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Murray-Darling Basin Authority

Independent Review of Proposed NSW Baseline Diversion Limits for Floodplain Harvesting: Barwon-Darling SDL Resource Unit

25 August 2023

Report for Murray-Darling Basin Authority

Independent Review of Proposed NSW Baseline Diversion Limits for Floodplain Harvesting: Barwon-Darling SDL Resource Unit

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EXECUTIVE SUMMARY

This report provides an independent review of the published hydrological model information for the Barwon-Darling Sustainable Diversion Limit (SDL) Resource Unit that determines the proposed Baseline Diversion Limit (BDL) re-estimates for unregulated river and floodplain harvesting take.

This review focussed on assessing whether NSW's proposal meets the requirements to update the published BDL estimates of the Basin Plan 2012:

- Consistency with the BDL description set out in Schedule 3 of the Basin Plan
- That the information is the best available, and
- The modelling is sufficiently documented.

In doing so, this review examined the Cap scenario model, which underpins the revised BDL estimate as per the BDL definition in the Basin Plan. Analysis of historical independent reviews of NSW BDL re-estimates was undertaken, to understand the maturity of model development.

Assessment framework

The BDL re-estimate assessment framework was developed according to the following:

- Terms of Reference for this review
- MDBA Position Statement 3C: Method for Determining Take
- MDBA Position Statement 3D: Changes to BDL
- BWR 2014 Framework for Incorporating Changes to BDL Estimates Presented in the Basin Plan
- MDBA Position Statement 12A: Best Available Information
- Summary of Best Available Information specific to this review.

Comparison of estimates

A comparison of previous and current estimates of take is integral to the process of assessment of BDL re-estimates. This comparison is complicated by differences in the basis of each estimate, with the primary difference being the inclusion or otherwise of FPH and/or rainfall runoff harvesting volumes.

The BDL estimate volumes reported in this review included all forms of rainfall runoff harvesting as floodplain harvesting (FPH). These include overbank flow harvesting, exempt and non-exempt rainfall runoff from developed irrigation areas. Comparisons of change in estimates, however, were made on the overall BDL estimate on an equal basis, i.e. inclusive or exclusive of rainfall runoff as required.

On an equal basis (i.e. all rainfall runoff harvesting excluded), the proposed BDL re-estimate for the Barwon-Darling unregulated river and FPH is 1.97% less than the current estimate in Basin Plan 2012; reducing from 198.0 GL to 194.1 GL per annum.

The BDL re-estimate for the Barwon-Darling, in full accordance with the BDL definition (which necessarily includes all rainfall runoff harvesting volumes), has increased by 1.82% over the Basin Plan 2012 estimate, from 198.0 GL to 201.6 GL of average annual take.

(It is noted that the meter recalibration project, currently underway, will result in an overall increase to pump capacity with potential to impact modelled diversions and the BDL estimate above.)

Findings

Consistency with the BDL description set out in Schedule 3 of the Basin Plan

The model reflects:

- The BDL description given in Basin Plan Schedule 3; as the Cap limit consistent with Schedule E of the Murray-Darling Basin Agreement and associated baseline conditions including level of development, irrigator behaviour, access conditions and climate sequence, noting:
  - The BDL re-estimate volume (Barwon-Darling Plan Limit) is proposed by NSW to correctly reflect the Cap scenario based on water management arrangements and infrastructure as of 1993/94 and utilises Cap scenario modelled inflows from upstream NSW tributaries, and MDBA-accredited BDL modelling for Qld tributaries (which is Cap in Qld). The reviewer agrees that this model configuration is the correct representation.
  - However, given differences in understanding the correct application of the Basin Plan 2012 definition of the BDL for the Barwon-Darling, the reviewer encourages MDBA to work with NSW to settle on the correct model configuration for the Barwon-Darling inflows, being Cap or Plan Limit, ahead of WRP model submission, noting:
    - The inconsistency in northern basin valleys' model harmonisation given usage of different models (Cap and Plan Limit) across valleys.
    - The use of Cap models for upstream tributaries requires that these models be updated and accredited for Cap. Currently the updated Macquarie-Castlereagh Cap model is unlikely to meet accreditation requirements, and the Namoi update is yet to be completed. In the absence of this, the currently accredited Cap models must be used however these do not explicitly model FPH.

Best available information

The review concluded that the Best Available Information has been used (as a combination of the requirements of MDBA Position Statement 12A and the definition of Best Available Information specific to this review), with the following key findings:

- This conclusion is drawn primarily from the IQQM improvement to the Cap Scenario now correctly configured to 1993/94 management rules and levels of development, and use of Cap modelled tributary inflows. The model underpinning the Basin Plan 2012 BDL estimate was incorrectly configured, meaning that the proposed BDL re-estimate is superior.
- Scientific information is the best currently available (albeit not comprehensive) with extensive use of multiple, independent lines of evidence used to mitigate uncertainty, particularly regarding level of on-farm development at reference dates. Barwon-Darling model-specific sensitivity testing would improve the scientific robustness of the model and meet with best practice.
- BDL re-estimate is scientifically robust with current data availability (noting the key limitation of lack of observed FPH measurement data as described below) with detailed independent reviews providing feedback for model and documentation improvement.
- The improved representation of FPH in the model is the largest area of change, with rainfall harvesting within the property from both developed and undeveloped areas represented, representation of overbank flow harvesting, more accurate infrastructure data and more accurate representation of other components of the farm water balance. Future collection of FPH measurement data and supporting on-farm operational decision-making information is critical to calibrating and validating the representation of FPH in the model, and confidence in results.
- The representation of physical and water user processes has been improved, particularly regarding the timing and nature of overbank flows, representation of farm-scale processes, crop water use and the property water balance.

- There are several identified improvements to the modelling that ideally would be actioned into this IQQM, however NSW has decided to collate these improvements into the new model rebuild in Source that is currently underway. This is an acceptable concession, in that effort into the model rebuild is of more value than updating the ageing IQQM. In summary, in due course this IQQM model will be superseded and no longer best available.

Modelling documentation

The review found that the modelling for the Cap scenario (the BDL re-estimate scenario) is sufficiently documented as published reports contain:

- All references to the data sources pertaining to the forms of take included
- Quality assurance practices undertaken along with the data review and prioritisation of data sources
- Conceptual and geographic spatial extents of the model
- Data periods used for various purposes in the river system modelling
- Process of infilling of data gaps for climate and flow data
- The assessment criteria used (which require sufficient graphical and statistical understanding of the raw data) to assess model performance, however this could be improved with the addition of flow calibration graphs and tables as an Appendix to the Model Build report.

Additional documentation and explanation of the treatment of river pump capacities in the model would be welcome given the pump meter recalibration project currently underway.

The method documentation could be improved regarding results post-processing for the derivation of rainfall runoff volumes. MDBA reported that their modelling team could reproduce the model results from the model scenarios provided and the estimates of unregulated diversions and FPH take, however required assistance from NSW to replicate rainfall runoff harvesting volumes.

The exercise in replication also revealed errors in published report figures that require amendment.

BWR 2014 Framework

An assessment was also undertaken under the BWR 2014 *Framework for Incorporating Changes to BDL Estimates Presented in the Basin Plan*, concluding that revision to the BDL estimate is appropriate and NSW's comprehensive response is commendable given the assessed high risk. However, continued effort is required as more model improvement is possible as identified throughout this review.

Current model limitations

The Terms of Reference for the review required the identification of current model limitations. 22 areas were identified, with the 13 most significant being:

1. There are differences in NSW & MDBA's understanding of the correct application of the Basin Plan 2012 definition of the BDL for the Barwon-Darling, to be applied for WRP model submission and accreditation. These differences pertain to the modelled basis of tributary inflows, be it modelled Cap inflows or modelled BDL inflows (which is the Water Sharing Plan Limit for NSW tributaries). Agreement is required on this aspect, noting the implications for northern basin valleys' model harmonisation and potential for re-accreditation of the updated Cap models that include specific representation of FPH.
2. Negligible FPH observed measurement data available for calibration/validation and incomplete or inaccurate watercourse river diversion measurement data. There are known accuracy issues with historical metered diversions data that is currently being resolved as part of the pump meter recalibration project, and

refinements to this data will directly (and inversely) affect FPH volumes to satisfy the farm water balance with potential to impact the BDL estimate.

3. Current models are best suited to whole-of-valley and river reach scale. This is fit-for-purpose regarding SDL compliance, however more work can be done to replicate on-farm behaviour.
4. The representation of water movement onto, within and returning from, the floodplain can be improved further regarding specific floodplain losses, capture to environmental assets and river returns, to increase confidence in the mass balance of water on the floodplain.
5. Farm-scale rainfall runoff remains as a significant source of uncertainty as there is still insufficient observed data for model calibration and validation.
6. Sustained (and adequately resourced) effort is required to continue to build datasets and information regarding on-farm cropping operations and water use, rainfall runoff characteristics, storage operational behaviour and floodplain harvesting opportunities and continued investment in remote sensing data collection, to support model improvement, calibration and validation purposes.
7. Barwon-Darling model-specific sensitivity testing was not undertaken and is required to meet with modelling best practice.
8. The inclusion of flow calibration graphs and tables would aid the review and adequacy of the model to replicate the main flow simulation and is recommended for inclusion in an update to the Model Build report.
9. Additional documentation is required for third parties to understand and replicate results post-processing, and the published reporting to be clearer regarding model parameters underpinning model results and clearly identify that the refined pump rates from the (incomplete) recalibration project have not yet been addressed in the model.
10. Some errors or conflicts were identified in the documentation regarding published development figures and diversions that slightly change the published BDL volume.
11. The model remains in IQQM however a rebuild of the model in Source is underway that will advance progress of many shortcomings of the existing model, which may affect the BDL estimate in future.
12. Model uncertainty remains due to the application of embargo on diversions. Whilst the current approach is consistent with the previously accredited Cap model, there is opportunity to improve the representation of embargoes in the future model upgrade in Source.
13. The most downstream gauge of a tributary is used to evaluate inflows into the Barwon-Darling system. However, in some tributaries this gauge is upstream of large terminal wetland systems and an estimate is made on the proportion of the gauged flow that discharges to the main channel flow. The modellers note that inflow factoring is undertaken to reflect high flow events bypassing gauges or backwater from the Barwon-Darling system affecting gauge readings. Both issues introduce model uncertainty to tributary inflow rates and volumes, and no better approach has yet been found to reduce this uncertainty.

Conclusions

It is concluded that, in accordance with the review Terms of Reference, the hydrological model for the unregulated Barwon-Darling SDL Resource Unit, that determines the proposed BDL re-estimate:

1. Is based on the best available information as given in Basin Plan s10.49 and therefore a better estimate of the BDL from Basin Plan 2012 BDL estimate. This conclusion is qualified by the following:
    a. Model-specific sensitivity testing was not undertaken and is required to meet with modelling best practice

b. Several identified improvements to the modelling that ideally would be actioned into this IQQM, however NSW has decided to collate these improvements into the new model rebuild in Source that is currently underway. This is an acceptable concession, in that effort into the model rebuild is of more value than updating the ageing IQQM. In summary, in due course this IQQM model will be superseded and no longer best available.

2. Represents the BDL description given in Basin Plan Schedule 3; as the Cap limit consistent with Schedule E of the Murray-Darling Basin Agreement and associated baseline conditions including level of development, irrigator behaviour, access conditions and climate sequence, given:

   a. Resolution of differences in understanding the correct application of the Basin Plan 2012 definition of the BDL for the Barwon-Darling to be applied for WRP model submission and accreditation, as it pertains to the modelled basis of tributary inflows to the Barwon-Darling, be it modelled Cap or modelled BDL inflows (which is the Water Sharing Plan Limit for NSW tributaries).

3. Includes sufficient documentation to provide evidence of the BDL re-estimate method and processes to be able to reproduce the BDL re-estimate.

   a. This conclusion is conditional upon the finalisation of updates to the published reporting to address errors, clarify that the revised river pump capacities arising from the (incomplete) meter recalibration project have not been used, and provide additional documentation to improve clarity in the post-processing of model results.

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ACRONYMS

ABS	Australian Bureau of Statistics
AHD	Australian Height Datum
APT	Annual Permitted Take
BAI	Best Available Information
BDL	Baseline Diversion Limit
B-D	Barwon-Darling
BoM	Bureau of Meteorology
FPH	Floodplain Harvesting
GL	Gigalitre (1,000 megalitres)
ha	Hectares
HEW	Held Environmental Water
IBQ	Irrigator Behaviour Questionnaire
IQQM	Integrated Quantity and Quality Model
LiDAR	Light Detection and Ranging
LTAAEL	Long Term Average Annual Extraction Limit
MDB	Murray-Darling Basin
MDBA	Murray-Darling Basin Authority
ML	Megalitre (1,000,000 litres)
NSW	New South Wales
NSW DPE	NSW Department of Planning and Environment
NRAR	NSW Natural Resources Access Regulator
OFS	On Farm Storage
OLF	Overland Flow
RRH	Rainfall Runoff Harvesting
SDL	Sustainable Diversion Limit
TWS	Town Water Supply
WRP	Water Resource Plan
WSP	Water Sharing Plan

GLOSSARY

Baseline Diversion Limit	The baseline limit of take (volume) from an SDL resource unit; an estimate of how much water was used in the Basin before the Basin Plan (s1.07 Basin Plan 2012)
Benchmark/datum	An on-farm, permanent survey mark to relate storage levels, the calibrated storage curve and the storage meter to AHD.
Cap	The Murray–Darling Basin Cap on Surface Water Diversions, introduced in 1995 by the Murray–Darling Basin Ministerial Council as described in Schedule E of the MDB Agreement, Schedule 1 of (Water Act, 2007)
Carryover	An arrangement that allows water entitlement holders to take their unused water allocation from one water year to the next.
Channel	An earth structure, including bed and banks, used to convey water above natural ground level.
Consumptive use	The use of water for private benefit consumptive purposes including irrigation, industry, urban and stock and domestic use.
Developed area	Irrigation fields with tailwater return drains.
Diversions	Volume of surface water taken for consumptive use.
Drain	An earth structure, including bed and banks, used to convey water below natural ground level.
Water access licence / water allocation / water entitlement	Legal right to receive a certain volume of water in a year.
Evaporation	Water lost to the atmosphere from an open water body.
Field	A unit of area within either the developed or undeveloped area that is uniformly managed for crop production.
Floodplain Harvesting	The taking of water from a floodplain, including after it leaves a watercourse during a flood.
Flood runner	A water flow path on the floodplain that only conveys water in flood events.
Flow gauge	A device used to measure the height of a river, from which the flow in the river can be calculated.
Flow meter	An electronic or mechanical device used to accurately measure instantaneous water flow rates in closed conduits (i.e. pipe or culvert) or open channels/drains.
Full supply volume/level	Maximum water level in a storage.
Held Environmental Water	Water that is held as part of a licensed volumetric entitlement for environmental use, held within the same licence categories as all other water access licences and subject to the same operating rules.
Hydrological model	A simplification of a real-world system, usually a mathematical model, that aids in understanding, predicting, and managing water resources.
Levee/bund/diversion bank	An artificial structure used to direct, divert, exclude or reduce the flow of overland flow onto or from land.
Level of development	The extent of water regulating, diversion, capture and storage infrastructure developed on- and off-farm, referenced to a particular point in time.
Long Term Average Annual Extraction Limit ('Plan Limit')	As defined in the Water Sharing Plan for the Barwon-Darling Unregulated River Water Source 2012 (noting that this WSP did not exist at the Basin Plan baseline date of 30 June 2009): *33 Calculation of the long-term average annual extraction limit*

	(2) The long-term average annual extraction limit is the long-term average annual extraction from the water source that would occur under Cap baseline conditions as agreed under the Murray-Darling Basin Agreement at the commencement of this Plan.
Non-FPH/OLF water	Water taken that does not originate from floodplain harvesting or overland flow. Examples include regulated river water, groundwater and irrigation tailwater.
On-farm infrastructure	Privately owned water regulating, diversion, capture and storage infrastructure in which water can be taken from a water source for direct or later use.
Photogrammetry	The use of photography in surveying and mapping to ascertain measurements between objects.
Quality Assurance	The maintenance of a desired level of quality in a service or product, especially by means of attention to every stage of the process of delivery or production.
Rainfall runoff harvesting	Capture of rainfall runoff from developed areas as outlined below. NSW has proposed different categories of accounting for rainfall runoff harvesting against FPH entitlements: • Exempt rainfall runoff harvesting is defined as that which occurs from developed areas (fallow or cropped) on days when no water is being harvested from outside the farm. • Non-exempt rainfall runoff harvesting is defined as all runoff harvesting that occurs when water is being harvested from outside the farm. Rainfall run-off from undeveloped land on a farm is not exempt.
Re-estimate	A new, revised or improved estimate of the volume of water taken.
Regulated river	A River, Stream or other Water Course, the flow of which is regulated by artificial structures such as Dams, Weirs, Off-takes, Storages, etc.
Remote sensing	The process of detecting and monitoring the physical characteristics of an area by measuring its reflected and emitted radiation at a distance, typically from satellite or aircraft.
River breakout / overbank flow / flood breakout	River flows that exceed the capacity of the watercourse and overflow onto the floodplain.
River reach	A section of a stream or river along which similar hydrologic conditions exist, such as discharge, depth, area, and slope.
SDL Resource Unit	The water resources, or particular parts of the water resources, of a water resource plan area that is either a surface water SDL resource unit or groundwater SDL resource unit (s1.07 Basin Plan 2012)
Seepage	Water lost into the soil profile (bed and banks).
Sensitivity testing	Analysis that determines how different values of an independent variable affect a particular dependent variable under a given set of assumptions.
Share components	The Share Component of the access licence is the volume share of water made available in a water source.
Source model	eWater Source, Australia's national hydrological modelling platform.
State water management law	Individual Basin State legislation pertaining to management of water resources within its jurisdiction (defined in s4 of Commonwealth (Water Act, 2007)
Storage	An on-farm structure that stores water. Otherwise known as a reservoir, cell, ring tank, dam or turkey nest where water is stored above natural ground level; or known as a ground tank or dam where water is stored below natural ground level. Filled with water from any source via gravity or pumping.
Storage curve	A storage-specific lookup table that relates storage water depth to volume and water surface area.

Supplementary licence / access	An event that temporarily changes water regulation and use in one or more sections of a stream. Supplementary Events include flooding (the most common supplementary event), tributary inflows and increases in flow due to spillage of storage.
Sustainable Diversion Limit	The long-term average volumetric limit on the quantity of water that can be sustainably taken from Basin water resources for consumptive use by towns, communities, industry and farmers, as defined in Water Act 2007 s22 Item 6 *"The maximum long-term annual average quantities of water that can be taken, on a sustainable basis, from (a) the Basin water resources as a whole; and (b) the water resources, or particular parts of the water resources, of each water resource plan area."*
Tailwater	Surface water runoff arising only from irrigation water applied to irrigation fields.
Telemetry / remote read	Automated, remote transfer of data from on-farm metering equipment.
Temporary / surge / buffer / field storage	An on-farm storage that is used to temporarily detain water for later use or transfer to long term storage.
Water balance	Accounting of inflows to any water system or area, equal to its outflows plus change in storage during a time interval.
Water Resource Plan	A statutory (Commonwealth) plan for each SDL Resource Unit that sets out the rules for how water is used at a local or catchment level, including 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 (defined in s4 of Commonwealth (Water Act, 2007).
Water Sharing Plan	A statutory document under NSW legislation that establishes the rules for sharing water between the environment and water users, and between competing water users.
Undeveloped area	Property area not developed for irrigation.

1. Introduction

Fifteen50 Consulting has been engaged by the Murray-Darling Basin Authority (MDBA) to review the published hydrological model information (Model Build and FPH Entitlements reports, May 2022), for the Water Resource Plan (WRP) area of NSW Barwon-Darling SDL Resource Unit that determines the proposed Baseline Diversion Limit (BDL) re-estimates.

1.1 Background

The *Murray Darling Basin Plan 2012* defines Sustainable Diversion Limits (SDLs) for each SDL resource unit in the Basin, which is the maximum consumptive water limit. For surface water, SDLs are defined in Basin Plan Schedule 2 and are equal to the BDL less water recovery. BDLs are defined in Basin Plan Schedule 3, which is the statutory point of reference for determining the BDL and is described for each form of take in each SDL resource unit. It generally provides, as a note, a volumetric estimate of long-term average take that was made by the MDBA at the time of Basin Plan development.

A Basin state may provide a BDL re-estimate for any form of take in any SDL resource unit (MDBA, 2011). If it is based on the best available information (Basin Plan s10.49 WRP requirement) and aligns with the Basin Plan Schedule 3 BDL description, then it is reasonable and appropriate for the MDBA to agree with the BDL re-estimate. This process is set out in MDBA's Position Statement 3D 'Changes to BDL' (MDBA, 2015) and the decision support framework (Barma Water Resources, 2014).

NSW is re-estimating the BDL for the take of water from regulated river and floodplain harvesting (FPH) water sources in five SDL resource units; the Barwon Darling Watercourse, NSW Border Rivers, Gwydir, Namoi and Macquarie-Castlereagh as part of WRP development and re-submission. The BDL re-estimates are determined using hydrological models that incorporate the rules and conditions found in State water management at the baseline date defined in Basin Plan Schedule 3 and run over the historical climate conditions. The baseline date is 1 July 2009 for NSW Border Rivers, 30 June 2009 for Gwydir and Macquarie-Castlereagh and 1 July 2010 for Namoi. At these dates, the baseline water sharing plans define the limit as the lesser of Long-Term Average Annual Extraction Limit (LTAAEL) or the long-term Murray-Darling Basin Ministerial Cap on Diversions (Cap). As there was no water sharing plan for the Barwon-Darling Watercourse SDL resource unit at the time of Basin Plan development, the BDL description is set to that under the Cap, given in Schedule E of the Murray-Darling Basin Agreement. This applies to Barwon-Darling Watercourse SDL resource unit SS19, which covers the main channel only from Mungindi to upstream limit of Menindee Lakes.

The long-term Cap limits therefore are an important consideration in the proposed BDL re-estimates.

1.2 Purpose

This review has been undertaken at the request of the MDBA, prior to the re-submission by the NSW Government of the Water Resource Plan for the Barwon-Darling that includes provisions for floodplain harvesting. It is based on the latest modelling information published by NSW in May 2022, on the expectation that this modelling (without significant changes) will be submitted to the MDBA as part of a proposal to re-estimate the watercourse and floodplain harvesting components of the BDLs, and as part of the water resource plan package.

Consistent with the MDBA's Position Statement on FPH (MDBA, 2019), this review is focussed on assessing whether NSW's proposal meets the requirements to update the BDL estimates, a key part of which is checking for consistency with the BDL description set out in Schedule 3 of the Basin Plan, and that the information is the best available and is sufficiently documented. In doing so, it has looked at the Cap model, which underpins the revised BDL estimate, to assess whether it is consistent with the requirements of Schedule E of the Murray–Darling Basin Agreement (for

example, it has considered whether any major differences from the formerly accredited, or provisionally accredited, Cap models are adequately described).

However, this review does not constitute a formal assessment of an NSW updated Cap scenario relative to all requirements for an analytical model set out in Clause 11 of Schedule E of the MDB Agreement.

The need for, and relevance of such a formal assessment is diminished given the transition from the Cap system to SDL accounting underway, and expectation that Cap compliance would be replaced by SDL accounting once all WRPs are accredited.

1.3 Review structure

NSW is proposing a staggered approach to the provision of its water resource plans for accreditation by MDBA. These reviews are proposed to be progressively completed in accordance with the project Terms of Reference (Appendix A).

The first two review tranches, being NSW Border Rivers and Gwydir, and Macquarie-Castlereagh, are complete (Fifteen50 Consulting, 2022) and (Fifteen50 Consulting, 2023). This report addresses the review for the Barwon-Darling SDL Resource Unit. The subsequent timing of the review for the Namoi SDL Resource Unit is to be confirmed upon finalisation by NSW.

1.4 Review objectives

This review of the relevant hydrological model for the NSW Barwon-Darling SDL Resource Unit, that determines the proposed BDL re-estimate, will inform the MDBA whether:

4. It is based on the best available information as given in Basin Plan s10.49 and therefore a better estimate of the BDL from Basin Plan 2012 BDL estimates.
5. It represents the BDL description given in Basin Plan Schedule 3; as the Cap limit consistent with Schedule E of the Murray-Darling Basin Agreement and associated baseline conditions including level of development, irrigator behaviour, access conditions and climate sequence.
6. There is sufficient documentation to provide evidence of the BDL re-estimate method and processes to be able to reproduce the BDL re-estimate.

Any limitations or uncertainties in the proposed BDL re-estimates are to be noted separately to the review conclusions in relation to points 1-3 above.

1.5 Acknowledgements

Fifteen50 Consulting undertook this review as follows, with assistance, contributions, and feedback as acknowledged:

- MDBA project management team for this engagement
  - Development of BDL re-estimates review framework specific to the Terms of Reference
  - Provision of historical reports and documents for literature review
  - Clarification of included diversion components of historical BDL estimates and supporting documentation
  - Draft report review.
- MDBA modelling team
  - Confirmation of updated WRP model information received
  - Clarification of documentation adequacy and ability to reproduce published numbers

  - Interrogation of specific model input parameter values
  - Draft report review.
- NSW modelling team
  - Engagement to clarify aspects of the published literature and representation of FPH in the WRP model
  - Draft report review (Andrew Brown & Siv Teh)
- Independent reviewers for NSW Floodplain Harvesting Policy modelling and implementation, Tony Weber and Greg Claydon (Alluvium Consulting)
  - Engagement regarding their previous reviews of hydrological WRP models and reporting
  - Draft report review.

2. Previous reviews

A summary of existing independent reviews of NSW BDL re-estimates are presented below in chronological order.

Barwon-Darling Valley – IQQM Cap Implementation Report by NSW Office of Water, July 2011 – Version 1 Report (NSW Office of Water, 2011)

This report summarises and documents the IQQM calibration, validation and model use for representation of Cap conditions in the unregulated sections of the Barwon-Darling River. It details the calibration and the 1993/94 configuration. This report states that the overall quality of the Barwon-Darling River Valley IQQM calibration suggests that it is suitably robust for Cap Auditing, 100+ year scenario running and for comparison of impacts from alternative management scenarios. Key recommendations for future improvements include improved procedures for streamflow calibration, upgrades to diversion calibration, and incorporating on-river weir modelling.

This reported on the existing IQQM model that was updated for WRP submission, the subject of this review.

Independent Baseline Model Review by Barma Water Resources (Daren Barma), June 2012 final report (Barma Water Resources, 2012)

This final report was a review of 24 surface water models in New South Wales and Queensland which were used to inform the inception of the Basin Plan. This was mostly on definition compliance with relevant plans or policy, and not a check for model compliance with the BDL. The key finding relevant to this report was that all models have been found to be representative of their respective baseline definitions, but some models including Barwon-Darling have been found to require updating for representation of the baseline diversion definition and associated diversion estimates to be improved. Several improvements were proposed, with the key improvement being the inclusion of floodplain and rainfall runoff harvesting in the model which have been subsequently addressed in modelling for BDL re-estimates.

Barwon-Darling Valley Independent Audit of Cap Model by Bewsher Consulting, January 2013 Final Report (Bewsher Consulting, 2013)

This final report was an independent audit of the Barwon-Darling Valley's IQQM model, to assess suitability for use under Schedule E of the Murray-Darling Basin Agreement. The report concluded that provisional accreditation of the model be given until the end of 2014 (provisional accreditation was subsequently given by MDBA until December 2015) because of improvements that need to be performed, and the importance of the Barwon-Darling IQQM being a key model in the basin that links many NSW and QLD cap models to the Murray-Lower Darling cap model. (*It is noted that the model subject to this 2023 review, whilst subject to some minor bug fixes over time, is essentially the same as the provisionally accredited Cap model.)*

The model as presented for this audit was shown to be reasonably replicating observed behaviour under cap conditions and that it is appropriate for the model to be approved for operation under Schedule E. Key recommendations arising from this audit include:

- The existing shortcomings of the Barwon-Darling IQQM, and model improvements be pursued. Some of these model improvements include recalibration of Sacramento modelling, extension of the simulation period, revision of method for estimating ungauged tributary inflow, updating of flow calibration (which is a large task), transmission losses including consideration of antecedent conditions, incorporation of fifteen on-river weirs into the Barwon-Darling IQQM, revision to metered diversion records and recalibration of diversions, OFS seepage and wet-up losses on initial filling, inclusion of town water supplies, revision of Colly Farms diversion in both the Barwon-Darling and Gwydir cap models to ensure total diversion is being accurately simulated, improvements to the existing Cap Report documentation, inclusion of tributary inflows from upstream model during annual target runs, and amalgamating intersecting Streams to reduce effort.

- The revised long term cap diversion of 189 GL/yr be adopted.
- Once the revised cap model and target model are available (at or before the end of 2014), revision of the long-term cap diversion and all the annual targets since 1997, be considered.
- The MDBA consider revising both the cap and target runs of the Murray/Lower Darling model to allow for improved simulation of the Barwon-Darling outflows into the Lower Darling once these are available as a result of the modelling improvements proposed by end of 2014. Prior to these improvements becoming available, the MDBA could consider revising its current adjustment for the 1956 flood volume.

Independent Review of NSW Floodplain Harvesting Policy Implementation by Alluvium (Tony Weber and Greg Claydon), July 2019 final report (Alluvium, 2019)

This final report was the culmination of the independent review of the modelling and implementation of the FPH policy in NSW. At the time Alluvium performed this review, draft reports were only available for NSW Border Rivers and Gwydir, but not the other valleys such as Barwon-Darling. A key finding is that in the Barwon–Darling, floodplain harvesting activities were not typically accounted for when *Water Act 1912* unregulated licences were volumetrically converted, so the Barwon–Darling was being treated like a regulated river in terms of its extraction limits and floodplain harvesting licensing.

This review found that the models represent a significant advancement in the determination of consumptive water use and the understanding of the various sources, extractions and uses of water taken in the regulated and unregulated systems (including the Barwon Darling) although opportunities for improvements remained with respect to modelling approaches, documentation, stakeholder engagement and communication and water planning and management. There were a few key findings about the model approach, the first of which is that there was no cross-verification of the FPH volume other than the need to satisfy the water balance in the model. It was also noted that the justification and evidence for the adopted parameters and modelling of rainfall-runoff were very limited, and it was a challenge to support the inclusion of rainfall-runoff volumes within the FPH take as currently modelled. Thirdly, existing models did not explicitly represent flood water returns to the river. As such, the models were not considered suitable for assessing the benefits and impacts of the FPH licensing framework, including the entitlement and account management rule framework, on specific downstream flows either in the rivers or on the downstream floodplains themselves. However, the existing models could estimate relative differences between two or more scenarios of FPH diversions (e.g. current levels vs historical levels of development).

The key recommendations addressed the points above such as further work to provide justification for the rainfall-runoff model used, comparison of floodplain breakout volumes assumed in the model against other evidence where possible, as well as undertake data collection and model reconfiguration to represent return flows and down floodplain flows so that downstream impacts could be better determined. There were also important recommendations concerning improved documentation and stakeholder engagement and communication to increase clarity and transparency. NSW Government accepted and agreed to all recommendations.

Independent Review of Interim Baseline Diversion Limits for NSW Floodplain Harvesting by Moroka Pty Ltd (Tony Ladson), December 2019 – final report (Moroka, 2019)

This final report was the outcome of an independent review of the FPH component of the proposed interim BDLs brought forward by NSW as part of the WRPs submitted to the MDBA in June 2020. This was performed for five SDL resource units in northern NSW (including Barwon-Darling) to determine if they are based on the best available information, if there are any better estimates, and if the interim BDL values are better than those published in 2012 in the Basin Plan. The conclusion drawn was that the interim BDLs were based on the best available information and are better than estimates published in the Basin Plan (e.g. Barwon-Darling Watercourse includes harvesting of rainfall runoff which was not part of the floodplain harvesting estimates in the Basin Plan), however the MDBA

assessment framework (Barma Water Resources, 2014) puts it at high to very high risk, with high costs but with substantial benefit. The key recommendation related to mitigating this risk by increasing the scientific robustness of the BDL estimates. Part of achieving scientific robustness necessitated peer review and quality assurance of models, and transparency of the data management process in the model.

For Barwon-Darling the issues to be overcome in future revisions of the model were that the Barwon-Darling Cap scenario runs depend on results from upstream Cap models which had not been updated at the time (report date December 2019; note as of July 2023 the NSW Border Rivers and Gwydir have since been updated) to reflect floodplain harvesting, and that individual farm level information was included in the Barwon-Darling IQQM Cap model but was not independently validated using objective information.

Review of floodplain harvesting modelling submissions – Barwon Darling by Alluvium (Tony Weber), April 2021 – letter sent to DPE (Alluvium, 2021)

This letter was a summary of the review of the fourteen revised Barwon Darling farm submission analyses and written responses for the Barwon Darling system modelling. These analyses were found to be undertaken with adequate thoroughness, along with good transparency of discussion around key methodological issues associated with upstream flows, arid land hydrology and the way that floodplain harvesting is modelled in the Barwon Darling system. The following points were noted:

- Modellers used observed data rather than Border Rivers model inflows to more accurately determine access for upstream users in the Barwon Darling for the purpose of eligible works scenario only, instead of less water available which would be implied if the modellers used Queensland Border Rivers simulation of full entitlement modelling
- Further research is required to quantify how other modelled inflows are handled in other models
- Arid regions of the Barwon Darling catchment (particularly in the western side) have used hydrological approximations based on data from similar landscapes in Queensland due to the lack of data availability. This is an area of further analysis and research
- Water access hierarchy at certain flow conditions (e.g. Class A, B or C licence) are present in Barwon Darling but not other systems, and this has implications in terms of floodplain harvesting access (as C Class access licences commence earlier than FPH, reducing available on-farm storage airspace for take of FPH, leading to lower than expected FPH diversions at some properties).

The review found that the results (post 17 March 2021) are equitable and consistent analyses of the submissions and are now reflected in the modelling.

Independent Review of Water Resource Plan Hydrological Models for the Barwon-Darling Watercourse by Bewsher Consulting, June 2021 – Final Report (Bewsher Consulting, 2021)

This was a review of the hydrological models that underpin the Barwon-Darling Watercourse Water Resources Plan (WRP) that was submitted to the MDBA in June 2020, to assist the MDBA in their appraisal of the Barwon-Darling Watercourse WRP prior to its accreditation and implementation under the Basin Plan. One of the principal findings of this review is that the BDL has been incorrectly estimated within the Basin Plan in 2012 and within the BDL and APT Reports in 2019 that support the WRP submitted by NSW in June 2020. The review recommended that the BDL needs to be reassessed based on 'Cap' conditions both within the Barwon-Darling and within its tributaries, noting that the net change in BDL may in fact be small despite the extensive changes recommended to the BDL model. This will also necessitate alterations to the APT model and the proposed scaling factor.

This review also believed that the improved WRP model suite would be suitable to support the Barwon Darling WRP once the recommendation in the review is implemented.

Review of NSW Barwon Darling Model Build and Scenarios reports relevant to Floodplain Harvesting Policy Implementation by Alluvium (Tony Weber and Greg Claydon), May 2022 – letter sent to DPE (Alluvium, 2022)

Following on from Alluvium's comprehensive review of the models in 2019, DPE produced more comprehensive documentation (a suite of reports) as part of the response to the recommendations made by the reviewers. This letter was a summary of the review of the draft final model build and scenario reports pertaining to the Barwon-Darling river system. The modelling and reports were endorsed by the reviewers to have addressed the recommendations from Alluvium's previous 2019 review. The reviewers also noted that the challenges of accounting for the way water resource access is allocated in Queensland and the implications for flows into NSW at Mungindi, and that further explanation and justification is required for observed versus modelled flows at this point.

3. Baseline Diversion Limits

Comparison with previous and current BDL estimates is integral to the process of assessment of BDL re-estimates. Table 1 describes the various published estimates in chronological order. The BDL re-estimate for Barwon-Darling is identified in the table as the re-estimate of Cap, given in Schedule E of the Murray-Darling Basin Agreement, given no Water Sharing Plan was in place at the time of Basin Plan development.

For the purposes of this review, the required comparison is between the Basin Plan 2012 as the current BDL estimate and the Cap re-estimate, as the proposed BDL re-estimate. The BDL estimates are based on descriptions outlined in Schedule 3 of the Plan.

The following important points are raised:

1. The differences in the estimated values are expected, noting the following:
    a. Estimates have been prepared at different points in time. It is expected that each successive estimate should be an improvement on historical estimates.
    b. There are differences in the simulation periods used to calculate estimates (that may have significant impacts, particularly when later, drier years are included) and scenarios used (to the extent that they are a better representation or better understanding of the same set of conditions).
    c. Early estimates may have excluded some elements of take if confidence in the volumes determined was low.
2. The MDBA Technical Report Comparison of watercourse diversion estimates in the proposed Basin Plan with other published estimates, 2011/01, Version 2 (MDBA, 2011) explains *"The Basin Plan has not included rainfall runoff harvesting in diversion estimates for any valley, because of lack of data to estimate it and potential of double counting in the interception estimates."*.

    The Cap Diversions Formula Register (MDBA, 2018) for Barwon-Darling includes land surface diversions (i.e. FPH) but excludes rainfall-runoff harvesting, meaning that Cap estimates made over time have included FPH but excluded rainfall-runoff harvesting, and this is itemised separately in Table 1.
3. Stakeholders are interested in the best estimates of all components and the methods by which those components have been determined. Comparisons between current and historical estimates are complicated with the inclusion or otherwise of rainfall-runoff harvesting as part of floodplain harvesting, and changes to modelling approaches to FPH and rainfall runoff that shifts the relative proportions of FPH components.
    a. The published floodplain harvesting reform reports for Barwon-Darling include exempt rainfall runoff in the Plan Limit total (NSW DPE, 2022) and the reviewer understands that the BDL re-estimate to be submitted in the Water Resource Plan for Barwon-Darling SDL Resource Unit will itemise the 6.8 GL of exempt rainfall runoff as part of FPH.
    b. The BDL estimate volumes reported in Table 1 have quantified all forms of rainfall runoff harvesting (taken by properties that take FPH) in floodplain harvesting, as per the Basin Plan definition (s1.07 Basin Plan, 2012). These include overbank flow harvesting, exempt and non-exempt rainfall runoff from developed irrigation areas. Comparisons, however, are made on an equal basis, i.e. inclusive or exclusive of rainfall runoff as required. [It is noted that rainfall runoff harvesting on non-floodplain harvesting properties is not modelled/reported.]
    c. It is acknowledged that rainfall runoff harvesting from developed areas is generally a higher percentage of rainfall (long-term average) than what would be experienced from undeveloped areas, given the practice of irrigation maintains a higher average soil moisture.

4. Whilst different sub-components making up the BDL estimates are examined to explain differences in the totals, it is only the overall total BDL for the SDL Resource Unit that applies as the limit, i.e. there may be shifts in modelled values of sub-components such as unregulated river, floodplain harvesting and rainfall runoff, however any assessment of change to the BDL is based on the overall total, in consideration of the included components.

Considering the above, the following changes are noted:

- The latest Cap estimate (BDL re-estimate) has decreased by 1.97%, inclusive of FPH but excluding all rainfall-runoff, for comparison on equal terms.
- The BDL re-estimate overall, including take from the watercourse and all forms of floodplain harvesting, has increased by 1.82%, noting the inequality in comparison given inclusion of rainfall-runoff harvesting.

The proposed BDL re-estimate for Barwon-Darling is 1.82% higher than the current estimate in the Basin Plan 2012.

Table 1: Estimates of FPH limits in Barwon-Darling (GL/yr; may include minor rounding error due to 0.1 GL precision)

	1: MDB long-term annual Cap target	2: Basin Plan 2012	3: Model underpinning Basin Plan 2012 estimate	4: Water Sharing Plan	5: Cap Audit	6: BDL interim re-estimate	7: Cap re-estimate
Long-term limit	Cap	BDL **Current BDL estimate**	BDL	LTAAEL (= Cap in B-D)	Cap	BDL	BDL & Cap re-estimates **Proposed BDL re-estimate**
Source	MDB Cap Register 2020-21 [6]	Basin Plan 2012 [11] MDBA Technical Report 2010/20 [1,2] and 2011/1 [3]	Moroka Independent Review of Interim BDLs for NSW FPH 2019 [4]	Water Sharing Plan for the Water Sharing Plan for the Barwon-Darling Unregulated and Alluvial Water Sources 2012 [10]	Barwon-Darling Valley: Independent Audit of Cap Model [5]	Proposed WRP submitted by NSW June 2020 (since withdrawn) [8]	Floodplain harvesting entitlements for the Barwon-Darling unregulated river system: Model scenarios report (May 2022) [9]
Date determined	2013	2010	2010	2012	2013	2019	2022
Simulation period	01/07/1895-30/06/2009	01/07/1895-30/06/2009	01/07/1895-30/06/2009	01/07/1895-30/06/2009	01/07/1895-30/06/2009	01/07/1895-30/06/2009	01/07/1895-30/06/2009
Watercourse	Not reported separately. Total in MDB Cap Register 2020-21 is 322.0 GL (including Lower Darling).	186.5	Not reported (assume 186.5 GL as per Column 2 Basin Plan 2012)	189.0	189.0	189.0	184.5
Floodplain harvesting	FPH not reported separately. Note rainfall runoff harvesting (RRH) is not listed in Cap Diversion Formula Register [7]	11.5 GL (FPH) Rainfall runoff harvesting (RRH) not included	11.0 GL (FPH) 10.9 GL (RRH)	14.3 GL (FPH) 10.9 GL (RRH)	14.3 GL (FPH) 10.9 GL (RRH)	14.3 GL (FPH) Rainfall runoff harvesting (RRH) not reported separately	17.0 GL comprising: • 9.6 GL overbank flow • 7.4 GL rainfall runoff harvesting (RRH) (Note that the published total RRH figure of 8.1 GL is incorrect (S Teh pers. comm. 23 June 2023))
Total (GL)	**322.0 (includes Lower Darling)**	**198.0 (includes FPH)** **198.0 (includes FPH & RRH)**	**197.5 (includes FPH)** **208.4 (includes FPH & RRH)**	**203.3 (includes FPH)** **214.2 (includes FPH & RRH)**	**203.3 (includes FPH)** **214.2 (includes FPH & RRH)**	**203.3 (includes FPH)** **203.3 (includes FPH & RRH)**	**194.1 (includes FPH)** **201.6 (includes FPH & <u>all</u> RRH)** **(note published report figure of 202.2 GL is incorrect)**
Relative change %							*Change from Column (2) Basin Plan 2012:* *-1.97% (-3.9 GL incl. FPH, excl. RRH)* *+1.82% (+3.6 GL incl. FPH, incl. all RRH)*

Refer to Section 10 References for full document reference details. Note that references 1-8 are available on the MDBA website.

1. (MDBA, 2020)
2. (MDBA, 2011)
3. (MDBA, 2011)
4. (Moroka, 2019)
5. (Bewsher Consulting, 2013)
6. (MDBA, 2020) (Table 6)

7. (MDBA, 2018) Barwon-Darling Cap includes land-surface (floodwater) diversions only, excludes rainfall runoff harvesting.
8. (NSW DPE, 2019)
9. (NSW DPE, 2022) https://www.industry.nsw.gov.au/__data/assets/pdf_file/0013/512500/model-scenarios-report.pdf
10. (NSW DPE, 2012) https://legislation.nsw.gov.au/view/html/inforce/2020-07-01/sl-2012-0488#sec.33
11. (Basin Plan, 2012) https://www.legislation.gov.au/Details/F2021C01067

4. BDL re-estimates assessment framework

The BDL re-estimate assessment framework developed for this review submits to the following expectation from the MDBA Floodplain Harvesting Position Statement (MDBA, 2019):

> *"To give confidence in estimates of floodplain harvesting volume used for water planning: data, processes and methods used to estimate historical and current levels of floodplain harvesting need to be transparent, make use of multiple lines of evidence, and have a strong focus on independent oversight and review."*

The overall framework for the assessment of the BDL re-estimates has been developed with guidance from:

- MDBA Position Statement 3C (MDBA, 2015)
- MDBA Position Statement 3D (MDBA, 2015)
- *Framework for Incorporating Changes to BDL Estimates Presented in the Basin Plan* (Barma Water Resources, 2014)
- MDBA Position Statement 12A (MDBA, 2015)
- Summary of Best Available Information specific to this review (Appendix B).

The above frameworks address all forms of take that comprise the BDL. The scope of this review is limited to the proposed BDL re-estimates for FPH however it is acknowledged that estimates for regulated river diversions will also be updated to maintain model integrity. Hence, the framework as applied for this review has been modified accordingly whilst retaining essential assessment criteria, as described further in Table 2.

Table 2: Assessment framework

Assessment criteria	Justification	This Review reference
MDBA Position Statement 3D: Preliminary checklist		
Evidence that the alternate FPH estimate is scientifically robust and reflects the best available information (BAI).	• (Barma Water Resources, 2014) Chapter 5 • MDBA PS12A • Summary of BAI specific to this review (Appendix B) • Relevant MDBA PS3C QA criteria	Refer below
Evidence that the method is an improvement to the current methods to estimate FPH take under BDL.	• Method criteria	Refer below
That the magnitude of change in the estimate of the FPH component of the BDL is significant enough to warrant consideration and an improvement to the current estimate of the BDL.	• (Barma Water Resources, 2014) Chapter 5	Refer below
MDB Position Statement 12A: Best Available Information		
That all significant sources of information on which the Water Resource Plan is based are identified and described (Basin Plan s10.49(2)). Information types: • Government: relevance and hierarchy • Scientific: fit for purpose, peer reviewed, national/international standard, externally audited, industry standard, most relevant and up to date.	• This review	• Section 5 & Table 3
• Modelling • Cultural.	• Relevant MDBA PS3C QA criteria • Out of scope for this review	• Appendix C
Summary of Best Available Information Specific to this Review (Appendix B)		
The new BDL estimate is superior to the currently adopted estimate, by demonstrating that:		

Assessment criteria	Justification	This Review reference
• It is scientifically robust, particularly in relation to the previous BDL estimate. • Uses improved knowledge of the relevant levels of development and the entitlements and rules (as per the definition of the BDL in Schedule 3 of the Basin Plan) and associated consumptive use occurring as a result.	• (Barma Water Resources, 2014) Section 5.3.2, Tables 6, 7, 8 & 9 • Basin Plan Schedule 3	• Section 7 & Table 3 • Table 4
• The new BDL estimate must use best available information in terms of data used and modelling methodology: – New or improved data that the method used to estimate a BDL take component is based on, such as climatic/streamflow data (July 1895-June 2009) or on-farm development data. – New methods for estimation of the BDL take component, such as new computer models (e.g. IQQM to Source). – Improved representation of physical and user processes in existing methods used to estimate take under the BDL such as processes to estimate tributary inflows and climate inputs, levels of development, understanding of irrigator behaviour including crop types, water use patterns and risk management strategies. – Better representation of policies, allocation, accounting and river operational rules that apply under the definition of the BDL estimate.	• This review	• Section 5 & Table 3
• It is sufficiently documented to be able to reproduce the BDL, with: – Clear reasoning and evidence to support any change to estimates of the volumes of any form of take – Descriptions of any planning assumptions or modelling settings that may impact the estimation of those volumes.	• This review	• Section 6.3
MDBA Position Statement 3D: Method criteria		
The method meets the definition of the BDL in Schedule 3 of the Basin Plan, including by reflecting the level of development at 30 June 2009 and all the entitlements and rules that were current in water planning instruments at June 2009 (or as otherwise specified in Schedule 3). For clarity:	• This review	Sections 3, 6.1 & Table 4
• It represents the BDL description given in Basin Plan Schedule 3; the State water management limit and baseline conditions associated with FPH, including irrigator behaviour, access conditions and climate sequence.	• Basin Plan Schedule 3	
• Includes a review of the updated long-term Cap model for consistency with the requirements of Schedule E of the Murray-Darling Basin Agreement.	• Schedule E of the MDB Agreement, Schedule 1 of (Water Act, 2007)	
The method incorporates all relevant data for the form of take (FPH).	This review	Section 6.2

Assessment criteria	Justification	This Review reference
The method is sufficiently documented such that estimates of FPH take under the BDL can be reproduced.	This review	Section 6.3
The method is sufficiently documented such that any limitations and uncertainties in the method are known.	This review	Section 6.4
Where the method involves a model to support the demonstration of meeting the SDL (s10.10), the model will be assessed using criteria from MDBA Position Statement 3C.	Relevant MDBA PS3C QA criteria	Section 6.5 & Appendix C
Framework for Incorporating Changes to BDL Estimates Presented in the Basin Plan (BWR, 2014): Chapter 5		
Significance of change	Section 5.3.1, Tables 4 & 5	Section 7.1
Risk assessment, as a combination of: • Likelihood of the revised BDL estimate being scientifically robust and defensible; and • Consequences that result from the new BDL estimate.	Section 5.3.2, Tables 6, 7, 8 & 9	Section 7.2
Cost-benefit assessment.	Section 5.3.3, Tables 10, 11 & 12	Section 7.3

5. Best available information

The first key objective of this review is to determine whether the BDL re-estimate is based on the best available information and is therefore a better estimate of the BDL from Basin Plan 2012 BDL estimates.

Table 3 describes this assessment as a combination of the requirements of MDBA Position Statement 12A (MDBA, 2015) and the definition of Best Available Information specific to this review (Appendix B).

Table 3: Assessment of Best Available Information

Category	Assessment criteria	Findings
Sources of information	That all significant sources of information on which the Water Resource Plan is based are identified and described (Basin Plan s10.49(2)).	Yes. Sources of information are adequately described in the Model Build Report (NSW DPE, 2022)
Information types are best available	Government: relevance and hierarchy	Yes, relevant Government legislation and regulation has been adopted, as outlined in Section 3.4 of the Model Build Report (NSW DPE, 2022) noting that: • The *Water Sharing Plan for the Barwon-Darling Unregulated and Alluvial Water Sources 2012* ('WSP') version in-force is current from 17 February 2023 and now includes provisions for licencing of FPH. • The WSP did not exist at the time of Basin Plan preparation, nor the baseline date of 30 June 2009, and therefore has no effect on the determination of the BDL. The BDL is defined in Schedule 3 of the Basin Plan, as the take of water in accordance with Schedule E to the Murray-Darling Basin Agreement. This is the Murray-Darling Basin Ministerial Council's Cap on diversions, the 'Cap Scenario' described as the baseline conditions, and defines the WSP 'Plan Limit'. • Water management rules, arrangements and levels of development relevant to the Cap scenario i.e. as of 1993/94 have been appropriately applied.
	Scientific: fit for purpose, peer reviewed, national/international standard, externally audited, industry standard, most relevant and up to date.	Yes, the use of scientific data and information is detailed throughout the Model Build Report (NSW DPE, 2022). A broad range of data and information is used, from public or government sources and it is generally considered to meet these assessment criteria. There were extensive efforts to collect information informing on-farm infrastructure and its operation, sourced from 'farm surveys' (Irrigator Behaviour Questionnaire) undertaken as part of the Floodplain Harvesting Project and the development history project (2002), remote sensing and other lines of evidence. The participants in the farm survey represented all but five currently active / modelled water users and ~60% of the licensed entitlement to water in the unregulated Barwon-Darling River system. However, the survey data, particularly relating to crop records, was often incomplete. Whilst well short of being 'comprehensive', this is the best available information regarding farm infrastructure and operation and local floodplain flow behaviour. Given the response from irrigators was less than complete, and often unreliable, extensive efforts to build multiple lines of evidence for cross-checking were undertaken with ground truthing by the NSW DPE and NRAR and the Floodplain Harvesting Review Committee. In the absence of complete data sets (e.g. in the

Category	Assessment criteria	Findings
		absence of physically measured FPH take), there is a higher reliance on modelling skill to assess suitability and relevance of alternative lines of evidence, model adequacy and performance (A Brown, pers. comm, 12 December 2022). This is accepted however requires a great deal of care to ensure that decision-making processes by modellers and data relied upon are recorded in detail for future model revision. Remote sensed data was used in preference to 'farm surveys' where available, as a more reliable source of information. However, remote sensed data was less reliable for some properties and in determining extent of winter crop areas. Hence there is risk of potential bias when relying on (limited) information submitted by landowners in the knowledge that it may influence the determination of FPH entitlements. Primarily there may be a tendency to overestimate infrastructure capacity (pumps, diversion works, storages), access to flood flows and irrigation water use, with the assumption that this overestimate may result in a larger entitlement for FPH. It is acknowledged that this risk has been mitigated as much as possible using multiple, independent lines of evidence however requires consistent application across all irrigators in an SDL resource unit. Where reasonable suspicions were held that farm survey information was likely in error and outside reasonable limits, NRAR audits and compliance checks to confirm eligible infrastructure and capacity were undertaken, along with reference to a range of alternative sources of information were used. This is the value of the multiple lines of evidence approach and the reviewer is comfortable with the approach to verify farm survey information to mitigate this risk. This farm survey information is not published in detail for privacy reasons. Summary information regarding valley total development is published, as reproduced in Table 5. The modelling undertaken, both current and previous, has been subject to multiple independent reviews and audits, which increases confidence in the scientific rigour of modelling methods and information and data accuracy. The reviewer recommends that NSW continue to build datasets and information regarding on-farm FPH take, cropping operations and water use, and investment in remote sensing data collection, to support on-going model improvement, calibration and validation purposes.
	Modelling.	Refer Section 6.5.
BDL re-estimate	The new BDL estimate is superior to the currently adopted estimate, by demonstrating that:	
	• It is scientifically robust, particularly in relation to the previous BDL estimate.	Yes, the BDL re-estimate is considered by the reviewer to be scientifically robust (as qualified) given the current available data, for the following reasons:

Category	Assessment criteria	Findings
		• Floodplain harvesting take is included in the modelling at the property scale and is improved over previous models in that better on-farm infrastructure information has been validated for use. • Implementation of detailed Quality Assurance practices, regarding data and information sources and review, farm scale data validation and review (current and historical development) and independent reviews, as outlined in Appendix A of the Model Build Report (NSW DPE, 2022). Reference is made to the Department's 'in-house modelling practice guidelines' to guide modelling approaches however these are not published given the difficult nature of doing so, as a living document that cannot categorically address all decision processes presenting to modellers (S Podger, pers. comm. 12 January 2023). It is recommended that NSW publish these guidelines to assist model transparency and repeatability. • The process largely meets with best practice (with the notable exception as discussed in the next dot point, and identified as a current model limitation) as outlined in eWater Source Australian Modelling Practice (https://wiki.ewater.org.au/display/SC/Australian+Modelling+Practice) and specifically *Practice note: Estimation of Unmetered Irrigation Diversions (On-Farm Water Balance)* https://wiki.ewater.org.au/pages/viewpage.action?pageId=263921336. • Uncertainty analysis and sensitivity testing was undertaken for Border Rivers and Gwydir valleys which informed the modelling approach and methodology for Barwon-Darling. From this, measures have been implemented/nominated to reduce current and future uncertainty. However, sensitivity analysis was not completed specific to the Barwon-Darling model, on the assumption that the sensitivity of models to certain parameters and changes is consistent between model builds of other river systems in northern NSW. – This is an assumption and modelling best-practice would require model-specific sensitivity testing to be carried out, especially given the use of non-traditional model validation (refer discussion in Appendix C). The reviewer recommends that sensitivity analysis specific to the Barwon-Darling model be undertaken to further instil model confidence (particularly for stakeholders) and robustness. – It is also noted that a quantitative analysis of uncertainty is not possible until observed FPH measurement data is obtained. The robustness of the model would be improved with comparison to observed FPH data from which to confirm and calibrate model configuration and parameters (Section 8). The current rollout of the NSW FPH Measurement Policy will address this however given the nature of FPH useful data is not likely to become available for this purpose for at least five years. • Subjected to independent review, revision and improvement: – The model application underpinning the BDL re-estimate has been subjected to independent reviews by Weber and Claydon (Alluvium, 2019) and (Alluvium, 2022), considering the model configuration, inputs and outputs but did not comprise a detailed audit of model compliance nor individual model component representations. The recommendations for improvement have been addressed

Category	Assessment criteria	Findings
		in the Model Build Report (NSW DPE, 2022) and Scenarios Report (NSW DPE, 2022) or otherwise identified for future investigation and model update as discussed further in Section 8 of this review.
	• Uses improved knowledge of the relevant levels of development and the entitlements and rules (as per the definition of the BDL in Schedule 3 of the Basin Plan) and associated consumptive use occurring as a result.	The BDL is defined in Schedule 3 of the Basin Plan, as the take of water in accordance with Schedule E to the Murray-Darling Basin Agreement. This is the Murray-Darling Basin Ministerial Council's Cap on diversions, the 'Cap Scenario', and defines the WSP 'Plan Limit'. Section 2.3 of the Model Scenarios report (NSW DPE, 2022) states that the Plan Limit described above (Cap Scenario) is the BDL estimate, as required by Schedule 3 of the Basin Plan 2012. In simple terms, the WSP Plan Limit = BDL = Cap. The BDL re-estimate is proposed by NSW to correctly reflect the Cap scenario based on water management arrangements and infrastructure as of 1993/94 and utilises Cap scenario modelled inflows from upstream NSW tributaries, and MDBA-accredited BDL modelling for Qld tributaries (note, this is also Cap). The previous BDL estimate used 2007/08 levels of development and Cap accounting rules of July 2007 (MDBA, 2011) however this is an incorrect configuration and not reflective of 1993/94 water management rules and levels of development (Bewsher Consulting, 2021). The levels of on-farm development at these dates were generally sourced from 'farm surveys', the Development History Project (2002), other lines of evidence, cross-checked and ground truthed by the NSW DPE and NRAR. The reviewer considers that the comprehensive work undertaken to understand the levels of development at these historical dates is the best available information. One area of improvement in the proposed model for the BDL re-estimate has been the inclusion of embargo rules that were not in the existing BDL model adopted by the MDBA for the Basin Plan 2012. However, the difficulty in applying water management rules in the Barwon-Darling model is the inconsistent historical application of embargoes on diversions, used occasionally to preserve flows to meet critical downstream needs at the Menindee Lakes, at the downstream end of the system for this SDL resource unit. The previously accredited Cap model applied a simple trigger to impose an embargo when the water stored in the lakes drops below 150 GL, and this rule has been maintained in the proposed model for the BDL re-estimate as the best available information, in the absence of a better method and to respond to independent review recommendations (Bewsher Consulting, 2021). However, this rule introduces model uncertainty in that this criterion for embargo has not historically been applied that simply. Given that embargoes (temporary water restrictions) applied under Section 324 of the Water Management Act 2000 are extraordinary, unplanned actions in response to critically low water supply, its application by rule is an approximation and technically incorrect. However, changing this approach is problematic given this embargo rule is a feature of the previously accredited Cap model, although better

Category	Assessment criteria	Findings
		approaches to modelling historical embargoes may be possible under the SDL framework. It is recommended that future updates to the modelling in Source improve the historical application of embargoes that is consistent with Cap.
	• The new BDL estimate must use best available information in terms of data used and modelling methodology:	The previously accredited (lapsed in December 2015), existing Barwon-Darling IQQM model was updated and enhanced to meet the overarching modelling objectives for improved representation of FPH. Whilst the existing model included representation of FPH, the revised model used improved information regarding historical levels of development and water management arrangements, as well as improved on-farm crop modelling. Therefore, the new BDL estimate uses best available information for data used and modelling methodology, given the improved representation of FPH in the model. This is the largest area of change (NSW DPE, 2018), as listed below: • Higher level of detail: Farms modelled individually where they are accessing FPH, though lumped modelling of smaller users still occurs (although this represents minor volume of take). • Improved representation of existing modelled overland flow processes • Representation of farm processes: On-farm processes were modelled in more detail, including the storage of overland flow in temporary storages (where appropriate) before transfer to permanent storages. The capture of farm runoff was represented, and the operation of multiple storages. This represents a step-change in the quantity of data and information required, verified using multiple lines of evidence, and used to configure, calibrate and validate the models, and is overall a significant improvement on previous modelling. Other relevant recommendations for improvement outlined in (Bewsher Consulting, 2021) outside of the representation of FPH, have also been progressed as part of the model update, described below: • Reconfiguration of the model to accurately reflect water management arrangements and levels of development as of 1993/94, to correctly represent the Cap scenario • Amended tributary inflows to also be modelled Cap scenario for all tributaries (Cap scenario in NSW tributaries and MDBA-accredited BDL models in the Qld tributaries, noting that in Qld the BDL = Cap.) • Addressed potential model double-accounting issues with some water users who access unregulated flows from both Barwon-Darling and lower end of tributary streams. (Particular to Colly Farms which accesses water from both the Gwydir and Barwon-Darling systems, NSW has noted that whilst total diversions are reasonably replicated across both models, the split of diversions may not be weighted correctly meaning an under-estimate of diversion in the Barwon-Darling).

Category	Assessment criteria	Findings
		• A substantial amount of work has been completed as part of the metering recalibration project (https://www.industry.nsw.gov.au/__data/assets/pdf_file/0010/509491/recalibrating-bd-water-models-using-more-accurate-water-metering-records.pdf) to improve accuracy of metered diversions in the Barwon-Darling, to rectify known issues with the transition from old time-and-event meters to pattern-approved meters. This work has resulted in a set of standard factors to adjust diversion capacity for each river pump. These adjustments can be made in the modelled diversion results post-processing however have not been applied to the model under review, and once applied will therefore affect the proposed BDL re-estimate figures in Table 1. The river pump capacities within the model itself remain the same as the existing IQQM Cap Scenario (refer to discussion in Section 6.4). This meter recalibration work has continued into 2023 and ideally would be updated into this IQQM model. However, given time constraints and the transition to Source being underway, this amendment will be made in the new model. The meter recalibration project will result in an overall increase to pump capacity (believed to be in the order of 12%), however the relationship to diversions is not expected to increase linearly given the complex model interactions with FPH, crop planting rules, irrigation volumes, on-farm storage, etc. It is strongly recommended that this be a high-priority area of focus for the new model build, given the potential to impact modelled diversions and the BDL estimate. NSW is also encouraged to continue its overall focus on improving the coverage and accuracy of non-urban metering in the Barwon-Darling valley (https://water.dpie.nsw.gov.au/nsw-non-urban-water-metering) as a means to develop a database of more accurate observed data to inform historical diversions, rather than retrofitting data with known accuracy limitations.
	– New or improved data that the method used to estimate a BDL take component is based on, such as climatic/streamflow data (July 1895-June 2009) or on-farm development data.	The relevant data to the estimation of FPH primarily relates to on-farm development data, irrigation water use and behaviour of flows on the floodplain that provide farms with access to FPH. The quality of on-farm development data is considered best currently available as described above, despite some limitations with coverage and accuracy of cropping records. A considerable amount of effort has been committed to better understand and reflect the use of on-farm infrastructure in the models, irrigation water use and particularly the quantity of on-farm rainfall runoff harvesting from irrigated and dryland, developed and undeveloped areas, which are now modelled individually (NSW DPE, 2018). The Model Build Report (NSW DPE, 2022) describes the most sensitive parameter (that is informed by farm survey) to the determination of FPH is the volume of on-farm storage, and accordingly a significant amount of work has been done to verify these volumes at the relevant historical dates. The farm survey information (current and historical) relied upon was extensively cross-checked through independent means including remote sensing. The NSW modelling team has also advised that FPH is sensitive to the frequency of overbank flow access in the model and is driven by the overbank flow threshold for the relevant effluent or breakout. The development of the Floodplain Management Plans has provided key

Category	Assessment criteria	Findings
		information for the understanding of effluent stream breakout, floodplain behaviour, for verification of the farm survey data and explicit representation of farm access to FPH. However, all effluent flows are modelled as permanent losses to the river system, whereas a portion of these flows returns to the river. This is a recommended area of focus for future model improvement as return flows are not currently accounted for within the model. Climatic and streamflow data is sourced from SILO (https://www.longpaddock.qld.gov.au/silo/) and Departmental sources and is considered best available.
	– New or improved models/methods for estimation of the BDL take component, such as new computer models (e.g. IQQM to Source).	The Barwon-Darling model is an update to the existing (previously accredited) Cap model within the IQQM platform and includes detailed representation of FPH. NSW is in the process of migrating the model across to the eWater Source platform, however this work is incomplete for WRP submission. This latest update of the model supersedes previous models and as such, is the best available. Whilst being best-available, the migration to Source provides opportunity to revise and improve the model further, i.e. improved flow calibration, improved metering data, inclusion of unmodelled elements, etc. as outlined in Table 8.
	– Improved representation of physical and user processes in existing models/methods used to estimate take under the BDL such as processes to estimate tributary inflows and climate inputs, levels of development, understanding of irrigator behaviour including crop types, water use patterns and risk management strategies.	The representation of physical and water user processes relating to FPH in the model has been improved over the previous model, as discussed above. It is considered the best currently available information and approach to modelling, particularly regarding the timing and nature of flood breakout flows, representation of farm-scale processes, crop water use and the property water balance. The representation of ungauged inflows to the model has also been improved, with a considerable amount of work invested in developing and calibrating hydrological models for these streams (some of which were not previously modelled), with robust parameterisation from similar, gauged catchments nearby and in Qld. This is the best available information in the absence of gauged data however continues to present an opportunity for improvement in future updates to modelling. It is recommended that this focus on data capture and model parameterisation for these is continued to improve the flow calibration in the Barwon-Darling. The overall volume of breakout flow is less well understood and return flows to the river are not modelled (as discussed in Section 8) and there is still no observed on-farm FPH data from which to refine the models. It is recommended that more work be done to better understand and quantify other floodplain losses and return flows to the river as part of future on-going model improvement and replication of physical hydrological processes. The modellers also noted that the most downstream gauge of a tributary is used to evaluate inflows into the Barwon-Darling system. However, in some tributaries this gauge is upstream of large terminal wetland systems and an estimate is made on the proportion of the gauged flow that discharges to the main channel flow. Also, the Model Build report (NSW DPE, 2022) states that "*10 out of 16 gauged*

Category	Assessment criteria	Findings
		inflows upstream of Bourke are factored to achieve satisfactory water balance at the four gauging stations that measure the full floodplain flow." The modellers note the factoring reflects high flow events bypassing gauges or backwater from the Barwon-Darling system affecting gauge readings. The modellers admit that this approach is not ideal however no better solution has been found and is a focus for the new model being developed in Source. Whilst the current approximations are the best currently available, it is recommended that this work continue to refine the approach to quantify these inflows more accurately. There is also room to validate and potentially improve model performance by collecting improved calibration data relating to on-farm decision making, cropping behaviour (including better representation of winter cropping), crop water demands and water use (including sequencing of water use on-farm). Future on-going measurement data and other relevant information collection is essential to make these improvements. While measurement may address some of these components (e.g. on-farm FPH data), others still remain outstanding with no specified measures in place to address them, i.e. a programme of on-going on-farm operational and cropping data survey/collection. It is recommended that NSW formalise program/processes to continue to collect high-quality FPH measurement data, in particular on-farm operational and cropping data. There are 15 fixed-crest weirs in the Barwon-Darling system that have not been modelled explicitly, given a lack of operability to manipulate flows (i.e. regulation) yet comprise a total weir pool volume of ~32 GL, noting that accurate infrastructure details of these weirs has not been available historically with recent higher-quality data collected by WaterNSW. The lack of these infrastructure in the model has significantly impacted the ability of the model to replicate observed low flows and cease-to-flow events and gives rise to small flows moving further through the system than otherwise observed, as these flows are captured in weir pools. The reviewer agrees with the modellers assertion that this makes little difference to the main objective of the model, in replicating unregulated or FPH diversions given commence to pump thresholds are well above this flow range. However, diversions have been found to commence slightly earlier than observed given the lack of flow loss into weir pool storage. Whilst a slight impact to timing is experienced, the impact to total diverted volume by event or annually is negligible. The modellers advise that the new Source model will include this infrastructure, for completeness and improved model low-flow performance and ability to replicate cease to flow events and providing the ability to quantify refuge pool persistence. It is recommended that this work is completed to improve accuracy of the new model and broaden model functionality for multiple low-flow objectives in addition to higher-flow diversions.

Category	Assessment criteria	Findings
	– Better representation of policies, allocation, accounting and river operational rules that apply under the definition of the BDL estimate.	As noted above, the update to the Barwon-Darling model focused on improving the representation of FPH, with other elements of the model subject to continual update and improvement. Therefore, the reviewer concludes that this is the best available information and approach to modelling. The re-estimate for the Cap scenario reflects management rules and arrangements in place at the applicable dates. There are no management rules per se regarding floodplain harvesting applicable to the Cap scenario, however the level of on-farm development is relevant. On-farm development in place at 1993/94 was used to parameterise the models, including capacity of on-farm storage, storage/river pumps, floodplain harvesting intake rates and irrigated and undeveloped farm areas. The model explicitly simulates A and B Class unregulated diversions; however these are mostly unmetered limiting calibration. Many are inactive. Of those that are active, some validation of water use can be undertaken through multiple lines of evidence such as ground-truthing, remote sensing or enforcement/compliance activities. Diversions by local water utilities (town water supply), Basic Landholder Rights (BLR) and Stock and Domestic are not modelled, which is consistent with all Cap modelling to date. The modellers confirm that these small volumes do not affect the flow simulation and (reportedly) aren't experiencing growth so are of little concern. However, this is a focus for the new Source model as more observed data is captured and local authorities seek to understand critical reliability of their water supply. Whilst BLR is rarely modelled explicitly (often just a system loss), the new Source model will also include a basic representation of this take, as well as stock and domestic take to allow quantification of reliability. The aim is to have all entitlements represented in the model in their correct locations, switched to reflect whether those entitlements are active or not. As mentioned above, a more comprehensive model in Source will improve accuracy of the new model and broaden model functionality for multiple low-flow objectives; in this case whether general river operations are able to meet the needs of small, but critical diversions at low or nil flows i.e. through access to persistent waterholes, weir pools, etc. It is recommended that NSW continue to pursue the development of a comprehensive model in the Source platform to improve system representation.
	• It is sufficiently documented to be able to reproduce the BDL, with:	
	– Clear reasoning and evidence to support any	Yes, the Model Build Report (NSW DPE, 2022) and the Scenarios Report (NSW DPE, 2022) provide clear reasoning and evidence to support the BDL re-estimate. As described above, a detailed process for Quality Assurance has been adopted to ensure model integrity and confidence in reported volumes.

Category	Assessment criteria	Findings
	change to estimates of the volumes of any form of take	
	– Descriptions of any planning assumptions or modelling settings that may impact the estimation of those volumes.	Yes, the Model Build Report (NSW DPE, 2022) and the Scenarios Report (NSW DPE, 2022) provide sufficient documentation that describes model parameters and scenarios. Uncertain parameters or settings have been openly described however it is noted that no observed data is available to quantitatively assess uncertainty. Sensitivity testing was undertaken for the Border Rivers and Gwydir models with the assumption that similar findings apply for Barwon-Darling. However, no sensitivity testing specific to the Barwon-Darling model was undertaken. The reviewer recommends that sensitivity testing be completed specific to the Barwon-Darling model. MDBA reported (S Rai, 16 June 2023, pers. comm.) that the required post-processing of results to determine the volume of rainfall-runoff was not clear and required substantial assistance from the NSW modelling team to replicate. It is recommended that the results post-processing requires additional, detailed documentation for use by third parties and future modelling personnel to minimise confusion and risk of error, particularly with the passage of time and comparison with the development of the model in the Source platform.

6. Method criteria

6.1 Does the method meet the definition of the BDL in Schedule 3 of the Basin Plan?

The method directly relevant to the BDL definition in the Basin Plan is the long-term annual average limit on the quantity of water that can be taken from all sources, in accordance with Schedule E to the Murray-Darling Basin Agreement. This is the Murray-Darling Basin Ministerial Council's Cap on diversions ('Cap Scenario'), the volume able to be taken using the irrigation infrastructure, water licences, and management rules in place at 30 June 1994.

There is a clear statement of objectives in the Model Build Report (NSW DPE, 2022) which references SDLs and BDLs consistent with the Basin Plan in the model design criteria to meet modelling objectives. While the definition of SDL is not interpreted explicitly as per Basin Plan Schedule 2, it references Schedule 3 in terms of stating the relevant reference period for estimating the BDL.

The described Cap Scenario modelled (NSW DPE, 2022) to arrive at the 'Plan Limit' is consistent with the level of development and State water management rules in place to accord with Schedule E to the Murray-Darling Basin Agreement and Basin Plan 2012 as described in Table 4.

Table 4: Consistency with Schedule 3 of Basin Plan 2012

SDL Resource Unit	Assessment criteria
Barwon-Darling	
BDL definition (relative to FPH) of long-term annual average extraction limit	a. The long-term annual average limit on the quantity of water that can be taken calculated by: i. Summing the quantity of water that would have been taken in accordance with Schedule E to the Agreement as at 30 June 2009 for each year of the historical climate conditions; and ii. Dividing that quantity by all of the years of the historical climate conditions. *Note: The modelling associated with the BDL definition above includes the rules and the levels of irrigation infrastructure and farm development in place in 1993/94 that were determined by the version of Schedule E that was in place at 30 June 2009, as interpreted by* (Bewsher Consulting, 2021) *and agreed by this reviewer.*
Development	Reflects level of development at the baseline date (refer analysis in Table 5). The baseline condition includes (not limited to): • Climate sequence • Irrigator crop area planting behaviour • Water access rules/conditions • Storage volumes • Unregulated inflows (off-farm) • Pump capacities • Maximum planted areas • Cropping mixes • Average water use per crop type.
Water planning	Reflects water entitlements, rules and planning instruments at the baseline date.
	Compliance assessment

SDL Resource Unit	Assessment criteria
Cap Scenario associated with FPH	As defined in the Model Scenario report, the basis for the Cap scenario is consistent with Schedule 3 of Basin Plan 2012. Consistency shown with the requirements of Clause 2(1)(a) of Schedule E of the Murray-Darling Basin Agreement, in consideration of analysis in Table 5, with on-farm storage capacity, river pumps and capacities that existed in 30 June 1994 are reflected, with maximum cropping areas and crop mix at 30 June 1994 and water management rules applicable in 1993/1994.

Given the higher level of detail and information available for modelling, refinements to the modelled levels of development have been made to the Cap scenario. A comparison of relevant entitlements and on-farm infrastructure modelled is made in Table 5.

Table 5: Levels of development modelled for Cap scenarios

	Barwon-Darling Valley – IQQM Cap Implementation Report (NSW Office of Water, 2011)	Cap scenario (published values) (Scenarios report) (NSW DPE, 2022)	Difference
Entitlements		**As of 1993/1994**	
Stock and domestic (ML)	Not modelled explicitly (no estimate of shares)	Not modelled explicitly (968 shares) [1]	N/A
Town water supply (ML)	Not modelled explicitly (no estimate of shares)	Not modelled explicitly (5,373 shares) [1]	N/A
Unregulated river (no class)	0	0	N/A
Unregulated river Class A (ML)	11,430 [3]	11,430 [2]	-
Unregulated river Class B (ML)	229,010 [3]	229,010 [2]	-
Unregulated river Class C (ML)	216,285 [3]	216,285 [2]	-
Total	*456,725*	*456,725*	-
On-farm infrastructure			
Storage capacity (ML)	191,000	209,887 (publishing error) Correct value is 208,722	+17,722 (+9.2%) [4]
Storage pump capacity (ML/day)	Not defined	Not defined	N/A
Maximum irrigable area (ha)	27,675	28,371 (publishing error) Correct value is 27,034[6]	-641
Undeveloped area (ha)	Not defined	Not defined	N/A
FPH intake rate (ML/day)	Not defined	9,153	N/A

	Barwon-Darling Valley – IQQM Cap Implementation Report (NSW Office of Water, 2011)	Cap scenario (published values) (Scenarios report) (NSW DPE, 2022)	Difference
River pump capacity (ML/day)	7,881 [5]	6,485 (publishing error) Correct value is 6,366	-1,515 [5]
Crop mix	94% cotton 4% winter cereal 2% other	Proportions not reported Stated as 'Majority cotton, comparatively small areas of winter/summer cereal and other crops'	Generally similar approach

1. Footnote 1 to Table 2 of the Model Scenarios report (NSW DPE, 2022) states that the small volumes of use associated with these licences have been represented implicitly in the river transmission losses within the model.

2. Footnote 3 to Table 2 of the Model Scenarios report (NSW DPE, 2022) states that this number includes entitlements associated with water users that were active in 1993/94 and included in the model. There was approximately 63,000 ML of additional entitlement that was inactive in 1993/94.

3. Footnotes to Table C.0.1 of the Barwon-Darling Valley – IQQM Cap Implementation Report (NSW Office of Water, 2011) state that not all licences were limited by specified entitlements or access conditions in 1993/94. However, the reviewer considers that this impact to the modelling is likely minor given the size of the associated licences.

4. This increase can be explained by improved (contemporary) surveys (LiDar or otherwise), applied to unchanged storages known to exist historically in 1993/94.

5. The meter recalibration project as discussed in Table 3, to address known pump capacity issues, is acknowledged. However, this does not explain this significant reduction in pump capacity between the 2011 and 2022 Cap scenario model runs as the pump capacities within the model have not been recalibrated. Further investigations undertaken by NSW in response to the reviewer's query has confirmed (S Teh, pers. comm. 23 June 2023) that the individual pump capacities in both models are the same, however there is likely a difference in which pumps were summed to make up the total. It has been concluded that there is no model error of any material nature, more so a publishing error in reporting the total in the Cap Implementation Report (NSW Office of Water, 2011).

6. S Teh, pers. comm. email 23 June 2023.

6.2 Does the method incorporate all relevant data for the form of take (FPH)?

Given the more comprehensive and consistent representation of floodplain harvesting that has been applied in comparison to the BDL estimate made in Basin Plan 2012, significantly more data was required in comparison to previous modelling, to understand and quantify how floodplain harvesting is undertaken at the property scale, and the volume of water taken. This requirement can be categorised as follows:

- Supply
  - Opportunity: how often the property experiences a flood and access rights (water access model rules)
  - Capacity: the rate of take of water from the floodplain and volume of on-farm storage
  - Rainfall runoff: availability from within the property
  - Other water: combination of non-FPH sources of water to the property
- Demand
  - Crop irrigation requirements (evapotranspiration)
  - On-farm irrigation management
  - On-farm losses.

The take of water through floodplain harvesting overwhelmingly (currently) supplies irrigated broadacre cropping properties producing cotton, with much smaller areas of summer and winter cereals. As measurement of FPH in NSW is yet to be implemented, there is negligible on-farm observed data available for estimates of FPH take or calibration/validation of models.

Therefore, as much confidence in the model methods and data used must be gained to infer confidence in the results, noting that this confidence cannot be quantified through model calibration or validation. The improvements in the models are generally summarised in Table 6, reproduced directly from (NSW DPE, 2018).

Table 6: Summary of key model changes, reproduced from (NSW DPE, 2018)

Area	Existing model	Updated model
Rainfall harvesting within the property from both developed and undeveloped areas represented	Runoff from property's area is a single model output and was estimated as part of overall demand calibration.	Runoff generated from the developed and non-developed area is calculated and reported separately and the rate of runoff assessed against published data sources.
Overbank flow represented separately	The river system models estimated losses to floodplains using a simple flow-loss relationship. This overbank flow loss, although partially harvested, was represented as completely lost to the system.	Improved, explicit representation of existing modelled overland flow processes, where breakouts from the mainstream of the Barwon-Darling are modelled at the farm scale, not as an effluent stream as modelled in other upstream valleys. Calibrated river reach loss represents instream transmission loss only. Return flows are still not represented in the model however these aren't significant in Barwon-Darling.

Area	Existing model	Updated model
Representation of overbank flow harvesting	Floodplain harvesting was implemented in various NSW river models but was limited in accuracy due to limited availability of data on floodplain harvesting infrastructure. It did not include floodplain harvesting from flood breakouts from the unregulated tributaries.	The models represent the infrastructure details for each eligible property, and their access to relevant flood breakout from the mainstream. Wherever appropriate floodplain harvesting from unregulated streams (gauge bypassing flow) is modelled.
More accurate infrastructure data	On-farm storage capacities were estimated based on NSW Department of Industry regional records. River pump capacities were estimated based on work approvals. Details on other infrastructure such as pipes and on farm storage pumps were generally not known. The relationship between volume and surface area did not account for the sequential filling and emptying of multiple storages or cells.	On-farm storage capacity (OFS), areas developed for irrigation, pump capacities and other forms of floodplain harvesting infrastructure have been assessed through a combination of irrigation surveys, field inspections and remote sensing data including LIDAR and Landsat. The volume to area relationship reflects the sequential filling and emptying of storages which allows for more accurate representation of losses.
More accurate representation of other components of the farm water balance	Irrigation demands are represented through crop models, which were calibrated to match metered diversions. In some instances, these may result in crop water use which is lower than actual, as ungauged water use such as floodplain harvesting was not properly accounted for.	Crop models have been configured in line with best available information on irrigation requirements and valley average application rates. Where possible, other water sources have also been represented, such as groundwater and unregulated diversions. However, due to lack of gauged data, (the accuracy of) simulated flow in the unregulated streams is unknown.

Further assessment of the additional model and data requirements is described below, with a brief assessment of the adequacy of the approach.

6.2.1 Supply

Opportunity – how often the property experiences a flood (water access model rules)

Breakouts and effluents can be modelled explicitly using relationships estimated from topographical surveys, geographical characteristics, flood works, hydraulic modelling, remote sensing and gauged flows. Breakouts and rainfall-runoff were modelled to represent floodplain harvesting that is available for water users.

There is only one significant effluent stream in the Barwon-Darling system, the Talyawalka Creek, with a well-defined channel and a stream flow gauge, providing data for modelling. However, no FPH is occurring on the Talyawalka Creek. Other breakouts onto the floodplain in the Barwon-Darling remain quite close to the main river channel, and as such, these floodplain breakouts were not explicitly configured as an effluent stream for the purpose of informing a property's ability to take FPH. As these floodplain breakouts remain close to, and usually rejoin, the main channel, the model does not separately simulate the floodplain breakout. Instead, FPH access by water users is simply defined by a high river flow threshold, with the flow rates for each breakout informed by:

1. Cross-section and rating information at flow gauges
2. Healthy Floodplain Irrigator Behaviour Questionnaires (farm surveys)
3. Bureau of Meteorology flood warning levels
4. Landsat data to compare historical flood extent along reaches to recorded flows
5. A regional hydraulic MIKE flood model developed for the Floodplain Management Plan

6. Water balance methods by comparing upstream and downstream flow rates.

In upstream valley models, breakout flows are treated as a permanent loss to the river system, which is not always true given some effluent streams return water to the river. In Barwon-Darling, breakout flows remain geographically close to the main channel and as such any water not diverted by FPH likely returns to, or remains within, the main stream. The volume of water possibly returning to the river is unknown and is a recommended area of improvement for future NSW valley models, albeit perhaps of lesser importance to the Barwon-Darling.

The development of detailed hydraulic flood models associated with the Floodplain Management Plans (https://www.industry.nsw.gov.au/water/plans-programs/plans) provided a wealth of information that has informed the modelling approach to overbank flows and floodwater movement. There is continuing work in this area given the knowledge gaps surrounding the component separation of water on the floodplain to harvesting, losses, capture to environmental assets or river returns. It is recommended that further work in this area be undertaken to assist to improve the representation of floodplain harvesting access conditions in the model, with refinements specific to individual properties.

Rainfall runoff – availability from within the property

A simple, separate rainfall–runoff model embedded in the crop water model is included for each property accessing FPH, continuously tracking the soil moisture of undeveloped, developed and irrigated areas. In a few instances, harvesting of localised rainfall-runoff (external to the property) was added to rainfall-runoff modelling within the property where this was found to be 1) eligible activity; and 2) comprised a significant proportion of the property's water supply and 3) not otherwise modelled as overbank harvesting.

This enables the calculation of different rates of runoff from these areas based on soil moisture and rainfall. Property area models were calibrated to produce a long-term average rate consistent with available data however significant uncertainty remains until farm-scale data is collected, especially regarding storage volume movements, to improve model accuracy at the farm-scale. It is recommended that a formal program of farm-scale data collection (measurement data and farm operational decisions) be implemented to ensure availability for future model improvement.

Capacity – the rate of take of water from the floodplain and volume of on-farm storage

Storage volumes

On-farm storage capacities strongly influence floodplain harvesting results. Significant work has been put into improving the accuracy of this aspect for calibration by using professional surveys (of good quality, with known date of capture), LIDAR, photogrammetry and ground-truthing. Storages at earlier dates were determined by using Landsat satellite imagery (refer volumes in Table 5).

In the model, the on-farm storages are represented as one storage, with the volume-surface area relationship defined based on storages being filled sequentially from most to least efficient. Therefore, smaller surface areas are reflected when stored water volumes are low and not all storages are in use.

Whilst this is a reasonable assumption, and the model may be insensitive, it is likely that each property will operate storages differently and this is not reflected in the model. Future data collection will inform these assumptions however it is recommended that a strong focus to ensure collection of this on-farm data, including remote sensing data indicating timing of storage fill/emptying behaviour, alongside FPH measurement data, as it will be critical for this purpose.

The reviewer considers that the approaches used, multiple lines of evidence and cross-verification is appropriate to instil a high level of confidence in the property storage volumes used in the modelling.

Pump capacities

Overbank flow harvesting extraction for NSW water users was simulated through overbank pump capacity. This capacity, or intake rate, was generally set to the total capacity of on-farm storage pumps for the property (obtained from NRAR). Pump flow rates for 'major' irrigators measured during tests undertaken by WaterNSW have been used to configure pump capacities, with pump capacities for the Cap Scenario (Plan Limit) taken from the Development History Project (2002), described in Appendix F of the Model Build report. River pump capacity was based on a standard set of rates, but variations to this were made where justified by the use of temporary storages or restricted by gravity pipe capacities (NSW DPE, 2022). The commentary regarding the metering recalibration project in Table 3 is noted here; whilst this has the potential to impact diversion volumes this work remains incomplete and therefore revised pump capacities not included in the current model, nor impacting the BDL re-estimate, reserved for inclusion once complete, in the newly developed Source model.

Generally, the reviewer considers this to be an appropriate representation of the storage intake rate.

Pump capacities for earlier development periods (such as Cap scenario) were assumed to be the same as later scenarios if the storage was found (via satellite imagery) to be in existence at that earlier time. This was assumed as there was little reliable data available for confirmation. This is accepted by the reviewer in the absence of better information. The meter recalibration project will also allow for refinement and improvement of historical pump capacities where it can be shown that contemporary pumps haven't changed from earlier scenario dates.

Temporary storages

Temporary storages (such as surge areas and sacrificial fields) are explicitly included in the model upon NRAR advice, based on verified usage during flood events from 30+ years of historical Landsat data. Temporary storages are not included in the storage capacity assessment for a property, however, provide a buffering effect that quickly detains water for slower transfer to permanent storages (within 14 days) which is attributed to FPH. This was found to be true for two properties in Barwon-Darling.

The comprehensive approach by NSW to interrogate the use of temporary storages is considered appropriate, especially considering the potential high total volume and corresponding impact to modelled FPH intake rates.

Other water – combination of non-FPH sources of water to the property

Inflows to the on-farm storage in the Barwon-Darling apart from FPH are limited to licenced unregulated diversions. The use of groundwater was not included in the determination of FPH in the Barwon-Darling model as no FPH properties access groundwater for irrigation.

6.2.2 Demand

Crop irrigation requirements (evapotranspiration)

Maximum planted areas

Remote sensing data from Landsat and MODIS were available from 2003/04 to 2013/14 and were used in preference to the farm survey information, which was unreliable. The model replicated the remote-sensed summer planted areas well, with seasonal variability in response to water availability also reasonably well captured. The winter planted areas were significantly under-simulated on occasion however the associated water use is minor.

The results described that modelled summer crop areas were 14% higher than that observed by remote sensing throughout the validation period. As summer cropping is strongly linked to water supply, this would be expected to increase both unregulated and FPH diversions to satisfy the farm water balance. Whilst this is a material difference, the remote sensing validation data was incomplete across the period and not available at all for three eligible properties. Additionally, winter cropping was consistently under simulated, in some years by a large amount, which would lead to over simulation of summer cropping.

As such, this result is accepted given little alternative information to refine further, however it is recommended that sustained effort be made toward better understanding and measurement of actual on-farm cropping behaviour.

Cropping mixes

Crop areas were reported in the farm surveys (complete and partial) covering about 30% of years for the 11-year period (2003/04-2013/14). This is a low proportion, and was considered unreliable, and required other lines of evidence to validate. Remote sensing data from Landsat and MODIS were available from 2003/04 to 2013/14 and were used in preference to the farm survey information.

Significant uncertainty surrounded the winter crop areas given inconclusive remote sensing data. These areas were estimated during model calibration if diversion data (2003/04-2013/14) indicated that winter irrigation was undertaken.

The reviewer considers that the significant uncertainty surrounding quality and quantity of on-farm cropping data, which is the core driver of water demand from both unregulated river and FPH sources, underscores the need for more comprehensive data collection regarding on-farm cropping activities to improve model performance, calibration and validation. Along with observed FPH measurement data, this is a recommended key focus to provide for future model improvement though it is unsure whether this routine data collection is being resourced by NSW.

Average water use per crop type

This is a combination of crop watering efficiency, crop factors and soil parameters. Crop water demands are modelled using the previously calibrated crop parameters (NSW Office of Water, 2011) which were based on the procedures of the *FAO Irrigation and Drainage Paper 56, Crop Evapotranspiration—Guidelines for computing crop water requirements* (Allen, 1998).

The reviewer considers this to be a sound approach as documented in the Model Build report, having been assessed through work done in other valleys whereby the crop water use simulation was checked against independent data sources or methods, and the broader description given in the document *Modelling and data collection for implementing floodplain harvesting* (NSW DPE, 2018).

On-farm irrigation management

Irrigator behaviour

Actual volumes harvested from overbank flow events or rainfall-runoff is difficult to calibrate and validate at all scales, requiring other lines of evidence such as the farm survey data. The parameters with most impact especially in long-term simulation regard planting decision rules, as irrigation efficiency has little impact on individual estimates of floodplain harvesting. A risk factor was used to define planting decision and water availability had to be simulated given the lack of recorded data, and this was only obtained for cotton for the farm surveys. All other crops had a default risk value and were calibrated if required.

Farm water balance checks showed that the models are reasonably accurate at valley and reach scale. At property scale, there are large differences, e.g. from differences in irrigation behaviour (i.e. deficit irrigation) and the accuracy of existing meters unknown and not accounted for (NSW DPE, 2022). Previous work to ground truth these farm scale water balances showed that the farm water balance checks should not be used at property scale due to less reliable results.

This is a recommended area for future improvement as identified by the NSW modelling team, however, requires the collection and use of observed on-farm storage level data.

On-farm losses

On-farm storage losses are modelled for evaporation using climatic data, and seepage individually calibrated to the property (ranges between 0-2 mm/d loss) based on the values in the existing Barwon-Darling model. A loss of 25-30% was applied for inefficiency in irrigation application across all historical scenarios, also informed by detailed industry research and advice. Future capture of observed FPH data on-farm will inform the adequacy of this assumption. Given on-farm efficiencies are continually improving, future models representing modern scenarios may include a lower loss percentage. It is recommended that continued work be undertaken to verify this assumption, particularly as it pertains to historical and modern model scenarios, given on-farm efficiencies continue to improve over time.

The reviewer considers this representation of on-farm losses to be appropriate and best available.

6.3 Is the method sufficiently documented such that estimates of FPH take under the BDL can be reproduced?

For the Barwon-Darling SDL Resource Unit model, the modelling for the Cap scenario (the 'Plan Limit') is considered sufficiently documented as the published reports contain:

- All references to the data sources pertaining to the forms of take included
- Quality assurance practices undertaken along with the data review and prioritisation of data sources
- Conceptual and geographic spatial extents of the model
- Data periods used for various purposes in the river system modelling
- Process of infilling of data gaps for climate and flow data
- The assessment criteria used (which require sufficient graphical and statistical understanding of the raw data) to assess model performance.

The MDBA modelling team interrogated the Barwon-Darling model input values and results as compared to the published numbers in the September 2022 Model Scenarios report (NSW DPE, 2022). A summary of the interrogated values and results are listed in Table 7.

This exercise demonstrated:

- That model results can be replicated, despite:
  - Confusion regarding model inclusion/exclusion of individual model parameters for total development figures
  - Resultant errors in published reporting in both development and diversions, although differences are relatively minor.

MDBA reported (S Rai, 16 June 2023, pers. comm.) that the required post-processing of results to determine the volume of rainfall-runoff was not clear and required substantial assistance from the NSW modelling team to replicate. It is recommended that the results post-processing requires additional, detailed step-by-step documentation for use by third parties and future modelling personnel to minimise confusion and risk of error, particularly with the passage of time and comparison with the development of the model in the Source platform.

Table 7: Comparison of Model Scenarios report published figures and replicated model

Item	Model Scenarios report (NSW DPE, 2022)	Replicated model (IQQM Version 7.103.0 RC4, scenario CAP_FPH_13.sqq)	Comment
Permanent on-farm storage capacity	209,887 ML	209,601 ML	NSW modellers have confirmed* that the published figure of 209,887 ML is incorrect, and the correct value is **208,722 ML**.
Installed river pump capacity	6,485 ML/d	6,566 ML/d	NSW modellers have confirmed* that the published figure of 6,485 ML/d is incorrect, and the correct value is **6,366 ML/d**.
Maximum irrigable area	28,371 ha	29,674 ha	NSW modellers have confirmed* that the published figure of 28,371 ha is incorrect, and the correct value is **27,034 ha**.
Diversions			
Unregulated river:			
• Class A	#	3.1 GL	
• Class B	#	137.4 GL	
• Class C	#	38.1 GL	
• Unmetered small Class A & B	#	5.9 GL	
Total Unregulated river	184.5 GL	184.5 GL	
Floodplain Harvesting (FPH):			
• Overbank flow harvesting	9.6 GL	9.7 GL	Difference due to rounding
• Exempt rainfall runoff harvesting	6.8 GL	6.1 GL	NSW modellers have confirmed* that the published figure of 6.8 GL is incorrect, and the correct value is 6.1 GL.
• Non-exempt rainfall runoff harvesting	1.3 GL	1.3 GL	
• Total exempt/non-exempt rainfall runoff harvesting	8.1 GL	7.4 GL	The published figure of 8.1 GL is incorrect*, the correct value is 7.4 GL.
Total diversions	**202.2 GL**	**201.6 GL**	When accounting for the publishing error identified above, the total diversions are the same (201.6 GL, ignoring rounding).

* S Teh, pers. comm. email 23 June 2023.

not reported separately.

6.4 Is the method sufficiently documented such that any limitations and uncertainties in the method are known?

For the Barwon-Darling SDL Resource Unit, the uncertainties and limitations were identified in the sensitivity analysis and uncertainty section of the Model Build report (NSW DPE, 2022) which ranked all uncertainties and discussed the potential errors. This is assessed further in Table 9 within Appendix C. Further discussion regarding the key limitations and uncertainties is also given in Section 8.

Critically, Section 9.1 of the Model Build report notes that:

> *"For the first floodplain harvesting models developed in the Border Rivers and Gwydir valleys, the 6 sensitivity tests referred to throughout Table 30 were done (DPIE Water 2020, 2021). These tests have not been repeated for the Barwon-Darling model because the sensitivity of the models to certain parameters and changes is expected to be consistent between model builds of other river systems in northern NSW."*

In other words, sensitivity testing was not undertaken specific to the Barwon-Darling model on the assumption of consistency. However, modelling best-practice requires model-specific sensitivity testing to be carried out, especially given the use of non-traditional model validation (refer discussion in Appendix C). The unregulated Barwon-Darling also exhibits unique characteristics as compared to other northern valleys, further reinforcing the need to undertake sensitivity testing. It is recommended that sensitivity testing be conducted specific to the Barwon-Darling model.

As recommended in the preceding Section, the method documentation could be improved regarding results post-processing for the derivation of rainfall runoff volumes.

The meter recalibration project, described in Table 3, is an important work to improve accuracy of historical unregulated diversions, however it was not clear in the published documentation if these revised pump flow rates were adopted. NSW modellers confirmed that this work remains in progress and therefore the original calibrations were not changed. Given the meter recalibration project is underway and publicly known to the stakeholder community (via the DPE website), it is recommended that this be clearly identified in an update to the Model Build report (NSW DPE, 2022).

6.5 Does the method involve a model?

For the Barwon-Darling SDL Resource Unit, the method involves a model, and to demonstrate its level of robustness and how well they meet the SDL (s10.10), the models were assessed using criteria from MDBA Position Statement 3C, as given in Table 9 within Appendix C.

The latest Barwon-Darling model retained the existing model flow calibration, as it already accounted for FPH by individual properties. The previous calibration was known to reproduce low flows poorly due to extreme variations in flows, however the modellers noted that this has very little effect on the simulation of metered diversions (given that A Class entitlements, in most years have far more flow opportunity to take their entire volume and B Class entitlement pump access conditions are in the flow range well above the poor performing flows) and no effect at all on floodplain harvesting, which for most entitlement holders is a result of high river flows.

Similarly, the model performance in the Wilcannia-Menindee reach is poor however there is very little diversion in this reach so the impact to the BDL estimate is negligible. When the model is rebuilt in Source, a new flow calibration is expected to substantially improve model performance.

The Model Build report (NSW DPE, 2022) reports that the model simulates the pattern of metered diversions well across the whole period however the 2008/09 scenario displays an under-simulation (approx. 7%) of diversions throughout the 2003/04-2013/14 model validation period. This conclusion is drawn in the Model Build report however

no further explanation is given. The under-simulation was difficult to assess further given that the flow calibration graphs and tables were not provided as an Appendix to the Model Build report, as was done for Border Rivers, Gwydir and Macquarie reports. This would aid the review and adequacy of the model to replicate the main flow simulation and is recommended for inclusion in an update to the report. Nevertheless, tables and information were provided in Section 8.2.2 that showed the model was able to replicate the number of high flow days at Walgett and Bourke (two gauging stations that accurately capture the majority of the flow range, with extreme floods excepted) to a good degree of accuracy.

The 7% under-simulation resulted from the validation of the 2008/09 scenario and as such no conclusion can be drawn as to the implications to the BDL re-estimate, given it is based on the Cap scenario.

The model calibration is constrained to a degree by the nature of high flows in the Barwon-Darling system bypassing gauges as they break out across wide floodplains. This is also true of flow gauges in lower reaches of tributaries contributing to the Barwon-Darling, and collectively this results in significant under-estimates of the actual flows during flooding (NSW DPE, 2022). Fortunately, there are four key flow gauging stations along the Barwon-Darling system where most flows (apart from extreme floods) remain in the main channel, at Walgett, Bourke, Wilcannia, and Menindee and these were relied upon for flow calibration.

Nevertheless, unregulated diversions are generally unaffected by these flow ranges being far higher than entitlement access conditions, with some effect on the commence to take flow for FPH diversions.

High flows that bypass gauges also affect the quantification of back-calculated end of system flows into the Menindee lakes, which is problematic given the lack of a river gauge upstream of Lake Wetherell. The new Source model will seek to address this with a revised back-calculation method to quantify inflows to the lakes, to improve the quality of end-of-system flow data and confidence in the mass balance of the lower reach of the model.

Future modelling will benefit from the Murray–Darling Basin Enhanced Water Monitoring and Information (EWMI) program that will install 20 new gauging stations across the northern basin, including one on the Darling River below Wilcannia that may address the above issue.

Overall, the model update is an improvement given the increased resolution and accuracy of FPH take at the property level, maintaining the valley and reach-scale model performance. Whilst the model can be improved, its shortcomings are not at the cost of accuracy in the critical mid flow range that impacts unregulated (particularly relevant to C Class entitlements) and FPH diversions.

7. Framework for Incorporating Changes to BDL Estimates Presented in the Basin Plan (BWR, 2014): Chapter 5

7.1 Significance of change

The significance of the change to the BDL estimates is assessed at both the SDL Resource Unit and Basin scales and is required for input to the risk assessment. For this assessment of significance, the floodplain harvesting component of the MDB Plan Limit Scenario (Barwon-Darling May 2022 model) was compared against the floodplain harvesting component of the Basin Plan 2012 Schedule 3 estimate.

The difference between the floodplain harvesting component of the BDL in the Basin Plan (11.5 GL) and the MDB Plan Limit Scenario floodplain harvesting BDL volume (9.6 GL) is -1.9 GL (Table 1; excluding rainfall runoff harvesting for accuracy in comparison). The framework classifies this change as being 'negligible', given it is less than ±5 GL/year or ±1% change to the current BDL estimate for the whole SDL Resource Unit (198.0 GL).

The discussion in Section 3 regarding the treatment of rainfall runoff harvesting in historical estimates is noted. The overall change to the BDL estimate for unregulated river and floodplain harvesting (excluding rainfall runoff harvesting for equal terms of comparison) is -1.97% (-3.9 GL). The overall change to the BDL estimate including all forms of rainfall runoff harvesting is +1.82% (+3.6 GL).

As a result, in both cases, the significance of change of the BDL re-estimate increases from 'negligible' to 'minor' for the Barwon-Darling.

7.2 Risk assessment

Likelihood

In the BDL assessment framework, the likelihood of the revised BDL estimates being scientifically robust and defensible is based on the scientific robustness of the revised BDL estimates which is assessed with quality assurance criteria and peer review findings.

In Section 6, this review found that the modelling undertaken and described in the Model Build report (NSW DPE, 2022) is more advanced and comprehensive in terms of defining and quantifying consumptive water use. The data management (from collection, verification, calibration, validation and modelling) undertaken by NSW DPE were sound and reach and valley scale results were reasonable. As such, these estimates are an improvement over those in the Basin Plan.

Given these findings, the framework classifies this likelihood of the revised BDL estimates being scientifically robust and defensible to be 'likely', noting that the estimate is based on best currently available information. Future model improvements will be possible with more accurate metered river diversions data and observed FPH meter data for more accurate calibration of floodplain harvesting, especially at the farm scale, and a better understanding and modelling of the fate of water that has broken out onto the floodplain.

Consequence

In the BDL assessment framework, the consequence of the revision of the BDL estimates is a function of stakeholder sensitivity and significance of change in the BDL estimate, as quantified in Section 7.1.

The nature, historical legacy, legality, volume, timing and downstream impacts of floodplain harvesting take are hotly debated, meaning that stakeholder sensitivity to these estimates is very high. Despite the assessed 'minor'

significance of change in the BDL estimate, the consequence measure is classified as 'major' due to this stakeholder sensitivity. According to the framework, the higher category must take precedence.

Risk rating

From the likelihood and consequence measures above, the revised BDL estimate has a high-risk rating, suggesting that a cost-benefit analysis be undertaken, as per the next Section. The framework suggests that the high-risk rating requires further investigations to scope whether, how and when risk may be reduced.

7.3 Cost-benefit assessment

The benefits of revising the BDL estimates of the Barwon-Darling are 'major' according to the framework due to the following reasons:

- There is major improvement in SDL reporting and compliance activities (and corresponding management of unaccounted components of take)
- There is major improvement in certainty and confidence building regarding the use of new knowledge and information.

The costs of revising the BDL estimates are 'high' according to the framework due to the following reasons:

- Revisions to methods used to estimate take under the BDL will lead to the need for revisions in other SDL Resource Units which will require large amounts of time, resources and funding
  - The revised methods have been identified, and already completed or committed, by NSW for relevant upstream valleys to the Barwon-Darling. The 2% change to the BDL re-estimate for the Barwon-Darling is not significant enough to warrant immediate changes to downstream valleys (Lower Darling and Murray), which will be addressed in the model harmonisation process as part of MDBA's SDL accounting improvement strategy.
- Data and information required for BDL revision needs to be continually developed and updated (particularly observed data and information) and can require large amounts of time, resources and funding.
- High costs and resources anticipated (already committed by NSW and requirement for on-going investment) for communicating the implications of BDL re-estimates to stakeholders.

Despite these findings where the benefits are major and costs are high, the BDL assessment framework recommends that revision is desirable but that the timeframe and support (in areas such as extensive data monitoring and collection, development of ancillary policies and stakeholder engagement for example) across the Basin states requires negotiation.

The commitment by NSW to licence FPH is the overarching driver for improving the Barwon-Darling model representation, which has led to the revised BDL estimate.

7.4 Summary

The assessment under this framework concludes that revision to the BDL estimate is appropriate. However, high stakeholder sensitivity to floodplain harvesting in the MDB, and particularly the Barwon-Darling, means that any re-estimates of the BDL are likely to be high-risk. In addition, the risks of not implementing reform in FPH management present a greater risk to overall water management, particularly in the northern MDB and the Barwon-Darling as the receiving valley. The current classification of high risk for the Barwon-Darling SDL Resource Unit within this framework requires a response, and the Commonwealth and NSW should be commended for the substantial investment in better understanding and modelling of user processes on the floodplain and the modes of floodplain harvesting, to provide a

transparent and defensible position regarding the quantification and management of this take of water, and the overall surface water resource.

Therefore, it is considered that NSW's response is appropriate as required by the framework described in this Section. It is noted however that this work is conducted within finite constraints of resources and time, in data collection and model/method improvement, and that the significant progress to date has brought model maturity forward to a point where future improvements are known and being actioned in the development of the new Source model.

Improvements to FPH diversion volume accuracy will largely be dependent on the collection of a body of observed floodplain harvesting measurement data that assists in calibration of uncertain elements such as rainfall runoff modelling and crop water use assumptions.

8. Current limitations and improvement opportunities

Given similarity of catchment, water use and modelling approach, many model limitations regarding FPH in the Barwon-Darling SDL resource unit are shared with other northern NSW valleys previously reviewed (Border Rivers, Gwydir, Macquarie SDL resource units). These are discussed in Table 8 with some being acknowledged throughout the Model Build report (NSW DPE, 2022).

Other limitations of the modelling and reporting as identified throughout this review are summarised in Table 8, along with opportunities for future improvement.

Table 8: Limitations and improvement opportunities

#	Limitation	Opportunity
1	The BDL re-estimate (Barwon-Darling Plan Limit) is proposed by NSW to correctly reflect the Cap scenario based on water management arrangements and infrastructure as of 1993/94 and utilises Cap scenario modelled inflows from upstream NSW tributaries, and MDBA-accredited BDL modelling for Qld tributaries (which is Cap in Qld). The reviewer agrees that this model configuration is the correct representation. However, queries raised by the reviewer and subsequent discussion between MDBA, NSW and peer reviewers to this report identified differences in understanding the correct application of the Basin Plan 2012 definition of the BDL for the Barwon-Darling to be applied for WRP model submission and accreditation, as it pertains to the modelled basis of tributary inflows to the Barwon-Darling, be it modelled Cap or modelled BDL inflows (which is the Water Sharing Plan Limit for NSW tributaries).	MDBA to work with NSW to settle on the correct model configuration for the Barwon-Darling inflows, being Cap or Plan Limit, noting possible implications: • The inconsistency in northern basin valleys' model harmonisation given usage of different models (Cap and Plan Limit) across valleys. • The requirement for use of Cap models for upstream tributaries requires that these models be updated and accredited for Cap. Currently the updated Macquarie-Castlereagh Cap model is unlikely to meet accreditation requirements, and the Namoi update is yet to be completed. In the absence of this, the currently accredited Cap models must be used however these do not explicitly model FPH.
2	The modelling results were able to be replicated however the exercise in doing so identified confusion or changes to inclusion/exclusion of individual model parameters for total development figures, and resultant errors in published reporting in both development (on-farm storage capacity, river pump capacity, developed irrigation area) and diversions figures.	Whilst the errors were relatively minor, it demonstrated the importance of clear record keeping and documentation of modelling decisions made, and changes performed in subsequent models. This opportunity is raised in #7 below. It is recommended that published reporting be updated to correct errors, particularly the error in the modelled rainfall runoff harvesting take for the Plan Limit scenario, and the corresponding BDL re-estimate in the Model Scenarios report (NSW DPE, 2022), along with the publishing error identified in #22 below.
3	The Model Scenarios report (NSW DPE, 2022) quotes in Section 4: *"This report has been completed prior to final decisions on eligibility being made for a small number of minor floodplain harvesting infrastructure, and this is not expected to make a noticeable difference to the model results presented in this report. The modelling will be updated for the final decisions on these infrastructure prior to the determination of individual licences."*	It is recommended that reporting be updated accordingly once these eligibility decisions have been resolved. The reviewer notes the expected minimal impact to model results is an assumption and may influence the conclusions of this review. Amendment of this review is advised should the change to the FPH diversion volume (FPH only, not overall BDL) exceed 5% resulting from the finalisation of infrastructure eligibility only, not resulting from other model changes arising from improved metering (i.e. pump meter recalibration project) or model platform (Source model rebuild).

#	Limitation	Opportunity
4	Sensitivity testing and uncertainty analyses were not specifically carried out for the Barwon-Darling. These were undertaken for the Border Rivers and Gwydir valley models, with the assumption that similar results apply to the Barwon-Darling model. Details of these Border Rivers and Gwydir analyses were reproduced for the Barwon-Darling model reporting. This is an assumption and modelling best-practice would require model-specific sensitivity testing to be carried out, especially given the use of non-traditional model validation (full data record was used for each reach and calibration element, and the model validation comprised a full model run to assess accuracy as a complete system). The unique features of Barwon-Darling further reinforces the need to undertake specific sensitivity testing.	The reviewer encourages NSW to undertake sensitivity testing and uncertainty analysis specific to the Barwon-Darling. This will foster further trust and credibility in the modelling with MDBA, independent reviewers and other Basin states to instil confidence in the robustness of the model.
5	NSW acknowledges that the models are best suited to modelling at whole-of-valley and river reach scale and increasing the spatial resolution to farm-scale requires very detailed understanding and characterisation of flow pathways and farm management at that scale. However, the simulated floodplain harvesting results had low sensitivity to farm scale assumptions.	Despite the significant improvements to date, there is still much more that could be done to understand or capture the decision drivers to replicate farm behaviour, for simulation and verification of modelled on-farm processes such as choice of planting date, managed crop water use (i.e. deficit irrigation) and cropped and fallow areas. This is an area for future improvement as identified by the NSW modelling team. Further improvements in the on-farm water balance can only be achieved through model parameter calibration and validation with observed data. Efforts to increase the spatial resolution rely heavily on farm operation, specific irrigation application data and water management, which is variable and is likely frustrated without observed data on actual volumes harvested as rainfall runoff or overbank flow harvesting.
6	As measurement of FPH in NSW is yet to be widely implemented, there is negligible observed data available for estimates of take or calibration/validation of models. Therefore, as much confidence in the model methods and data used must be gained to infer confidence in the results, noting that this confidence cannot be quantified through model calibration or validation. A significant body of work and analysis has been completed by NSW to address this, as outlined in Section 9 of the Model Build report. This is the key limitation to the scientific robustness of the models, with reduced ability to minimise uncertainty in the model and to verify the accuracy of the modelling.	Whilst it may take up to 10 years or more of consistent observed data, the implementation of the NSW Floodplain Harvesting Measurement Policy will provide a crucial dataset from which to reduce uncertainty by refinement of floodplain processes, model configuration, crop model parameters, rainfall runoff parameters and irrigation behavioural assumptions. This underscores the need to keep pressing on with the FPH measurement program. Observation data includes the management and use of Held Environmental Water as environmental watering plans are implemented. Observed data is critical, but equally so is the continued collection of 'other lines of evidence' data, particularly comprehensive and regular remote sensing data, to assist model calibration and validation, in addition to on-farm data, as discussed in #5 below.
7	There was a clear inadequacy in information regarding on-farm infrastructure (particularly historical), cropping information and water use. This was mitigated as much as possible using multiple, independent lines of evidence. The quality and completeness of the data relating to on-farm crop areas is best-available, however is far from perfect and	There is a clear need to focus on collecting high-quality on-farm data, not just observed FPH measurement data but also all on-farm decision making such as crop areas and types (including irrigated winter crops), associated water use and storage use behaviour. The reviewer considers that significant uncertainty surrounding quality and quantity of on-farm cropping data, which is the core driver of water demand from both regulated and FPH sources, underscores the need for

#	Limitation	Opportunity
	is a focus for future effort to provide better input parameterisation and calibration data. Table 30 of the Model Build report states that *"Uncertainty in total irrigation water use has a significant impact on the assessment of the diversion limit",* which underlines the critical nature of this data to improve the BDL estimate. Continued investment in improved remote sensing data is also critical to verify on-farm data surrounding crop areas, irrigation water movements and water volume held in storage.	more comprehensive future data collection regarding on-farm cropping activities to improve model performance, calibration and validation. 25-30% loss for inefficiency in irrigation application across all historical scenarios is a broad assumption despite being informed by detailed industry research and advice. Future capture of observed FPH data and other information on-farm will inform the adequacy of this assumption however as on-farm efficiencies are continually improving, future models representing modern scenarios may need to include a lower loss percentage. Sustained (and adequately resourced) effort is required to continue to build datasets and information regarding on-farm cropping operations, storage management and water use, and continued investment in remote sensing data collection, to support model improvement, calibration and validation purposes. Along with observed FPH measurement data, this is a key focus to provide for future model improvement, particularly regarding on-farm rainfall runoff though it is unknown whether this routine data collection is being resourced by NSW, i.e. a formal programme of on-going on-farm operational and cropping data survey/collection.
8	As discussed above, there is a lack of on-farm data to support model parameterisation and calibration/validation. In the absence of complete data sets, there is a higher reliance on modelling skill to assess suitability, relevance and truth of alternative, multiple lines of evidence, model adequacy and performance (A Brown, pers. comm, 12 December 2022).	The approach taken by NSW in applying modelling best practice in assessing best available data and information to be used is supported, however it requires a great deal of care to ensure that subjective decision-making processes by modellers and data relied upon are guided and recorded in detail for future model revision. The reviewer encourages the continued development of modelling guidelines and methodologies to foster consistency and reliability, alongside detailed record keeping of specific model decision making, providing for future comparison, revision, and amendment of models, particularly by different modellers. Record-keeping must not only address what model parameters were used but the reasoning and data sources behind such decisions. Comprehensive model build reporting and documentation for each model revision is encouraged to provide sound justification for model results, transparency to stakeholders and to inform future model improvements.
9	The modelling over-simulated summer crop areas than observed for the validation period, and lower for winter crops, with some significant variations. The two issues are likely linked, with under-simulation in winter cropping probably contributing to the model over-simulation of summer cropping.	As summer cropping is strongly linked to water supply, the over-simulation would be expected to increase both unregulated and FPH diversions to satisfy the farm water balance. As mentioned previously in this table, sustained effort is required toward better understanding and measurement of actual on-farm cropping behaviour, including remote sensing, to calibrate and improve the model performance to observed crop areas.
10	Processes of recording and understanding water movement onto, within and returning from, the floodplain are continually improving. However, there is still work to be done to better represent these processes and improve	On-farm FPH measurement data will help to calibrate the explicit modelling of effluents and breakouts, particularly relating to breakout commence to flow levels in the Barwon-Darling main channel, assisting to understand the actual FPH opportunity available to properties.

#	Limitation	Opportunity
	confidence in the mass balance of water moving onto the floodplain. The 'demand' created by floodplain environmental features i.e. wetland capture, does not appear to be well-represented in this model. The reviewer is uncertain if the volumes of water moving onto the floodplain satisfies the demand implied by remote sensing observations with persistent water bodies, greening assessments and the like. The models are limited in that return flows from floodplains to river channels are not represented, apart from that required to satisfy the mass balance between river gauges, with all breakout volume from the river ending up as harvested volumes or a simple loss to the system.	The revised models are focused on the improved representation of on-farm processes, to inform the estimates of FPH take and development of FPH entitlements, and the overall estimate of consumptive diversions that make up the BDL. However, FPH take is only one component of the floodplain water balance. The model does not appear to adequately represent other components, including specific floodplain losses, capture to environmental assets or river returns. These components are bulked up as system losses to satisfy the volume balance of water leaving the river less modelled take by FPH for each modelled reach. It is noted that further research is underway to help fill some of these knowledge gaps and develop specific model representation of floodplain return flows to the river. It is noted that Held Environmental Water is not a relevant concern for Cap scenario modelling, as no HEW entitlement existed in 1993/94. There is opportunity to improve the modelling of these floodplain 'losses' in this mass balance, but also as a further measure to validate on-farm processes in the absence of observed data, of which a useful dataset is still some 10 years away.
11	Rainfall runoff is notoriously difficult to model and calibrate on-farm, given farm operations and manipulation of soil moisture through irrigation and agronomic practices. Hence, this remains as a significant source of uncertainty as there is still insufficient data to provide high-quality inputs to farm-scale rainfall-runoff estimates. Whilst it may be a smaller component of overall take, there is still risk of significant effects to the timing and volume of other forms of take, for example, if rainfall runoff occurs prior to the take of overbank flows or supplementary access, taking up space in the on-farm storage. Given that rainfall runoff is proposed to be partially exempted from FPH entitlement accounting in NSW, there is a risk that on-farm water movement records may not be sufficiently comprehensive to attribute rainfall runoff when analysing historical on-farm storage data, undermining future calibration and model improvement efforts.	The current model representation and confidence in the modelled volumes of on-farm rainfall runoff is unlikely to be further improved until observed data is available. Careful attention will be required to collect data and information to correctly attribute water movements on-farm to rainfall runoff given the lack of accounting imperative, to allow for this.
12	Any error in watercourse river diversion measurement is linearly offset by FPH to satisfy the farm water balance. As river diversions are the more significant source of water to a property, the relative error in FPH is magnified. This is a particular issue in the Barwon-Darling, with the metering recalibration project underway to improve accuracy of metered diversions in the Barwon-Darling (reportedly increase by average 12%), to rectify known issues with the transition from old time-and-event meters to pattern-approved meters.	The best currently available data has been used in the model, given the meter recalibration project remains incomplete. NSW modellers confirmed that this work remains in progress and therefore the original calibrations were not changed, and the BDL re-estimate does not account for these revised pump capacities. The implementation of new meters under the NSW non-urban water metering framework will provide improved observed data to refine the calibration of the on-farm water balance. As noted above, this could take up to 10 years or more before a valid dataset is available for this purpose.

#	Limitation	Opportunity
	The meter recalibration project, described in Table 3 of this review, is an important work to improve accuracy of historical unregulated diversions, however it was not clear in the published documentation that these revised pump flow rates were not adopted.	Given the meter recalibration project is underway and publicly known to the stakeholder community (via the DPE website), it is recommended that model treatment of recalibrated pump capacities be clearly identified in an update to the Model Build report (NSW DPE, 2022). It is strongly recommended that the meter recalibration project continue to be a high-priority area of focus for the new model build in Source, given the potential to impact modelled diversions and the BDL estimate.
13	Quality Assurance practices, regarding data and information sources and review, farm scale data validation and review (current and historical development) and independent reviews, are outlined in Appendix A of the Model Build Report. Reference is made to the Department's 'in-house modelling practice guidelines' to guide modelling approaches however these are not published.	It is recommended that the Department publish the in-house modelling practice guidelines for model transparency, repeatability and alignment with the Australian Hydrological Modelling Practice Notes (wiki.ewater.org.au/display/SC/Australian+Modelling+Practice). It is noted that the guidelines are somewhat of a 'living document', and cannot cover every modelling decision required, and may not be in a form that is immediately publishable. As such, guideline transparency will need to be prioritised and resourced accordingly.
14	The model remains in IQQM although work is currently underway to rebuild the model in the industry-standard Source platform. The rebuilt model in Source was incomplete and not available for use in the WRP submission.	The migration of the model to the Source platform will provide opportunities to further improve the model performance, such as: • Recalibration to improve low flow representation • Recalibrated observed meter data • Better model representation of triggers for embargo on diversions • Improved methods to address tributary inflow uncertainty from flows bypassing gauges, losses beyond end-of-system gauge or backwater-affected readings • Inclusion of all weirs and block banks infrastructure explicitly in the modelling • Inclusion of local water utilities, BLR and stock and domestic water diversions
15	There is significant model uncertainty arising from the inconsistent, unplanned application of Water Management Act 2000 Section 324 Temporary Water Restrictions (embargoes), and the current rule-based model representation.	Embargoes are extraordinary, unplanned actions in response to critically low water supply, and their application by rule is an approximation and technically incorrect. However, changing this approach is problematic given this embargo rule is a feature of the previously accredited Cap model, although better approaches to modelling historical embargoes may be possible under the SDL framework, and in consideration of the secure alternative TWS to Broken Hill subsequently provided by the Murray pipeline. It is recommended that future updates to the modelling in Source improve the historical application of embargoes that is consistent with Cap.
16	Modelling arid land hydrology is a challenge, and the representation of ungauged inflows to the model has been improved, with a considerable amount of work invested in developing and calibrating embedded AWBM hydrological models for these streams (some of which were not previously modelled), with robust parameterisation from similar, gauged catchments nearby and in Qld.	This is the best available information in the absence of gauged data however continues to present an opportunity for improvement in future updates to modelling. It is recommended that this focus on data capture and model parameterisation for these ungauged streams is continued to improve the flow calibration in the Barwon-Darling.

#	Limitation	Opportunity
17	The most downstream gauge of a tributary is used to evaluate inflows into the Barwon-Darling system. However, in some tributaries this gauge is upstream of large terminal wetland systems and an estimate is made on the proportion of the gauged flow that discharges to the main channel flow. Also, the Model Build report (NSW DPE, 2022) states that "*10 out of 16 gauged inflows upstream of Bourke are factored to achieve satisfactory water balance at the four gauging stations that measure the full floodplain flow*." The modellers note the factoring reflects high flow events bypassing gauges or backwater from the Barwon-Darling system affecting gauge readings. Both issues introduce model uncertainty to tributary inflow rates and volumes.	The modellers admit that this approach is not ideal however no better solution has been found to account for these unique features of the Barwon-Darling and is a focus for the new model being developed in Source. Whilst the current approximations are the best currently available, it is recommended that this work continues to refine the approach to quantify these inflows more accurately.
18	There are 15 fixed-crest weirs (total volume ~32 GL) in the Barwon-Darling system that have not been modelled explicitly, given a lack of operability to manipulate flows (i.e. regulation). The lack of these infrastructure in the model has significantly impacted the ability of the model to replicate observed low flows and cease-to-flow events and gives rise to small flows moving further through the system than otherwise observed, as these flows are captured in weir pools.	Recent higher-quality data on weirs and block banks has been collected by WaterNSW, providing data for model inclusion. The reviewer agrees with the modellers assertion that this makes little difference to the objective of the model, in replicating unregulated or FPH diversions given commence to pump thresholds are well above this flow range. The modellers advise that the new Source model will include this infrastructure, for completeness and improved model low-flow performance and ability to replicate cease to flow events and providing the ability to quantify refuge pool persistence. It is recommended that this work is completed to improve accuracy of the new model and broaden model functionality for multiple low-flow objectives in addition to higher-flow diversions.
19	The model does not explicitly simulate minor diversions. A and B Class unregulated diversions are simulated however these are mostly unmetered limiting calibration. Diversions by local water utilities (town water supply), Basic Landholder Rights and Stock and Domestic are not modelled, which is consistent with all Cap modelling to date.	The modellers confirm that these small volumes do not affect the flow simulation and aren't experiencing growth so are of little concern. However, this is a focus for the new Source model as more observed data is captured and local authorities seek to understand critical reliability of their water supply. A and B Class unregulated diversions will be metered in future as part of the non-urban water metering framework, and this will provide data for calibration of these minor diversions. Whilst BLR is rarely modelled explicitly (often just a system loss), the new Source model will also include a basic representation of this take, as well as stock and domestic take to allow quantification of reliability. The aim is to have all entitlements represented in the model in their correct locations, switched to reflect whether those entitlements are active or not. A more comprehensive model in Source will improve accuracy of the new model and broaden model functionality for multiple low-flow objectives; in this case whether general river operations are able to meet the needs of small, but critical human-needs diversions at low or nil flows i.e. through access to persistent waterholes, weir pools, etc.

#	Limitation	Opportunity
		It is recommended that NSW continue to pursue the development of a comprehensive model in the Source platform to improve system representation.
20	MDBA reported (S Rai, 16 June 2023, pers. comm.) that the required post-processing of results to determine the volume of rainfall-runoff was not clear and required substantial assistance from the NSW modelling team to replicate.	It is recommended that the results post-processing requires additional, detailed documentation for use by third parties and future modelling personnel to minimise confusion and risk of error, particularly with the passage of time and comparison with the development of the model in the Source platform.
21	The Model Build report (NSW DPE, 2022) reports that the model simulates the pattern of metered diversions well across the whole period however the 2008/09 scenario displays an under-simulation (approx. 7%) of diversions throughout the 2003/04-2013/14 assessment period. However, this was difficult to investigate given that the flow calibration graphs and tables were not provided as an Appendix to the Model Build report, as was done for Border Rivers, Gwydir and Macquarie reports. This under-simulation result is also queried given the over-simulation of observed summer crop areas, which serves to increase water demand over observed diversions. It is noted that the 7% under-simulation resulted from the validation of the 2008/09 scenario and as such no conclusion can be drawn as to the implications to the BDL re-estimate, given it is based on the Cap scenario.	Tables and information were provided in Section 8.2.2 of the Model Build report that showed the model was able to replicate the number of high flow days at Walgett and Bourke (two gauging stations that capture the full range of flows) to a good degree of accuracy. This is relevant to unregulated and FPH diversions. The inclusion of flow calibration graphs and tables would aid the review and adequacy of the model to replicate the main flow simulation and is recommended for inclusion in an update to the report.
22	There is conflict in the permanent on-farm storage capacity figures for 2008 listed in Table 11 (279,967 ML), and the corresponding figure in Table 12 (276,235 ML), whereas they should be identical.	NSW modellers confirmed (A Brown, 12 May 2023, pers. comm.) that the figure in Table 12 (276,235 ML) is correct and the report requires correction. This oversight is of no consequence to the Cap scenario modelling that forms the basis for the BDL.
	Item 23 is not a model limitation, rather a discussion regarding modelled volumes of rainfall runoff included in BDL reporting.	
23	Rainfall runoff from developed irrigation areas is defined in the Basin Plan 2012 as floodplain harvesting. NSW models allow for separate reporting of overbank flows and rainfall runoff harvesting, providing confidence in the overall estimate of floodplain harvesting. The published reports for the Barwon-Darling include exempt rainfall runoff in the Plan Limit total (NSW DPE, 2022). For the Barwon-Darling, all forms of water taken are included in the BDL definition in Schedule 3 of the Basin Plan 2012.	The BDL estimate analysis in this review has included all forms of rainfall runoff, as described in Table 1. There is opportunity to create, clarify and maintain consistency in the approach to estimating FPH take going forward to instil confidence in reported volumes and manage the high sensitivity to FPH by the broad range of stakeholders, particularly downstream interests. Moving forward, NSW's approach to separately quantifying the components of FPH will help in addressing the issue of comparing "apples and oranges" (which is demonstrated in Table 1) when comparing previous, current and proposed BDL estimates within an SDL Resource Unit.

9. Conclusions

This review has been conducted prior to NSW's re-submission of the Barwon-Darling WRP for MDBA accreditation and is based on the referenced modelling data and reporting (May 2022) that is expected to be submitted to support the re-estimate of the BDL. Changes to modelling and reporting in response to this review and other MDBA feedback may occur, particularly regarding the model configuration of tributary inflows, however this is not expected to materially change this review's conclusions.

The BDL re-estimate for the Barwon-Darling, in full accordance with the BDL definition (which necessarily includes all rainfall runoff harvesting volumes), has increased by 1.82% over the Basin Plan 2012 estimate, from 198.0 GL to 201.6 GL of average annual take.

An assessment was undertaken under the BWR 2014 *Framework for Incorporating Changes to BDL Estimates Presented in the Basin Plan*, concluding that revision to the BDL estimate is appropriate and NSW's comprehensive response is commendable given the assessed high risk. However, continued effort is required as more model improvement is possible as identified throughout this review.

The current limitations and opportunities for future improvement as discussed in Section 8 are noted for context. It is concluded that the hydrological model for the unregulated Barwon-Darling SDL Resource Unit, that determines the proposed BDL re-estimate:

1. Is based on the best available information as given in Basin Plan s10.49 and therefore a better estimate of the BDL from Basin Plan 2012 BDL estimates.
    a. This conclusion is drawn primarily from the IQQM improvement to the Cap Scenario now correctly configured to 1993/94 management rules and levels of development. The model underpinning the Basin Plan 2012 BDL estimate was incorrectly configured, meaning that the new BDL re-estimate is superior. However, this conclusion is qualified given model-specific sensitivity testing was not undertaken and is required to meet with modelling best practice and to confirm best available information. Also, it is noted that there are several identified improvements to the modelling that ideally would be actioned into this IQQM, however NSW has decided to collate these improvements into the new model rebuild in Source that is currently underway. This is an acceptable concession, in that effort into the model rebuild is of more value than updating the ageing IQQM.

       In summary, in due course this IQQM model will be superseded and no longer best available.
2. Represents the BDL description given in Basin Plan Schedule 3; as the Cap limit consistent with Schedule E of the Murray-Darling Basin Agreement and associated baseline conditions including level of development, irrigator behaviour, access conditions and climate sequence.
    a. This conclusion notes that the BDL re-estimate volume (Barwon-Darling Plan Limit) is proposed by NSW to correctly reflect the Cap scenario based on water management arrangements and infrastructure as of 1993/94 and utilises Cap scenario modelled inflows from upstream NSW tributaries, and MDBA-accredited BDL modelling for Qld tributaries (which is Cap in Qld). The reviewer agrees that this model configuration is the correct representation.
    b. However, given differences in understanding the correct application of the Basin Plan 2012 definition of the BDL for the Barwon-Darling, the reviewer encourages MDBA to work with NSW to settle on the correct model configuration for the Barwon-Darling inflows, being Cap or Plan Limit, ahead of WRP model submission, noting:
        i. The potential for inconsistency in northern basin valleys' model harmonisation given usage of different models (Cap and Plan Limit) across valleys.

ii. The use of Cap models for upstream tributaries requires that these models be updated and accredited for Cap. Currently the updated Macquarie-Castlereagh Cap model is unlikely to meet accreditation requirements, and the Namoi update is yet to be completed. In the absence of this, the currently accredited Cap models must be used however these do not explicitly model FPH.

3. Includes sufficient documentation to provide evidence of the BDL re-estimate method and processes to be able to reproduce the BDL re-estimate.

    a. This conclusion is conditional upon the finalisation of updates to the published reporting to address errors, clarify that the revised river pump capacities arising from the (incomplete) meter recalibration project have not been used, and provide additional documentation to improve clarity in the post-processing of model results.

The Barwon-Darling is an important model in that it is the link between the northern and southern basins. The critical nature of the model is challenged by a range of constraints unique to this valley, including:

- It is not a headwater stream, nor regulated with headwater storage or in-stream weirs, that can provide key stream reference data through regulated storage and in-stream weir releases.
- The model relies entirely on modelled inflows from gauged and ungauged tributaries, including different bases for modelling between Qld and NSW tributaries.
- Mostly arid landscape that introduces hydrological modelling difficulty.
- Flat topography where high flows bypass most in-stream gauges and tributary end of system gauges.
- End of system flow data (to Menindee lakes) requires inferred calculation given lack of formal end of system river flow gauge and is therefore sub-optimal to directly gauged data.
- Available metered diversion data is known to be inaccurate or incomplete which requires post-processing to improve, however is also sub-optimal to accurate, direct meter data.

NSW has done an admirable job in responding to this difficult modelling task and has successfully developed a model that replicates flow behaviour in the critical ranges where most diversion occurs. The above constraints do not change the conclusions drawn in #1-3 above. However, this is presented to establish context that these challenges to modelling in the Barwon-Darling mean that there is still room to refine and improve the approach and raise the quality of modelling equivalent to that in other northern valleys, and NSW is strongly encouraged to continue this work beyond WRP submission as they develop the model in Source, and it is expected that a future revision to the BDL estimate will occur, particularly in response to the pump meter recalibration work underway.

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APPENDIX A

Terms of Reference

Terms of reference for independent review of proposed NSW floodplain harvesting baseline diversion limit re-estimates in the Macquarie-Castlereagh and Barwon-Darling Watercourse SDL resource units

September 2022

1. Background

The Murray Darling Basin Plan 2012 defines sustainable diversion limits (SDLs) for each SDL resource unit in the Basin, which is the maximum consumptive water limit. For surface water, SDLs are defined in Basin Plan Schedule 2 and are equal to the baseline diversion limit (BDL) less water recovery. Baseline diversion limits are defined in Basin Plan Schedule 3, which is the statutory point of reference for determining the BDL and is described for each form of take in each SDL resource unit. It generally provides, as a note, a volumetric estimate of long-term average take that was made by the MDBA at the time of Basin Plan development.

Ahead of water resource plan (WRP) accreditation, a Basin state may provide a BDL re-estimate for any form of take in any SDL resource unit. If it is based on the best available information (Basin Plan s 10.49 WRP requirement) and aligns with the Basin Plan Schedule 3 BDL description, then it is reasonable and appropriate for the MDBA to agree with the BDL re-estimate. This process is set out in MDBA's Position Statement 3D[1] and established in Daren Barma's 2014 report '*A framework for incorporating changes to BDL estimates presented in the Basin Plan*'.

Ahead of WRP re-submission, NSW is re-estimating the BDL for take from floodplain harvesting (FPH) in five SDL resource units - the Barwon Darling Watercourse, NSW Border Rivers, Gwydir, Namoi and Macquarie-Castlereagh. The FPH BDL re-estimates are determined using hydrological models that incorporate the rules and conditions found in State water management law at the baseline date defined in Schedule 3 and run over the historical climate conditions. The baseline date is as at 1 July 2009 for NSW Border Rivers, 30 June 2009 for Gwydir and Macquarie-Castlereagh and 1 July 2010 for Namoi. At these dates, the baseline water sharing plans define the limit as the lesser of long-term average annual extraction (LTAAEL) or the long-term Cap on diversions. As there was no water sharing plan for the Barwon-Darling Watercourse SDL resource unit at the time of Basin Plan development, the BDL description is set to that under the Murray-Darling Basin Cap on Diversions, given in Schedule E of the Murray-Darling Basin Agreement. The long-term Cap limits therefore are an important consideration in the proposed FPH BDL re-estimates.

A review of the NSW Border Rivers and Gwydir valleys has been completed in June 2022.

Consistent with the MDBA's position statement on FPH[2], the Authority seeks the services of an independent reviewer to review the proposed BDL re-estimates for take from FPH in the Barwon Darling Watercourse and Macquarie-Castlereagh SDL resource units (with Namoi at a later stage). The review will advise the MDBA on whether the FPH BDL re-estimates are based on the best available information as defined by Basin Plan s 10.49 and align with the BDL description for this form of take in Basin Plan Schedule 3. The independent review will be published.

2. Objectives of project

This review will increase confidence and transparency in relation to proposed NSW FPH BDL re-estimates. This review will be published with the proposed NSW WRP packages when re-submitted and will underpin MDBA advice on the suitability of the FPH BDL models to meet the requirements of the Basin Plan.

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[1] https://www.mdba.gov.au/sites/default/files/pubs/WRP-position-statement-3D-changes-to-BDL_0.PDF

[2] https://www.mdba.gov.au/publications/mdba-reports/floodplain-harvesting-position-statement

3. Scope of the project

Undertake a review of the relevant Barwon Darling Watercourse and Macquarie-Castlereagh hydrological models that determine the proposed BDL re-estimates for FPH to inform the MDBA that:

1. It is based on the best available information as given in Basin Plan s 10.49 and therefore a better estimate of the FPH BDL from Basin Plan 2012 BDL estimates. MDBA's Position Statement 3C[3] Attachment 1 - SDL model evaluation criteria sets out relevant aspects of the BDL model for the reviewer to consider in relation to s 10.49. (Refer Attachment 'Summary of what constitutes 'best available information' with regards to modelling and planning assumptions.')
2. It represents the FPH BDL description given in Schedule 3, i.e. that it represents the State water management law limit and baseline conditions associated with FPH, including irrigator behaviour, access conditions, climate sequence.

   The reviewer will review the updated long-term Cap models for consistency with the requirements of Schedule E of the MDB Agreement[4] ; and the LTAAEL models for consistency with the description of the state limit set out in NSW water sharing plans at baseline dates. The reviewer will subsequently confirm the proposed FPH BDL re-estimate is the lesser of:

   a. the updated long-term Cap or

   b. the LTAAEL.

   The MDBA will support the reviewer in extracting data from the relevant models as required.

   This should include a review of whether the updated long-term Cap models are consistent with the requirements of Schedule E of the Murray–Darling Basin Agreement, for example whether any major differences from the formerly accredited, or provisionally accredited, Cap models are justified.
3. There is sufficient documentation to provide evidence of the FPH BDL re-estimate method and processes to be able to reproduce the FPH BDL re-estimate.

The reviewer is to also note any limitations or uncertainties in the proposed FPH BDL re-estimates by SDL resource unit, but that do not affect the advice in relation to points 1-3 above.

Issues around the legal status of floodplain harvesting are out of scope for the purposes of the reviews under these Terms of Reference. In addition, the review is not required to be a formal assessment of NSW' updated Cap scenario relative to all of the requirements for an analytical model set out in Schedule E of the MDB Agreement.

In considering the points above, the reviewer will consult with Tony Weber and Greg Claydon and build upon existing relevant reviews and reports, including the following:

- *Independent Review of Interim Baseline Diversion Limits for NSW Floodplain Harvesting* by Tony Ladson, December 2019
- *Independent Review of NSW Floodplain Harvesting Policy Implementation* by Tony Weber and Greg Claydon, April 2019,

[3] https://www.mdba.gov.au/sites/default/files/pubs/WRP-Position-Statement-3C-method-for-determining-take.PDF

[4] Schedule E of the Agreement in the Commonwealth Water Act 2007 at https://www.legislation.gov.au/Details/C2016C00469 and Diversion Formula Register at https://www.mdba.gov.au/sites/default/files/pubs/diversion-formula-register-v6.pdf

https://www.industry.nsw.gov.au/__data/assets/pdf_file/0004/272146/Final-floodplain-harvesting-independent-review.pdf

- '*A framework for incorporating changes to BDL estimates presented in the Basin Plan*' by Daren Barma (Barma Water Resources) 2014
- '*Independent review of models to assess their representation of the baseline conditions specified in the Basin plan and estimating BDLs'* by Daren Barma (Barma Water Resources) June 2012 Independent peer review of NSW FPH modelling reports for five valleys:
    a. *Review of NSW Macquarie River Valley Model Build, Scenarios and Environmental Outcomes reports relevant to Floodplain Harvesting Policy implementation*, March 2021 https://www.industry.nsw.gov.au/__data/assets/pdf_file/0008/357956/final-summary.pdf
    b. *Review of NSW Barwon-Darling Model Build and Scenarios reports relevant to Floodplain Harvesting Policy implementation*, May 2022 https://www.industry.nsw.gov.au/__data/assets/pdf_file/0010/512659/Barwon-Darling-reports-review-summary-May-2022.pdf
    c. Note for the Namoi River, the review will be available when the modelling report has been completed, refer to https://www.industry.nsw.gov.au/water/plans-programs/healthy-floodplains-project/harvesting/policy-modelling-reports
- Independent audit of Cap models:
    a. Barwon-Darling Valley, Independent audit of Cap model, Bewsher Consulting, January 2013 Barwon-Darling Valley independent audit of cap model (mdba.gov.au)
    b. Macquarie / Castlereagh / Bogan Valley, Independent audit of Cap model, Bewsher Consulting, September 2011 Macquarie / Castlereagh / Bogan Valley independent audit of cap model (mdba.gov.au)
    c. Namoi Valley, Independent audit of Cap model, Bewsher Consulting, February 2005 Namoi Valley independent audit of cap model (mdba.gov.au)

4. Reporting

The reviewer will provide a final review reports that advise whether the FPH BDL re-estimates in each of the relevant SDL resource units is based on the best available information, aligns with Basin Plan Schedule 3 BDL description and is sufficiently documented. This will be published with the proposed NSW WRP packages when re-submitted.

APPENDIX B

Summary of Best Available Information specific to this Review

ATTACHMENT A – Summary of what constitutes 'best available information'…

Independent review of NSW floodplain harvesting baseline diversion limits – 2022.

Summary of what constitutes 'best available information' with regards to modelling and planning assumptions. (This summary does not supersede the referenced MDBA position statements and is intended for use only by the independent reviewer of NSW floodplain harvesting baseline diversion limits in 2022).

Any change in BDL estimates must satisfy the definition of the BDL in Schedule 3 of the Basin Plan and must satisfy the Basin Plan requirement for the new BDL estimate to be the ***best available information*** such that the resulting WRP can be demonstrated to be based on the ***best available information.***

The primary requirement to be tested in an assessment is that the new BDL estimate is superior to the currently adopted BDL estimate. A proposal for a new BDL estimate must be supported by evidence that demonstrates the extent to which the alternate estimate is scientifically robust generally, and specifically in relation to the previous estimate. Any new BDL estimate must reflect the ***best available information*** in terms of data used and in modelling methodology.

In assessing a proposal for a new BDL estimate, 'Best available information' would be expected to result from improved knowledge of the relevant levels of development and the entitlements and rules (as per the definition of the BDL in Schedule 3) and associated consumptive use occurring as a result.

MDBA encourages that best practices are used in developing any models that form part of any re-estimation of BDL to simplify the assessment process and improve the transparency and understandability of the proposed new method.

MDBA recommends that the demonstrations of 'best available' could result from:

- New or improved data that the method used to estimate a BDL take component is based on. This can be climatic data such as rainfall, temperature and streamflow information, or development data such as runoff dam characteristics and on farm storage volumes. The Basin Plan requires use of best available hydrological and meteorological information for the July 1895 to June 2009 period.
- New methods for estimation of the BDL take component, such as new computer models (e.g. IQQM to Source).
- Improved representation of physical and user processes in existing methods used to estimate take under the BDL (e.g. processes to estimate tributary inflows and climate inputs, levels of development, understanding of irrigator behaviour including crop types, water use patterns and risk management strategies).
- Better representation of policies, allocation, accounting and river operational rules that apply under the definition of the BDL estimate.

Documentation is key to supporting any change in BDL estimates; any improvement must be sufficiently documented to be able to reproduce the BDL. There must be clear reasoning and evidence to support any change to estimates of the volumes of any form of take and any planning assumptions or modelling settings that may impact the estimation of those volumes.

MDBA requires that any limitations in, or qualifications of, the planning material under review should be noted in the independent reviewer's report.

References:

MDBA Basin Plan Water Resource Plan Requirements Position Statements:

3C - Method for determining take (WRP Position Statement 3C method for determining take (mdba.gov.au)

3D (Changes to BDL) WRP position statement 3D changes to BDL (mdba.gov.au)

APPENDIX C

MDBA PS3C model evaluation

Table 9: MDBA Position Statement 3C: review against relevant evaluation criteria for Barwon-Darling SDL Resource Unit

Basin Plan Chapter 10: Assess				Assist		
Principal Section	**Related Section**	**Assessment**	**Review Response**	**Guidance No.**	**Guidance Note**	**Review Response**
S10.10		**ANNUAL DETERMINATIONS OF WATER PERMITTED TO BE TAKEN**		**1**	**DOCUMENTATION AND MODEL OVERVIEW**	
	s10.10(1)	Is the method – for determining the maximum quantity of water that the plan permits to be taken for consumptive use during a water accounting period – a model?	Yes, this was clearly stated in the objectives of the model build report.	1.1	Has a complete model report been provided which documents all the matters necessary to allow peer review consistent with the Basin Plan and these evaluation criteria?	Yes, MDBA provided the full suite of documents associated with the model report.
				1.2	Has sufficient effort been directed to documentation? (i.e. is the model report readable and clear?)	Yes, MDBA provided the full suite of documents associated with the model report.
				1.3	Where previous reports, including any peer reviews, are essential to evaluation of the model, have copies of these reports been provided?	Yes, MDBA provided this.
	S10.10(2)	Does the WRP set out the method, for example, by reference to a model report?	No, there is no WRP document yet at this stage.	1.4	Is there a clear statement of objectives in the report? Do the objectives include use of the model to compute SDL(s) (and BDLs) consistent with Chapter 10 of the Basin Plan?	Yes, there is a clear statement of objectives in the model build report which references SDLs and BDLs consistent with the Basin Plan in the model design criteria to meet modelling objectives.
				1.5	In the model report, has the definition of SDL in Schedule 2 of the Basin Plan been correctly interpreted and documented? Where interpretations or assumptions have been made concerning the application of Schedule 3, have these been documented and are they appropriate?	Partially. The definition of SDL is not interpreted explicitly with regard to Schedule 2, but it references Schedule 3 in terms of stating the relevant reference period.
				1.6	Have the WRP area(s) and the SDL resource unit(s) to which the model has been applied been clearly and accurately defined? If the model is applied to only part of these area(s) or resource unit(s), have the areas of application been clearly defined?	Yes, the WSP area and SDL resource unit which the model applies to has been stated clearly. This model applies to the full area of the resource unit.
	s10.10(3)(a) s10.12(1)(a)	Has the model accounted for all forms of take from the SDL resource unit and all classes of water access right?	Yes, the model build report lists all major water sources in the Barwon-Darling which are limited to unregulated water and floodplain harvesting water.	1.7	Is there a clear statement, in the model report, which specifies the 'forms of take' that are included in the model and those which are not? Should other forms of take have been included in the model, given its coverage and application within the WRP(s)?	Yes, the forms of take were broken down to more explicit categories with statements on data sources and modelling approach. No other forms of take need to be included considering their limitations or insignificance as a source.
	s10.10(2)	Has the model been designed to be applied after the end of the relevant water accounting period, having regard to the water resources available during the period?	Yes.	1.8	Has the model report established that the model can be used to provide a practical and reliable method to determine the annual permitted take in a water accounting period (for the forms of take to which the model is applied)?	Yes, the model build report describes practical and reliable methods to determine take.
				1.9	If these models were independently reviewed (e.g. when the model was applied as a cap model), have the recommendations of these reviews been considered in formulating the SDL model? If not, have the reasons been documented and are they appropriate?	Yes, a full response to recommendations from previous independent reviews was provided.
				1.10	Have the diversion results been individually reported for each form of take simulated in the model? Where the model covers more than one surface water SDL resource unit, have the diversion results been reported for each SDL unit, and for each form of take simulated in the model?	Yes, the model scenario report has reported diversion results for each form of take included in the model.
	s10.10(1)	As per 10.10(1) above		1.11	Are the model report's conclusions and recommendations reasonable and supported by evidence?	Yes. The model build report includes a range of conclusions and recommendations (Section 10) specific to this valley.
S10.49		**BEST AVAILABLE INFORMATION**		**2**	**DATA ANALYSIS**	
	s10.49(1)	Is the model based on the best available information?	Yes	2.1	Have all relevant data been collected and analysed? (surface water, groundwater, land use, diversions, climate, etc)	Yes, all references to the data sources pertaining to the forms of take included in the model were made in the model build report. Groundwater has not been represented in the model as use of significant groundwater

Basin Plan Chapter 10:	Assess					Assist
						has not been identified for any of the floodplain harvesting properties on the river system. The model report also outlines quality assurance practices along with the data review and prioritisation of data sources. The quality and completeness of the data relating to on-farm crop areas is best-available.
				2.2	Has information on the spatial and temporal extent, together with the quality of the relevant data, been provided?	Yes, the model build report details the conceptual and geographic spatial extent of the model, as well as the data periods used for various purposes in the river system modelling.
				2.3	Has the recorded diversion data (for the forms of take simulated in the model) been analysed and reported in sufficient detail to allow calibration/validation of the model? Are the accuracy/limitations of this diversion data adequately described?	Yes, all relevant data sources underwent a structured review process, checked for completeness, consistency, accreditation, and verifiability. The assessment criteria listed (which require sufficient graphical and statistical understanding of the raw data) were made clear to assess model performance. Detailed commentary on the accuracy and limitations of these source data were provided. Issues regarding calibration/validation of the model have been outlined in this review.
				2.4	In respect of the relevant surface water, groundwater and climatic data used in the model, has the process of infilling data gaps and extending data beyond the period of record been properly documented? Where these data extensions relied on separate modelling, has this modelling been documented and provided for review?	Yes, the process of infilling of data gaps for climate and flow data were documented. For the main river gauges, the Sacramento model was used to extend (to meet the modelling period) and fill gaps.
				2.5	Has the process of infilling gaps and extending data been carried out appropriately?	Yes, the model report provided figures that show the validation test conducted for main river gauges, where 'final flow data inputs' (a combination of gauges flows and Sacramento model infilling) are compared to observed flows.
				2.6	Have all locations been identified where recorded flow data already includes for upstream take (e.g. from runoff dams, groundwater usage or diversions from unregulated systems)? Have appropriate procedures been included to allow for this upstream take?	Yes. Appropriate procedures have been included to allow for upstream take at each location via flow calibration and diversion calibration.
S10.10 & S10.12		**ANNUAL DETERMINATIONS OF WATER PERMITTED TO BE TAKEN MATTERS RELATING TO ACCOUNTING FOR WATER**		**3**	**MODEL STRUCTURE**	
	s10.10(3)(b)	Is the model consistent with the other provisions of the water resource plan?	Yes	3.1	Is there a clear description of the model structure and its spatial coverage? Is the model structure and coverage appropriate for SDL assessment?	Yes, the model build report details the conceptual and geographic spatial extent of the model. The model structure and coverage is appropriate for SDL assessment.
				3.2	Has a complete link-node diagram or other representation been provided to identify all the components of the model within each reach?	Yes, the model build report provided a figure to show the overall link-node diagram of the model.
	S10.10(3)(a) s10.12(1)(b) (c)(d)(g)(h)(i) s10.12(2) s10.12(3)	Does the method account for all matters in s10.12 of the Basin Plan?	Yes	3.3	Are all the system conceptualisations appropriate for a SDL model (and consistent with the WRP) when properly calibrated, including those required under Basin Plan s 10.12? This includes, but is not limited to, conceptualisation of: principal water inputs and outputs, flow routing, transmission losses/gains, storage operations, diversions for each form of take, permanent and temporary trade, water sharing rules, resource assessments, other management rules, procedures to manage HEW, carryover, return flows, water used for aquifer recharge and Is the model time step(s) appropriate?	Yes, as best as possible. The system conceptualisation (including for the components above) are documented in the model build report. The daily model timestep is appropriate.
	s10.12(1)(e)	Has the model accounted for water resources which have a significant hydrological connection to the water resources of the SDL resource unit?	Yes	3.4	Where there are water resources with a significant hydrological connection to adjacent systems (including groundwater systems), has the structure of the model been prepared appropriately? If this inter-connection has not been simulated, has the likely impact on model results been assessed? Is the model appropriately structured to interface with	For surface water, the model scenario report (Section 3) stated that the upstream tributary models used to simulate inflows into the Barwon-Darling Valley river system are all from the relevant scenario (e.g. Cap scenario, Current Conditions scenario, Plan Limit Compliance: Valley Scale

Basin Plan Chapter 10:	Assess				Assist
				other SDL models (surface water and groundwater), both upstream and downstream? Where the model interfaces with other SDL models (upstream and/or downstream) are the linkages to these other models clearly described and appropriately established? Have the upstream models been independently reviewed and accredited?	Compliance Scenario) in each NSW and Queensland valley prepared to represent the Baseline Diversion Limit for Water Resource Plan accreditation by the Murray-Darling Basin Authority (NSW DPE, 2022). The only exception is for the Eligible Development Scenario (and Plan Limit Compliance: Individual Impact Scenario), for upstream tributary flow from the Border Rivers valley, where observed flows have been used at Mungindi. The Border Rivers BDL model represents Queensland water use based on full use of entitlements, rather than at current levels, and modelled flows at Mungindi were found to systematically degrade the representation of historical small–medium flow events in the Barwon Darling model. Other tributary models have not been found to affect flows in this way. For groundwater, the model has not represented this because use of significant groundwater has not been identified for any of the floodplain harvesting properties on the river system.
	S10.12(1)(f)	Has the model accounted for circumstances in which there is a change in the way water is taken or held under a water access right?	Yes, the model has accounted for this as best it could with limited data.	3.5	Has the conceptualisation of held environmental water (i.e. managed by CEWH, TLM, VEWH, OEH, Water for Rivers and others), if any been sufficiently described? Is this conceptualisation appropriate for this SDL model, when properly calibrated?	This is not applicable as HEW entitlement did not exist in 1993/94 for Cap scenario modelling relevant to this review. The conceptualisation of HEW is only relevant for scenarios later than 2008/09 as no water licences had been purchased for HEW at that date. For the modelling of later conditions described in the companion Scenarios report (NSW DPE, 2022), such as the Current Conditions and Valley Scale Compliance scenarios, entitlements owned by the Commonwealth are treated as inactive water users for modelling purposes, as this reflects current practice of HEW managers at this time.
	s10.10(4)	Does the model demonstration relate to the SDL of each resource unit in such a way that, if applied over a repeat of the historical climate conditions, it would result in meeting the SDL for the resource unit, including as amended under section 23B of the Act?	Yes	3.6	Is the model flexible enough to demonstrate it will meet the SDL, including an adjusted SDL? Is a reason provided why, if this is not currently the case?	Yes, the model report states that the IQQM model can demonstrate that it will meet the SDL. The Barwon-Darling model is being migrated across to the Source platform (although no timeframe provided for this) and has been designed for models built with it to be easily updated and extended, through inclusion of more data and/or new or improved component models.
				3.7	Is the model operated over historical climate conditions consistent with the requirements of the Basin Plan, for each form of take simulated in the model?	Yes, the Barwon-Darling model is operated over the period: 1/7/1895–30/6/2020. This encompasses the 1895-2009 period specified in the Basin Plan for calculating the SDLs and BDL.
S10.49		**BEST AVAILABLE INFORMATION**		**4**	**CALIBRATION**	
	s10.49(1)	Is the model based on the best available information?	Yes	4.1	Every model has different components that can be calibrated. These usually involve some or all of the following: flow calibration, storage calibration, diversion calibration and planted area calibration. For each of model components requiring calibration, has the calibration period been specified? Are the climatic and resource conditions over each of these calibration periods, described? Is the selection of these periods appropriate?	Yes. The model build report describes calibration across the full record of data. However, use of the full data record means there is no ability to validate the model calibration separately or independently, and a different approach is used (described in #5 below).
				4.2	Has sufficient effort been expended to obtain data for calibration of each model component?	Yes, sufficient effort can be seen in the work that has taken place to reduce uncertainty as much as possible. However, there is no calibration data for on-farm FPH take, given lack of measurement.
				4.3	Has the calibration 'fit' been documented for each model component requiring calibration? Have an appropriate range of statistics of the 'fit' and time series plots of observed and predicted values been provided? Have the model parameters that were 'forced' during each component of the calibration been documented?	Yes, assessments of fit of all the various model components (including flow calibration of each reach) were documented. Statistical and graphical results of observations and simulations were presented. Model parameters that were 'forced' were documented, such as crop areas 'forced' to

Basin Plan Chapter 10:	**Assess**					**Assist**
						historical data in early model runs to check adequacy of metered water use simulations.
				4.4	Is each component of the model sufficiently calibrated against spatial and temporal observations? Are the calibrated values plausible and resultant 'fit' appropriate?	Yes, this was addressed in the report against Criteria 3 and 4 of the modelling objectives. Calibration to inform parameterisation of the model was better at a reach and valley scale (compared to individual farm scale) where flow gauges, breakout volumes, and reach water balance can be assessed. Calibration is not possible for some parameters given lack of data on actual volumes harvested as either rainfall–runoff, or from overbank flow, as well as incomplete management detail on each farm, including application rates specific to that farm, and on-farm water management. For temporal observations, the model build report stated that the modelled frequency and number of overbank flow events reasonably matches the observed behaviour. It was also recognised that the Barwon-Darling model does not reproduce low flow behaviour well. For Walgett and Bourke, where the flow gauging station represents the full range of flows, there is a relatively good overall match between simulated and observed days during the validation period. The under-simulation of days where flow at Bourke exceeds the moderate flood threshold largely occurs in the very wet periods during the 1950s, 1970s, and 1980s, which is expected as the contemporary irrigation development in the model was much higher than what was actually in place. The effects of using the observed inflows at Mungindi diminishes along the Barwon-Darling Valley river system and only has a discernible impact for properties in the upper reaches. Use of these observed flows will improve the assessment of floodplain harvesting capability between individual properties under historical climate, however is not relevant for Cap modelling which uses modelled inflows for all tributaries. A review of other modelled inflows did not indicate any systematic issues.
				4.5	If the calibration components share a sufficient common period, has the overall calibration been reported? What is the quality of the resultant 'fit'? For each of model components requiring calibration, has the calibration period been specified? Are the climatic and resource conditions over each of these calibration periods, described? Is the selection of these periods appropriate?"	The overall calibration of flow simulation and water use has been reported in Section 8. The fit is good, noting that low flows have not been a focus (until the model is prepared in Source) so the flow simulation assessment has focused on the higher flows. The climatic and resource conditions over the calibration periods have been described and are based on best available information.
				4.6	Has the robustness of the model to operate outside the calibration period been considered? What is the robustness likely to be having regard to the variability of climatic and other factors during the calibration periods?	Yes, given the calibration period was for the full data record.
S10.49		**BEST AVAILABLE INFORMATION**		**5**	**VERIFICATION/TESTING**	
To a	s10.49(1)	Is the model based on the best available information?	Yes	5.1	Where appropriate, have all reasonable avenues for verifying and testing the model been undertaken and documented? Alternatively if verification or testing has not been undertaken, have the reasons been documented and are they appropriate?	Yes. Given the approach to calibration where the full data record was used for each reach and calibration element, the model validation comprised a full model run to assess accuracy as a complete system. In the validation scenario, releases from headwater storages and diversions data are forced to identify model performance compared to stream gauging. Verification was conducted for on-farm storage and pump rates and summarised in the model build report.
				5.2	Have the climatic and resource conditions over the validation period, been described? Is the selection of this period appropriate and has its duration been maximised?	Yes, validation of the model took place as the final step in the calibration process by amalgamating the individual reach models. The validation model

Basin Plan Chapter 10:	Assess			Assist
				is used to confirm the performance and accuracy of the model run as a complete system and provides a foundation for the development of scenario models. The diversions and water management components have been tested over the period 01/07/2003 – 30/06/2014, which includes key benchmark years for the NSW floodplain harvesting policy and the Basin Plan. A scenario was configured to represent the 2008/09 level of development which was the validation scenario.
			5.3	While the initial conditions were not directly mentioned in the model build report, the initial values at commencement of simulation were addressed in the independent audit of the cap model where NOW confirmed that the IQQM model run was commenced in June 1895 (Bewsher Consulting, 2013).
			5.4	Yes, these were provided in the model build report. The quality of the resultant fit is good.
			5.5	Yes, results of simulated diversions from the fully assembled, calibrated model for the 2008/09 validation scenarios were compared with recorded diversions with statistical results shown. This scenario simulates all system operations and management rules applying to unregulated diversions such as commence to pump river flow rates. Due to this, there is confidence in the quality of the resultant fit.
S10.49		**BEST AVAILABLE INFORMATION**	**6**	**PREDICTION**
	s10.49(1)	Is the model based on the best available information?	6.1	While this was not explicitly documented in the model build report, the initial conditions were documented in the audit of the cap model (Bewsher Consulting, 2013)
		Yes	6.2	Yes, observed flow from Border Rivers was used as it was more appropriate than simulated flows, however does not apply for the Cap scenario. Refer to our review comments in Guidance Notes 3.4 and 4.4 in this table.
			6.3	No, this was not documented in the model build or model scenario report. A comparison between take from the 2012 Basin Plan and the modelled components of the BDL take in the modelled scenario report is presented in Section 3 of this report. The most significant differences relate to the way floodplain harvesting is simulated and reported.
			6.4	A water balance has been provided in the model scenario report which defines the values of all principal model outputs, not inputs. Water balance checks (statistical metrics) of the inputs were outlined in the model build report as part of the farm water balance check at three different scales. A satisfactory water balance was achieved, although it is recognised that the on-farm water balance is where the greatest uncertainty remains.
S10.49		**BEST AVAILABLE INFORMATION**	**7**	**SENSITIVITY AND UNCERTAINTY ANALYSES**
	s10.49(1)	Is the model based on the best available information?	7.1	Partially. A sensitivity and uncertainty analysis was undertaken for the Border Rivers and Gwydir valley models, with the assumption that similar uncertainties and potential errors apply to the Barwon-Darling model. This was reproduced for the Barwon-Darling model reporting, however is not specific to the Barwon-Darling.
		No		

Basin Plan Chapter 10:		Assess				Assist
				7.2	Have the potential uncertainties in the model outputs been estimated, and in particular, the simulated annual take and SDL?	No. Specific sensitivity and uncertainty analyses were not carried out for the Barwon-Darling.
S10.49		**BEST AVAILABLE INFORMATION**		**8**	**MODEL IMPROVEMENTS**	
	s10.49(1)	Is the model based on the best available information?	Yes	8.1	Where model development has been constrained by limitations in the available data, have these been identified?	Yes, the constraints in the availability of input data were discussed in the model assessment and uncertainty analysis sections of the model build report.
				8.2	Have the model's limitations been considered and has a potential list of improvements been prepared? Are these limitations and improvements appropriate?	Yes. The model build report includes a range of conclusions and recommendations (Section 10).
				8.3	Is it necessary to collect more data or obtain further information to improve the model? If so have these been documented and scheduled?	Yes, there is a need to collect more data to improve the version of the model. Improvement of the model is an ongoing process. The need to collect more data will be beneficial for the next iteration and update of the model.
				8.4	Where any model improvements are considered essential within a specified timeframe, has this timeframe been documented?	Not applicable.
S10.49		**BEST AVAILABLE INFORMATION**		**9**	**QUALITY ASSURANCE**	
	s10.49(1)	Is the model based on the best available information?	Yes. Given that work is continuing to improve the simulation of floodplain harvesting consistent with the NSW Floodplain Harvesting Policy, better information will become available over time.	9.1	Has the model run number, the software version and all relevant model input been defined to enable the SDL model run to be repeated, at a later date, if required?	Yes, model version details were included in the Appendix C of the model scenario report.
				9.2	Where the model relies on input data generated by other models, have sufficient details been provided to uniquely define those other models and their operating assumptions. Has the source and date of supply of those other models' results been documented?	Yes, sufficient details have been provided. Refer to our review comments in Guidance Notes 3.4 and 4.4 in this table.
S10.15		**DETERMINATION OF ACTUAL TAKE MUST BE SPECIFIED**		**10**	**DETERMINATION OF ACTUAL TAKE**	
	10.15(3)	If the determination for any form of take is to be made by estimating the quantity of water actually taken, is the method for making the determination consistent with the method set out in the WRP in response to the requirement in s10.10(1)?	N/A for the terms of reference of this review.		-	-
	10.15(4)(a)	Does the model demonstrate that the quantity of water taken includes water that was held environmental water which was disposed of and then used in the SDL resource unit for consumptive use?	N/A for the terms of reference of this review.		-	-
	10.15(4)(b)	Does the model demonstrate that the quantity of water taken excludes water sourced from the Great Artesian Basin and released into and taken from a Basin water resource?	N/A for the terms of reference of this review.		-	-