# Murray-Darling Basin constraints modelling

Report by the NSW and Victorian Ministers' Independent Expert Panel

Report prepared for the Victorian and New South Wales Governments

16 December 2019

The Hon. Melinda Pavey MP Minister for Water, Property and Housing
The Hon. Lisa Neville MP Minister for Water

12 December 2019

Dear Ministers,

The Independent Expert Panel Review of Constraints Modelling (the Panel) is pleased to submit the report of our review of constraints modelling for your consideration. The review has been conducted in accordance with your terms of reference.

The Panel convened a series of workshops to consult with modelling, operational and environmental experts from Victorian and NSW state departments and agencies and the Murray-Darling Basin Authority. The Panel also invited independent technical experts to attend these meetings and provide advice to the Panel. The technical experts also provided comments on an earlier draft of this report.

The Panel considers that the existing modelling undertaken for the Constraints Measures Program is insufficient to provide relevant and accurate information:

- about the costs and benefits of relaxing the constraints
- required for meaningful engagement and participation in the decision-making processes related to delivering the required flows needed to achieve the environmental benefits sought
- to landholders, local government and infrastructure managers about the consequences of inundating land

The Panel considers that continuing with the existing approach given the current community concerns whilst maintaining the June 2024 deadline for completion, has a high chance of failure. Instead, the Panel suggests that applying an adaptive management approach to progressively relax river operating constraints will provide the opportunity for achieving immediate benefits, will foster improved landholder engagement and has the best chance of achieving the lasting environmental benefits specified in the Basin Plan.

The Panel appreciates the considerable time, effort and resources that staff from your State and agencies provided. Their cooperation was invaluable in assisting our inquiries throughout the review.

Please do not hesitate to contact the Panel if you require further information about our findings.

Yours sincerely,

Greg Wilson (Chair)

On behalf of the Independent Expert Panel

Campbell Fitzpatrick, George Warne and Greg Wilson.

# Executive Summary

In August 2019, at the Ministerial Council meeting, the Victorian and NSW Ministers for Water appointed the Independent Expert Panel Review of Constraints Modelling (the Panel) in response to community concerns about proposals to operate rivers at notified flow rates.

The terms of reference require the Panel to examine whether the existing models and modelling results provide adequate information for:

a) Assessing and communicating third party risks.
b) Informing the development of detailed design of flood mitigation measures and determining associated costs.
c) Articulating environmental outcomes associated with constraints projects
d) Quantifying the change in system operator risk and increased risk of inadvertently inundating landholders.
e) Supporting operational real time decision making. This includes piggybacking and synchronising operating system releases, within and across the Southern Connected Basin.
f) The extent to which use of the environmental portfolio relies on implementation of constraints measures.

If the Panel believed there were gaps, it is to make recommendations to inform future work to address any such gaps. Appendix 1 contains further information about the terms of reference and the Panel's background.

The Panel has considered numerous reports; conducted workshops with the Murray-Darling Basin Authority (MDBA), river operators, floodplain managers and environmental water holders; and engaged its own expert advisers.

**Modelling**

The Panel has formed the view that the various models used for system planning, river operations, floodplain management and measuring environmental benefits were adequate for the purpose for which they were intended, but insufficient to give confidence in relation to the matters listed in the terms of reference.

The Panel notes that this is generally acknowledged by the delivery partners and that enhancements to models are planned or underway so that they better inform the implementation of the Constraints Management Strategy (CMS).

The current modelling is not suitable for assessing and communicating the 3$^{rd}$ party risks. The modelling has been undertaken at an aggregate scale for planning purposes. Landholders need to know the impacts of inundation at the property scale. The available modelling does not produce the information required to assess and communicate risks to landholders, local governments and infrastructure managers at that scale.

In terms of detailed design, the Panel has found that hydrodynamic models have not been completed for all focus areas and are insufficient to support detailed design. A hydrodynamic model of the Edward-Wakool sub-system is due to be completed by the end of 2019; and the development of hydrodynamic models for the Murrumbidgee are being investigated. Detailed hydrodynamic

modelling is progressing to improve water management in the Living Murray sites and to support the detailed design of structures to be built as part of the nine Sustainable Diversion Limit (SDL) offset environmental works projects (i.e. the Victorian Murray Floodplain Restoration Projects).

The Panel has found that "the extent to which the use of the environmental portfolio (of water allocations) relies on implementation of constraints measures" has been partially assessed. The Sustainable Diversion Limit Adjustment Mechanism (SDLAM) model was used in 2017 to assess if the ecological system reach scores of the 36 SDL offset measures considered together would provide equal or better score compared with the score achieved assuming 2,750 GL of water was recovered (but no SDL offset works were implemented). The scores can be used to assess changes but they do not represent environmental outcomes.

SDLAM modelling was not undertaken to calculate the change in the ecological system reach scores attributable to the measures proposed in each individual focus area concept business case. The concept business cases did estimate the areas of various vegetation classes that would be inundated for different flow rates. However, the changes in the area, frequency and duration of inundation of compared to a 'do nothing' case were not presented. This information would have helped (and will assist in the future) to clarify the environmental outcomes in each focus area of adopting the notified flows compared to the 'do nothing' cases.

The Panel found modelling information about changes in flooding risk have not been presented at a scale needed to build the confidence of landholders. The reports seen by the Panel have not focused on the changes expected in flooding risk to landholders[1].

Continued development of real time river operations models is required to help manage the risks of supplying overbank flows for environmental purposes. The Panel has been advised that the development of the next-generation of real-time river operations models using the 'Source' modelling platform is progressing in the Murray and Murrumbidgee systems, but the development of a real time operating model for the Goulburn system should be accelerated.

River operators have identified that investment in additional rainfall and stream gauging is required at various locations to enable better informed decisions about regulating overbank flows.

Finally, the Panel considers that further model development is required to update the flow trigger rules in the models that release water for the environment. The rules need to be updated to incorporate the operational experience of environmental water holders and managers gained in recent years.

The Panel has been advised that significant environmental benefits from the existing environmental water allocations that are currently available are being foregone. These benefits would be generated

[1] MDBA reports in 2012 on the Hydrological modelling of the relaxation of operational constraints and 2017 SDL Adjustment modelling provides some data about the frequency of flooding events, but not in a form that is accessible to landholders

by watering low-lying wetlands in Victoria and New South Wales if current constraints were relaxed. Even small changes in operating rules would improve environmental outcomes.

Further modelling analysis should be undertaken to improve the representation of environmental outcomes and to optimise outcomes. The modelling should be undertaken to explore options for carrying over environmental water and using the water market.

This modelling should also investigate the effects of low, median and high climate change scenarios on environmental water availability, flooding characteristics and environmental outcomes. All of this information should then be used to optimise the investment in relaxing constraints. This information would also help build confidence and increase the transparency of the environmental flows program.

There are two further points to note about the models and their improvement.

First, it is likely that the negotiation of easements and the design of mitigation works will need to be based on multiple sources of information rather than that produced by models alone. This is likely to include inundation maps, aerial photography, satellite imagery, watering trials, LiDAR data, gauge height records and relatively coarse hydrodynamic models.

Second, irrespective of improvements in real time river operation models, they will still require weather forecasts as an input, the accuracy of which falls away beyond several days. Given that it takes one to two months for water to flow through the length of the Murray system, a degree of uncertainty and residual risk will remain. This limits the confidence that can be achieved in real time river operating models. The Panel has been advised that given these uncertainties, flows of 80,000ML/d at the South Australian border will occur when there is a coincidence of large rainfall and 'natural' flow events in the Murray or its key tributaries, but river operators will not be creating 'managed' 80,000 ML/d flows at the South Australian border.

**Further Work**

The Panel was asked to make recommendations to inform future work to address any gaps in the modelling and to gain community confidence. The Panel is of the view that even when models are upgraded, more needs to be done if the CMS is to be successful in achieving environmental benefits with landholder and community confidence and acceptance.

Community confidence requires three things –

- relevant and accurate information about implications and benefits detailed
- meaningful engagement and participation in the decision-making processes
- recognition of the cost to owners and managers of floodplain assets of intentionally inundating land

This has been acknowledged by the Ministerial Council. In considering progress of the constraints projects at its meeting in December 2018. It referred to significant community concerns and agreed to progress the Constraints Measures Coordinating Work Plan noting, amongst other things, that community concerns will be addressed as a priority and that community engagement and co-design in the implementation will be fundamental to its successful delivery. It also noted the importance of

understanding the implications and benefits of the notified constraints flow rates for delivery of the constraints package (MDBA, 2018).

The importance of engagement and information is also emphasised in the CMS itself, which contains the foundational principle that:

> *"Affected communities, including land holders and managers, water entitlement holders, traditional owners, management agencies and local government need to be involved from the beginning to identify potential impacts and solutions."*[2]

The CMS also notes that in the lead up to implementation, work would:

> *"… get down to a property-by-property assessment with regard to landholder impacts and mitigation options. If there are complex mitigation activities to be put in place, then the planning to be 'implementation ready' may extend past 2015."*[3]

However, the concept proposal business cases did not do property-by-property assessments and these still have not occurred in most focus areas because of:

- the lack of detailed property scale information about inundation and nuisance.
- concern that small managed overbank events will make subsequent natural floods more damaging
- opposition to the notion that private land can be intentionally inundated
- the considerable opposition of some landholders to the Basin Plan generally.

The original CMS timetable is more than three years behind schedule. Much more than modelling needs to be done to restore community confidence, over and above the work done already to improve modelling. But it is most unlikely that effective engagement could occur while the current severe drought persists.

The Panel considers that applying an adaptive management approach to progressively relax river operating constraints will provide the opportunity for immediate benefits and has the best chance of achieving the lasting environmental benefits specified in the Basin Plan. The objective of the adaptive management approach would be to build the necessary community support for the constraints measures through the co-design process required by the Ministerial Council.

The approach should be based on well managed trials, with a clear impact-assessment process. The trials of higher flow events would be conducted on discrete sections of rivers, not on the whole system. They would be done at known channel constrictions that involve landholders that are constraining beneficial environmental watering. Enduring landholder agreements would be finalised after the trials were completed, not before.

This approach would enable:

- landholders to see and assess first-hand the effects of intended inundation on their properties and businesses, with the confidence that the cost of the impacts would be promptly recognised
- river operators to build the new skills and capabilities required to release overbank flows

[2] Constraints Management Strategy (page ix)
[3] Constraints Management Strategy (page 32)

- environmental manager to effectively engage with landholders and the broader community to demonstrate environmental benefits
- local operational rules to be developed and refined to manage local benefits and costs.

The approach is consistent with the co-design principles and would start to address community concerns. However, it will only be effective if it is acknowledged that the process cannot be rushed and may result in communities recommending flow rates that are less than the notified flow rates, thereby reducing the volume of the SDL offsets.

A constraints program applying this adaptive management approach would be a constructive step forward. It would lead to improvements in model development and a better understanding of the benefits and costs of inundation.

**Concluding Remarks**

The objective of the original CMS was to maximise environmental benefits using water that is already held for environmental use, thus avoiding the need to acquire more water through purchases or efficiency measures. A foundational principal of the CMS was to involve affected communities from the beginning.

More modelling and additional information will be important but delivering the constraints program is not likely to be successful unless community confidence is regained. The Panel believes the adaptive approach outlined in this report, co-designed and trialled with affected communities, is more likely to be successful than working up business cases based on the pre-determined notified flow rates and June 2024 deadline for SDL offsets. As noted in the Productivity Commission's Murray-Darling Basin Plan five-year assessment (Productivity Commission, 2018), meeting the 2024 deadline is highly ambitious, if not unrealistic in any event.

The alternative to adopting the Panel's recommended approach is to attempt to go ahead with implementing the notified flows without the co-design process that is necessary to win community support and the confidence of landholders. It is likely that this approach will fail because the necessary landholder agreements will not be achieved, and river operators will not be prepared to release overbank flows unless they are indemnified for the liability that arises for inundating private land. Nothing will be achieved and opportunities to get better local environmental outcomes from the water that has already been recovered will be lost. Any additional water purchased for the environment would not achieve desired benefits because it too could only be released within the current operating constraints.

It is worth noting that the same problems would have occurred if the option of recovering 2,750 GL without relaxing the constraints was adopted. Much of the additional water would have been held back in storages increasing spills during natural minor, moderate and major flood events. The legal liabilities of increasing flood flows by holding environmental allocations in storages has not been examined, it is likely that there would be a strong adverse community reaction regardless of the legal position.

The Panel is aware that its preferred strategy is likely to mean that the Constraints Management Strategy does not meet the June 2024 timeline for completion.

# Table of Contents

*Executive Summary* ..... *2*

*1 Introduction* ..... *10*

**1.1 Purpose** ..... **10**

**1.2 Terms of reference** ..... **10**

**1.3 Outline of report** ..... **10**

*2 Approach* ..... *12*

**2.1 Method** ..... **12**

**2.2 Related investigations** ..... **13**

2.2.1 Enhanced Environmental Water Delivery Project ..... 13

2.2.2 Review of the Water for Environment Special Account ..... 13

2.2.3 Murray River Capacity Risks Project ..... 14

*3 Background* ..... *15*

**3.1 Legal framework for river operations** ..... **15**

3.1.1 Murray-Darling Basin Agreement ..... 15

3.1.2 Water Act 1989 (Vic) ..... 16

3.1.3 Water Management Act 2000 (NSW) ..... 16

**3.2 River operations** ..... **16**

**3.3 Flow constraints** ..... **17**

**3.4 The Constraints Management Strategy** ..... **18**

*4 The modelling challenge* ..... *22*

**4.1 Information needs** ..... **22**

**4.2 Modelling river hydrology for planning purposes** ..... **24**

4.2.1 Background ..... 24

4.2.2 Further development ..... 27

4.2.3 Panel observations ..... 27

**4.3 Hydrodynamic modelling of floodplain inundation for planning purposes** ..... **29**

4.3.1 Background ..... 29

4.3.2 Future development ..... 32

4.3.3 Panel observations ..... 33

**4.4 Modelling river hydrology for operational purposes** ..... **34**

4.4.1 Background ..... 34

4.4.2 Further developments ..... 36

4.4.3 Panel observations ..... 37

**4.5 SDL offset modelling** ..... **39**

4.5.1 Further developments ..... 42

4.5.2 Panel observations ..... 42

*5 Addressing terms of reference ..... 44*

**5.1 Modelling to assess and communicate 3rd party risks ..... 44**

**5.2 Modelling to support detailed design ..... 44**

**5.3 Modelling to articulate environmental outcomes ..... 44**

**5.4 Modelling to assess change in (increased and decreased) flooding risks ..... 45**

**5.5 Modelling to supporting real time operations ..... 45**

**5.6 Modelling to assess use of environmental portfolio and its reliance on implementation of constraints measures ..... 46**

*6 Strategies and future work ..... 48*

**6.1 Panel considerations ..... 48**

**6.2 Possible approach ..... 50**

**6.3 Alternative approach ..... 53**

**6.4 Other consequences ..... 54**

**6.5 Suggested areas for additional work ..... 55**

*7 References ..... 58*

**7.1 Legislation ..... 59**

*8 Glossary ..... 60*

*Appendix 1 – Terms of Reference ..... 65*

*Appendix 2 – Workshops and attendees ..... 68*

*Appendix 3 – Technical advisors list ..... 70*

*Appendix 4 – Reference material provided to Panel ..... 71*

# 1 Introduction

## 1.1 Purpose

The purpose of this report is to assesses whether the modelling undertaken for the Constraints Management Strategy (CMS) is adequate to inform efforts to resolve community concerns, evaluate trade-offs, assess deliverability and understand the implications and benefits of the notified constraints flow rates.

## 1.2 Terms of reference

The terms of reference require the Panel to specifically address whether the existing models and modelling results provide adequate information for:

a) Assessing and communicating third party risks.
b) Informing the development of detailed design of flood mitigation measures and determining associated costs.
c) Articulating environmental outcomes associated with constraints projects.
d) Quantifying the change in system operator risk and increased risk of inadvertently flooding landholders.
e) Supporting operational real time decision making. This includes piggybacking and synchronising operating system releases, within and across the Southern Connected Basin.
f) The extent to which use of the environmental portfolio relies on implementation of constraints measures.

The Panel is to recommend strategies and future work to address areas where current modelling cannot satisfy these requirements.

The Panel also took into consideration existing policy positions from the Victorian and NSW Governments for delivering constraints projects; information used to prepare the Constraints Management Strategy (CMS), the availability of environmental water and climate change.

## 1.3 Outline of report

Chapter 2 of the report details the two-part approach the Panel took to undertake the review. The first part involved conducting a series of workshops with agencies from New South Wales, Victoria and the Commonwealth involved in developing and delivering the constraints measures. The second part was to read a large number of reports on the subject matter.

Chapter 3 provides a high-level outline of the complex legal framework that guides river operations in the Murray-Darling Basin, Victoria and New South Wales together with brief descriptions of the river operation function, key constraints in operating the Southern Connected Basin and the CMS. Information has been limited to that needed to provide context for the remainder of the review.

Chapter 4 describes the challenges involved in undertaking the modelling required for developing and evaluating constraints management proposals. The chapter starts by describing the information needed for decision making. This is followed by a description of the modelling undertaken to date, proposals for additional modelling and the Panel's observations about gaps and the need for further work. Three types of modelling are considered; river hydrology modelling used for planning

purposes, inundation/hydrodynamic modelling used to investigate the inundation of floodplains and real time river operating models used by river operators to inform their day-to-day decisions about how much water to release from storages.

Chapter 5 sets out the Panel's conclusions about the adequacy of modelling in response to the terms of reference.

Finally, Chapter 6 provides the Panel's advice on possible future works and adaptive management strategies to progress the CMS. Under the proposed approach trials of overbank flows would be undertaken at selected river locations. The trials would generate immediate environmental benefits, but more importantly, generate the detailed data required to enhance models and successfully negotiate landholder agreements. The proposed strategy is consistent with the co-design process required by the Ministerial Council.

# 2 Approach

## 2.1 Method

The Panel's approach involved a series of workshops with Commonwealth, NSW and Victorian government entities that have formal roles in aspects of river operations to explore their information needs and identify the issues that they needed to be resolved. The entities included:

- The Murray-Darling Basin Authority (MDBA)
- Department of Planning, Industry and Environment (NSW) (DPIE)
- Department of Environment, Land, Water and Planning (Vic) (DELWP)
- River operators (MDBA, Goulburn-Murray Water (GMW) and WaterNSW)
- Environmental water holders (Commonwealth Environmental Water Office, Victorian Environmental Water Holder, NSW Office of Environment and Heritage (OEH) (now NSW Environment, Energy and Science)
- Environmental water managers (Mallee Catchment Management Authority, North Central Catchment Management Authority, Goulburn Broken Catchment Management Authority and North East Catchment Management Authority, NSW OEH)
- Floodplain managers and modellers
- River modellers

Appendix 2 lists the workshops and who attended.

Experts nominated by the Panel attended the workshops to provide technical support. Appendix 3 lists the technical experts who assisted the Panel.

The Panel also had access to a large number of reports that have been written for the Constraints Measures Program (CMP) including supply measure concept business cases, reach-specific reports and other documents. Appendix 4 lists the reports that the Panel accessed.

The Panel received administrative support from DELWP. DELWP also seconded a staff member to provide secretariat support.

Teleconferences were periodically held with DELWP and DPIE to report progress.

The Ministerial Council, at their meeting of 14 December 2018, acknowledged the community concerns about proposals to operate rivers at the notified flow rates[4]. Therefore, the Panel was not requested to consult directly with landholders. Instead, the Panel has assessed whether the existing modelling is sufficient to accurately identify the land that will be inundated, determine the change in the frequency, duration and timing of inundation caused by flow regimes utilising increased flows up to the notified flow rates and assess how the environment will benefit. The panel members are aware of the concerns expressed by a number of landholders and local governments regarding inundation, landscape 'pre-wetting', and nuisance inundation caused by the release of water from storages to meet environmental targets.

[4] Notified flow rates are the maximum flow rates proposed to be targeted for environmental flows as part of constraint measure projects. The flow rates were Notified in concept business cases prepared as part of the Basin Plan's Sustainable Diversion Limit Adjustment Mechanism process.

The Panel quickly found that no entity was suggesting that the modelling undertaken to date was adequate for providing precise information at an individual property scale, therefore the Panel decided not to undertake a forensic review of all of the available modelling outcomes. Instead it has focussed on identifying significant information gaps and how these gaps may be addressed. The Panel took the view that modelling was an important tool to evaluate options, understand relative changes in the frequency, duration and extent of inundation of land at a system and regional scale, issues, trade-offs and risks to aid decisions- but modelling does not make the decisions.

It was also clear that it was very ambitious to expect that modelling will be able to provide precise and highly accurate information at the property scale given the many uncertainties that currently exist. The Panel has heard that while some causes of uncertainty are likely to be reduced over time, significant uncertainties will persist, mainly because of the difficulty of forecasting the amount of rainfall to occur over the one to two month period river operations require.

## 2.2 Related investigations

The Panel is aware of the following investigations that have some bearing on the future operations of the river system and the constraints measures.

### 2.2.1 Enhanced Environmental Water Delivery Project

The Enhanced Environmental Water Delivery (EEWD) Project was formerly known as Hydro Cues. The project is building on the existing knowledge of environmental water managers and river operators to improve the operational coordination of environment water deliveries across the Southern Connected Basin. Key elements of the project include:

a) improving the forecasting of river flows

b) aligning the release of held environmental water with natural or operational flows to influence the peak and/or duration of a flow event

c) making use of increased channel capacity (resulting from complementary projects to relax physical constraints to water delivery) to allow increased managed flows

d) coordinating environmental flow releases across tributaries of the Southern Connected Basin to maximise downstream and system-wide connectivity outcomes.

The outcomes and SDL offsets delivered by this project are dependent on the outcomes of the constraints measures (see element c above). South Australia, New South Wales and Victoria are the joint proponents of this project which is now underway and is being delivered by the MDBA on behalf of the States.

### 2.2.2 Review of the Water for Environment Special Account

The Water for Environment Special Account is established by the *Water Act 2007* to fund works and measures to recover an additional 450 GL of water for the environment by 2024 and ease or remove constraints to delivery of environmental water by 2024. Section 86AJ of the Act requires the Minister to cause an independent review of whether there are adequate funds available to recover the water and ease constraints. An independent panel has been established to conduct the review and is to report back to the Minister in early 2020 (Department of Agriculture, 2019).

Advice from this panel will influence the level of funding available to implement constraints measures.

### 2.2.3 Murray River Capacity Risks Project

The Murray-Darling Basin Ministerial Council was briefed at their meeting of 14 December 2018 that there was insufficient channel capacity to deliver water ordered for the environment during the spring of 2018/19 (MDBA, 2018). The Commonwealth Environmental Water Holder advised that this had impacted on the environmental benefits that could be achieved from Hume Dam to the Murray mouth. Ministers were also briefed about work being undertaken to minimise water delivery shortfall risks. This work is part of the Murray River Capacity Risks Project.

Ministers were updated on the work being undertaken to resolve the risk of **water delivery shortfall** on the River Murray at their meeting of 4 August 2019 (MDBA, 2019b). They decided to appoint an independent panel of experts to peer review the work program of the Murray River Capacity Risks Project. This Panel is due to report back to the Ministerial Council meeting of December 2019.

# 3 Background

## 3.1 Legal framework for river operations

River operators must operate the rivers and respond to related challenges within a legal framework established by Commonwealth and State legislation.

The Murray is managed for the shared benefit of New South Wales, Victoria and South Australia (the States) using a federal governance model. Authority is divided between the Commonwealth government and the State governments. Section 100 of the Australian Constitution[5] says -

> *"The Commonwealth shall not, by any law or regulation of trade or commerce, abridge the right of a State or of the residents therein to the reasonable use of the waters of rivers for conservation or irrigation."*

The States manage their shared interests through the Murray-Darling Basin Agreement. Each States' share of Murray water resources is managed in accordance with the relevant state's legislation.

The Commonwealth's legal authority for matters included in the Basin Plan are mainly established through section 51 of the constitution that establishes its role in external affairs, trade and corporation law.

The following sections briefly outline some key features of the legal framework for managing the shared Murray river within its operational constraints.

### 3.1.1 Murray-Darling Basin Agreement

The Murray-Darling Basin Agreement is Schedule 1 of the *Water Act 2007* (C'wth).

The Murray and Lower Darling rivers are operated by the MDBA in accordance with the legal framework established by the Murray-Darling Basin Agreement on behalf of Victoria, New South Wales and South Australia.

Victoria, New South Wales and South Australia have agreed that the MDBA manages River Murray operating assets on their behalf[6]. This arrangement is often described as a joint venture. In practice this means that the MDBA issues instructions to GMW, WaterNSW and SA Water to manage flows down the Murray. The MDBA is accountable for any compensation arising from the management and operation of the Murray. Victoria, New South Wales and South Australia must meet in equal shares the cost of any compensation[7].

However, the Basins Officials Committee (BOC) established by the *Water Act 2007*[8] is responsible for high-level river operating decisions and has developed formal River Operations Objectives and Outcomes. BOC members focus on maintaining each States' right to the shared water resources of

[5] Clause 100 Australian Constitution http://classic.austlii.edu.au/au/legis/cth/consol_act/coaca430/: http://classic.austlii.edu.au/au/legis/cth/consol_act/coaca430/
[6] Clause 54(3) of the Murray-Darling Basin Agreement
[7] Clause 84 of the Murray-Darling Basin Agreement
[8] Clause 201 of the Water Act 2007 (C'wlth)

the Murray. BOC's decisions must be unanimous. Where disagreements occur, the status quo prevails. BOC may escalate disagreements to the Ministerial Council (Minco) for resolution.

Other important committees in the management framework include the:

- **River Murray Operations Committee (RMOC**) is established by the MDBA to provide support and advice to the BOC on responsibilities with regards to River Murray Operations.
- **Independent River Operations Review Group** has been established by the MDBA to review the Authority's compliance with the BOC's formal River Operations Objectives and Outcomes.
- **Water Liaison Working Group (WLWG)** is established by the MDBA to provide advice to the MDBA and RMOC on River Murray operations, and membership is drawn from river operators from each State.
- **Southern Connected Basin Environmental Watering Committee (SCBEWC**) is an advisory committee established by the MDBA to support coordination of delivery of water for the environment across multiple water holders and jurisdictions in the Southern Connected Basin.

### 3.1.2 Water Act 1989 (Vic)

Flows in the Goulburn River and other Victorian tributaries of the Murray River downstream of Doctors Point are regulated by GMW in accordance with the Victorian *Water Act 1989*. GMW is liable for damage to property caused by intentionally regulating flows to flood land[9]. This means GMW must enter into agreements with landholders or purchase easements to intentionally inundation land in Victoria to avoid legal liability and compensation payments.

### 3.1.3 Water Management Act 2000 (NSW)

The legal framework that WaterNSW operates under is created by four Acts. WaterNSW is responsible for regulating flows in the Murrumbidgee River. The Panel has been advised that WaterNSW is liable for nuisance caused by intentionally inundating land.

The *Water Management Act 2000* was amended by the *Water Management (Amendment) Act 2018*[10]*.* Clause 399B of the amending Act enables the government to make regulations to provide schemes to facilitate consultation and negotiations with owners and occupiers of land, and other persons, who may be affected by proposed releases of water for environmental purposes. A regulation has not yet been made using these provisions[11].

## 3.2 River operations

River operators traditionally aim to control river flows within the banks of the rivers and avoid overbank flows. In particular they strive to avoid inundating private property to avoid contributing to damage for which they may be liable. During natural flood events they operate storages to reduce

[9] Clause 157 of the Water Act 1989 (Vic)
[10] https://www.legislation.nsw.gov.au/#/view/act/2018/31/sch1 Schedule 1 Amendment of Water Management Act 2000
[11] https://www.legislation.nsw.gov.au/#/view/act/2000/92/regulations

flood damage to the extent this is consistent with their obligations to dam safety, and to store and supply water.

Delivering the environmental flows envisioned by the Basin Plan requires river operators to release water from storages to create overbank flows to inundate low areas of the floodplain. This could be achieved by releasing flows for combined consumptive and environmental purposes that exceed 'bankfull' limits. It could also be achieved by releases that top up existing natural flows and/or extend the duration of the natural overbank events. Environmental water managers advised that most inundation levels created by topping up existing events would be below minor flood levels. Releases would be designed not exceed the notified flow rates[12].

The river operators will be required to ensure the overbank flows do not overshoot and contribute to larger flood events that cause significant costs and disruption to the community. This risk occurs when rainfall contributes to higher than expected river flows and storage releases cannot be reduced in time to compensate.

The risk is relatively low in focus reaches when close to headworks (storages) where management is informed by short-term weather forecasts and where river flow responds quickly to a change in the released flow. The risk increases when overbank flows are being targeted a long way downstream of storages and it is necessary to rely on more uncertain long-term weather forecasts, downstream tributary inflows and the response of river flow to slowing the rate of release is delayed.

The risk is highest for the CMS proposal to provide flows of up to 80,000 ML per day at the South Australian border, which requires releases from storages in the upper catchments of the Murrumbidgee, Goulburn, and Murray rivers to be coordinated with releases from the lower Darling River to produce flows of up to 80,000ML/d at the South Australian border. Travel times to the South Australian border from key storages can vary from four to nine weeks, depending on weather and demand. These travel times far exceed the ability to accurately forecast rainfall events that could increase unregulated flows in the many tributary streams that contribute to inundation events.

## 3.3 Flow constraints

The delivery of a flow of up to 80,000 ML per day at the South Australian border would require river operators to release flows from storages that would exceed river channel capacity at some locations to build on natural events in one or more of the Darling, Murrumbidgee and Goulburn Rivers. Figure 1 shows a simplified schematic of the Murray, Murrumbidgee and Goulburn Rivers, the key river channel capacity constraints and the approximate time it takes for flows to travel down the system.

[12] I.e. events that exceed the nominated Minor Flood Level.

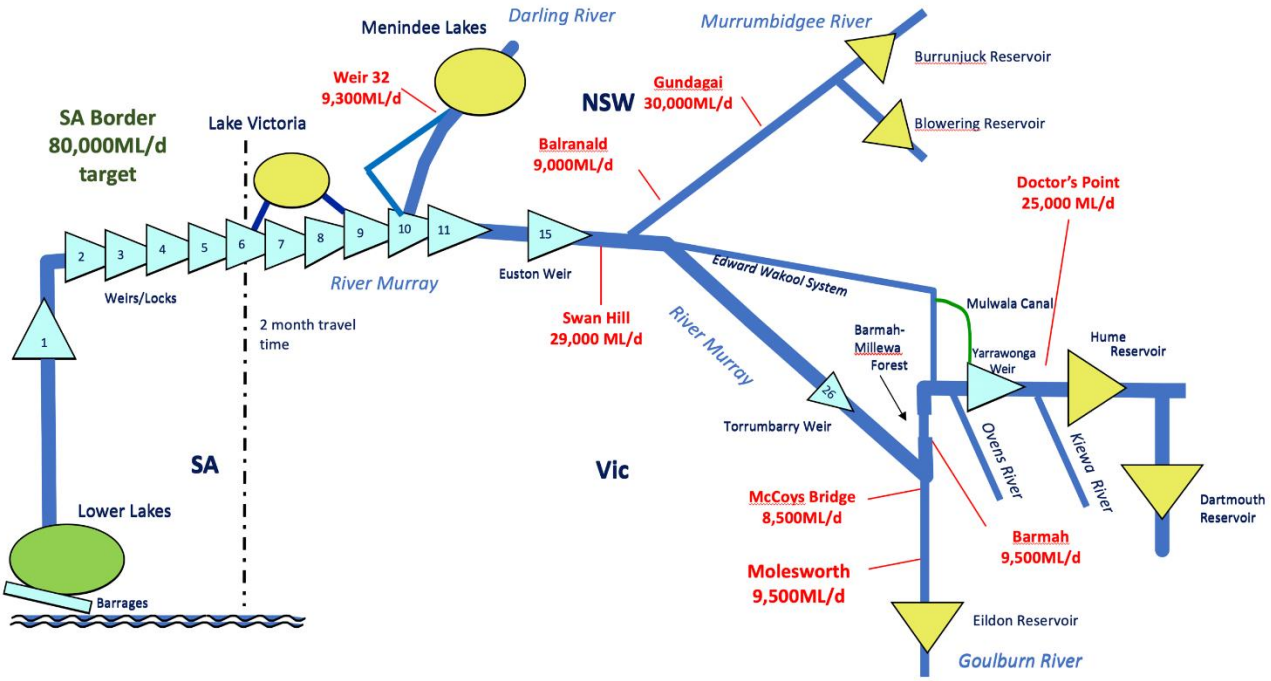


*Figure 1 Schematic of key flow constraints on the Murray and its major tributaries together with flow travel times.*

River operators currently regulate releases from storages to ensure flows remain within channel at these constrained points. Once river operators release water from storages they have very limited ability to reduce the flows as they move down the system. Maintaining flows within channels involves monitoring flows coming into the rivers from tributaries below the major storages and varying storage releases to ensure the combined flows do not exceed channel capacities at points of constriction.

The notified flow rates require river operators to release water from storages that will cause overbank flows but stay below minor flood levels. This is a narrow operating band that would be a relatively straightforward task if the volumes of tributary flows that occur downstream of the storages during the two month period storage releases take to travel through the system were accurately known. However, forecasts of inflows downstream of storages are heavily dependent on the accuracy of the rainfall forecasts. These forecasts are reasonable for perhaps two to five days ahead, but there are large uncertainties in the forecasts that match the two month travel times. Therefore, river operators face significant uncertainty and so they make conservative decisions to avoid the liability of causing damages from overbank flows that flood low lying land.

## 3.4 The Constraints Management Strategy

The CMS (2013) was published by the MDBA. Its aim was -

> *"… to maximise environmental outcomes that can be obtained from managing all water available for environmental use (and managing water for other purposes on route)"*[13]

[13] Constraints Management Strategy (page ix)

The CMS was part of the SDL adjustment mechanism and thus there are effectively two aims for the CMS. The first is the original stated aim of maximising the environmental benefits from managing environmental water. The second is to maximise the SDL offset.

However, over time it would appear that more weight has progressively been given to achieving SDL offsets by the due date, relative to maximising benefits over time. Affected communities have had little say in identifying potential impacts and solutions and evaluating trade-offs. There has been little emphasis on revising flow targets in response to community concerns or re-evaluating trade-offs and environmental outcomes as part of a Phase 2 Basin-scale analysis.

The Strategy proposed an ambitious program of modelling to understand the potential impacts of increasing peak regulated flow heights. Modelling was used to provide a broad scale understanding of how managed environmental releases could be managed with natural flood events. Anticipated negative impacts included:

- reduced agricultural production due to increased inundation of both pastures and crops.
- reduced use and/or access to parts of farms with consequent effects on agricultural production due to increased inundation (i.e. nuisance impacts)
- public and private infrastructure (including roads, low-level bridges and causeways) being subject to more frequent inundation.

The CMS recognises that it is unreasonable to intentionally generate overbank flows that cause damage to private and public property. It proposes that the damage can be minimised or offset by mitigating actions that could include:

- flow advice so landholders know in advance of a flow
- building or improving levees to protect land from inundation
- building new bridges or raising existing bridges to allow continued access during higher flow peaks (i.e. reduce nuisance impacts of flows)
- acquiring an interest in land through covenants or easements to compensate landholders for the impacts.

The CMS includes the important principle that:

> *"Affected communities, including land holders and managers, water entitlement holders, traditional owners, management agencies and local government need to be involved from the beginning to identify potential impacts and solutions."*[14]

A three phase process for reviewing and where feasible improving the efficiency of delivering environmental water was specified. They are:

1. *"Pre-feasibility phase 1: 2013–2014.*
2. *Feasibility phase 2: 2015–2016.*

[14] Constraints Management Strategy (page ix)

3. *Planning and implementation phase 3: 2016–2024."*[15]

A Basin-scale analysis was proposed as part of Phase 1:

> *"This work will take into account trade-offs, interdependencies and flow-on effects across constraints to identify potential investment options and support recommendations to governments."*[16]

Phase 2 involves the preparation of 'concept proposal business cases' for each focus area using Phase 1 flow targets; the preliminary assessment of the impacts of changes to constraints on environmental water delivery and third parties; downstream impacts; and the initial assessment of options to address those impacts.

Modelling for the Phase 2 business cases used the following flow rates:

- Hume Dam to Yarrawonga Weir 40,000 ML per day
- Yarrawonga to Wakool Junction 50,000 ML per day[17]
- Lower Darling River 14,000 ML per day
- Goulburn River (Shepparton) 20,000 ML per day[18]
- Murrumbidgee River (Wagga) 40,000 ML per day
- The River Murray in South Australia 80,000 ML per day

The CMS envisions that Phase 2 would:

> *"… get down to a property-by-property assessment with regard to landholder impacts and mitigation options. If there are complex mitigation activities to be put in place, then the planning to be 'implementation ready' may extend past 2015."*[19]

A similar Basin-scale analysis was also proposed for the end of Phase 2.

However, the concept proposal business cases did not do property-by-property assessments and these still have not occurred in most focus areas because of:

- the lack of detailed property scale inundation information (aligned to local height gauges)
- concern that small, managed overbank events will make subsequent natural floods more damaging
- opposition to the notion that private land should be intentionally inundated
- the considerable opposition of some landholders to the Basin Plan generally.

The original CMS timetable is approximately three years behind schedule.

Flow targets for six focus areas were put into models run by the MDBA to achieve a notified flow rate of up to 80,000 ML per day at the SA border. Flow rates were notified in 2017. They were generally lower than the modelling undertaken for the Phase 2 business cases (see Table 1).

[15] Constraints Management Strategy (page 30)
[16] Constraints Management Strategy (page 30)
[17] 30,000ML/day target at Yarrawonga, and up to 50,000 ML/day at Yarrawonga under certain circumstances
[18] 17,000 ML/day target with a 3,000 ML/day unregulated flow risk management buffer
[19] Constraints Management Strategy (page 32)

The Ministerial Council considered progress with the Constraints projects at its meeting in December 2018 and responded to mounting concerns. The meeting Communique indicated that:

> *"Ministers agree to progress the Constraints Measures Coordinating Work Plan, noting:*
>
> - *The importance of addressing constraints to the achievement of the full 605 gigalitres Sustainable Diversion Limit Adjustment Mechanism;*
> - *That system constraints are impacting the delivery of both consumptive and environmental water and are likely to cause negative socio-economic and environmental impacts if not holistically addressed;*
> - *That the significant community concerns about the constraints program, including transparency and deliverability, will be addressed as a priority;*
> - *That community engagement and co-design in the implementation of this work plan will be fundamental to its successful delivery; and*
> - *The importance of understanding the implications and benefits of the notified constraints flow rates for delivery of the constraints package."* (MDBA, 2018)

The Victorian and NSW Ministers decided to appoint the Constraints Modelling Independent Expert Panel Review at the August 2019 Ministerial Council meeting in response to community concerns about the effect of higher flows inundating their land and businesses and doubts about the claimed ecological benefits. The Panel has been asked to help the Ministers provide transparency by considering whether the modelling and related work carried out to date is adequate to inform efforts to resolve community concerns, evaluate trade-offs, assess deliverability and understand the implications and benefits of the notified constraints flow rates.

# 4 The modelling challenge

Sophisticated modelling involving different types of planning models is required to inform efforts to resolve community concerns, evaluate trade-offs, assess deliverability and understand the implications and benefits of the notified constraints flow rates.

The steps and types of models required are illustrated in Figure 2.

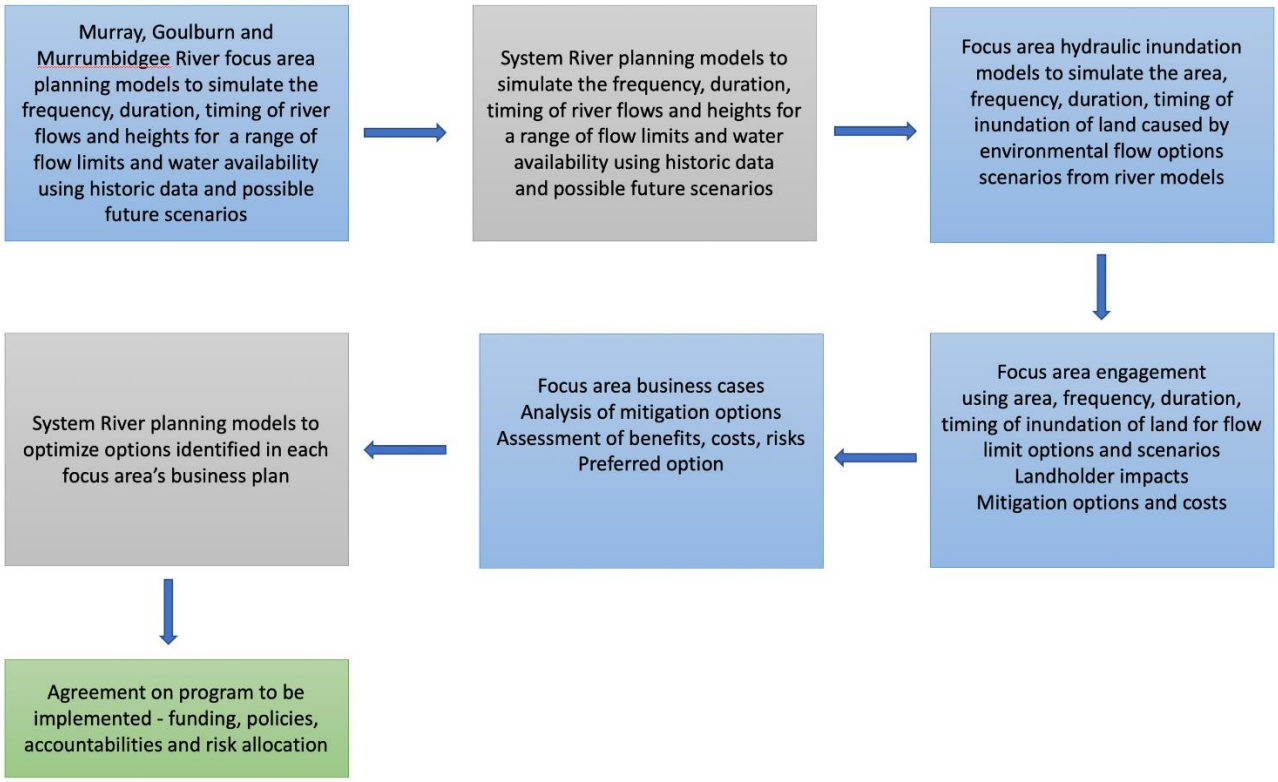


*Figure 2. Schematic of the steps and modelling required to develop and agree on an integrated constraints management program*

Operational models are required to assist river operators and environmental mangers to make decisions about the magnitude and timing of environmental releases to generate environmental flows whilst managing the risks that flows will exceed operational flow limits. Two, and potentially three, types of linked operational models will be required –

1. Rainfall runoff models to forecast unregulated flows including flood events
2. River models that forecast river flows and heights at key locations along the length of the river system
3. Inundation models aligned to river heights at key locations, that forecast the areas to be inundated by the forecast flows including the areas with environmental values.

## 4.1 Information needs

The Panel started with the information needs of landholders who may have land inundated by the notified flow rates, as landholder agreements are critical. Affected landholders and businesses need to know:

- the river gauge height being targeted
- what parts of their land will be inundated
- how often will it be inundated
- how long will it be inundated for
- what time of year will it be inundated
- how they will be informed of an impending event
- how much time they have to prepare for the event to arrive (for example: relocating livestock, or lifting pumps)
- what assistance will be available if the events are larger than intended (including compensation)
- how the wetting created by the flow events reduces or increases the risk of future flood damage
- how the effects of managed events compare to unregulated natural flooding events
- the aims of the over-bank flows for environmental and other benefits at a local level
- the flood mitigation benefits (at a local level) of the larger releases that are to be made to create the environmental flow events.

This information is essential for many landowners and land managers, to understand potential impacts on their businesses, to consider mitigating actions and the terms of agreements to permit inundation. It is also important that emergency managers are informed to ensure their community messaging is in line with the delivery of water down the system.

Public land managers will have similar information needs to private land holders. They will also need information to make decisions about closing public-access to areas likely to be inundated and providing warnings to people using the river and adjacent public land.

Local councils will need information about which of their roads and bridges may need to be closed because of the managed events. They will also need to consider the effect of higher river flows on their urban storm water drainage systems.

Environmental water managers will need information to make decisions about which environmental sites are to be watered. They will need to use this information to work with river operators to assess the risk of exceeding notified flow rates to confirm that the releases of environmental water allocations can be made.

River operators will need forecasting information to have the confidence to release the environmental flows within planned risk thresholds.

Governments will need to aggregate all of this information to develop business cases that optimise investment to improve the operational flexibility to deliver environmental water at a system level, allocate costs, to prioritise inundation events, agree arrangements to manage residual risks, be satisfied that benefits exceed costs, be confident that there is sufficient community support to implement the proposed measures and to fund implementation.

The following sections summarise the modelling that has been done for the CMS.

## 4.2 Modelling river hydrology for planning purposes

### 4.2.1 Background

A longstanding function of the MDBA is modelling to simulate flows down the Murray. Victoria and New South Wales have developed models that simulate flows in their tributaries.

The models are designed to simulate the principal hydrological processes of the River Murray and Lower Darling River systems including:

- river flow and tributary inflows
- operation of various dams and structures including:
    - operating rules for system constraints
    - rate-of-change rules to protect structures and the integrity of river banks
    - releases to meet forecast demands
    - pre-releases from each storage for flood mitigation
    - the allocation and use of environmental water
- transfers required between storages to ensure that demands can be met further downstream
- conveyance losses
- demand for water in the key irrigation regions throughout the system
- water sharing arrangements between NSW, Victoria and SA using the rules in the Murray-Darling Basin Agreement (Schedule 1 to the *Water Act 2007* (C'wth).

The purpose of the hydrological modelling work program undertaken for the Basin Plan was to inform the decision on the SDLs by illustrating the ecological outcomes that could be achieved with water recovery under the Basin Plan (MDBA 2017b).

The modelling undertaken to inform the Basin Plan linked 24 river system models developed by State agencies, the MDBA and Snowy Hydro. The models for the Southern Connected Basin were run using historic climate data over the 114 year period from 1 July 1895 to 30 June 2009 (MDBA 2012). The MDBA's MSM-BigMod platform was used for the River Murray, and NSW's IQQM and Victoria's REALM platforms used for the Murrumbidgee and Goulburn System respectively. IQQM was run on a daily time step and REALM was run on monthly time steps. MSM-BigMod was run in 'mixed mode' with some operating decisions being made monthly and others daily.

The following management scenarios were initially modelled:

- the baseline scenario
- the 'without development' scenario
- Basin Plan scenarios (multiple scenarios, with 2800 GL reduction basin-wide being the key scenario).

The baseline scenario was used to define **Baseline Diversion Limits** (BDL) to represent the river operating arrangements, constraints and policies at 2009 together with the diversion limits established by the Murray-Darling Basin Cap, state water sharing rules, and the environmental allocations available at that time.

The ‘without development’ scenario was used to simulate natural conditions. It was based on the baseline scenario, but all the dams, irrigation and environmental works/infrastructure, all consumptive users (such as irrigation, town water supply and industrial water uses) and the rules governing flows such as channel capacity constraints were removed. The natural conditions were used to compare and assess environmental flow scenarios with natural conditions.

The Panel has been advised that the Basin Plan modelling shows that the unused balance of environmental allocations is in most years was very high. There were many years when releases were not made to supply extra flow. This implies that much of the environmental benefit achieved were the result of storage levels being higher and storage spills being larger and longer. Questions about any legal liability associated with increased flooding arising from decisions to store rather than release environmental allocations were not resolved.

Making greater use of environmental allocations rather than storing them, for example by supplying extra regulated water to the Lower Lakes and the Murray Mouth utilising long period of high but in-channel flows, is likely to reduce the environmental benefits that have been assigned to the Basin Plan water recovery.

The Basin Plan scenarios were used to represent the changes in the flow regimes that can be achieved through the recovery and use of water for the environment under the Basin Plan. The key Basin Plan scenarios modelled were:

- BP-2800 - 2800 GL/y reduction in consumptive use basin wide
- BP-2400 - Alternative scenario of 2400 GL/y reduction in consumptive use basin wide
- BP-3200 - Alternative scenario of 3200 GL/y reduction in consumptive use basin wide

BP-2400 is closest to the level of water recovery required assuming the 605 SDL offsets are acquired.

The model runs produced a time series of flow rates at key locations along the rivers. These sites were called hydrologic indicator sites. The hydrologic indicator sites, and flows described at those sites, were used to represent the broader environmental flow needs of river valleys or reaches.

Time series of environmental demands comprising desired flow events were created for a subset of the hydrologic indicator sites, based on environmental objectives and targets. The modelled environmental water demands were designed to address shortfalls in various ecologically significant components of the natural flow regime.

The achievement of desired flows at indicator sites were used as performance measures to test the environmental outcomes for different scenarios. The hydrological outcomes and consequent environmental improvements for the scenarios were assessed based on the degree of success in meeting the site-specific flow indicators.

One of the key insights gained through this work was that the requirement to retain flows within the river channel was limiting the ability to deliver sufficiently high flows to inundate mid to high elevation floodplains. Without the ability to deliver higher daily flow rates, outcomes such as watering river red gum and black box woodlands on these floodplains was unachievable, regardless of how much environmental water was available.

The Murray–Darling Basin Ministerial Council responded to this insight by requesting that the MDBA model some 'relaxed constraints' scenarios. The MDBA completed two 'relaxed constraints' model scenarios representing Basin-wide water recovery of 2800 and 3200 GL/y respectively. These scenarios were referred to as 'BP-2800-RC' and 'BP-3200-RC'.

The MDBA did further modelling in 2017 to make agreed updates to the Basin Plan Benchmark model to simulate the implementation of the Basin Plan to achieve 2,750 GL of water recovery for the environment (MDBA 2017a).

This model was then further developed as the Sustainable Diversion Limits Adjustment Mechanism model (SDLAM) by including the supply measures package that included relaxing constraints. An overview of constraints used in the modelling scenarios is provided in Table 1.

*Table 1: Modelling of relaxing of constraints compared to current operating practice*

| Focus area | Location | Current operations (ML/d) | Basin Plan relaxed constraints (ML/d) | SDLAM (605GL) (ML/d) |
|---|---|---|---|---|
| Murrumbidgee | Gundagai | 30,000 | 50,000 | 38,000[1] |
| | Balranald | 9,000 | 12,000 | 12,000 |
| Goulburn | Alexandra | 9,500 | 15,000 | 9,500 |
| | McCoys Bridge | 8,500 | 40,000 | 17,000[2] |
| Murray | Hume to Yarrawonga | 25,000 | 40,000 | 40,000 |
| | Yarrawonga to Wakool | 15,000 | 40,000 | 50,000[3] |
| Lower Darling | Weir 32 | 9,300 | 18,000 | 14,000 |
| Murray | SA Border | | 80,000 | 80,000 |

Notes

1. Equivalent to 40,000 to 45,000 ML/d at Wagga Wagga, the concept business case assumed 30,000 ML/d with a buffer to 50,000 ML/d.
2. Goulburn concept business case assumed 17,000 ML/d at Shepparton with buffer to 20,000 ML/d
3. Yarrawonga to Wakool 30,000ML/d with buffer of 50,000 ML/d

The next major improvement in modelling capability is to convert existing models to a common modelling platform called 'Source'. The MDBA is developing and calibrating the 'Source' model for the Murray and Lower Darling. This model will operate on a daily time step to simulate hydrologic behaviour within the Murray River (from Khancoban to the barrages) and along the Lower Darling River (from Menindee Lakes to Wentworth) using a daily time step. A daily 'Source' model has also

been developed for Victoria's Goulburn system. This model is well advanced and is currently being independently reviewed.

Further work is required to link the Murray 'Source' model to the Goulburn model and a 'Source' model of the Murrumbidgee which is still under development. Linking the models should enable enhanced optimisation at the system scale.

Murray 'Source' model has been independently reviewed (Jakeman et al. 2019). Basin States made various suggestions to the reviewers to improve the model. The reviewers found that the model comprises the best available knowledge and information and is fit for purpose for estimating the BDL, and as part of the method for estimating annual permitted take in Water Resource Plans (WRPs).

While concluding the results indicated that the model was performing satisfactorily, several improvements to model performance assessment processes were suggested to the Panel. Among these are practical methods of sensitivity analysis and uncertainty assessment. Wherever possible, performance should be assessed against observed stream gauge heights and inundation data.

The MDBA acknowledges that although the evidence base used to date to implement constraints measures is fit for purpose for long term planning such as Basin Plan development and SDL adjustment determination, it is not adequate for assessing risks, local scale impacts and operationalising the enhanced environmental water delivery project of the SDLAM projects (MDBA, 2019a).

### 4.2.2 Further development

The hydrology models of the Murray, Murrumbidgee and Goulburn river systems have been developed and improved over many years as better data becomes available or flow behaviour extends beyond the range of previous calibrations. There is a high level of confidence in using these models for planning water deliveries for irrigators, for end-of-system commitments and for water accounting purposes. The panel were advised during consultation that improvements to these models are ongoing.

Different software platforms are used to model the three river systems. This has meant that it is necessary to run the Murrumbidgee and Goulburn models to provide flow inputs to the Murray model.

Work is currently underway to transfer the models for each river system onto the 'Source' modelling platform. The 'Source' Murray Model is continuing to be developed so that it can replace the current MDBA Murray modelling software.

The ultimate aim is to link the Goulburn and Murrumbidgee 'Source' models with the 'Source' Murray model to enhance the capability to deliver better planning at the system scale.

### 4.2.3 Panel observations

The Panel, having regard to the discussions at the workshop and with the technical experts, is of the opinion that the river hydrology planning models are fit for the purposes they were originally developed for (i.e. understanding flow-rates and assuring delivery of at least the minimum ordered volumes of water downstream), but need further development to enhance their capabilities to

inform landholders of the level and area inundated by *managed* inundation events, the extent of 'natural' flood events and the final designs of the CMP.

Areas the Panel considers would assist in improving transparency, reduce the level of uncertainty of modelled outcomes and contribute to improved confidence include:

- ensuring that the current river operating rules are accurately reflected in the baseline model runs
- incorporating contemporary environmental flow management rules into the models rather than the flow-based triggers that are currently modelled
- enhancing the capabilities of the models to estimate and present environmental outcomes. One possibility would be to improve the linkages between the river planning models and the inundation models to:
    - represent the areas where environmental values will be improved
    - assess the consequences of inundation for landholders
- linking the Murrumbidgee, Goulburn and Murray models together to enable the model to optimise the system as a whole
- upgrading models to better reflect how carryover is being used by both irrigators and environmental water holders, and how this may impact subsequent season flood events.

The Panel also considers that there would be merit in modelling a range of realistic future scenarios using the existing modelling platforms or ideally using the enhanced and integrated models. Matters warranting scenario based analysis include:

- the reductions in flows projected by climate change models and the consequent reductions in the amount of water available to water users including the environment. Currently MDBA modelling is based on 114 years of data for the period 1895 to 2009. Victoria's DELWP (2016) recommends that when assessing climate change impacts on water availability a 'current climate' baseline period from July 1975 to date be used and four plausible future climate scenarios be considered. Low, medium and high climate change scenarios developed by CSIRO based on the RCP8.5 emissions and a fourth scenario to represent a step-change in the climate.
- the effects of recovering different volumes of water for the environment on the environmental outcomes and how this would change the choice of the notified flow rates
- the optimum combination of notified flow levels in each focus area to enable environmental benefits and costs to be assessed together.

The Basin Plan was based on historic flow data and did evaluate climate change projections. However, the Panel considers that including some consideration of climate change in the CMP will improve the chances for a successful program. The reductions in flows projected by climate change assessments should be carefully evaluated. For example, the amount of water available for the environment may be reduced, expensive easements may no longer required at some locations, the magnitude and timing of irrigation demands, and the notified flow rates may need to be changed. It may also be necessary to change environmental management objectives at some locations to take account of the effects of climate change on future flow regimes and water availability.

## 4.3 Hydrodynamic modelling of floodplain inundation for planning purposes

### 4.3.1 Background

Flood inundation models, also called hydrodynamic or hydraulic models, are a major tool for understanding and mitigating the effects of flooding. Traditionally they were used to provide predictions of flood extent, depth and flow paths for the development of spatially accurate risk maps for planning purposes. These allow the assessment of risk to life and property in the floodplain, and the prioritisation of either the maintenance of existing flood defences or the construction of new ones. Typically, the focus of this work was related to understanding the risks of potentially damaging flood events, and not related to better understanding environmental watering (i.e. small events that are just above overbank height).

In Victoria, the first large-scale hydrodynamic model developed for floodplain rehabilitation was of the lower Goulburn River for the Lower Goulburn Floodplain Rehabilitation Scheme. The use of hydrodynamic models for environmental purposes then became standard, as the approach was applied to most of the icon sites as part of The Living Murray program. Over time these hydrodynamic models have been enhanced and others have been developed to cover more floodplain wetlands.

The CMP has used flood inundation models in two ways. Firstly, detailed models have been prepared to provide the hydraulic information needed to design the water control structures (regulators and levees) to water key wetlands and environmental assets. Secondly, models have been developed to assess the areas potentially inundated by the notified overbank flow rates to provide input to some of the constraint key focus area concept business cases. The models for environmental watering use more detailed data and are more granular than those used for the development of the business cases.

Six distinct categories of data are required for modelling:

- topographic data of the channel and floodplain to act as model bathymetry
- time series of flow rates and water levels to provide model input and output boundary conditions
- roughness coefficients for channel and floodplain, which may be spatially distributed
- loss rates for variable levels of soil seepage and evapotranspiration
- structure details of regulators, weirs, culverts, levees etc.
- observed inundation data for model calibration, validation and assimilation.

River channel topography data is traditionally generated from a series of cross-sections along the channel using ground surveying techniques, then interpolating between the cross-sections. Generating sufficient channel topographical data to support accurate modelling of complex, and geographically flat floodplains such as the Edward-Wakool area is data intensive and challenging.

High quality topographic data is required of embankments and levees controlling overbank flow (~10cm vertical accuracy and 2m spatial resolution) to model inundation around the threshold between bank full and overbank flow. The micro-topography of relict channels and floodways on the floodplain are also important. This topography is typically described using aerial laser survey, also known as LiDAR (Light Detection and Ranging), which typically offers vertical accuracies of plus or

minus 10 to 20 cm. At higher flood depths, inundation is controlled mainly by the larger scale valley morphology and detailed knowledge of the micro-topography becomes less critical.

Accurate modelling of the inundation caused by the notified flow rates, which are all below minor flood level, requires detailed micro-topographic data, including surveys of river bank and levee levels. Understanding the condition of the levees, some more than a century old, will also be critical for developing and costing detailed mitigation plans.

The management, ownership and liability arrangements of levees on both private and public land are complex. The Panel has been advised that the condition of many levees is not known and that many are likely not to be in good condition of levees failing even though managed flows are expected to be below minor flood levels.

Bulk flow rates and stage data are required to provide model boundary conditions. The data are usually acquired from stream gauging stations. Accurate modelling requires stream gauges at critical locations on the river network and generally not too far apart (10-60 km). Ideally it requires gauged flow rates to be accurate to 5% for all flow rates, with all significant tributaries in a catchment gauged. Reliable gauges and reference gauge-heights for river flows are the key to building community confidence in the river operations and are likely to be the key definitive reference points in discussions and negotiations with impacted landowners. Actual flow rates (e.g. 31,000 ML/day) are a secondary reference point, derived from flow gauge readings. The availability of appropriate gauging stations (and the rapid and clear communication of these gauge heights during flow-events) is a limitation, particularly in the Goulburn and Murrumbidgee focus areas.

For successful validation, two-dimensional flood inundation models require spatially distributed observational flood data at a scale commensurate with model predictions. The observations may be maps of inundation extent, water level/depth or flow velocity. Calibration improves as the number of events modelled increases.

The hydrology models are also used to simulate time series of bulk flows and stage data for planned environmental flows as inputs to the flood inundation models.

In addition to the hydrodynamic models developed throughout the Basin, the CSIRO developed the RiM-FIM model, which uses inundation extents from satellite imagery and associates them with a flow rate at a nearby streamflow gauge at the time of the image.

Table 2 lists the inundation models used for the CMS.

*Table 2: Models used for developing CMS business cases, their current status and future plans (Source MDBA)*

| Reach | Development of business case | Current Status | Future Plan |
|---|---|---|---|
| Hume to Yarrawonga | MIKE-11 and LiDAR assessment | Major improvement is completed by MDBA to develop and calibrate a combined 1-D and 2-D model | Scenario modelling as required |
| Edward-Wakool | RiM-FIM (1 m of LiDAR and 30 m of Landsat image) | A MIKE hydrodynamic model is currently being developed and calibrated | Scenario modelling as required |

| | | | |
|---|---|---|---|
| | | by MDBA (expected finish by end 2019) | |
| SA Murray | MIKE-21 | - | Scenario modelling as required |
| Lower Darling | RiM-FIM (5 m of LiDAR and 30 m of Landsat image) | 1 m of LiDAR available, modelling requirement is being assessed by NSW SDLAM delivery team | Develop/refine model as requested by NSW. Work not yet defined |
| Goulburn | MIKE-11 and MIKE-21 | - | Scenario modelling as required |
| Murrumbidgee - Upper | MIKE-11 | CARM Operation | Modelling requirement is being assessed by NSW SDLAM delivery team |
| Murrumbidgee - Yanco | RiM-FIM (5 m of LiDAR and 30 m of Landsat image) | SOBEK (2-D) | Modelling requirement is being assessed by NSW SDLAM delivery team |
| Murrumbidgee - Lower | RiM-FIM (5 m of LiDAR and 30 m of Landsat image) | - | Modelling requirement is being assessed by NSW SDLAM delivery team |

Detailed hydrodynamic models have been prepared for the wetland watering sites along the Murray shown in Figure 3.

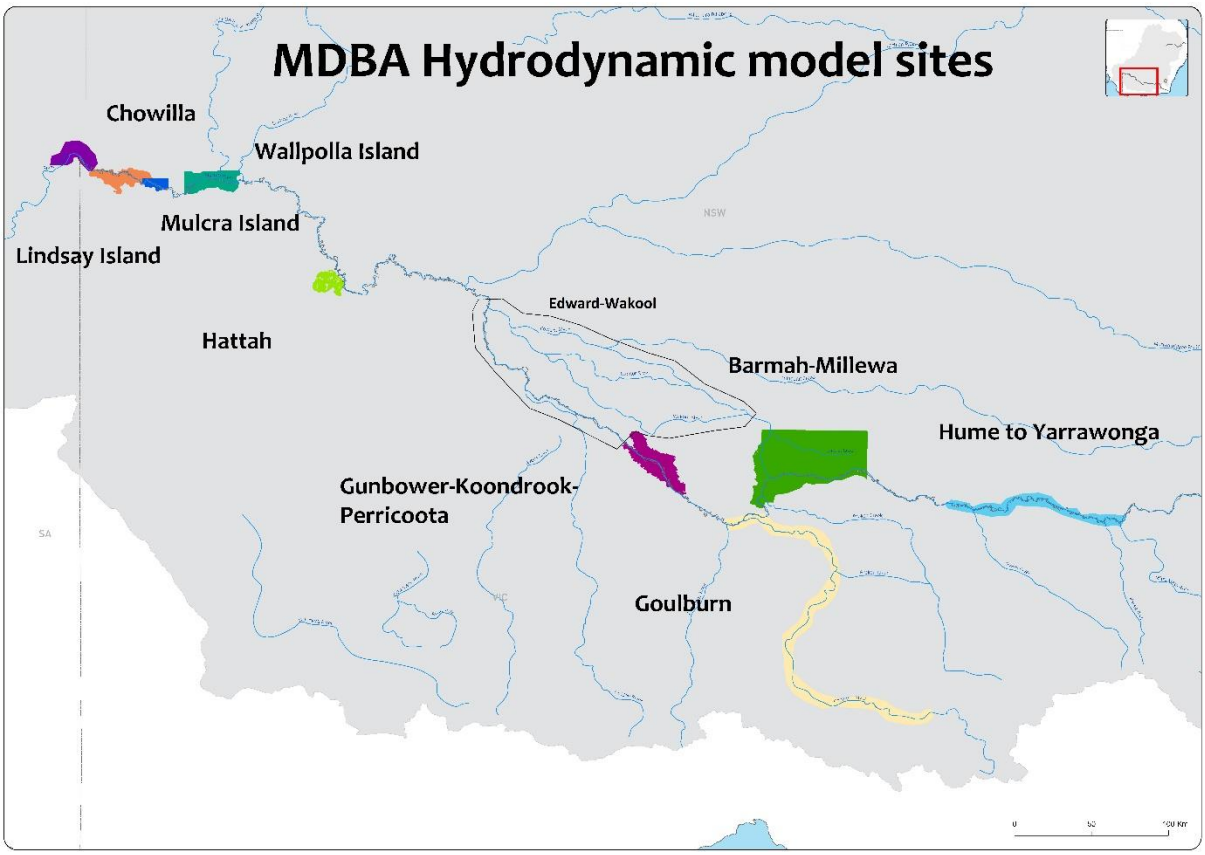


*Figure 3: Location of primary hydrodynamic models held and maintained by MDBA (Source MDBA)*

These models are being progressively upgraded to high resolution mesh models (these enable the grid size to be varied to match the complexity of the hydraulics) and are being used to generate operational advice and monitoring, estimates of water-use, inundation extents and data for further development of the models of river hydrology.

The flood inundation modelling done in 2015 for the relatively simple Goulburn floodplain (i.e. compared to the Edward Wakool area) was reviewed by Fluvial Systems in 2016.

The reviewer reported that model predictions for the lower Goulburn model for three flows of 25,000, 30,000 and 35,000 ML/d were within -0.17m to 0.08m. At the higher flow rate of 55,000 ML/d the model fit ranged from an underestimation of 0.45m to an overestimation of 0.37m.

The review concluded that the modelling was 'fit for purpose', the purpose being to provide information for the development of the business case. But the reviewer considered that the level of modelling uncertainty would be too high for a detailed study of flood impacts on natural and cultural assets. This level of uncertainty is also an issue for landholders that are expected to be subject to some inundation under the notified flow rates.

### 4.3.2 Future development

The proposed future development of the inundation models is included in Table 2. The MDBA has also advised the Panel of the work program needed to improve data to enhance the calibration of the models and run them. The current work program includes:

- **Bathymetry**: SA Water has been contracted to capture cross section data for the MDBA. As at July 2019, SA Water had captured the Edward, Wakool and the Murray area.

- **LiDAR capture**: MDBA has coverage of LiDAR data for all the Key Focus Areas and also has access to Geoscience Australia LiDAR/ DEM program.
- **Aerial Imagery**: Aerial imagery along the Murray, Goulburn and Murrumbidgee River reaches of interest was captured at various flow levels during the 2016 flood event. The imagery was taken at flow rates under consideration for the Constraints Business cases/concept proposals at the time. This imagery has assisted with calibration of the Hydrodynamic models.
- **Further calibration**: the existing hydrodynamic models were established before the 2016 floods had occurred, and thus were not able to take advantage of the observed flood data for validation and refinement of model parameters. This flood included floodplain inundation behaviour of direct relevance to environmental watering and represents a valuable increase the information that could be used to improve confidence in the hydrodynamic model simulations.
- **Satellite imagery**: During 2018 the MDBA began development of a Basin-scale satellite imagery monitoring program named "MDBSat", which uses in the first instance, free and publicly available "Sentinel" satellite imagery provided by the European Space Agency. Sentinel provides a fresh image across the Basin to 20m resolution every 5 days, with an archive extending back to 2016. The aim of MDBSat is to produce a regularly updated Basin-wide satellite imagery dataset, coupled to gauge flow information and other supporting data, from which specific studies into the broad-scale presence of water and vegetation in the landscape can be made.
- **Datacube:** is a digital imagery platform and data product service provided by Geoscience Australia. Currently, the Datacube processes Landsat imagery into different data products for analysis, which can take a number of weeks for the automated algorithms to complete their processes. The imagery and analysis in the Datacube requires specific expertise for access. Geoscience Australia is currently working towards the inclusion of Sentinel imagery and reducing processing times and increasing accessibility.
- MDBA is working with Geoscience Australia to develop an inundation history tool which can determine historical inundation footprints based on 30 years of satellite imagery. This project is currently being considered by the MDBA to refine useability. The expectation is a useable product will be available in 2020 with information supporting Constraints projects available at that time.

An important benefit of the inundation modelling is that it provides information that is needed to improve the performance of river planning and river operating models.

### 4.3.3 Panel observations

The Panel, after considering the discussions at the workshops and with the technical experts, considers that the flood inundation models, where they were available, have made a valuable contribution to the pre-feasibility assessment of the constraints measures but are currently inadequate to determine with adequate confidence the extent, depth and duration of inundation at the property scale. Landholders require information at the property scale to assess the consequences of the notified flow rates on their properties and businesses.

The Panel is concerned that the projected extent of inundation in the Edward Wakool area and the Murrumbidgee area relied on Lidar and satellite imagery of varying resolution. It is pleasing to hear that a more accurate model is being developed for the Edward Wakool area and the modelling needs for the Murrumbidgee are currently being assessed.

The Panel has been advised that significant effort has been made to improve the accuracy of the inundation models required for managing wetland watering. It is possible that landholders will expect models of equivalent accuracy to be developed to simulate the inundation of their

properties. However, based on the peer review of the Goulburn inundation modelling (Fluvial Systems, 2016), there is still considerable uncertainty about the extent and depth of inundation particularly at higher flows

The Panel recognises that accurate inundation modelling is data intensive and that data is currently not available or very sparse in some areas (e.g. the lower Murrumbidgee). The Panel has been advised that aerial photography of flood events is an important source of information for calibrating and verifying models. Aerial photography cross referenced to gauge height information is also a very valuable resource for consulting with landholders. The Panel has been advised that in general, people have more confidence in the photography (aligned recent height gauge height data) than they have in the modelling. However, only limited aerial photography at around the notified flow rates levels is available. More photography and high resolution satellite imagery – particularly that relevant to the 2016 flood event – would greatly benefit the CMP but this currently depends on natural events which are highly unpredictable unless agreements can be reached with landholders to conduct trials on a 'no regrets' basis. While the satellite imagery is a very good observational tool that will assist in landholder engagement, it cannot be used for mitigation investigations or to understand flow behaviour in instances where something out of the ordinary occurs (like a levee failure). Hydrodynamic models are better suited to these sorts of investigations. The high quality modelling and high resolution satellite imagery together, in combination will provide the tools required to understand inundation extents and how to effectively manage risk.

Areas that the Panel considers would assist in improving transparency, reduce the level of uncertainty about the extent, depth and duration of inundation and contribute to improved confidence include:

- complete the inundation model for the Edward Wakool area
- confirm the modelling approach to be used for the Murrumbidgee and undertake the modelling as a matter of priority
- undertake an active program of trials to collect more aerial photography and other data to supplement satellite imagery to develop a trusted library of information that will decrease modelling uncertainty and provide a robust basis for negotiating landholder agreements
- establish arrangements to collect additional data from the 2016 flood event and future natural flood events
- supplement the stream gauging and rain gauging network to provide definitive reference points for discussions and negotiations with impacted landowners and, overtime, improve the calibration of inundation models to local stream gauge heights.
- acknowledge the extended period of time it will realistically take to engage landowners, conduct trials and develop the information required to have the constructive conversations with landholders needed to settle enduring agreements at both local and system-wide scales.

## 4.4 Modelling river hydrology for operational purposes

### 4.4.1 Background

The main role of river operators is to release water from storages to satisfy downstream water demands. Their role changes during floods when they operate rivers to mitigate flood damage, but

only to the extent that their dam safety and water supply functions are not compromised. River operators aim to manage rivers efficiently by minimising delivery shortfalls while also minimising delivery losses.

River operators aim to:

- minimise the amount of water released from storage
- maximise the use of inflows from tributaries below the storages to meet demand
- avoid supplying more water than required by users
- avoid supplying more water than is required to meet flow targets at specified points
- minimise conveyance losses (which typically involves avoiding overbank flows)
- transfer water to downstream storages to supply peak summer demands in South Australia that would otherwise exceed channel capacity at potentially environmentally damaging times (i.e. avoid high flows in mid-late summer)
- maintain storage space in downstream storages to enable excess flows to be captured to supply demands further downstream, without drawing on upstream storages.
- mitigate flood events.

To do this the river operators must forecast future:

- inflows from tributaries downstream of storages
- demand from water users (i.e. what is needed to be supplied)
- conveyance losses (i.e. leakage, seepage and evaporation losses that occur while the water is in transit and storage)
- travel times (i.e. the time it takes for the water to arrive at where it is to be used, a factor that is dependent on flow magnitude and antecedent conditions).

This information is used to determine how much water should be released from storages to supply downstream demands. Information is updated daily and storage releases are adjusted as required. River operators are also required to comply with various operating rules (i.e. limits on how quickly storage releases can be increased or decreased (i.e. the rate of rise or fall of river heights).

River operators use a variety of models of varying sophistication to help them perform their duties. The starting point is assembling measured data on weather conditions, flows, water orders from users, and estimated transit times. This is then supplemented by estimates of some parameters that are based on past operational experience, past water demand, known irrigated crop areas, and forecast information which can come from a range of modelling sources. The various data are then aggregated in spreadsheet models or more sophisticated river operating models. Models are used to assemble the various data and route flows down the rivers.

There are uncertainties associated with these forecasts which are compounded by the time it takes for water released from the upper catchment storages to travel through the system. The uncertainties are relatively small in reaches immediately downstream of storages, but are substantial when delivering water to the South Australian border. Approximate travel times are shown in Figure 4. The times are approximate because the actual times depend on the river flow rates and antecedent conditions. Times are shorter when flow is contained in channel. The major source of uncertainty is the ability to forecast the weather which has a major effect on water use demand (i.e. irrigation demands during prolonged summer heat waves) and tributary flows which

are closely related to the location, amount and intensity of rainfall. The Panel has been advised that the accuracy of the forecasts required by river operators decline rapidly as the length of the forecast extends beyond two to five days.

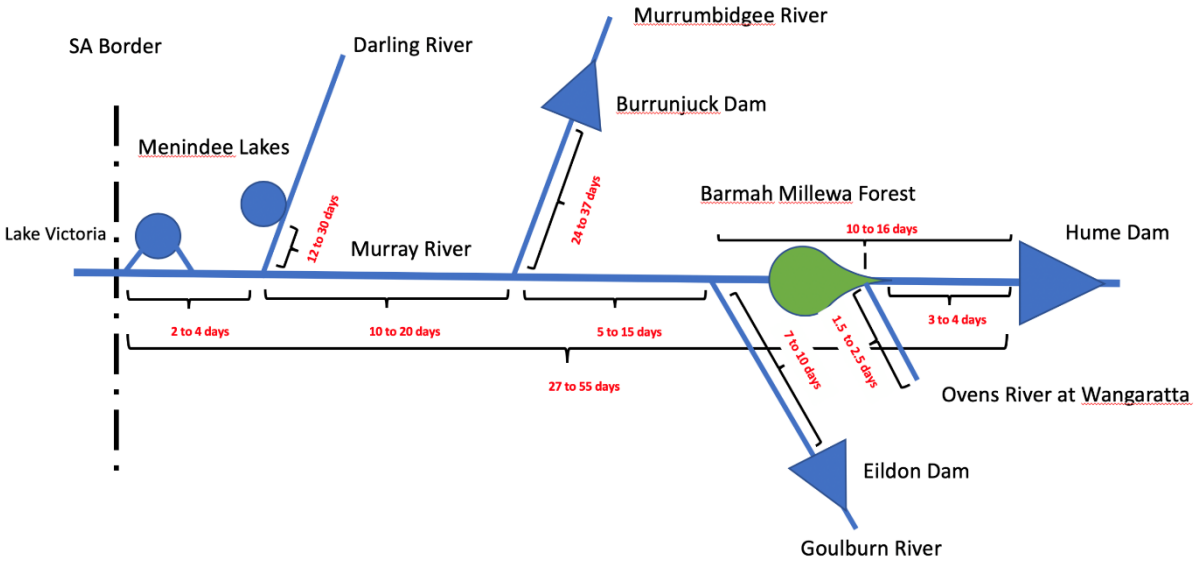


*Figure 4. Schematic showing approximate travel times.*

The Panel has also been advised that no two flood events are alike: they are affected by many factors which vary naturally from flood to flood event, and represent uncertainties that can never be wholly reduced.

### 4.4.2 Further developments

Work is underway to improve the performance of the models used by river operators. Workshop attendees representing both state agencies and the MDBA confirmed this work is ongoing. A combined real-time operating model of the Murrumbidgee, Goulburn and Murray systems is currently not available.

New South Wales uses Excel spreadsheets to support its Murrumbidgee River operators and has also developed a model called the Computer Aided River Management (CARM) decision support system. This model is still being trialled, but it has been used successfully in recent years to improve river delivery efficiency of ordered water, and to help better-manage environmental flow events down the Murrumbidgee.

GMW currently has no plan to upgrade the models used to operate the Goulburn River, but it has flagged that it may be necessary to move to a 'Source' model in the future to manage more complex environmental water releases. 'Source' allows for greater daily streamflow predictive capacity under relaxed operating constraints and enhanced resource use under continuing climate change impacts.

The MDBA uses linked databases and a complex spreadsheet model to inform Murray River daily operational decisions. It is also well advanced in developing a 'Source' river operating model for the Murray River. It is expected that this will provide the next generation of river operations decision support tools. It will ultimately replace the system of Excel spreadsheets currently used for daily river operations. The 'Source' river operating model is a more sophisticated representation of the Murray River system. It includes more accurate flow routing and loss representation. It will also

provide improved functionality (i.e. the ability to run scenarios) to support more complex decision-making and risk analysis associated with environmental water delivery and demand forecasting.

The Enhanced Environmental Water Delivery Project discussed in section 2.2.1 is a longer term project to improve the operational coordination of environmental water deliveries across the Southern Connected Basin. The work involves developing sophisticated triggers for releasing environmental flows based on analyses of historic information, improved weather forecasting and better coordination of releases from storages on the Murray and its tributaries.

### 4.4.3 Panel observations

It is clear to the Panel that river operators already make decisions in the face of significant uncertainty. River operators have advised that releasing water to provide overbank flows for the environment significantly increases the risks of unintended and unwanted consequences.

Under current arrangements if an operator is making large within-bank releases to supply downstream demands and they receive a forecast of heavy rain in the next few days, they reduce releases to avoid potential flood damage. In the event that significant rains occur and there are subsequently overbank flows those overbank flows are considered to be ‘natural’. The river operators are not liable as long as they have taken reasonable steps to avoid flood damage. In addition, these high releases tend to occur when irrigation demands are high. High irrigation demands typically occur under dry conditions, the catchments are relatively dry and there is not a rapid, large runoff response if rainfall does occur. This also reduces risks of flood damage and provides a margin of safety.

River operators are required to follow formally adopted rules when managing flood events. Generally the objectives of the flood operating rules are to reduce flood damage, but only to the extent that this does not conflict with objectives to conserve water and maintain the structural safety of dams and other major control structures. In practical terms the operators may make pre-releases to create air space in storages to reduce the size of a forecast flood and may release water after the peak has past to create 'air space’ to mitigate follow-up inflow events. Generally, the river operators do not pass-through large events, and are careful to ensure that the releases from storages are less than the flows entering the storages at any given time. They do this to avoid liability for the damage the flood causes.

The risks of releasing environmental water to produce environmental flows are substantially higher because the river operator will be asked to increase releases to produce an overbank flow when rainfall occurs. They will not have acted to reduce risks. They will have acted to increase the risk of damage to crops and other assets and may not be able to argue that the subsequent overbank flow was ‘natural’. They may not be able to argue that they took reasonable steps to reduce flood damage. This may not be a problem if the subsequent overbank flows stay within the design limits. However, the ability to stay within the design limits is highly dependent on the accuracy of weather forecasts and predictions of inflows below the storages. In the absence of tools available to increase accuracy of weather forecasts and reduce uncertainty, detailed design should include significant buffers to provide a greater likelihood that flows stay within the design limits.

The Panel has been advised that it is likely that the models used to route water down the rivers will improve as more data, particularly actual event-observations, becomes available to calibrate them. However, the Panel has also been advised about the high levels of uncertainty associated with rainfall and runoff forecasts, particularly in high runoff areas of the upper-catchment. This means that there is a significant risk of getting it wrong and the forecasts:

- over-estimate rainfall and runoff and environmental water is released but the desired overbank flows do not occur, the environmental benefits are not realised. This would be a non-financial risk for the environmental water holders.
- under-estimate rainfall and runoff and notified flow rates are exceeded, causing damage and inundating areas not covered by landholder agreements. This would be a financial risk for river operators under the current legal framework.

The river operator risks are exacerbated because the environmental releases are expected to occur in the spring when the catchments are likely to be wet, significant rainfall events are more likely, and produce significant runoff when it rains (i.e. the margins of safety are relatively low).

Decisions about undertaking controlled burns for bushfire control have a similar dependence on the ability to forecast weather and catchment conditions. However, controlled burns are targeted to the times of year when the risks of fires escaping from control lines is low (i.e. in the autumn and early spring). Despite these precautions, controlled burns occasionally escape their control lines. The difference with environmental releases is that they will be targeted to occur in spring when the risks of flood inducing rainfall is high – not low.

The Panel considers that it is unreasonable to expect or depend on improvements in river operating models to eliminate the risks of unintended flooding. There will always be a residual risk and the CMP will need to determine who will be accountable for these risks: Options include:

- the Commonwealth government alone
- the States and Commonwealth governments through the existing Murray-Darling Basin Agreement arrangements (extended to the Murrumbidgee and Goulburn)
- environmental water holders
- river operators
- landholders.

The other approach to manage the residual risks would be to design large buffers into the constraints measures projects. For example, this would mean that a margin of safety would be added to the design of structures and landholder agreements (e.g. accounting for land that would be flooded at a flow of 50,000 ML/ even though design flows would not exceed 40,000 ML/d). Building in a margin of safety would increase the financial costs, increase the number of landholder agreements that would be needed and increase risk that governments' reputation would be damaged by building excessively oversized structures, particularly if climate change reduces future flows.

Areas that the Panel considers requiring continued investment include:

- development of the next generation of river operating models
- improvements in the stream gauging networks and access to the data in real time

- improvements in the rainfall gauging networks and access to the data in real time
- analysis of the sources and levels of uncertainty in the models and the potential to reduce these uncertainties
- a realistic assessment of the risk tolerance of governments and the associated costs
- work to determine accountabilities for residual risks.

## 4.5 SDL offset modelling

The effect of implementing the measures outlined in the business cases for the six focus areas[20] were not modelled together to show the system-wide benefits. Instead, the MDBA modelled the 36 SDL supply measures together in the SDL Adjustment scenario model (MDBA, 2017c). Results from this model run were compared with the SDL Benchmark scenario model (MDBA, 2017a).

It is not possible to confirm from the published report (MDBA, 2017a) that the operating rules in the benchmark model are the same as the current operating rules. The Panel did confirm that the assumed rules for making environmental releases are not the same as how the environmental flows are currently released. This is to be expected because the current environmental flow releases are normally designed to not exceed the bank full flows.

The modelling incorporated the Ecological Elements method to assess incremental changes in an environmental index and the "Limits of Change" provisions in the Basin Plan.

The Sustainable Diversion Limits (Adjustment) - Ecological Elements method ('SDL-EE method') was developed by CSIRO for the MDBA. The Panel notes that the CSIRO (CSIRO, 2014) described the method as a highly simplified hydro-ecological model that does not try to predict a score that relates to actual ecosystem health; it is an ecological scoring model that uses simple hydrological metrics in a marginal change scenario. It is also not designed to evaluate the in-channel and near-channel ecological benefits.

The draft method was reviewed in 2014 by an Independent Review Panel (MDBA, 2014). This review concluded the method to be fit for the SDL-adjustment purpose subject to the completion of further testing by the MDBA, but the method was also novel and untried. Further trials were undertaken by CSIRO (MDBA, 2015a). The Independent Review Panel considered this additional work and wrote to the MDBA in 2015 advising that the SDL-EE method complies with the review objectives (MDBA 2015b). Details about the how the method was adjusted in response to their initial findings were not published with their letter.

The aim of the modelling was to ensure that the ecological score for the SDL Adjustment scenario was equal to or greater than the score for the benchmark run (2,750 GL recovered and no easing of constraints). Results were expressed in terms of the change in the environmental index, or 'ecological elements reach' points score[21]. The results in Table 3 show that the 36 offset measures

[20] The Constraints Management Strategy includes seven focus areas. However, the Gwydir focus area is in the Northern Basin and is not part of the SDLAM.

[21] These scores are very sensitive to natural climatic variability and as such are not "robust". They indicate incremental change but do not articulate environmental outcomes.

provide a slightly higher score than the benchmark score. Note, the major improvements occur in the central, mid and lower Murray areas with slightly inferior results in other focus areas.

*Table 3. Comparison of the ecological elements reach score for the benchmark and SDL offset model runs*

| Assessment Reach | Benchmark (2,750 GL) | SDL605 | Difference | Percent |
|---|---|---|---|---|
| Upper Murray - Barmah Millewa Forest | 5100 | 5017 | -83 | -2% |
| Central Murray - Gunbower Perricoota | 5567 | 6376 | 809 | 15% |
| Mid Murray - Hattah | 3387 | 3955 | 568 | 17% |
| Lower Murray - Chowilla | 3970 | 4271 | 301 | 8% |
| **Sub total** | 18024 | 19619 | 1595 | 9% |
| Mid Murrumbidgee | 4646 | 4495 | -151 | -3% |
| Lower Murrumbidgee | 6502 | 6331 | -171 | -3% |
| **Sub total** | 11148 | 10826 | -322 | -3% |
| Lower Goulburn | 8219 | 8038 | -181 | -2% |
| **Total** | 37391 | 38483 | 1092 | 3% |

The system level modelling does not show the environmental benefits of the constraints programs alone. This makes it practically impossible for the community and the Ministerial Council to make trade-off decisions about the benefits and costs of investment in the CMP and to explain and communicate these benefits and costs more widely.

The SDLAM model does not provide a clear comparison of the ecological condition scores with and without the CMS in each focus reach. The absence of a comparison like this is a weakness of the business cases. Additional model runs could be undertaken to assess the relative incremental improvements in environmental outcomes for the constraints measures alone. The 'do nothing' scenario needs to be defined and agreed. There are a range of options, but it is important that a model run is undertaken that reflects current operational practice that landholders can relate to (e.g. use existing system flow constraints). This will be an important reference point for meaningful discussions with landowners.

It is possible to review each of the business cases and to determine the modelled areas inundated in each focus area and to get an aggregated view. For example, the business cases for the Hume to Yarrawonga and Yarrawonga to Wakool focus areas include tables that show estimates of the areas of wetlands and flood dependent native vegetation that would be inundated for different flow rates.

This is useful information, but the changes in the frequency and duration of flooding in these areas compared to the 'do nothing' case are not shown. They also include estimates of the amount of private land that would be inundated or have restricted access based on the flow rates included in the 2012 relaxed constraints modelling rather the notified flow rates modelled in 2017.

The Panel has been advised that the constraints measures will provide floodplain landholders with flood mitigation benefits. However, the focus area concept business cases do not show the frequency and severity of flooding under current management arrangements or the expected incremental changes that are expected if the constraints measures are implemented. This makes it difficult to assess and communicate the changes in flooding extent, frequency and duration and to weigh up the potential flooding costs and benefits to landholders of the proposed constraints measures.

The SDLAM model applies the "Limits of Change" method described the Basin Plan to limit trade-offs between environmental outcomes for river-dependent ecosystem in different locations. Schedule 6 (S6.07) of the Basin Plan describes a set of limits of change. The limits are associated with four sets of outcomes: bankfull and overbank flow events; the Coorong, Lower Lakes, and Murray Mouth (CLLMM); and fresh and base flow requirements.

The Panel has been advised that it was possible for floodplain projects to satisfy the Ecological Elements criteria for up to 605 GL of SDL adjustment relatively easily but the limits of change restricted recovery to about 450 GL unless projects such as EEWD were implemented and that this required action on the constraints.

A report that consolidates the results of the concept business cases for the six focus areas has not been prepared. This makes it difficult to get a whole of system overview of the proposed constraints measures and the anticipated environmental benefits.

The Panel was consistently advised by environmental water holders and environmental managers that:

- the improved environmental flows are providing benefits to river environments including improved growth and breeding of fish, but some benefits, like productivity and nutrient processing are difficult to quantify
- substantial environmental benefits are being achieved by watering the Living Murray wetlands. These benefits are clearly visible and supported by scientific monitoring
- adoption of the notified flow rates would enable similar environmental benefits to be achieved on the low level parts of the floodplain that cannot be watered by environmental works
- the additional local benefits would also provide cumulative system-wide benefits
- the inability to provide overbank flows means that the full potential benefits of the environmental water allocations that are currently available are not being achieved
- there is sufficient environmental water currently available to provide the environmental flow regimes that are possible with the existing constraints, but there is limited ability to use any additional environmental water if the constraints are not relaxed
- the provision of overbank flows should not change the risk profile of river operators and the river operators should manage the residual risks of providing overbank flows.

### 4.5.1 Further developments

See section 4.2.3.

### 4.5.2 Panel observations

The Panel observed at the workshop with environmental water holders and managers that the lack of progress in regard to constraints was causing significant frustration. The general view of participants at the environmental water holders and waterway managers workshop was that they were keen for progress to be made and that an adaptive approach is a reasonable way to progressively develop operational arrangements to manage overbank flows. Most favoured proceeding with landholder agreements and mitigation measures now despite the level of community opposition to the Basin Plan. The problem of building landholder and broader community support for this approach was not resolved.

However, the Panel was advised of cases where small numbers of easements were successfully negotiated. For example, GMW negotiated with nine landholders to create flood easements required for the Gunbower Living Murray project. The easements were for land behind existing levees and acted as extra insurance in the event that the levee failed. Eight easements were finalised. The MDBA decided to accept the risk of the incomplete coverage of easements and proceed with watering.

The Panel was also advised that the area of inundated area is only one aspect of enhanced flows and environmental benefits. Future work should explain the ecological benefits for a range of flow within the notified flows envelope and the flow regimes that would achieve them. These would include in-channel and near-channel flows that provide:

- greater turbulence in the channel which is critical to breeding and growth in Murray Cod and Trout Cod
- stronger seasonal flow cues which are critical to movement and breeding in Silver Perch and Golden Perch
- better connectivity between the river and low-level riparian areas which maintain local population of fish, frogs and birds throughout the river corridor
- generating and dispersing organic matter on which riverine food webs depend
- activating channels that connect wetlands and rivers, which increases plant and animal dispersal and makes populations more resilient.

This is well-established scientific knowledge and is available to support the program. Better communication of these benefits is needed to inform landholders of the localised and system-wide environmental benefits that constraints relaxation provides.

The Panel is satisfied that greater environmental benefits could be generated if the environmental water that is already available could be used to inundate low parts of the floodplain. The Panel was told of cases where the opportunity for additional benefits was being lost because of the opposition from a very small number of landholders. Capturing these opportunities would not require the constraints measures to be implemented in full, but progress is being held up while decisions are made about the CMP.

The Panel considers that the hydrology models need continued development and should be used to investigate:

- a range of relaxed flow rates for each focus area to identify local costs and benefits and optimise them at both a local and at a system scale
- a range of climate change scenarios to investigate the amount of water that may be available in the future (climate change is expected to reduce allocations to all water entitlements and could also reduce the opportunities to 'piggyback' environmental entitlements on natural flows). This information is required to investigate practical relaxed flow rates for each focus area
- the risks and estimated costs to landowners of unintended inundation and therefore what buffers should be built into the designs
- the incremental local and whole-of-system environmental benefits of inundating additional land
- the assumptions about the management of private land for environmental benefits that is expected to be inundated.

The Panel considers that, regardless of improvements in the confidence of modelling results, other information sources need to be developed to better communicate the flooding effects of the CMS. The Panel was advised that the combination of the increased the number of gauging station installations in some river-reaches, modelling, aerial photography and satellite imagery can be effective. It is also likely there are going to be natural events or possibly local trials between now and constraints implementation that will mimic potential flow rates that can be used to gather additional data and provide valuable communication-material. It is important that the opportunities to collect data from these events are taken.

The Panel has been advised that the resolution of satellite products such as 'RapidEye' is improving and that it would be good to have a clear plan on capturing imagery around future events to improve the calibration of models, contribute to the design of works and to negotiate landholder agreements.

# 5 Addressing terms of reference

This section is to be read in connection with Section 4 which provides more detailed explanations of the modelling undertaken and information gaps.

## 5.1 Modelling to assess and communicate 3rd party risks

The Panel has found that the current modelling is not suitable for the assessment and communication of local 3rd party risks. The modelling has been undertaken at a coarser scale for planning purposes. Landholders need to know the impacts of inundation at the property scale. The available modelling information does not provide the information required to assess and communicate risks to landholders at the property scale.

The Panel considers that it will be necessary to use a combination of calibrated modelling results, high resolution aerial and satellite imagery and localised higher flow watering trials to assess and communicate 3rd party risks to affected landholders.

## 5.2 Modelling to support detailed design

The Panel has found that hydrodynamic models have not been completed for all focus areas and existing modelling is insufficient to support detailed design. A hydrodynamic model of the Edward Wakool sub-system is due to be completed by the end of 2019 and the need for hydrodynamic models for the Murrumbidgee is being considered.

Detailed hydrodynamic modelling is progressing to improve water management in the Living Murray sites and to support the detailed design of structures to be built as part of the nine SDL Adjustment Mechanism offset environmental works projects (e.g. the Victorian Murray Floodplain Restoration Projects).

It is likely that the negotiation of easements and the design of mitigation works will need to be based on multiple sources of information including inundation maps, aerial photography, watering trials and relatively coarse hydrodynamic models. More accurate hydrodynamic modelling would be helpful, but this depends on capturing more information from recent and future inundation events. Additional accurate hydrodynamic modelling may assist in adjusting the size of buffers to match the residual levels of modelling uncertainty.

## 5.3 Modelling to articulate environmental outcomes

The Panel has found that the environmental outcomes have been partially assessed. The SDL Adjustment Mechanism model applies the Ecological Elements method that does not predict a score that relates to actual ecosystem health; it uses simple hydrological metrics that are compared for different scenarios. Future work should explain the ecological benefits in broader terms.

The model was used in 2017 to assess if the environmental outcomes of the 36 SDL offset measures considered together would provide equal or better outcomes compared with the outcomes that would be achieved assuming 2,750 GL of water was recovered. The problem with this 'all-or-nothing' approach is that the environmental outcomes attributable to the constraints measures for each focus area or for the focus areas considered together have not been assessed separately.

Modelling was not undertaken to calculate the change in the ecological system reach scores attributable to the measures proposed for each individual focus area concept business case. The business cases did estimate the areas of various vegetation classes that would be inundated by the notified flow levels. However, these were not compared with the times, frequencies and durations of inundation under a 'do nothing' scenario. Incremental changes in the area, frequency and duration of inundation of environmental sites were not presented. This information would have helped to describe the environmental outcomes of adopting the notified flows compared to the 'do nothing' case. The modelling did enable the whole of system ecological system reach scores to be calculated. This is important because the benefits in one reach can be dependent on relaxing of constraints in upstream reaches. For example, the benefits of relaxing constraints in the Hume to Yarrawonga zone are mainly achieved in the Yarrawonga to Wakool reach.

## 5.4 Modelling to assess change in (increased and decreased) flooding risks

The Panel found modelling information about changes in flooding risk has not been presented at a scale needed to build the confidence of landholders. The reports seen by the Panel have not focussed on the changes in flooding risk to landholders[22]. For example, published modelling results indicate that there would be twice as many flows above 25,000 ML per day upstream of Doctor's Point on the Murray River. This is useful data but it has not been translated into information about the consequences this could have on the floodplain landholders. In the absence of a discussion of the consequence it may be expected that landholders will imagine the worst.

The land that would be inundated by managed environmental releases is also subject to natural flooding. It would be helpful to compare consequences for landholders of the modelled frequency, extent and duration of natural flooding for the current management arrangements with the consequences if the constraints measures were implemented and floodplain inundation becomes more frequent.

It is possible that this data would provide a better understanding of the trade-offs between more inundation events below minor flood levels but fewer moderate and major floods because storage levels should be lower as a result of the water releases to meet the early season environmental flow events. This information would enable a more informed conversation with both individual landowners and the community.

## 5.5 Modelling to supporting real time operations

The Panel has found that modelling to support real time river operations needs to improve. Work is underway to develop the next generation of 'Source' models for the Murray and Murrumbidgee systems. An enhanced real time model is not being prepared for the Goulburn system although it is

[22] MDBA reports in 2012 on the Hydrological modelling of the relaxation of operational constraints and 2017 SDL Adjustment modelling provides some data about the frequency of flooding events, but not in a form that is accessible to landholders

needed in the longer term. River operators have identified that investment in additional rainfall and stream gauging in tributaries below Eildon Reservoir is required to deliver environmental flows given the very short travel times in flows from these tributaries.

The Panel has been advised that river operating models are reliable when the volume of water in the catchment is known and is being routed down the system. However, there are high levels of uncertainty associated with weather forecasts over the one to two month period it takes for water to flow through the Murray system. In fact the accuracy of rainfall forecasts rapidly falls away after two to five days. This limits the confidence that can be achieved in real time river operating models. River operators currently manage this uncertainty by taking conservative decisions to minimise the risks of overbank flows.

The Panel has been advised that, despite the development of the next generation of real time river operation models, river operators will not be able to guarantee that they will not contribute to flows that exceed the notified flow rates because of the inherent uncertainty in weather forecasting. Policies to manage residual risks are required.

The Panel considers that the necessary development of the next generation of real time river operations models is progressing but work on a real time operating model for the Goulburn should be accelerated.

## 5.6 Modelling to assess use of environmental portfolio and its reliance on implementation of constraints measures

The Panel considers that further model development will be required to incorporate how environmental water holders and managers use the available environmental water portfolio.

Modelling is not available to describe how environmental water is drawn down and carried over in the environmental water accounts by the current environmental watering regimes. The Panel has been advised that significant environmental benefits are being foregone because of the current constraints on overbank flows but these foregone benefits have not been clearly described.

It would be possible to determine how the environmental water allocations in each system are used or carried over each year and the ecological reach system scores could be calculated for a model with and without relaxed constraints. However, the Panel notes that the CSIRO (CSIRO, 2014) described the ecological elements method used in the SDL Adjustment Mechanism model as a highly simplified hydro-ecological model that does not try to predict a score that relates to actual ecosystem health; it is an ecological scoring model that uses simple hydrological metrics in a marginal change scenario.

Proposed model developments using daily time steps could be used to show relative changes in the extent, frequency and duration of inundation of the various categories of environmental sites on the floodplain.

Additional modelling should also be done to provide some high-level analysis of the effects of low, median and high climate change scenarios on environmental water availability, ecological reach scores, and flooding characteristics. This information could be used to optimise the constraint relaxation flow rates and build confidence and transparency in the program. The Panel considers

that it would be very difficult to respond to current community concerns and lack of trust without undertaking and presenting some analysis of the implications of climate change.

# 6 Strategies and future work

The Panel formed the view in the previous section that the current modelling is not sufficient to:

- give communities confidence that it is practical to deliver the notified flow rates
- assess and manage risks associated with inundation
- clearly identify environmental outcomes.

The Panel is therefore required by the Terms of Reference to recommend strategies and future work to address the gaps that have been identified. The Panel has considered this task in the following three inter-related parts:

i. completing the design of the works and measures
ii. implementing the works and measures
iii. operating the rivers when the constraints have been relaxed.

## 6.1 Panel considerations

The Panel is aware that the efficient design and delivery of works and measures requires a tightly defined scope. However, a successful engagement and co-design process requires flexibility to evaluate the benefits and costs of the notified flow rates and alternatives flow rates. The evaluation of options is necessary to identify a practical program of works that balances private rights with public benefits, is supported by the community and has a high chance of success. This essential flexibility means that it is not possible to 'lock down' the notified flow rates and have a co-design process.

Standard processes for preparing business cases requires a range of options to be considered. A range of flow rates should be tested and discussed for each focus area. The preferred option for each area would then be modelled to determine the optimal combination of operational flow limits for the system as a whole. These should then be used to undertake detailed design in each focus area.

Locking down the notified flow rates at the outset of the engagement process is not consistent with co-design or adaptive management principles.

The Panel has assumed that the success of the constraints measures is dependent on the ability to implement voluntary agreements (easements or other binding arrangements) with landholders to allow river operators and/or environmental managers to intentionally inundate their land. The civil engineering works required to provide access to land isolated by inundation are relatively simple to design and build, although debate about ownership, service requirements and design standards can be expected.

The Panel has been advised that the ownership, construction, refurbishment and ongoing maintenance of levee banks in NSW and Victoria and is a much more complex matter, but this has not been considered further by the Panel.

The MDBA and the state constructing authorities have extensive experience in negotiating easements for land that is adversely affected by river operations. The Panel understands agreements have been reached in a number of river reaches including the Mitta Mitta downstream of Dartmouth

Dam, the Tumut River downstream of Blowering Dam and in the Murray between Hume Dam and Yarrawonga. The most recent large-scale project was to negotiate easements between Hume Dam and Yarrawonga to codify the prevailing practice of providing regulated flows of up to 25,000 ML/d. The project commenced in 2001 in the wake of the 1996 Hume Dam emergency water releases, and the lessons from this project were documented by the MDBA in 2017 (MDBA, 2017b). There were 116 landholders affected by regulated flows at 25,000 ML day. One hundred and seven were approached to voluntarily create easements in recognition of the damage caused by the long-standing operating practices. Payment for the past damage caused by river operations was offered as part of the negotiations. At the time the report was written, 16 years after the commencement of the project, 85 landowners, or 79 percent agreed to the offers and easements were created; and 23 landholders have still not signed the agreements.

The trial flows, surveys and aerial photography used to generate data to support the negotiations were considered to be important in getting a successful outcome.

The report states that the MDBA still faces some residual risks from property owners that have not formally agreed to the easements. The two risks identified are:

- liability for compensation for impacts of river operations on agriculture on properties without easements
- landholders could challenge a decision to provide releases from Hume dam to provide flows of 25,000 ML/d at Doctor's Point and seek an injunction to prevent environmental releases.

The report considers that landholders could potentially bring two types of claims against the MDBA:

- liability in nuisance
- liability in negligence.

There have been no legal claims made based on the standard operating rules (the MDBA successfully defended a claim for damages resulting from releases made from Hume dam for dam safety reasons in 1996).

This project showed that it is possible to negotiate agreements with land holders, but it is a slow process and it is not realistic to expect all landholders to agree. However, it is also important to recognise the easements that were created simply recognised long standing river operating practices and their associated costs. They were not for increased inundation to implement the Basin Plan. Establishing easements for increased frequency of inundation to supply environmental flows will possibly be a more difficult task. A success rate of less than 79 percent could be anticipated with subsequent increased liability risks.

The Panel considers that there is presently insufficient information available to negotiate landholder agreements in each of the focus areas.

The Panel has been advised that operating the rivers once the constraints measures have been implemented will not be a simple process. River operators have expressed concern to the Panel about the residual risks of unintentionally exceeding the agreed notified flow rates. On the other hand, environmental managers consider that existing risk-management arrangements for environmental flows are reasonably effective and appropriate to manage flows under the CMS. The

environmental water managers believe that delivery of flows up to minor flood levels should present no difficulties.

River operators have some management control of overbank flows in the upper reaches of the Murrumbidgee, Goulburn and Murray rivers. They have very limited ability to regulate and control overbank flows further downstream. Environmental water managers didn't distinguish between the changing delivery risks between upper, middle and lower reaches. The Panel was advised the risk of unwanted inundation causing damage is lower in the lower reaches.

River operators are very experienced in operating rivers within channel and mitigating flood damage caused when large inflows to dams and tributaries occur. With the exception of environmental flows to Barmah-Millewa Forest, there is, however very little operational experience of releasing environmental allocations to piggy-back or extend overbank flows. It will take time to develop this knowledge. The Panel has been advised that advances in real time river operating models will help to reduce the risks of exceeding nominated flows, but significant residual risks will remain. This is because the confidence of the forecasts of these models will always be tied to the confidence of rainfall forecasts. Travel times of water released from the upper catchment storages to the South Australian border can be in the order of 2 months. The Panel has been advised that the accuracy of forecasts of rainfall beyond a two to three days in key catchments rapidly decreases.

River operators must manage this uncertainty within the legal framework whereby they could be liable for damage caused by their actions that inundate land without agreement.

The implication is that large buffers above the nominated flow rates will be required and/or river operators will expect to be indemnified for the costs of damage caused by unintentional inundation of land without agreements. The acceptance of the requirement for large buffers will either reduce the notified flow rates, or significantly increase the extent and cost of easements.

The Panel is also aware of the growing resistance of some landholders to even enter into discussions regarding environmental releases creating overbank events. In some cases this resistance is based on opinions related to the overall aims of the Basin Plan, in other cases landowners do not believe the cost of the impacts of, or nuisance created by, the inundation will be adequately recognised.

## 6.2 Possible approach

The Panel considers that applying an adaptive management approach to progressively relax river operating constraints will provide the opportunity for immediate benefits and has the best chance of achieving the lasting environmental benefits specified in the Basin Plan. The objective of the adaptive management approach would be to build the necessary community support for the constraints measures through the co-design process required by the Ministerial Council.

An adaptive management approach would enable:

- landholders to see and assess first-hand the effects of intended inundation on their properties and businesses, with the confidence that the cost of the impacts would be promptly recognised
- river operators to build the new skills and capabilities required to release overbank flows
- environmental managers to effectively engage with landholders and the broader community to demonstrate environmental benefits
- local operational rules to be developed and refined to manage local benefits and costs.

A constraints program applying the adaptive management approach would be a constructive step forward. It would lead to improvements in model development and a better understanding of the impacts and costs of inundation.

The adaptive management approach should be based on well managed trials, with clear impact-assessment processes. It should also start to address the current levels of community outrage and improve future landowner engagement. The trials of higher flow events would be conducted on discrete sections of rivers not on the whole system. They would be done at known known channel constrictions that involve landholders that are constraining beneficial environmental watering.

State authorities provided a number of constructive suggestions related to where useful and beneficial trials could be conducted. The trials would be conducted at a local scale with landowner approval.

The program of trials would 'ground truth' many of the assumptions made to date and:

- demonstrate to landholders the true effects of the intended levels of inundation and dispel unwarranted fears
- inform landholders and governments of the costs of inundation that will need to be reflected in landholder agreements
- establish clearer understanding and definition of natural flooding, and events created or extended by deliberate releases of water
- inform models with high quality flow and inundation data to improve their accuracy
- accurately confirm the type and scale of infrastructure needed to minimise the adverse impacts of the higher flows
- inform the development of local environmental watering plans
- create broader community confidence in the increased flow requirements and demonstrate that governments are willing to recognise the costs to landowners
- be a strong catalyst for broader engagement
- provide immediate additional environmental benefits.

The trials would involve small groups of receptive landowners in locations that provide the opportunity for progressively higher flows at known constriction points. They should be designed and negotiated as part of the next stage of implementing a program of works to relax constraints. The trials would be designed to:

- ensure participants are entering the program on the basis that it is a trial and is not binding beyond the trial period
- clearly communicate design flows based on agreed triggers, months before the trials are conducted
- provide for any adverse impacts of the trial releases on farming operations to be independently assessed and will be compensated promptly
- have an agreed method to assess adverse impacts on farmland
- have an agreed method for determining compensation
- include a monitoring program to assess local and broader environmental benefits.

The program of trials would involve environmental water holders, state water managers and river operators working with private and public land owners to establish a clear program of planned trials,

with a clear understanding of the precedent conditions required to trigger the trial. Trials should be undertaken in each focus area but be carefully targeted.

Work on developing and conducting small local trials should start now and be funded from the constraints measures budget. They should not be delayed until after the detailed business cases for each focus area are completed, notified flow rates are confirmed and funding for the whole program agreed.

The timing of trials would be unpredictable because it depends on seasonal conditions and water availability. This means that it is likely to take several years to conduct the trials and assess the benefits, particularly if an adaptive management approach is taken. The Panel's outline of the elements of a well-designed trial are shown in Table 4.

*Table 4. Elements that should be included in trial design.*

- A binding agreement for a defined term between each landowner in the trial zone, the State or Federal Environmental agency owning the water to be released, and the Agency releasing the water
- A statement clearly indicating why the trials are being conducted and how the trials will assist the understanding of the impacts of higher flows
- A clear agreement on how and when Agencies releasing the water will communicate intended flow increases, cessation of flows etc.
- A statement of the conditions required to trigger the creation of the increased flows, recognising natural events are likely to limit or shape release opportunities over the current year and the whole term of any agreement. (The *statement of triggers* should be issued to participants annually, more than 2 months before the design flow is to be released)
- A description of the estimated incidence and extent of naturally occurring flows and enhanced flows based on the best available modelling that are clearly understood by participants
- An outline of the expected environmental benefits locally (on the inundated land) and in other stretches of the river both upstream and downstream
- A commitment to deliver only up to the maximum design flow to be created, at a nearby flow reference point (e.g. 28,500 ML/day at Yarrawonga Weir)
- An outline of how increases in natural flows (i.e. heavy rain in downstream tributaries) after commencement will be dealt-with by the agency releasing the flows from storages
- A commitment and agreement on the timing of inspection (pre-event and post event) and the terms of assessment for compensation of any adverse impacts of the higher flows. This would include payment for loss as a result of direct inundation of crops/pasture, or actual costs of the impacts of compromised access as a result of the deliberate inundation (i.e. independent and appropriately qualified assessment panel or an individual expert). Agreeing to work with, and to engage the landowner's own agronomist in any impact assessment may also help increase trial participation
- A commitment to a maximum period of flow duration (or a commitment to the maximum period of flow *extension*, if the releases are used to extend a natural event) (e.g. "Flows

will not be deliberately created or extended using environmental water releases, for a combined period in any calendar year of more than 30 days“)

- The prescribed window of time the flows will be created (or extended) (e.g. “The trial flow of 28,000ML/day will not be created from environmental water releases prior to 15 June and will not be released to extend flows beyond 15 December”)
- Payment terms: The trial agreements with landholders should clearly outline the basis of a payment or other compensation (if any), when payments will be made, and what will and will not be included in any assessment of loss or impact.

## 6.3 Alternative approach

The Panel considered the alternative adaptive management approach which would be to firstly establish landholder agreements to match the notified flow rates and undertake mitigation works before trialling overbank flows. Progressively larger overbank flows would be provided to build the capabilities needed to run the rivers overbank and to optimise environmental outcomes.

The Panel heard significant support for this approach and recognised that the adaptive management approach would be easier to implement if landholder agreements and mitigation works were in place. However, the Panel considers that the chances of this approach being successful are very low because:

- of the likelihood that a significant number of landholders will not voluntarily enter into agreements
- the requirement for upfront voluntary agreements would encourage landholders to demand unreasonable terms and conditions before agreeing
- the level of confidence in the modelling and other data currently available is low – mistakes would be likely and trust would be eroded
- given the level of confidence in the data, buffers would be required to be extensive, increasing the number of landholder agreements, the costs and the number of potential opponents
- access structures would need to be designed with significant freeboard, increasing costs and, if oversized, risking reputations
- of the failure to describe the local environmental benefits in a compelling way that resonates with landholders and the broader community
- of the lack of trust in the institutions involved in delivering the Plan
- of the strong opposition to the Basin Plan in some communities.

For the above reasons and given the lessons from the negotiating the Hume to Yarrawonga 25,000 ML/d easements from 2001 to 2017, the Panel considers that there would be very little prospect of negotiating the necessary landholder agreements on reasonable terms. In fact, there would be a significant risk that many landholders would object to the proposed constraints measures creating new groups that oppose the Basin Plan.

Large sums of government funding could be expended but with no overbank flows released, damaging the reputation of the Commonwealth and MDBA. This would lead to additional tensions

and ‘finger pointing’ between State and Commonwealth governments and further undermining of the Basin Plan.

While some, but not all of the problems listed above could be overcome by using State or Commonwealth powers to compulsorily acquire easements, this would generate very strong opposition and the Victorian and New South Wales governments have ruled this out. The option enabling the *Commonwealth Lands Acquisition Act 1989* has not been considered.

## 6.4 Other consequences

The Panel is aware that the suggested way forward may take 10 to 20 years or more to implement and it is not possible to prescribe the final outcome. This is challenging because of the prescriptive rules in the Basin Plan that requires measures to be negotiated, formalised, constructed and commissioned by 30 June 2024 if they are to be included as SDL offsets.

Section 7.12(3)(a) of the Basin Plan prescribes that constraints measures may only be notified as an Offset if they will enter operation by 30 June 2024. Section 7.12(5) requires any notification to amend a constraints measure should be made as soon as possible after information about the measure has changed. Amendments cannot be made after 31 December 2023.

The Panel note that the Productivity Commission (2018) found that –

> *“The 2024 deadline for a number of these projects (particularly the constraints projects) is highly ambitious, if not unrealistic. …*
>
> *To enable worthwhile projects to be implemented in realistic timeframes, Basin Governments should be open to the possibility of extending the 30 June 2024 deadline…”*

Enough is known now for the Panel to conclude that it will be very difficult for the constraints measures to be in place by 30 June 2024 using either approach. Regardless of the approach taken it is likely that the prescribed dates in the Basin Plan will need to be amended. Therefore, the Panel considers that the 30 June 2024 date should not be a consideration in determining the best approach to be taken.

The Panel is also aware that the co-design process may result in communities recommending that flow rates that are less than the notified flow rates be adopted, reducing the SDL offsets. This would present significant challenges to the prescriptive Basin Plan. The current default is for the Commonwealth to purchase more water if SDL project underperformances were to occur.

The Panel has been advised that it is not possible to deliver existing environmental water holdings to achieve the required environmental outcomes effectively with the current operating constraints. Therefore, there would be little environmental benefit in purchasing additional water. It has been suggested to the Panel that environmental water allocations could simply be held back in storages so that the storages spill more often creating an environmental benefit through earlier, larger and more frequent spill events from storages.

The possible legal liability issues that may arise if flooding risks were intentionally increased by purchasing extra water and holding it in storage have not been investigated by the Panel.

The Panel is of the view that Governments should seek to adopt practical, long-lasting river operating arrangements that improve environmental outcomes. The Panel considers that, on balance, the approach of conducting trials and using adaptive management before establishing enduring easements has the best chance of building the necessary capabilities, trust, confidence and community support to achieve this objective.

## 6.5 Suggested areas for additional work

Section 4 of this report reviews the modelling and other data available to assess and implement the constraints measures. The broad conclusion of the Panel was that the information available was adequate to prepare the focus area concept business cases but much more information, at a finer scale, is needed to improve transparency, reduce the level of uncertainty of modelled outcomes and build confidence.

However, the Panel recognises that improving the confidence of the information available to decision makers, river operators, environmental managers and affected landholders cannot be achieved through modelling alone. Modelling is dependent on the information available to calibrate the models. The Panel has been advised that it will be very difficult to improve the confidence in the models without additional information. In particular, data about *experienced* areas of inundation from more overbank flow events is required to improve the calibration of the models and evaluate the costs and benefits of inundation. The Panel notes that it was suggested that operational trials be conducted through existing river management processes in the Hume to Yarrawonga Constraints Management concept business case.

Funds should be made available as soon as possible to identify and to support potential local trials, design the trials of overbank flows based on the elements listed in Table 4 and, if supported by communities, through co-design process and the opportunity arises, run the trials. The Panel has been advised that it may be appropriate to conduct trials at:

- Collingullie/Yarragundry on the Murrumbidgee River – NSW
- Perricoota Forest (Barbers Creek)[23] – NSW
- Gunbower Forest (Gunbower Creek) – Vic
- Goulburn River – Vic

Further work is required to develop up a detailed program of local trials. The program should also consider opportunities to help overcome channel capacity limitations that currently pose a risk to the supply of irrigation and environmental requirements during high demands.

The Panel has also been advised that there is potential to implement a range of works and measures on a 'no regrets basis' (i.e. the works and measures will provide benefits regardless of the ultimate level of the notified flow rates). Examples of possible works that will support a better understanding of inundation, and trials include:

- supplementing the stream gauging network in the:
    - Murrumbidgee focus area

[23] Noting that Panel Member, George Warne, is a past landowner in this area, and has family members that own property with Barbers Creek frontage.

    - Edward Wakool system
    - Goulburn tributaries downstream of Eildon Reservoir
- supplementing the rain gauge network
- building a real time river operating model for the Goulburn
- upgrading farmers pump installations (i.e. typically with submersible pumps) to reduce the risk of damage to pump installations at the notified flow rates.

The Panel considers that establishing a program of 'no regrets work' has the potential to accelerate the relaxation of constraints, generate immediate environmental benefits, build capabilities and improve confidence and trust.

The CMS described anticipated benefits in very general terms and without the benefit of the concept proposal business cases for the six focus areas. The CMS was not updated after the concept proposal business cases were completed. Information was not consolidated therefore proponents need to go through all of the concept business cases to understand the benefits and costs of the program.

The Panel considers that models should be re-run to test a range of realistic future scenarios using the existing modelling platforms or ideally using the enhanced models. Matters warranting scenario based analysis that will impact on the design flow rates, duration and frequency of events include:

- the effects of climate change on water availability in the system generally and the amount of water available to the environment specifically
- the effects of recovering different volumes of water for the environment on the environmental outcomes and the effect this has on the level of target overbank flow rates
- a range of options for overbank flow targets for each focus area to enable the system benefits and costs to be optimised.

The focus of the analysis to date has tended to be on generating environmental benefits and 'bankable' SDL offsets. Less attention has been given to evaluating the consequences of the notified flow rates on the extent, frequency and duration of inundation experienced by landholders and the costs and benefits this has on their businesses. The Panel considers that the concept business cases for each focus area will need to be updated to include the adaptive approach including a program of case studies. Additional modelling will be required to include the do nothing base case and a number of overbank flow options to more clearly describe the incremental consequences for landholders as well as for environmental benefits.

The Panel has been advised that, regardless of the improvements in the confidence of the modelling, there will remain a risk that managed overbank flows will sometimes exceed planned levels and unintentionally inundate land. The Panel considers that further work is required to assess these risks, determine the risk tolerance of governments and decide on who will manage and be accountable for these residual risks.

The Panel notes and supports the work that is continuing to upgrade and link:

- river hydrology models used for planning purposes
- real time river operating models used to operate the rivers.
- hydrodynamic models used to investigate overbank flows and inundation

Suggested areas for additional modelling work are listed in Section 5.

Finally, considerable frustration has been evident in the workshops about various elements of the constraint measures program. The Panel considers that much of this frustration could be resolved by shifting attention away from the notified flow rates to the very substantial issues involved in achieving voluntary agreements with landholders to inundate their land to provide environmental benefits elsewhere. The focus needs to be firmly on understanding, managing and delivering on the expectations of these landholders. The central and local constraints measures governance arrangements need to be reviewed to provide this focus.

# 7 References


CSIRO (2014) *Development of the Murray-Darling Basin Plan SDL Adjustment Ecological Elements Method. Report prepared by CSIRO for the Murray-Darling Basin Authority*. Murray-Darling Basin Authority 2014. Retrieved from: https://www.mdba.gov.au/sites/default/files/pubs/CSIRO-Report.pdf

DELWP (2016) *Guidelines for Assessing the Impact of Climate Change on Water Supplies in Victoria.* State of Victoria Department of Environment, Land, Water and Planning.

Department of Agriculture (2019) *WESA Review Terms of Reference.* Retrieved from: https://www.agriculture.gov.au/sites/default/files/sitecollectiondocuments/water/policy/tor-wesa-review-1.pdf.

Fluvial Systems (2016) *Review of Goulburn River hydraulic modelling work by Water Technology and hydrological modelling work by Jacobs.*

Jakeman T, Croke B and Iwanaga T (2019) *Independent Review of the Source Model of the Murray and Lower Darling Rivers (SMM)*. Canberra: Australian National University. Retrieved from: https://www.mdba.gov.au/sites/default/files/pubs/Independent%20review%20of%20Source%20Murray%20Model%20%28SMM%29%20report_1.pdf

MDBA (2012) *Hydrologic modelling to inform the proposed Basin Plan: methods and results.* Canberra: Murray-Darling Basin Authority

MDBA (2013) *Constraints Management Strategy 2013 to 2024.* Canberra: Murray-Darling Basin Authority

MDBA (2014) SDL *Adjustment Ecological Elements Method Development Report- Review of Final Project Report*. Retrieved from: https://www.mdba.gov.au/sites/default/files/pubs/IRP-Final-Review-of-SDL-Ecological-Elements-Project.pdf

MDBA (2015a) *The Ecological Elements Method for adjusting the Murray–Darling Basin Plan Sustainable Diversion Limit Overview of method development and evaluation*. Retrieved from: https://www.mdba.gov.au/sites/default/files/pubs/CSIRO-summary-of-the-scoring-method_0.pdf

MDBA (2015b) *Letter from Independent Review Panel for the Sustainable Diversion Limit Adjustment – Ecological Elements*. Retrieved from: https://www.mdba.gov.au/sites/default/files/pubs/IRP-advice-letter_0.pdf

MDBA (2017a) *Benchmark conditions of development for assessment of the SDL supply contribution.* Canberra: Murray-Darling Basin Authority

MDBA (2017b) *Lessons from easement programs. MDBA's experience with the Hume-Yarrawonga Easement Program*.

MDBA (2017c) *Modelling assessment to determine SDL Adjustment Volume.* Retrieved from: https://www.mdba.gov.au/sites/default/files/pubs/FINAL%20Modelling%20assessment%20to%20determine%20SDL%20Adjustment%20Volume.pdf

MDBA (2018) *Murray–Darling Basin Ministers meet in Melbourne - 14 December 2018.* Retrieved from: https://www.mdba.gov.au/media/mr/murray-darling-basin-ministers-meet-melbourne

MDBA (2019a) *Further information on Constraints program and associated modelling.* Retrieved from: https://www.mdba.gov.au/sites/default/files/pubs/Further-information-on-constraints-program-and-associated-modelling.pdf

MDBA (2019b) *Murray–Darling Ministerial Council, 4 August 2019.* Retrieved from MDBA: https://www.mdba.gov.au/media/mr/murray-darling-ministerial-council-4-august-2019

Productivity Commission (2018) *Murray-Darling Basin Plan: Five Year assessment, Productivity Commission Inquiry Report*, No. 90, 19 December 2018. Retrieved from: https://www.pc.gov.au/inquiries/completed/basin-plan/report/basin-plan.pdf

## 7.1 Legislation

Commonwealth *Water Act 2007*. Retrieved from: https://www.legislation.gov.au/Details/C2019C00312

Commonwealth *Basin Plan 2012*. Retrieved from: https://www.legislation.gov.au/Details/F2018C00451

New South Wales *Water Management Act 2000*. Retrieved from: https://legislation.nsw.gov.au/#/view/act/2000/92

Victoria *Water Act 1989*. Retrieved from: http://classic.austlii.edu.au/au/legis/vic/consol_act/wa198983/

# 8 Glossary

| | |
|---|---|
| Baseline diversion limit | In the Murray-Darling Basin Plan the baseline limit of take from a SDL resource unit is:<br>(a) for a surface water SDL resource unit – the quantity of water calculated in accordance with column 2 of the table in Schedule 3 for that SDL resource unit; and<br>(b) for a groundwater SDL resource unit – the quantity of water specified in column 3 of the table in Schedule 4 for that SDL resource unit. |
| CARM | Computer Aided River Management system (CARM) is an expert Decision Support System (DSS) specifically created for river operations. Its primary role is to integrate both real time and expert modelled flow scenario information using a computer based hydrodynamic modelling system, to enhance the tools available to river operators, to make better informed decisions on daily releases from dams and weirs. |
| Constraints projects | Constraints projects aim to overcome some of the physical barriers that impact delivering water in the system. Constraints projects can include changes to physical features such as crossings and bridges. They can also change river operating practices and rules. They could allow water managers more flexibility in releasing and moving water through the system.<br>No changes to flows will occur until all third party impacts have been resolved in consultation with affected communities. |
| Hydrodynamic modelling | Hydrodynamic (also called hydraulic) models consider the topography of the river channel and floodplain, and can include structures such as wetland regulators. Hydrodynamic models are calibrated using the best available data, including measured flows, water levels and satellite images of flooding.<br>These models help water managers and river operators with:<br>• Predictions of likely flood behaviour during environmental watering<br>• Documenting flooding after watering events and estimates of environmental water-use. |
| Hydrologic indicator sites | 124 sites chosen to cover specified environmental objectives and targets, environmental water requirements or environmental demands. Flows described at those sites are intended to represent the broader environmental flow needs of river valleys or reaches. The selection of sites and flows |

| | |
|---|---|
| | described focus on those areas and issues with greatest sensitivity to the environmentally sustainable level of take. |
| Hydrological modelling | Hydrological modelling is used to represent and test environmental water requirements and flow regimes. They are the best available tools for representation of long term flow regimes in the Basin under current water sharing arrangements (baseline conditions) and without development conditions. These models also allow thorough assessment of changes in flow regimes under different water availability conditions, water sharing arrangements and environmental flows over the last 114 years of climate records and variability. |
| IQQM model | A computer-based water supply system model used by NSW in the<br>Allocation and management of NSW's water resources. It is an abbreviation of Integrated Quantity and Quality Model |
| Limits of change | Limits in score or outcome that ensure that the total increase/decrease in the SDLs for the units affected by a notified measure maintain<br>environmental outcomes within identified limits |
| MIKE-11 | MIKE 11 is a computer program that simulates flow and water level, water quality and sediment transport in rivers, flood plains, irrigation canals, reservoirs and other inland water bodies. MIKE 11 is a 1-dimensional river model. |
| MIKE-21 | A two-dimensional version of MIKE-11. |
| MSM-BigMod | A modelling suite for simulating water and salt transport processes, water management, infrastructure and water sharing arrangements of the River Murray and Lower Darling River System. Was around for over 40 years. Replaced by Source. |
| Ministerial Council | The Ministerial Council is made up of Ministers responsible for water from each Basin jurisdiction and the Commonwealth.<br><br>The Council has policy and decision-making roles for:<br>• state water shares<br>• funding and delivery of natural resource management programs<br>• issues relating to critical human needs as provided for in the Water Act 2007. |
| Minor flooding | Victorian State Emergency Service and Bureau of Meteorology classifies minor flooding as causing inconveniences such as closing of minor roads and the submergence of low level bridges. In urban areas inundation may affect some |

| | |
|---|---|
| | backyards and buildings below the floor level as well as bicycle and pedestrian paths. In rural areas removal of stock and equipment may be required. |
| Murray-Darling Basin Agreement | Schedule 1 of the *Water Act 2007* (C'wth). The purpose of this Agreement is to promote and co-ordinate effective planning and management for the equitable, efficient and sustainable use of the water and other natural resources of the Murray-Darling Basin, including by implementing arrangements agreed between the Contracting Governments to give effect to the Basin Plan, the Water Act and State water entitlements |
| Notified flow rates | Maximum flow rates proposed to be targeted for environmental flows as part of constraint measure projects. The flow rates were 'notified', as per requirements under subsection 7.12(1) or (1A) of the Basin Plan 2012, in concept business cases prepared as part of the Basin Plan's Sustainable Diversion Limit Adjustment Mechanism process. |
| Nuisance flooding | Flooding that doesn't cause major property damage or seriously threaten public safety. It can however, put strain on infrastructure systems and disrupt routine activities |
| Pre-wetting | Where inundation saturates a dry area and increases future rainfall runoff, which raises the risk of a subsequent rainfall event to provide larger inflows. |
| RapidEye | A constellation of five Earth Observation satellites that contain identical sensors, are equally calibrated and travel on the same orbital plane (at an altitude of 630 km). Together, the five satellites are capable of collecting over 4 million km² of 5m resolution, 5-band colour imagery every day. |
| REALM model | A computer-based water supply system model used by Victoria in the allocation of Victoria's water resources. It is an abbreviation of Resource Allocation Model. |
| 'Relaxed-constraints' model scenario | A model scenario that explored the flow regime changes and potential environmental benefits that would result if some major existing river operating constraints in the Southern connected system were relaxed. |
| RiM-FIM model | River Murray Floodplain Inundation Model created as a research and decision support tool for environmental flow management in the River Murray. It encompasses the River Murray floodplain from Hume Dam at Albury (Victoria) to Lake Alexandrina at Wellington (South Australia) and uses a Geographical Information System (GIS), remote sensing and hydrological modelling. |

| | |
|---|---|
| River Operations Objectives and Outcomes | The MDBA directs river operations in the River Murray System in accordance with objectives and outcomes set by the Basin Officials Committee.<br><br>The 'Objectives and Outcomes for River Operations in the River Murray System' are based around five themes:<br>• Water storage, delivery and accounting;<br>• River Murray Operations (RMO) assets;<br>• People and communities;<br>• Environment; and<br>• Information and communication<br><br>They can be at: https://www.mdba.gov.au/publications/mdba-reports/objectives-outcomes-river-operations-river-murray-system |
| SDL | The maximum long-term annual average quantities of water that can be taken on a sustainable basis from Basin water resources as a whole, and from each SDL resource unit. The Water Act 2007 (Cth) requires that these reflect an environmentally sustainable level of take. |
| SDL adjustment mechanism | Allows the sustainable diversion limit to be adjusted under certain<br>Circumstances. The mechanism requires a suite of projects to be implemented – some projects allow Basin Plan environmental outcomes to be achieved with less water. |
| SDL-EE method | The Ecological Elements Method compares environmental outcomes at the regional scale for benchmark and SDL adjusted scenarios. The test requires the region environmental outcome score for the SDL-adjusted scenario to be equivalent or higher than the score for the benchmark scenario. The region is the southern connected Basin of the Murray-Darling Basin. |
| Site-specific flow indicator | Flow targets used in the development of the Environmentally Sustainable Level of Take. They were used to express environmental water requirements at hydrologic indicator sites. The indicators include the volumes, frequency, duration and the periods during which flows are required at hydrologic indicator sites. |
| Southern-connected basin | The Southern-connected basin is a network of rivers that feed into the Murray River between the Hume Dam and the sea (Murray mouth in SA). The network includes Victoria's Goulburn, Ovens, Kiewa, Campaspe and Loddon rivers; and NSW's Wakool, Murrumbidgee and Darling rivers. |
| 'Source' model | A state of the art daily time-step model that represents river systems and used to maintain the models in contemporary and consistent approaches across the |

| | |
|---|---|
| | Basin. It uses the Source IMS software platform. Some models, including for the Murray, have been prepared already. |
| 'Step change' | A climate scenario that captures many of the seasonal changes in rainfall that have occurred over recent years that are not fully reflected in the global climate models and therefore not captured in the low, medium and high scenarios. |
| Victorian Murray Floodplain Restoration Projects | The VMFRP consists of nine discrete environmental works projects that aim to return a more natural inundation regime across approximately 14,000 ha of high-ecological-value Murray River floodplain in Victoria through the construction of new infrastructure and the modification of existing infrastructure. |
| Water Resource Plans | A water resource plan sets out the rules for how water is used at a local or catchment level, including new limits on how much water can be taken from the system, how much water will be made available to the environment, and how water quality standards can be met. Basin state governments are responsible for complying with water resource plans and accounting for water taken from the river system. |

# Appendix 1 – Terms of Reference

**Victorian and New South Wales Bilateral Review of Constraints Modelling**

**Independent Expert Panel**

**Terms of Reference**

**Introduction**

Restoring flows to floodplains by releasing water from storages on top of high natural flows will have impacts on public and private land, infrastructure, assets and people. Communities across the Basin have expressed concern about the flood impacts of proposed higher flows on their land and businesses, whether claimed ecological benefits are achievable and the ability to 'manage' or limit the delivery of higher flows to the targeted flow rates. They have a high level of distrust about the ability of authorities to manage and mitigate these impacts and protect private holdings, particularly in the context of natural flow events.

The Victorian and NSW Ministers want to provide transparency to communities about modelling and related work done to inform the constraints program and restoration of flows to floodplains.

**Background**

The Basin Plan sets a 2750 gigalitre (GL) water recovery target across the basin; this target may be offset by up to 650 GL through projects that deliver equivalent environmental outcomes using less water. Projects that contribute to this offset are called supply measures. An additional 450 GL can be recovered if there are no socio-economic impacts of doing so.

In simple terms river operators are responsible for managing water availability and the release and delivery of water for a range of purposes including irrigation supply and environmental needs. River operators apply a risk-based approach to managing releases of water for downstream needs. Specific risks are 1) third party impacts e.g. flooding of private land and 2) hydrological risks e.g. uncertainty in rainfall run-off. To date, these risks are partly managed by keeping the delivery of water within the river channel. Within existing operational constraints, environmental water holders can seek to coordinate their regulated releases and align these releases with natural flows. This will provide some environmental benefit. To gain additional environmental benefit, physical and operational constraints to environmental watering need to be addressed and managed overbank flows introduced.

The Constraints Management Strategy (CMS) released by the MDBA in 2013 identified key focus areas for removal of physical or operational constraints and flow targets to maximise ecological outcomes from available environmental water. These key focus areas have been further considered by the Basin states through the development of constraints measure projects and most projects propose some level of floodplain inundation. Generally, each of these projects include environmental flow targets (notified flows) that are less than those in the MDBA's 2013 strategy.

NSW, Victoria and South Australia have put forward a package of 36 supply measures to support the health of local rivers and wetlands along the Murray River and its tributaries, including five constraints measure projects. Victoria has also put forward the Goulburn constraint measure project. This project was not formally notified as a supply measure, however, the success of other constraints projects rely on the higher operational limit on flow rates for environmental water delivery nominated in the Goulburn project. The six constraints projects are:

- Hume to Yarrawonga
- Yarrawonga to Wakool
- South Australian Murray

- Lower Darling
- Murrumbidgee
- Goulburn.

Based on these projects, the Sustainable Diversion Limit set out in the Basin Plan was increased by 605 GL in 2018.

**Purpose**

On behalf of the Victorian and NSW Governments, the Independent Expert Panel is to apply its extensive experience and expertise to add transparency, scientific rigour and practical knowledge to the Basin Plan's constraints program.

The Panel will assess whether the existing modelling undertaken for the constraints program is sufficient to give communities confidence that it is practical to deliver the targeted flow rates (notified flow rates), assess and manage risk and that the environmental outcomes are clear.

The Panel's advice will also consider the environmental benefits of additional water recovery under the efficiency measures and the extent to which this relies on the package of constraint projects.

Based on its high-level assessment of the adequacy of modelling the Panel will also provide, if required, recommendations to inform future work on constraints, including modelling, timing and resources.

In undertaking their assessment, the Panel should determine the validity and consequences of assumptions, including those related to water availability (e.g. available environmental water, 450 GL of additional environmental water recovery and climate change) and notified flow rates.

The Panel should also consider:

- related investigations being undertaken as part of the Murray River Capacity Risks Project
- the relationship between the constraints program and the Enhanced Environmental Water Delivery (EEWD) Project; and
- any other matter they see as relevant to the constraints program.

**Governance and deliverables**

The Independent Expert Panel will report directly to the Victorian and NSW Water Ministers' with a view to discussing its findings and recommendations with the Ministerial Council in December 2019.

The findings and recommendations will be used to inform Ministers' decisions about remaining Basin Plan implementation activities associated with constraints projects, and communities about the practicality of implementing constraints measures.

**Independent Expert Panel**

The following experts have been appointed to the Panel:

***Mr Greg Wilson – Chairperson***

Greg has extensive experience within Victorian government departments. He was appointed as Chair of the Transport Accident Commission in March 2019 and is currently with the Department of Premier and Cabinet. Greg was previously the Secretary of the Department of Justice and Regulation, Secretary of the Department of Sustainability and Environment (DSE), and Deputy Secretary Policy and Cabinet Group, Department of Premier and Cabinet. His roles while with DSE included Deputy Secretary of the water portfolio.

Greg formerly chaired the Victoria's Essential Services Commission and has held a number of senior leadership roles including General Manager of Regulatory Policy at the Essential Services Commission (formerly Office of the Regulator-General) and Senior Economist, Department of Treasury and Finance.

***Mr Campbell Fitzpatrick – Panel member***

Campbell has worked in the water industry for over 30 years and in senior executive positions in government for close to 20 years. He currently runs his own consulting company.

Campbell led the delivery of Victoria's Sharing the Murray program which involved working closely with regional communities to establish secure well-defined Victorian water rights on the Murray River. He also drove Victoria's major water reform agenda through the development of Victorian Government's Our Water Our Future White Paper and Sustainable Water Strategies.

Campbell has been responsible for the development and implementation of water resource policy with the Victorian government department. He was responsible for leading collaborative, consultative, evidence-based approaches for resolving complex water resource management issues. Campbell has worked closely with Ministers, senior public servants, the Murray-Darling Basin Authority, water corporations, CMAs, non-government organisations and water users.

***Mr George Warne – Panel Member***

George Warne is recognised as a leader in the rural water sector and has over 27 years of experience in the water sector across a broad range of roles and organisations. George has experience in both the public and private sector including prior roles as CEO and Project Director of the Northern Victorian Irrigation Renewal Program, Managing Director of the NSW State Water Corporation, CEO of Murray Irrigation Limited and as a board member of the MDBA between 2014-2019. George brings a wealth of knowledge and understanding about water and natural resource management, river operations and irrigated agriculture.

# Appendix 2 – Workshops and attendees

The panel conducted six workshops with stakeholders over the course of the review. Information on the meetings and their attendees are below. Each workshop included an opportunity to discuss common themes, issues and information needs; as well as a whip around the table to discuss key issues, information gaps, outstanding questions / suggestions and any other matters.

| Purpose | Topics | Participants | Date |
|---|---|---|---|
| **Modelling and River Operations workshop** | • River operations<br>• Hydrological and hydraulic modelling<br>• Environmental benefits | Andy Close (Tech. Advisor)<br>Andrew Keogh (MDBA)<br>Andrew Reynolds (MDBA)<br>Ben Tate (Tech. Advisor)<br>Campbell Fitzpatrick (IEP)<br>George Warne (IEP)<br>Graeme Turner (Tech. Advisor)<br>Greg Wilson (IEP)<br>Jong Lee (MDBA)<br>Marcus Cooling (Tech. Advisor)<br>Matthew Coleman (MDBA)<br>Pradeep Sharma (MDBA)<br>Simon Lang (Tech. Advisor)<br>Yi-Ming Ma (IEP) | 17/10/2019 |
| **River operators workshop** | River operations:<br>• Murrumbidgee<br>• Victorian tributaries<br>• Murray (and Lower Darling) | Adrian Langdon (Water NSW)<br>Andrew Shields (GMW)<br>Andy Close (Tech. Advisor)<br>Campbell Fitzpatrick (IEP)<br>George Warne (IEP)<br>Greg Wilson (IEP)<br>Neville Garland (MDBA)<br>Mark Bailey (GMW)<br>Rory Nathan (Tech. Advisor)<br>Trevor Jacobs (MDBA)<br>Vince Kelly (Water NSW)<br>Yi-Ming Ma (IEP) | 28/10/2019 |
| **Hydraulic modelling workshop** | • Existing suite of models and information<br>• MDBA future work program | Andy Close (Tech. Advisor)<br>Ben Tate (Tech. Advisor)<br>Campbell Fitzpatrick (IEP)<br>Simon Lang (Tech. Advisor)<br>Steve Muncaster (EMV)<br>Yi-Ming Ma (IEP) | 01/11/2019 |
| **Floodplain management workshop** | • Floodplain management<br>• Modelling<br>• Coordination and response to inundation | Ben Tate (Tech. Advisor)<br>Campbell Fitzpatrick (IEP)<br>Guy Tierney (GBCMA)<br>Ian Burns (DPIE)<br>James Kellerman (MCMA)<br>Kate White (SES)<br>Keith O'Brien (SES)<br>Shaun Morgan (NCCMA)<br>Tim Loffler (NECMA)<br>Yi-Ming Ma (IEP) | 04/11/2019 |

| | | | |
|---|---|---|---|
| **NSW floodplain management workshop** | • Floodplain management<br>• Modelling<br>• Coordination and response to inundation | Adrian Langdon (WaterNSW)<br>Christine MacRae (DPIE)<br>George Warne (IEP)<br>Iwona Conlan (EES)<br>Jeff Hillan (EES)<br>Tracey Macdonald (DPIE)<br>Yi-Ming Ma (IEP) | 11/04/2019 |
| **Environmental water holders and waterway managers workshop** | • Environmental water delivery<br>• Environmental outcomes and benefits associated with constraints projects<br>• What is needed for constraints relaxation to work?<br>• Coordination and response | Anna Parker (NCCMA)<br>Ben Tate (Tech. Advisor)<br>Beth Ashworth (VEWH)<br>Catherine McInerney (NECMA)<br>Campbell Fitzpatrick (IEP)<br>Chris Norman (GBCMA)<br>Daniel Lovell (GBCMA)<br>Derek Rutherford (DPIE)<br>Greg Wilson (IEP)<br>Helen Wilson (NECMA)<br>Hilton Taylor (CEWO)<br>James Kellerman (MCMA)<br>Jenny Collins (MCMA)<br>Jody Swirepik (CEWO)<br>Justen Simpson (DPIE)<br>Katie Warner (NECMA)<br>Marcus Cooling (Tech. Advisor)<br>Paul Childs (DPIE)<br>Rohan Hogan (NCCMA)<br>Rory Nathan (Tech. Advisor)<br>Yi-Ming Ma (IEP) | |

# Appendix 3 – Technical advisors list

NSW and Victoria procured technical support for the Independent Expert Panel. Technical advisors involved are in the table below.

| **Name** | **Information** |
|---|---|
| Andy Close | Ex Modeller of the Murray-Darling Basin |
| Ben Tate | Senior Principal Engineer, Water Technology |
| Graeme Turner | Ex Director of Water Resources, DELWP |
| Marcus Cooling | Principal Ecologist, Ecological Associates |
| Rory Nathan | Associate Professor Hydrology and Water Resources, Melbourne University |
| Simon Lang | Senior Water Resources Engineer, Hydrology and Risk Consulting |

Additional technical expertise was provided by key staff within the Victorian Department of Environment, Land, Water and Planning (DELWP), NSW Department of Planning, Industry and Environmental (DPIE), WaterNSW, Goulburn-Murray Water and the MDBA via access to key documents, modelling and associated reports and interviews.

# Appendix 4 – Reference material provided to Panel

The following documents were provided to the Panel to support their workshops and writing of the report. This is not a comprehensive list of documents considered by the Panel, as extra information was made available through workshops and other discussions.

| No. | Title | Author | Year |
|---|---|---|---|
| | Constraints/Modelling general | | |
| 01 | Constraints Management Strategy 2013 to 2024 | MDBA | 2013 |
| 02 | Lessons from easement programs. MDBA's experience with the Hume-Yarrawonga Easement Program | MDBA | 2017 |
| 03 | Summary of analysis undertaken to support the experienced river operators' workshop (April 19, 2012) | MDBA | 2013 |
| 04 | Changing operations to enhance overbank flow events in the Murray – Preliminary Senior River Operators Workshop 15 March 2012 | MDBA | 2012 |
| 05 | Draft MDBA presentation on relaxing constraints and coordinating flows (for MINCO Aug 2019) | MDBA | 2019 |
| 06 | Further information on Constraints program and associated modelling | MDBA | 2019 |
| 07 | Model improvement program for MDBA hydrological models – Responding to Action 2 of the Murray-Darling Basin Water Compliance Review | MDBA | 2018 |
| 08 | Constraints Measures Program Risk Management Strategy, Final draft v2, May 2019 | MDBA | 2019 |
| | Hydrologic modelling | | |
| 10 | Hydrologic modelling of the relaxation of operational constraints in the southern connected system: Methods and results | MDBA | 2012 |
| 11 | Benchmark conditions of development for assessment of the SDL supply contribution | MDBA | 2017 |
| 12 | Modelling assessment to determine SDL Adjustment Volume | MDBA | 2017 |
| 13 | Independent Review of Hydrologic Modelling for SDL Adjustment | Bewsher Consulting Pty Ltd | 2017 |
| 14 | Basin Officials Committee advice to MDBA re the SDL Adjustment Determination | BOC | 2017 |
| 15 | Murray-Darling Basin SDL adjustment mechanism – Report by the Victorian and NSW Ministers' Independent Expert Panel | Don Blackmore, Chris Arnott, Brett Tucker Peter Davies | 2017 |

| | | | |
|---|---|---|---|
| 16 | SDLAM Determination Modelling presentation 28 June 2018 | MDBA | 2018 |
| 17 | Constraints background modelling workshop presentation 7 May 2019 | MDBA | 2019 |
| 18 | CMS Modelling presentation | MDBA | 2019 |
| | Hydrodynamic modelling | | |
| 30 | Flow inundation mapping & impact analysis. CMS prefeasibility technical report | MDBA | 2014 |
| 31 | Draft presentation on Constraints data for inundation layers | | |
| 32 | Hydrodynamic modelling presentation | MDBA | 2019 |
| 33 | Hume to Yarrawonga hydrodynamic model – MDBA 2018 1D/2D update | MDBA | 2018 |
| 34 | Hume to Yarrawonga Hydrodynamic Model Mike 1D/2D | MDBA | 2019 |
| 35 | Inundation modelling stocktake, August 2019 | MDBA | 2019 |
| | Also see 17 above | | |
| | Constraints Projects Concept business cases | | |
| 40 | Menindee Lakes Water Savings Project – Phase 2 Business Case June 2017 | NSW DPI | 2017 |
| 41 | Yarrawonga to Wakool Junction Reach Constraints Measure – Concept Proposal Business Case | NSW DPI | 2016 |
| 42 | Murrumbidgee River Constraints Measure – Concept Proposal Business Case | NSW DPI | 2016 |
| 43 | Hume to Yarrawonga Constraints Measure Business Case | MDBA | 2016 |
| 44 | River Murray in South Australia Constraints Measure Business Case | SA DEWNR<br>MDBA | 2016 |
| 45 | New Goulburn Constraints Measure Business Case | VIC DELWP | 2017 |
| | Constraints Reach Reports | | |
| 50 | River Murray from Hume Dam to Yarrawonga Weir reach report | MDBA | 2015 |
| 51 | River Murray from Yarrawonga Weir to Wakool Junction reach report | MDBA | 2015 |
| 52 | South Australian River Murray reach report | MDBA | 2015 |
| 53 | Murrumbidgee reach report | MDBA | 2015 |
| 54 | Lower Darling reach report | MDBA | 2015 |
| 55 | Goulburn River reach report | MDBA | 2015 |
| | River operations and risk | | |
| 60 | Exacerbated Flood Risk in the Murray and Goulburn: Scoping an approach to analysis. An approach to analysing exacerbated flood risk from environmental watering | Jacobs | 2015 |
| 61 | Update of above report by Jacobs and CSIRO 2017 | | |
| 62 | Assessment of Risks in Delivering Overbank Environmental Watering - Headroom Framework | Rory Nathan | 2017 |

| | | | |
|---|---|---|---|
| 63 | Examining Trade-Offs in Piggybacking Flow Events while Making Environmental Release Decisions in a River System | Simranjit Kaur, Avril Horne, Rory Nathan… | 2019 |
| | Environmental outcomes | | |
| | | | |
| | | | |
| | | | |
| | | | |