing to determine the level of compliance with statutory requirements and/or pollutant levels in various media or in humans animals and other living things

**Percentile** — A way of describing sets of data by ranking the dataset and establishing the value for each percentage of the total number of data records. The 90th percentile of the distribution is the value such that 90% of the observations fall at or below it.

**Ramsar Convention** — This is an international treaty on wetlands titled *The Convention on Wetlands of International Importance Especially as Waterfowl Habitat*. It is administered by the International Union for Conservation of Nature and Natural Resources. It was signed in the town of Ramsar Iran in 1971 hence its common name. The convention includes a list of wetlands of international importance and protocols regarding the management of these wetlands. Australia became a signatory in 1974.

**SA EWRs –** Environmental Water Requirements defined by South Australia

**SDL** – Sustainable Diversion Limit

**Surface water** — (a) water flowing over land (except in a watercourse), (i) after having fallen as rain or hail or having precipitated in any another manner (ii) or after rising to the surface naturally from underground; (b) water of the kind referred to in paragraph (a) that has been collected in a dam or reservoir

**Threshold** – a point at which a change in conditions (e.g. change in a quality property or phenomenon) produces a response/shift. For an example a decline in water level to a point where a shift in the ecological community is observed.

**Tributary** — A river or creek that flows into a larger river

**Water allocation** — (1) In respect of a water licence means the quantity of water that the licensee is entitled to take and use pursuant to the licence. (2) In respect of water taken pursuant to an authorisation under s.11 means the maximum quantity of water that can be taken and used pursuant to the authorisation

**Water body** — Includes watercourses riparian zones floodplains wetlands estuaries lakes and groundwater aquifers

**Watercourse** — A river creek or other natural watercourse (whether modified or not) and includes: a dam or reservoir that collects water flowing in a watercourse; a lake through which water flows; a channel (but not a channel declared by regulation to be excluded from the this definition) into which the water of a watercourse has been diverted; and part of a watercourse

**Water-dependent ecosystems** — Those parts of the environment the species composition and natural ecological processes that are determined by the permanent or temporary presence of flowing or standing water above or below ground; the in-stream areas of rivers riparian vegetation springs wetlands floodplains estuaries and lakes are all water-dependent ecosystems

**Water-use year: South Australia** — The period between 1 July in any given calendar year and 30 June the following calendar year; also called a licensing year

**Water-use year: Murray-Darling Basin Authority** — The period between 1 June in any given calendar year and 31 May the following calendar year

**Wetlands** — Defined by the Act as a swamp or marsh and includes any land that is seasonally inundated with water. This definition encompasses a number of concepts that are more specifically described in the definition used in the Ramsar Convention on Wetlands of International Importance. This describes wetlands as areas of permanent or periodic to intermittent inundation whether natural or artificial permanent or temporary with water that is static or flowing fresh brackish or salt including areas of marine water the depth of which at low tides does not exceed six metres.

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