MURRAY-DARLING BASIN COMMISSION

VICTORIAN MURRAY, NSW MURRAY AND LOWER DARLING VALLEYS

INDEPENDENT AUDIT OF CAP MODEL

30 June 2008

Bewsher Consulting Pty Ltd
MURRAY-DARLING BASIN COMMISSION

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30 JUNE 2008

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EXECUTIVE SUMMARY

This audit presents an independent and unbiased assessment of the suitability of the MDBC’s Murray Simulation Model (MSM) for use under Schedule F of the Murray-Darling Basin Agreement. MSM simulates the principal water diversions within the NSW Murray and the Victorian Murray Valleys which are designated under Schedule F. The model also simulates diversions within the Lower Darling Valley which is the southern component of the designated valley comprising the Darling and Barwon Rivers.

The NSW and Victorian Murray Valleys are the ninth and tenth valleys to have models prepared and submitted to the MDBC for approval under Schedule F. In due course, models from the other 14 Designated Valleys in the Basin are also to be audited and approved under Schedule F. The models are necessary to allow for the effects of climate, resource availability and other factors, when determining Cap targets across the Basin.

It should be recognised that all models are only approximations of actual behaviour. The accuracy of any model in simulating real behaviour is heavily dependent on the availability of historical records from which the model’s performance can be calibrated and validated. As there is a wide variability in the available data across the 24 Valleys within the Basin, some variability in model performance should be anticipated between the Valleys. Further, it is always possible to improve model performance by including additional details and modelling refinements. The justification for including such improvements and refinements however must be based on the likely ‘return’ for the efforts involved, having regard to the requirements of Schedule F. Consequently, this is a subjective assessment made by all agencies prior to submitting models for approval to the MDBC.

The majority of MSM is devoted to the simulation of the NSW and Victorian Murray systems (including the Kiewa and Ovens) and in the auditor’s opinion, this work has been completed and documented to a very high standard. This is an important finding given the pivotal role that MSM has in simulating water management behaviour in the Basin. The auditor has therefore no hesitation in recommending that MSM be approved for simulating the NSW and Victorian Murray diversions.

Nevertheless, as acknowledged in the Cap Report which describes the MSM, it was not possible to achieve satisfactory replication the Lower Darling diversions under 1993/94 levels of development. The MSM modellers were hindered in developing the model by a lack of data and an inability to construct a complete understanding of the water management practices governing behaviour at that time. Further improvements to the existing model of the Lower Darling system, or the adoption of different acceptance criteria, are recommended before this component of MSM can be approved under Schedule F.

In addition to recommending approval of the NSW and Victorian Murray components of MSM, other procedural recommendations are provided in Sections 1.6 and 5.8 of this report. These involve recommendations for the MDBC to allow interim use of the approved MSM model with different tributary inflow data from that currently used in MSM. This concession recognises that in the future, small changes to any of the upstream models or estimation procedures that provide flow data to MSM, might occur. Under the current
arrangements, such changes, however small, would require re-approval of MSM which would be unnecessarily cumbersome. This audit report contains some suggestions for the Water Audit Panel to consider in setting the bounds of such interim approvals, including the establishment of a register to record the status of all tributary inflow data used in MSM cap or target runs.

In line with other completed cap model audits, a graph of the recorded and simulated annual diversions over the last 20 years or so has been prepared to facilitate some comparison of the performance of all the models that will be provided for approval under Schedule F. Graphs have been prepared for the NSW and Victorian Murray components of MSM and are provided in Figures 5.1a and 5.1b.

The information presented in these figures and other material which has been the subject of this audit indicate that the NSW and Victorian Murray components of MSM are reasonably\(^1\) replicating observed behaviour under cap conditions and that it is appropriate for MSM to be approved to simulate these components under Schedule F.

An updated summary of some key characteristics of all of the cap models submitted for auditing to date is provided in Table 2.1. The long-term average annual diversions predicted by MSM are summarised below.

### AVERAGE ANNUAL DIVERSION PREDICTED BY CAP MODEL

<table>
<thead>
<tr>
<th>Component</th>
<th>Predicted Diversions</th>
</tr>
</thead>
<tbody>
<tr>
<td>NSW Murray</td>
<td>1,880 GL/year</td>
</tr>
<tr>
<td>Vic Murray</td>
<td></td>
</tr>
<tr>
<td>Vic Murray, excluding Kiewa and Ovens</td>
<td>1,660 GL/year</td>
</tr>
<tr>
<td>Kiewa</td>
<td>7.1 GL/year</td>
</tr>
<tr>
<td>Ovens</td>
<td>22.4 GL/year</td>
</tr>
<tr>
<td>Vic Murray, including Kiewa and Ovens</td>
<td>1,690 GL/year</td>
</tr>
<tr>
<td>Lower Darling</td>
<td>n.a.</td>
</tr>
</tbody>
</table>

Note (a): This table summarises the diversions predicted by the Cap Model. There are other diversions (e.g. some unregulated diversions in the upper tributaries) that are listed in the Diversion Formula Register and have not been included in the Model. These diversions will need to be separately estimated before the total average diversion can be determined for each valley.

Note (b): Kiewa and Ovens diversions have been rounded to 0.1GL/year. Other diversions have been rounded to the nearest 1GL/year.

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\(^1\) The recorded annual diversion data reflects not only water use behaviour in response to varying climate and resource availability, but also the impacts of a range of other factors such as market forces, variations in farming practice, changes in water management policies, etc. Because of these other factors, a Cap model simulating 1993/94 levels of development cannot ‘reasonably’ be expected to exactly replicate historical diversions, even after the diversion data have been adjusted for trends (e.g. growth).
1. INTRODUCTION

1.1 BACKGROUND

In 1995 the Murray-Darling Basin Ministerial Council agreed to cap water diversions from the Basin at 1993/94 levels. As part of the implementation of this ‘Cap’, numerous computer models need to be developed to set Cap targets across the Murray-Darling Basin for each of the 24 river valleys that have been designated under Schedule F.

Computer modelling is necessary to allow for the effects of climate, resource availability and other factors when determining Cap targets. In any year the targets provide an indication of the diversions which would have occurred under 1993/94 levels of development. The models are being developed by the relevant agencies in the States that are signatories to the Murray-Darling Basin Agreement, and also by the Murray-Darling Basin Commission’s (MDBC’s) office.

Schedule F of the Murray-Darling Basin Agreement (see Appendix A) addresses implementation and compliance considerations with regard to the Cap. The schedule includes the following conditions within subclause (4) and (5) of Clause 11:

“(4) An analytical model developed under this clause:

(a) must simulate the long-term diversion cap in the relevant designated river valley; and

(b) must be tested against relevant historical data to determine the accuracy of the model in estimating the annual diversion; and

(c) must be approved by the Commission before it is used to determine an annual diversion target under this Schedule; and

(d) may, from time to time, be modified in such ways as the Commission may approve; and

(e) must be used to determine the average annual diversion under the conditions of the relevant long-term diversion cap determined under this Schedule for either:

(i) the period between the start of the 1891 water year and the end of the 1997 water year; or

(ii) such other period as may be approved by the Commission.

(5) The Commission may only approve an analytical model or a modification to an analytical model if the Commission considers that the model, when approved or modified, will fairly determine the relevant annual diversion target given the climatic conditions experienced in any year.”
The Independent Audit Group (IAG) has recommended that cap models undergo an independent technical audit before they are submitted to the Ministerial Council for adoption.

This report presents the findings of the audit of the MDBC’s Murray Simulation Model (MSM) of:

- the designated valley comprising the Victorian portion of the Murray Valley including the Kiewa and Ovens catchments (hereinafter referred to as “the Victorian Murray”);
- the designated valley comprising the New South Wales portion of the Murray Valley including the portion of the Lower Darling Valley influenced by the Wentworth Weir Pool (hereinafter referred to as “the NSW Murray”); and
- the Lower Darling Valley from upstream of Menindee Lakes to the Wentworth Weir Pool. This is the southern portion of the designated valley which includes the Darling and the Barwon River valleys.

The NSW and Victorian Murray are the ninth and tenth out of the 24 designated valleys for which models are to be submitted for audit. Noting that some models will cover more than one designated valley and vice versa, MSM is the eighth of what is likely to be approximately 23 models that will eventually be submitted for audit.

1.2 AUDIT TERMS OF REFERENCE

The principal objective of this audit is to ensure the requirements of Schedule F have been satisfied in relation to the model for the Murray and Lower Darling Valleys.

In particular, the audit is required to provide an independent assessment of:

- the accuracy of the model in predicting annual total diversion and the annual end of Valley flows;
- the methodology for establishing the 1993-94 levels of development;
- the method of adjusting water use for climatic and hydrologic variation;
- how the algorithm for water use at 1993-94 levels of development has been incorporated into the models;
- the capability of the model to simulate long-term diversions; and
- the robustness of the model to simulate outside the calibration period.
1.3 MODEL TERMINOLOGY AND PROCESSES

1.3.1 Overview

The models that are the subject of Schedule F and this audit, simulate the long-term diversions of water from river valleys designated under Schedule F. In most cases, the models do this by simulating the behaviour of various components of the water management system within the Valley. This includes water storages, river flows, irrigators and other water users, and various natural processes such as rainfall and evaporation.

The simulation period of the models is typically approximately 100 years.

However there is some variability between the models and not all models simulate a valley’s water management system. The model for South Australia’s highland pumpers’ diversion, for example, is derived from a regression relationship based on temperature and rainfall during a year.

Further, whilst the principal function of the models is to simulate diversions, simulation of ‘end-of-valley’ flows is also important as most of the valleys discharge into other designated valleys. Thus the simulation of flows at a valley’s outlet may become an ‘input’ to the model of the downstream valley.

1.3.2 What is a Model?

The term ‘model’ is not specifically defined in Schedule F, however following discussions with MDBC staff and the previous Water Audit Working Group (WAWG), it was agreed that the term ‘model’ should be used to refer to:

› computer software; and

› all input data used by the software, i.e.
  – parameters specifying irrigation levels and management rules;
  – climatic data, including rainfall, evaporation, etc;
  – tributary inflow data;
  – initial conditions of storages, antecedent wetness indicators, etc., at the start of a simulation.

Thus this audit of the MDBC’s Murray Simulation Model (MSM) includes not only an audit of the computer software, but also the software parameters and data utilised during a simulation.
1.3.3 Cap, Target and Calibration Models

Typically three types of models have been prepared or are being prepared by the relevant agencies in the States and by the Commission itself, to comply with the requirements of Schedule F. For the purposes of this audit, the three models are referred to as the ‘cap model’, ‘target model’ and ‘calibration model’ (see Table 1.1). The same computer software is used for each of these three models in any valley. However the model parameters and input data vary.

The calibration model is used to establish appropriate model parameters by comparing model output with historically observed values. The calibration model has also been used to refine transmission and other system losses and is discussed in Chapter 6.

The cap model provides a long-term simulation of a valley under 1993/94 levels of development. The average annual diversion from this model is required under Schedule F to calculate the cumulative cap debit or credit (see Clause 11(8) b and c). A cumulative cap debit may trigger a Special Audit by the Independent Audit Group (i.e. Clause 14).

Both the model software and the various model inputs (i.e. tributary flows, climatic data, crop areas, etc.) for MSM have been provided for auditing. Chapter 7 discusses the manner in which the 1993/94 levels of development have been included in the cap model.

The target model will be used by the various agencies to determine their annual diversion targets for reporting under Schedule F. This model is identical to the cap model except that the simulation commences in July 1997 and uses recorded climatic inputs. The results of the target model in a given year allow for auditing of the actual valley diversions against the simulated model diversions under 1993/94 levels of development.

The target model per se including the model software and the input data, are not the subject of this audit. As the target model will be run in future years to simulate future performance in a river valley, the data used in that model cannot be audited now. The model software however can be audited as it is identical to the cap model software (refer Table 1.1). Therefore it is important to ensure the target model software used in future years is identical to the cap model software which is the subject of this audit.

1.4 DATA PROVIDED AND DOCUMENTS REVIEWED

During this audit, a formal request for information about the model was forwarded to the MDBC. The MDBC’s response is provided in Appendix D.

A copy of the model software and various data files were supplied and installed on the auditor’s computer in July 2007. The MDBC also provided the following documents:

TABLE 1.1: — TYPES OF MODEL USED TO COMPLY WITH SCHEDULE F

<table>
<thead>
<tr>
<th>MODEL</th>
<th>SIMULATION PERIOD</th>
<th>WATER DEMANDS, INFRASTRUCTURE AND MANAGEMENT RULES</th>
<th>STARTING STORAGE VALUES AND OTHER INITIAL CONDITIONS</th>
<th>CLIMATIC INPUTS</th>
<th>TRIBUTARY INFLOWS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cap Model</td>
<td>From 1891/92 to 1997/98, or possibly a period starting earlier and/or finishing later</td>
<td>As for the 1993/94 levels of development, or other conditions agreed with the IAG/MDBC</td>
<td>Actual if available, otherwise synthetic data.</td>
<td>Recorded if available, otherwise synthetic data.</td>
<td>Inflow data adjusted to represent 93/94 levels of development on the tributary. Otherwise, recorded or synthetic data is used.</td>
</tr>
<tr>
<td>Target Model</td>
<td>From the start of the 1997/98 water year until the current year</td>
<td>As for the cap model</td>
<td>Recorded values as at beginning of July 1997</td>
<td>Recorded values</td>
<td>As for the cap model. Where data after the end of the cap model is required, this is derived using procedures identical to those for the cap model.</td>
</tr>
<tr>
<td>Calibration Model</td>
<td>From 1983/84 to 1993/94, or other period if this better represents 1993/94 conditions.</td>
<td>As for the cap model (or varying with time where established using a trend analysis to reflect structural or policy changes during the calibration period).</td>
<td>Recorded values</td>
<td>Recorded values</td>
<td>Recorded values</td>
</tr>
</tbody>
</table>

Notes:

1. The term "model" is used to refer to: software; and all input data, i.e.:  
   - parameters specifying irrigation levels and management rules 
   - climatic data including rainfall, evaporation, etc. 
   - tributary inflow data 
   - initial conditions at start of simulation.

2. It is assumed that the same software is used for the Cap, Target and Calibration Models.

3. The contents of the above table were agreed at the MDBC Water Audit Working Group meeting on 14 August 2001. (Minor wording changes were subsequently made by MDBC staff in June 2002).
In general, the auditor is very pleased with the standard of documentation provided by the MDBC in the Cap Report. The report has been well written and comprehensively addressed all the necessary issues.

1.5 PERSONAL CONTACTS AND INTERVIEWS

During the course of the audit, the following people were contacted by telephone or email, or were personally interviewed:

- Mr Pradeep Sharma, Senior Modelling Engineer, MDBC;
- Mr Andy Close, Director, Water Resources, MDBC;
- Mr Barry James, Manager Water System Modelling, Office of Water, DSE, Melbourne;
- Mr Paul Simpson, Water Analysis & Audit Unit, DWE, Sydney;
- Mr Jarrod Eaton, Senior Policy Officer, DWLBC, Adelaide; and
- Mr Tony Garr, Snowy Hydro Limited, Cooma.
1.6 QUALITY ASSURANCE (QA) PROCEDURES

As part of previous Cap model audits, recommendations were made to ensure that standardised procedures were established to maintain digital copies of relevant software and its input data at the MDBC office. These procedures covered both the Cap and Target models.

In addition to these procedures, other requirements for managing the transfer of data between adjoining models, have been recommended in Section 5.8. These relate especially to MSM given its location near the outlet of the Basin. However the requirements might also apply to other models such as the Barwon-Darling IQQM, which rely on outputs from other Cap models located upstream.

1.7 REGISTER OF DIVERSION FORMULAS

When dealing with the Cap, it is important to understand precisely what constitutes diversions under the Cap. To assist in this task, a Diversion Formula Register has been prepared by the MDBC. A copy of the relevant details and background to the diversion formulas are provided in Appendix C.
2. DESCRIPTION OF MODEL

2.1 OVERVIEW OF MSM

The Murray Simulation Model (MSM) has been custom-written to simulate the movement of water resources within the Murray and Lower Darling systems from Dartmouth Dam and Menindee Lakes to the South Australian border. The software was initially developed in the 1960s using Fortran and has been under continuous development since that time.

MSM has been the principal long-term planning tool used by the MDBC and its predecessor (the River Murray Commission) for water resource management for over four decades. It is arguably the most important water resource planning model in Australia and has probably been used to justify more management decisions and capital expenditure than any other water resource model in Australia.

Whilst the auditor is not aware of the model having been formally audited previously, because of its wide use and long history it has been subject to close scrutiny by many of Australia’s most eminent water resource management specialists within the MDBC, various government jurisdictions and the private industry. As such, the broad credentials of MSM have already been established through this process. The model’s shortcomings (such as its use of a monthly timestep and its reliance on regression equations for demand estimation) have also been considered and evaluated by a wide range of organisations and specialists over the years that the model has been operated. This process has also allowed opportunity for improvements to the model to be implemented where appropriate and it is clear that the shortcomings in the model have not prevented MSM from being relied upon for major projects such as the Salinity and Drainage Strategy, planning for Dartmouth Dam, the Snowy Water Inquiry, water accounting between the States, the Living Murray, the CSIRO Basin Sustainable Yields Project and the evaluation of many other dozens if not hundreds of water management decisions in the Basin.

With the preparation of the audit reports for the cap models of other designated valleys which have been prepared to date, the auditor felt compelled to provide a detailed description of the particular cap model and its capabilities given that the readership may not have previously been aware of these issues. However, in the preparation of this audit report for MSM, the auditor does not believe that such detailed documentation is necessary given the history of MSM and the relatively high standard of documentation which has been provided by the MDBC in the Cap Report.
2.2 MODEL STRUCTURE

2.2.1 Model Timestep

The model operates on a monthly timestep with some coarse non-linear flow routing within the reaches of the model. The use of the monthly timestep imposes a constraint on the usefulness of the model for various water management assessments which are dependent on flow behaviour at a finer timescale, (e.g. assessment of rain rejections, salinity modelling, etc.). To meet this need, the MDB Commission has developed a companion model known as BigMod which runs at a daily timestep and includes for flow and salinity routing. BigMod runs in conjunction with MSM and relies on MSM for the principal water management behaviour relating to diversions, storage releases and losses, etc. In this way, BigMod preserves the overall monthly water balance behaviour determined by MSM.

Whilst the MSM/BigMod modelling suite provides the MDB with quasi daily modelling capabilities, the MDB Commission has been planning for the development of a new Murray daily model for nearly a decade. Nevertheless, the MSM/BigMod suite has served the Commission well in addressing many of the flow, salinity and environmental issues that arise in fulfilling its water management functions.

In relation to cap issues however, the MDB Commission has demonstrated that the use of MSM in isolation from BigMod provides sufficient accuracy to determine both the long-term average annual cap and the annual targets. This is in part due to the relatively long data records that are available and the low variability in daily/monthly behaviour compared with other river valleys in the northern part of the Basin.

2.2.2 Schematic Layout

The schematic layout for MSM provided by the MDB Commission in the Cap Report, has been reproduced in Figure 2.1.

The figure shows all the principal irrigation diversions, tributary inflows, drain inflows and storages that are simulated in MSM.

A summary of the key characteristics of MSM is presented in Table 2.1. Also included are details of the other cap models that have been presented for audit. Table 2.1 will be extended to include cap models from other designated valleys, as the models are finalised and provided for auditing.

2.2.3 Storages Simulated

MSM simulates the behaviour of Dartmouth Dam, Hume Dam, Lake Victoria and the Menindee Lakes system. Within the Menindee Lakes system, Lakes Menindee,
### TABLE 2.1 — SUMMARY OF KEY CHARACTERISTICS OF MDBC CAP MODELS SUBMITTED FOR AUDITING TO DATE

<table>
<thead>
<tr>
<th>MODEL CHARACTERISTICS WITHIN EACH DESIGNATED VALLEY</th>
<th>Gwydir</th>
<th>Namoi</th>
<th>Macquarie/Castlereagh/Bogan</th>
<th>All Other Uses of Water from the Murray within South Australia</th>
<th>Goulburn/Broken/Loddon</th>
<th>Campaspe</th>
<th>Lachlan</th>
</tr>
</thead>
<tbody>
<tr>
<td>DATE OF APPROVAL UNDER SCHEDULE F</td>
<td>Pending</td>
<td>June 2005</td>
<td>Audit in progress</td>
<td>9 November 2004</td>
<td>Pending</td>
<td>10 December 2002</td>
<td></td>
</tr>
<tr>
<td>SOFTWARE</td>
<td>IQQM Version 7.50.23</td>
<td>IQQM Version 6.74.3</td>
<td>IQQM Version 6.61.04</td>
<td>EXCEL, Siemens-DONCH.xls</td>
<td>REALM (Version Beta 4.34) and PRIDE (Version unknown)</td>
<td>IQQM Version 6.54.2</td>
<td></td>
</tr>
<tr>
<td>NAME</td>
<td>Fortran 95</td>
<td>Fortran 90</td>
<td>Not applicable</td>
<td>Fortran</td>
<td>Fortran 90</td>
<td>Fortran</td>
<td></td>
</tr>
<tr>
<td>PROGRAMMING LANGUAGE</td>
<td>NSW DWE (formerly DNR) and NSW DNRM</td>
<td>NSW DNRM (formerly DLWC) and NSW DNRM</td>
<td>NSW DNRM (formerly DLWC) and NSW DNRM</td>
<td>NSW DNRM (formerly DLWC) and NSW DNRM</td>
<td>Vic DSE (formerly DNRE) and former Vic DWR</td>
<td>NSW DNRM (formerly DLWC) and NSW DNRM</td>
<td></td>
</tr>
<tr>
<td>TYPE</td>
<td>Deterministic, link-node</td>
<td>Deterministic, link-node</td>
<td>Deterministic, link-node</td>
<td>Regression analysis</td>
<td>Network Linear Program</td>
<td>Deterministic, link-node</td>
<td></td>
</tr>
<tr>
<td>TIME Step</td>
<td>Daily</td>
<td>Daily</td>
<td>Daily</td>
<td>Monthly</td>
<td>Monthly (PRIDE is daily)</td>
<td>Daily</td>
<td></td>
</tr>
<tr>
<td>OPERATING SYSTEM</td>
<td>DOS and Windows</td>
<td>DOS and Windows</td>
<td>DOS and Windows</td>
<td>Windows</td>
<td>DOS and Windows</td>
<td>DOS and Windows</td>
<td></td>
</tr>
<tr>
<td>VALLEY REPRESENTATION</td>
<td>Copeton Dam</td>
<td>Keepit, Split Rock</td>
<td>Windamere, Ben Chifley, Burendong</td>
<td>Nil</td>
<td>Nil</td>
<td>Nil</td>
<td></td>
</tr>
<tr>
<td>SOFTWARE</td>
<td>IQQM Version 6.54.2</td>
<td>IQQM Version 6.54.2</td>
<td>IQQM Version 6.54.2</td>
<td>ExCEL, filename tO NCJCHS.xls</td>
<td>REALM (Version Beta 4.34) and PRIDE (Version unknown)</td>
<td>IQQM Version 6.54.2</td>
<td></td>
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<tr>
<td>TYPE</td>
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<td>Deterministic, link-node</td>
<td>Regression analysis</td>
<td>Network Linear Program</td>
<td>Deterministic, link-node</td>
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<tr>
<td>TIME Step</td>
<td>Daily</td>
<td>Daily</td>
<td>Daily</td>
<td>Monthly</td>
<td>Monthly (PRIDE is daily)</td>
<td>Daily</td>
<td></td>
</tr>
<tr>
<td>OPERATING SYSTEM</td>
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<td>DOS and Windows</td>
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<td>Windamere, Ben Chifley, Burendong</td>
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<td>Monthly</td>
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### TABLE 2.1 — SUMMARY OF KEY CHARACTERISTICS OF MDBC CAP MODELS SUBMITTED FOR AUDITING TO DATE

<table>
<thead>
<tr>
<th>MODEL CHARACTERISTICS WITHIN EACH DESIGNATED VALLEY</th>
<th>NSW Murray</th>
<th>Victorian Murray</th>
<th>Lower Darling</th>
<th>Warrego</th>
<th>Paroo</th>
<th>Nebine</th>
<th>Moonie</th>
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<tr>
<td>Date of approval under Schedule F</td>
<td>Audit in progress</td>
<td>Audit in progress</td>
<td>Audit in progress</td>
<td>Audit in progress</td>
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<td>Programming language</td>
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<tr>
<td>Author</td>
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<td></td>
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<td>Type</td>
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<td>Deterministic, River Murray and Lower Darling system specific model</td>
<td>Deterministic, River Murray and Lower Darling system specific model</td>
<td>Deterministic, River Murray and Lower Darling system specific model</td>
<td>Deterministic, River Murray and Lower Darling system specific model</td>
<td>Deterministic, River Murray and Lower Darling system specific model</td>
<td>Deterministic, River Murray and Lower Darling system specific model</td>
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<tr>
<td>Time step</td>
<td>Monthly, however Menindee Lakes are modelled on a daily time step.</td>
<td>Monthly, however Menindee Lakes are modelled on a daily time step.</td>
<td>Monthly, however Menindee Lakes are modelled on a daily time step.</td>
<td>Monthly, however Menindee Lakes are modelled on a daily time step.</td>
<td>Monthly, however Menindee Lakes are modelled on a daily time step.</td>
<td>Monthly, however Menindee Lakes are modelled on a daily time step.</td>
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<td>Windows and DOS</td>
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<td></td>
</tr>
<tr>
<td>Types of water uses simulated</td>
<td>Total diversions at 11 demand centres. However for resource assessments, different access rules for allocations/licenses for town water, stock and domestic, general security, irrigation, high security irrigation, Victorian sales allocation and environmental flows are taken into account.</td>
<td>Total diversions at 11 demand centres. However for resource assessments, different access rules for allocations/licenses for town water, stock and domestic, general security, irrigation, high security irrigation, Victorian sales allocation and environmental flows are taken into account.</td>
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<td></td>
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<tr>
<td>Number of separate water uses simulated</td>
<td>Total diversions for 5 NSW demand centres and 9 Victorian demand centres.</td>
<td>Total diversions for 5 NSW demand centres and 9 Victorian demand centres.</td>
<td>Total diversions for 5 NSW demand centres and 9 Victorian demand centres.</td>
<td>Total diversions for 5 NSW demand centres and 9 Victorian demand centres.</td>
<td>Total diversions for 5 NSW demand centres and 9 Victorian demand centres.</td>
<td>Total diversions for 5 NSW demand centres and 9 Victorian demand centres.</td>
<td>Total diversions for 5 NSW demand centres and 9 Victorian demand centres.</td>
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<tr>
<td>Number of tributary inflows simulated</td>
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<td></td>
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<tr>
<td>Number of separate transmission losses</td>
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<td>Designated diversions not included</td>
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<tr>
<td>Number of rainfall stations used</td>
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<tr>
<td>Number of evaporation stations used</td>
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<td>Number of temperature stations used</td>
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<tr>
<td>Method of tributary flow data extension</td>
<td>Regression with neighbouring gauging stations having long-term records</td>
<td>Regression with neighbouring gauging stations having long-term records</td>
<td>Regression with neighbouring gauging stations having long-term records</td>
<td>Regression with neighbouring gauging stations having long-term records</td>
<td>Regression with neighbouring gauging stations having long-term records</td>
<td>Regression with neighbouring gauging stations having long-term records</td>
<td>Regression with neighbouring gauging stations having long-term records</td>
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<tr>
<td>Method of rainfall data extension</td>
<td>Gap filling using adjacent stations</td>
<td>Gap filling using adjacent stations</td>
<td>Gap filling using adjacent stations</td>
<td>Gap filling using adjacent stations</td>
<td>Gap filling using adjacent stations</td>
<td>Gap filling using adjacent stations</td>
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<tr>
<td>Method of evaporation data extension</td>
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<td>Extended using regression with other climate variables</td>
<td>Extended using regression with other climate variables</td>
<td>Extended using regression with other climate variables</td>
<td>Extended using regression with other climate variables</td>
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<td>Type of river routing</td>
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<td>Non-linear at monthly time step</td>
<td>Non-linear at monthly time step</td>
<td>Non-linear at monthly time step</td>
<td>Non-linear at monthly time step</td>
<td>Non-linear at monthly time step</td>
<td>Non-linear at monthly time step</td>
</tr>
</tbody>
</table>

| SIMULATION PERIODS                                  |            |                 |              |         |       |        |       |
| Flows                                              | N/A        |                 |              |         |       |        |       |
| Diversion                                          | N/A        |                 |              |         |       |        |       |
| Crop areas                                          | N/A        |                 |              |         |       |        |       |
| Storages                                           | N/A        |                 |              |         |       |        |       |

| AUDITOR’S ASSESSMENT OF CAP MODEL AGAINSTRecorded DATA (DE-TRENDED AND FACTORED) |
|---------------------------------------------|---------------------------------|---------------|-------------|-------------|-------------|-------------|-------------|
| Correlation Coefficient r                   | 0.90                            | 0.93          | 0.78        |
| Standard Error                              | 209L (11%)                      | 80L (4.8%)    | 58L (43%)   |
| Mean Error                                  | +82GL (+4.4%)                   | +9.9GL (+0.6%)| +6.1GL (+0.8%)|
Wetherell, Cawndilla and Pamamaroo are simulated on a daily timestep within each month.

Major on-river re-regulating storages such as Lake Yarrawonga, which are important for day-to-day river operations, are not simulated in MSM. This is a significant shortcoming when investigating some operational issues, such as rain rejection behaviour. However, the inclusion of Lake Yarrawonga within MSM would be unlikely to alter the Cap uses of the model to any significant extent.

### 2.2.4 Simulation Period

When configured for a cap model run, MSM operates over a 115 year period from the beginning of May 1891 to the end of April 2006.

### 2.2.5 Input Data

MSM makes use of various climatic and tributary flow inputs. Many of these are depicted in Figure 2.1. They include:

- four locations where net evaporation data is provided. These locations comprise Dartmouth and Hume Dams, Lake Victoria and Menindee Lakes. Net evaporation is computed from rainfall and evaporation records at these sites and nearby;
- seven rainfall stations, extending from Hume Reservoir to Wentworth and Broken Hill.
- three temperature stations at Hume Dam, Mildura Airport and Wilcannia;
- twenty-one tributary inflows. Many of these inflows have been derived by separate modelling of the water management systems within the tributary valleys. Such modelling is mostly carried out by other organisations and provided to the MDBC and comprises:
  - outputs from the Snowy Mountains Scheme to the Upper Murray, which in the main have been provided by Snowy Hydro Limited;
  - outputs from the Goulburn, Broken, Loddon and Campaspe River Valleys which have been determined by the Victorian Department of Sustainability and Environment (DSE) and provided to the MDBC;
  - outputs from the Murrumbidgee and Darling River systems which are simulated by the NSW Department of Water and Energy using IQQM models; and
– outflows to the Murray from the Kiewa and Ovens Rivers in Victoria which have been determined by MDBC staff using sub-models and assessment procedures for these two Victorian valleys.

\[\begin{itemize}
  \item flows from numerous outfalls and drains into the River Murray which are simulated using recorded data when available although generally mean monthly values of flows are used for input to MSM.
\end{itemize}\]

2.3 DEMAND SIMULATION

2.3.1 NSW and Victorian Murray

Demands within MSM are simulated at eleven demand centres along the River Murray in addition to demands from the Lower Darling. The NSW demand centres along the Murray comprise:

\[\begin{itemize}
  \item net Mulwala diversions;
  \item Wakool diversions;
  \item NSW Sunraysia diversions;
  \item NSW private diversions upstream of Murrumbidgee confluence; and
  \item NSW private diversions downstream of the Murrumbidgee confluence.
\end{itemize}\]

The Victorian demand centres on the Murray comprise:

\[\begin{itemize}
  \item net Murray Valley diversions;
  \item net Torrumbarry diversions;
  \item Victorian Sunraysia diversions;
  \item other Victorian private diversions upstream of Barmah;
  \item other Victorian private diversions from Barmah to Nyah; and
  \item other Victorian private diversions downstream of Nyah.
\end{itemize}\]

MSM uses regression equations to predict irrigation demands. The equations relate to the water available and the rainfall and temperature for the current and previous months. In total, some nineteen regression equations have been developed to simulate NSW and Victorian demands.

Prior to developing the regression equations, any linear trends in the recorded diversion data were removed to account for the impacts of growth. This adjustment was made to the diversions both prior to and after 1993/94 to ensure that the predicted demands were at 1993/94 levels of development in accordance with the requirements of Schedule F. The derivation of the regression equations has been updated by the MDBC at regular intervals over the last few decades. It is noted that the last major revision (MDBC, 2003) was further revised during the preparation of the Cap Report. Whilst the trend analysis reported (MDBC, 2003) remains current, the format of the most up to date regression equations is now reported in Appendix G of the Cap Report. These comprise eight regression equations for the NSW Murray and the Lower Darling, and eleven regression equations for the Victorian Murray (including the Kiewa and Ovens catchments).
The procedures adopted by the MDBC in the development of the regressions equations, including the trend analyses, are well documented in the Cap Report and the earlier report (MDBC, 2003). The statistical analyses that have been undertaken are comprehensive and but for a few exceptions, indicate a very ‘good fit’ has been obtained.

The auditor is aware that there has been some criticism of the regression equation approach adopted by the MDBC because it is not deterministic and does not necessarily reflect the physical processes involved. This is a potential deficiency should the regression equations be used beyond the range of the climate and water availability information that was present in the data used to develop the equations. This in turn detracts from the robustness of the demand simulation within MSM.

The accuracy of the long-term average annual diversions and annual targets produced by MSM are dominated more by the accuracy of the regression equations than any other component within MSM. Nevertheless, it is the auditor’s opinion that the continued use of the regression equations is appropriate given the monthly timestep of the model and the relatively long data sets that are available from which to derive the regression equations. Whilst there may well be a need for the MDBC to update its demand estimation in the future, this more likely will be driven by other operational requirements rather than the need to produce cap and target runs using MSM.

2.3.2 Lower Darling

Most of the demands within the Lower Darling originate from both on- and off-allocation water use by Tandou Limited and the Anabranch.

The Anabranch receives an on-allocation allowance of about 50GL each year and may receive further off-allocation water. Within the Cap Report, the MSM modellers have highlighted their difficulties in simulating the Anabranch water use as there appears to be a lack of clear rules governing the timing and volume of releases from Lake Cawndilla for the Anabranch. Given this lack of understanding by the modellers, it has been difficult for them to analyse and simulate the historical pattern of Anabranch water use.

In regard to the water use by Tandou Limited, it is noted that this company is one of the largest irrigators in NSW and operates on-farm storages with a total capacity of approximately 129GL. Tandou has also traded water from a property which it owns in the Murrumbidgee Valley since the early 1990s. From the comments in the Cap Report, it appears that the MSM modellers have also had difficulty in modelling Tandou’s use of both on- and off-allocation water. The report states that the on-allocation diversion to Tandou appears to have been affected by “ad hoc allocations made to Tandou from time to time”.

Given these difficulties with both the Anabranch and Tandou water use, it is not surprising that modellers have been unable to obtain a reasonable simulation of the historical diversions. This is despite what appears to be a considerable additional modelling effort to improve the simulation of water demands for Tandou and Anabranch during the preparation of the Cap Report.
The Tandou demands themselves are now modelled using a planting decision crop model including simulation of the total on-farm storage available within Tandou. The simulation of both summer (i.e. cotton) and winter cereals are included in MSM. An important issue in modelling Tandou’s water use appears to be its access to off-allocation water and the Cap Report notes that Tandou has on occasions accessed water that was unavailable to other Lower Darling irrigators, due to Tandou’s special location adjacent to Lake Cawndilla.

2.4 RESOURCE ASSESSMENT

Resource assessment is the process through which the model determines, at each monthly timestep, the water available for use by NSW and Victoria after determining the quantities that need to be held in reserve. It is also the process by which periods of ‘special accounting’ are introduced for either NSW or Victoria.

Resource assessments are complex because they must consider a wide range of operational factors (storage reserves, losses, minimum flows, channel capacity constraints, etc.) and the different approaches to the allocation of water and the acceptance of the risk adopted by NSW and Victoria. Further these factors are not static and have continually changed over the last few decades.

The auditor is pleased that the Cap Report provides a detailed description of many of these rules and the history of changes that have occurred (refer Appendix E of the Cap Report).

During the course of the audit, comments were sought on the accuracy and appropriateness of the water management rules adopted in MSM and documented in the Cap Report. This information was sought from Mr Paul Simpson (DWE, NSW), Mr Barry James (DSE, Vic) and Mr Jarrod Eaton (DWLBC, SA). The comments received have been reproduced in Appendices E and F.

2.5 TRANSMISSION LOSSES

Transmission losses are notoriously difficult to accurately determine in practice and to simulate with any accuracy in models such as MSM. Actual losses (and gains) are strongly dependent on antecedent conditions, particularly flows and rainfall during previous days and months.

Given the monthly timestep in the model, the approach used in MSM has been to ignore antecedent conditions but to vary losses based on:

- evaporation, when flows are in-bank; and
- flow, when flows are overbank.
Separate loss equations have been derived for the ten reaches of the river from Hume Dam to the South Australian border. Separate relationships have been developed for in-bank flows, when the losses are relatively low and dependent on evaporation, and overbank flows, when losses can on occasions be very large.

2.6 OPERATIONAL LOSS

In MSM, operational loss is the additional release which is made from a storage, over and above that required to meet downstream requirements. It can occur for example as a result of rain falling in irrigation areas after orders have been placed on the upstream storage and releases have been made.

Within MSM, operational loss is only considered for Hume Dam. Hume’s operational loss has been determined using a regression equation that relates the loss to the downstream demands, the monthly rainfall recorded at Denimein, the flows in the Kiewa and Ovens Rivers, and the water availability in the month.
3. CALIBRATION AND VERIFICATION

The MDBC adopted the period from May 1983 until April 2000 for calibration, and the follow-on period from May 2000 to April 2006, for validation. Compared with many of the other valleys in the Basin, particularly those in the northern part of the Basin, the Murray (and to a lesser extent the Lower Darling) are ‘data rich’. This enables a higher standard of calibration to be achieved and greater confidence in the robustness of the model to be established.

The normal practice during calibration of models such as MSM, is for various time-varying operational parameters such as resource assessment procedures, storage capacities and operational rules to be ‘forced’ during the calibration. This removes the influence that these parameters can have on the calibration procedure. As has been previously noted in this report, there have been numerous changes in these parameters in the Murray and Lower Darling over the calibration period (see Appendix E of the Cap Report), and therefore it is has been important for the MDBC to systematically consider these changes during each year of calibration.

As explained in the Cap Report, the process of calibration and validation of MSM was undertaken in four stages:

- Stage 1 — Demand Calibration;
- Stage 2 — Transmission Loss Calibration;
- Stage 3 — Operational Loss Calibration;
- Stage 4 — Model Testing and Validation.

The above four stages are discussed in Sections 3.1–3.4 below.

3.1 DEMAND CALIBRATION

Development of the regression equations to simulate demand could proceed independently from MSM, had it not been for the fact that the ‘available water’ appears as a variable in many of the regression equations. This in turn is directly dependent on the operational parameters which were in place in each calibration year.

It is understood that step-wise, multiple linear regression analyses were undertaken for each month of the year. Only independent variables which were statistically significant (at a 90% confidence level) were included.

A comparison of the observed annual irrigation demands with those estimated using the regression equations indicated that:

- the major NSW diversions at the Mulwala Canal and at the Wakool Canal were simulated with standard errors of less than 9% and 7% respectively;
the diversion along the Lower Darling (excluding Tandou) and the pumping to Broken Hill had standard errors of 15% and 23% respectively;

the major Victorian diversions, being those at Torrumbarry and Yarrawonga were reproduced with standard errors of less than 6% and 8% respectively.

The Victorian diversions were predicted with greater accuracy than those of NSW which is to be expected given the reduced variability in the Victorian demands. The Cap Report also noted difficulties in reproducing some peak demands experienced by Murray Irrigation Limited (MIL) in some January and March months. Nevertheless, the net Mulwala Canal Diversions were simulated reasonably well.

Overall, the regression relationships for the NSW and Victorian Murray appeared to be reasonably replicating the observed behaviour.

It is noted that regression equations were not developed for Tandou which represents the major demand in the Lower Darling system. The reasons given for this in the Cap Report were the “inadequate amount of data on its diversions and on-farm management practices”. Consequently, Tandou’s demands were estimated from the assessed crop area and assumed evapo-transpiration requirements of the crop. The summer crop was assumed to be cotton and the area planted was determined based on a 10ML/ha water requirement. The winter crop was assumed to be cereals with the areas determined based on a 5ML/ha requirement when the water in storage exceeded 40GL.

### 3.2 TRANSMISSION LOSS CALIBRATION

During this second stage of the calibration, regression equations were developed for estimating transmission losses in the ten river reaches within MSM. Two relationships were developed for each reach, one for the losses which occurred when flows are in bank, and the second when flows are overbank.

During the calibration process, the releases from storages and the diversions were fixed, or were forced to historical values, and the resulting river flows, including for the effects of the transmission losses, were compared with recorded river flows. Comparisons were made over various flow ranges and the loss equations were modified to improve the simulation of the observed river flows.

A statistical comparison between the observed and simulated river flows over the 1983-2000 calibration period indicates that MSM’s ability to reproduce the historical transmission losses is poor, with the result that a comparison of observed and simulated river flows suggests:

- the simulated Doctors Point flows are close to the observed with standard errors of less than 2%;
- the Torrumbarry and Wakool junction flows have standard errors around 30%;
- the Euston flow has a standard error slightly in excess of 40%;
4 the Burtundy flow has a standard error approaching 30%; and
4 the flow to South Australia has a standard error approaching 20%.

Nevertheless, given the data that is available and the use of the monthly timestep, the auditor does not believe that existing transmission loss estimates can be improved.

It is noted that the current version of MSM still utilises Barmah-Millewa Forest losses that were derived based on limited data in 1991. The relationship is very approximate and there is no doubt further data available from which this relationship could be updated.

3.3 OPERATIONAL LOSS CALIBRATION

The first step in this process was to develop a time series of operational losses by subtracting the modelled orders at Hume Dam from the historical releases. As discussed in Section 2.6, regression analysis was then carried out using various water availability, demand and rainfall parameters in order to simulate the time series values.

No statistical parameters were presented in the Cap Report from which to evaluate the fit of the regression equation used to estimate Hume Dam’s operational loss. Nevertheless, the Cap Report does detail a comparison of the recorded and simulated storages for Dartmouth, Hume, Lake Victoria and Menindee Lakes in its Appendix I. Generally the storage behaviours are reasonably well replicated and where differences occurred, these were satisfactorily explained in the Cap Report.

3.4 MODEL TESTING AND VALIDATION

In this last phase of the calibration/validation, MSM was used to simulate both releases and irrigation demands, however only the policy and management rules were ‘forced’. The model was run over the period from May 1983 to April 2005, and thus the last five years from May 2005 to April 2005 represent the true validation period. Nevertheless very limited details of this period were presented in the Cap Report.

The primary interest in the Cap and Target models relate to their ability to replicate annual diversions. The key statistical summary between the observed and simulated diversions presented in Table 21 of the Cap Report indicates:

4 the total NSW diversions (excluding Lower Darling) are being reproduced with a correlation coefficient of 0.68 and a standard error of 9.2%;
4 the total net Victorian diversions (excluding Kiewa and the Ovens) are reproduced with a correlation coefficient of 0.92 and a standard error of 4.4%; whereas
4 the total Lower Darling diversions (including Tandou) are reproduced with a correlation coefficient of 0.47 and a standard error of some 42%.
The data in Table 21 supports the comments made earlier that the Victorian diversions are being simulated more accurately than those in the NSW Murray but nevertheless both total net diversions are being simulated well by MSM. However, due to a lack of data and an insufficient understanding of the water management practices that have been employed in the Lower Darling and within Tandou Farm in particular, the Lower Darling net diversions are poorly replicated.
4. REPRESENTATION OF 1993/94 LEVELS OF DEVELOPMENT

4.1 MODEL SIMULATION PERIOD

MSM has been used to simulate cap conditions over the 115 year period from May 1891 to April 2006.

Under Schedule F, the cap model should start from the beginning of the 1891 water year and terminate at the end of the 1997 water year, unless another period has been approved by the Commission. As part of the findings of the 2002 Lachlan audit, it was recommended to the MDBC that the finishing date for all cap models should be extended beyond the 1997 water year, to include all available data at the time the model is submitted for approval.

The period used by the MDBC for MSM starts a year earlier and ends nine years later than specified in Schedule F.

In relation to MSM and other cap models, it would seem appropriate for any agency preparing a cap model to use the longest possible period for simulation. Whilst some models of designated valleys may therefore use slightly different periods, this disadvantage is offset by the opportunity to include greater climatic variation in the simulation, therefore improving the representativeness of the results. Consequently the simulation period adopted by the MDBC for the MSM model is close to the maximum that is currently possible and is considered by the auditor to be appropriate.

4.2 INFRASTRUCTURE AND MANAGEMENT RULES

The infrastructure and management rules that have been adopted in MSM for the Cap and Target runs have generally been clearly documented in the Cap Report and have been reviewed by the auditor. The key items comprise:

- South Australian entitlement flows specified in Clauses 86 and 127 of the Murray-Darling Basin Agreement;
- additional dilution flows to South Australia from Menindee Lakes as agreed to by the Ministerial Council in 1989;
- an additional dilution flow to South Australia of 250ML/d provided by Victoria as a consequence of the construction of Mullaroo Creek regulator and irrigation development on the Lindsay River;
minimum flow requirements downstream of Dartmouth and Hume Dams, in addition to other flow requirements at Albury, downstream Yarrawonga, Swan Hill, Euston, Wentworth, Weir 32, Edward Gulpal offtake, Stevens Weir and the Edward escape, as specified in Table 25 of the Cap Report;

20GL/yr allowance for watering of the Barmah-Millewa Forests;

releases from the Menindee Lakes to meet the Lake Victoria target storage levels which were adopted in April 1987 and remained current through the 1993/94 season. This includes adoption of a full supply capacity of 677GL;

Menindee Lakes target storage levels specified in Table 23 of the Cap Report. In addition, the total surcharge capacity of the Lakes was set to 2,346GL for the period April–November and 1,731GL for December–March;

continuous accounting but without a carryover policy in NSW;

Tandou allocation of 16.55GL/year;

NSW entitlements and utilisation factors listed in Tables 26 and 27 of the Cap Report;

Victorian entitlements and utilisation factors listed in Tables 27 and 28 of the Cap Report;

Anabranch and Tandou on an off-allocation as best represents the historical behaviour over the period 1983-2000;

no limits on access to off-allocation water by NSW or Victorian irrigators; and

no adjustments for interstate water trade.

4.3 TRIBUTARY DATA UTILISED

The tributary flow data used as input to the Cap and Target runs originates from both regulated and unregulated tributaries entering the Murray and Lower Darling.

The procedures for the derivation of the unregulated tributary flow data has been properly documented in the Cap Report. However, in respect of the flow data from the regulated tributaries such as those emanating from the Snowy Mountains Scheme or the Goulburn, Campaspe, Broken or Loddon Rivers in Victoria, or the Billabong Creek, Murrumbidgee or Lower Darling flows into Menindee Lakes within NSW, it is understood that the data utilised is the “latest available” from the respective authorities that operate models of these regulated systems. Given that these models are somewhat dynamic and may change from time to time, it is important that the origin and nature of flow data from these sources that are used in MSM be properly documented. Specific recommendations in this regard have been made in Section 5.8.
All of the major regulated tributaries of the Murray and Lower Darling have sophisticated hydrologic models established to simulate the behaviour in each of the tributary catchments and their outflows to the Murray or Lower Darling. With the exception of the Snowy Mountains Scheme’s catchments, the models of the other major regulated tributaries are themselves subject to the requirements of Schedule F and the models have, or will be, approved for operation in accordance with Schedule F.

Because the tributary flows emanating from the Snowy Mountains Scheme lie outside this process, the auditor spent some time trying to investigate and validate the various recorded and modelled tributary flow inputs to MSM from the Snowy Mountains Scheme. Unfortunately, despite numerous telephone and email correspondence between the auditor and Snowy Hydro Limited, that organisation was unable to provide a suitable level of documentation to verify the tributary data inputs currently used in MSM. It would appear that following corporatisation of the Snowy Scheme, details of the synthetic generation of streamflows for the period prior to construction of the scheme have not been well maintained. Nevertheless, the auditor notes that a reasonable description of the various Snowy tributary inflows and the manner in which they are combined to derive the flow inputs to MSM, are provided within the Cap Report.
5. MODEL ROBUSTNESS AND OTHER COMMENTS

5.1 INITIAL STORAGE VOLUMES AND OTHER INITIAL VALUES

The basis for the initial storage volumes and other parameters required by MSM at the commencement of the model run in May 1891, are not documented in the Cap Report. It is understood from discussions with MDBC staff that the initial conditions in MSM were set to approximately median values based on an earlier benchmark run. However given that all storages spill in the winter of 1891 and in most of the next few years, the initial conditions in MSM are of little significance.

In the opinion of the auditor, the approach adopted by the MDBC to initialise the MSM run in May 1891 is appropriate.

5.2 WATER BALANCE CHECK

A detailed water balance check is built into MSM.

Table 30 of the Cap Report provides details of the water balance assessment and indicates that a satisfactory water balance is achieved.

5.3 POTENTIAL MODEL IMPROVEMENTS

All models are only approximations of actual behaviour. With additional effort, it is always possible to improve the manner in which a model represents the real world. However, in considering the merits of such improvements, an assessment must be made as to whether the additional effort required to make the improvements is warranted having regard to the likely benefits and the potential use of the model. This requires a subjective assessment by the model managers.

For MSM, the MDBC has identified a well-considered list of potential improvements to the model software, input data and procedures. The inclusion of this list of model improvements within the Cap Report is to be commended as it indicates that the shortcomings of the model have been given some consideration.

The potential model improvements identified by the MDBC, together with some additional suggestions by the auditor, comprise:

(a) the time series of inflows to Menindee Lakes from the Darling IQQM will need to be revised as the cap models in the northern part of the basin that contribute to these flows, are progressively refined;
(b) it is possible that as the tributary models are progressively refined, better estimates of the historical tributary flows may emerge. This in turn could possibly alter MSM’s calibration. This will need to be considered as improved tributary data becomes available and an assessment made as to whether changes to MSM’s calibration may be required;

(c) Commission approval of the Victorian REALM model simulating outflows from the Goulburn/Broken/Loddon and Campaspe/Coliban Valleys to the River Murray under 1993/94 levels of development, is pending. Once approved, updated flow data from these valleys should be provided to the MDB. Similarly, when the Murrumbidgee IQQM is approved and tributary outflows from the Murrumbidgee River and Billabong Creek are available, these data sets should also be utilised in MSM. This will likely lead to slightly revised Cap estimates for the NSW and Victorian Murray;

(d) revisions to the simulation of Anabranch replenishments and Tandou demands. Further comments on these improvements are provided in Section 5.5.

(e) improved transmission loss estimates, particularly for losses in the Barmah-Millewa Forests, need to be prepared; and

(f) the current monthly timestep utilised by MSM is adequate for the estimation of the long-term average cap and annual targets under Schedule F. Nevertheless, if and when a new Murray daily model is developed for use in operation and water resource planning, the opportunity will exist to use this daily model as the Cap and Target models and so provide improved simulation of:

- crop water requirements based on crop areas, assumed crop mixes, soil moisture accounting, irrigation techniques and efficiencies, etc;

- improved transmission losses; and

- improved simulation of rain rejection and operational losses.

It is the auditor’s opinion that this is a realistic set of improvements. With the exception of the Anabranch/Tandou improvements noted in (d), none of the improvements listed above warrant immediate inclusion in MSM before approval under Schedule F.

5.4 VISUAL ASSESSMENT OF MODEL PERFORMANCE

In order to allow some comparison of the performance of models prepared for different designated valleys, a comparison of the recorded and simulated annual diversions over the last 20 years or so is considered to be a useful component of each cap model audit.

This data has been plotted for the NSW and Victorian Murray Valleys\(^2\) and for the Lower Darling, in Figures 5.1a, 5.1b and 5.1c, respectively. It is intended that similar plots be

\(^2\) Note that the diversions from the Kiewa and Ovens catchments have not been included in Figure 5.1b.
prepared for each designated valley as new models are audited, as this will allow a visual comparison and a brief statistical comparison of model performance between valleys to be made. The principal features shown on the graphs comprise:

- **Recorded diversions.** These diversions were provided by Mr Pradeep Sharma of the MDBC on 22 June 2007 and were extracted from the MDBC’s data base.

- **Recorded diversions adjusted for trend.** The recorded annual diversions were regressed against the water year and the climate to identify any linear trend (i.e. growth) in diversions. (This was a slightly more sophisticated analysis than had been undertaken in previous cap model audits). The analyses showed there were no significant trends except in the NSW Murray diversions before 1993/94 where a very small growth of just under 0.2GL per year had occurred. This value was used to increase the diversions before the 1993/94 year to produce the ‘de-trended’ diversions shown in Figure 5.1a. Given the small magnitude of the change and the lack of trends observed in the Victoria Murray and Lower Darling diversions, there is no apparent difference between the ‘recorded’ and ‘detrended’ diversions shown on any of Figures 5.1a, 5.1b or 5.1c.

- **Cap model diversions.** These are the annual diversions predicted by MSM.

- **Average annual cap diversion.** This is the long-term average annual diversion predicted by the cap model.

- **Climatic index.** This was prepared to provide a visual guide to the representativeness of the catchment rainfall over the period, compared with the simulation period. This index was derived from an average of the rainfall records at Hume, Deniliquin, Tocumwal, Kerang, Wentworth and Lake Victoria. This was considered to be broadly representative of rainfall in the irrigation areas within the valley. Statistics were then derived from the time series. The climatic index represents the probability of exceedence of the rainfall over the simulation period.

- **Storage index.** This index is similar to the climatic index and provides an indication of the total storage volume variations over the 23 year period shown in Figures 5.1a, 5.1b and 5.1c. The storage index was derived from the average of the volumes in storage in Dartmouth, Hume, Lake Victoria and the Menindee Lakes at the beginning of October each year. As for the climatic index, the storage index represents the probability of exceedence of the storage values, with reference to the simulation period.

A statistical comparison between the recorded annual diversions (adjusted for trend where appropriate) and the cap model diversions (plotted in Figures 5.1a, 5.1b and 5.1c) over the 23 year period from May 1983 to April 2006, identified that:
VIC MURRAY DIVERGIONS (JULY 1983 TO JUNE 2006)

Average Annual Cap Diversion 1660 GL
(Over period July 1891 - June 2006, excluding Kiewa and Ovens)

Cap Model vs Recorded (De-trended)
R squared = 0.93
Standard Error = 79.6 GL
Mean Error = +9.9 GL

Water Year

Key to Climatic and Storage Indices

- R squared = 0.93
- Standard Error = 79.6 GL
- Mean Error = +9.9 GL

NOTES
1. Climatic Index determined from average rainfall at Forbes, Lake Cargellico and Booligal, over recorded (detrended) Cap Model
2. Storage Index determined from Wyangala simulated volumes at 1 September each year.
3. De-trended recorded diversion data obtained by applying 9.8 GL/year adjustment from 1993/94 season.

Figure 5.1b

Average Annual Cap Diversion 1660 GL
(Over period July 1891 - June 2006, excluding Kiewa and Ovens)

Bewsher Consulting Pty Ltd VicMurray_01.xls 14/03/2008
LOWER DARLING DIVERGENS (JULY 1983 TO JUNE 2006)

Key to Climatic and Storage Indices

- Dryer or Lower Storages
- Wetter or Higher Storages

Average Annual Cap Diversion 134 GL
(Over period July 1891 - June 2006)

Cap Model vs Recorded (De-trended)
R squared = 0.78
Standard Error = 58.3 GL
Mean Error = +9.1 GL

NOTES
1. Climatic Index determined from average rainfall at Forbes, Lake Cargellico and Booligal, over recorded (Detrended) data.
2. Storage Index determined from Wyangala Cap Model simulation volumes at 1 September each year.
3. De-trended recorded diversion data obtained by applying 9.8 GL/year adjustment from 1993/94 season.

Average Annual Cap Diversion 134 GL
(Over period July 1891 - June 2006)
the correlation coefficient $r^2$ = 0.90, 0.93 and 0.78 for the NSW Murray, Victorian Murray and Lower Darling Valleys, respectively;

the mean error$^3$ = +81.5GL, +9.9GL and + 9.1GL;
or +4.4%, +0.6% and +6.8% of the long-term average diversion cap for the NSW Murray, Victorian Murray, and Lower Darling Valleys, respectively; and

the standard error$^4$ = 209GL, 79.6GL and 58.3GL.
or 11.1%, 4.8% and 43% of the long term average diversion cap for the NSW Murray, Victorian Murray and Lower Darling Valleys respectively.

It must be recognised that in comparing the recorded and modelled data using the above statistics, there is an inherent assumption that the conditions before and after 1993/94 represent cap conditions (after allowing for the trend adjustment used by the auditor).

Whilst mean errors of up to +7% have been identified by this procedure, the calibration procedure used by the MDBC may not have generated mean errors of this magnitude and adjustment to the model to remove the mean errors quoted above may not be necessary.

However, the mean error (and standard error) statistics have been provided as they may allow useful comparisons to be made between models of other Designated Valleys.

**5.5 PARTICULAR CONCERNS WITH THE LOWER DARLING**

The analysis presented in Section 5.4 and the comparison of modelled and recorded Lower Darling diversions (and particularly those of Tandou Ltd and the Anabranch which comprise 90% of the total), suggest that the model is only poorly replicating the recorded behaviour.

This deficiency with MSM is acknowledged in many places in the Cap Report. For instance, whilst regression equations are used throughout MSM to predict diversions, the Cap Report notes that in respect to Tandou’s diversions, no regression equations could be prepared “due to inadequate data on its diversions and on-farm management

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$^3$ ‘Mean error’ is a common measure of model bias. It is defined as the arithmetic sum of the differences between the modelled and recorded versions divided by the number of years.

$^4$ ‘Standard error’ is the square root of: the sum of the squares of the differences between the modelled and observed diversions divided by the number of years. It provides an indication of the typical variation between modelled and observed diversions.
practices”. Nevertheless the auditor recognises that the MDBC modellers have expended considerable effort in attempting to rectify these deficiencies, both during the preparation of the Cap model and during the audit itself. The Cap Report also acknowledges that the performance of this component of the model is unsatisfactory when measured against the model performance indicators described in the Report.

Discussions with the MDBC and NSW DWE during the audit, together with the comments made in the Cap Report, suggest to the auditor that the principal reasons for the poor performance of the model are:

- the historical pattern of Anabranch releases has not been regular and has been influenced by various factors including the timing and magnitude of previous releases or floods, and water quality issues in weir pools along the Anabranch;

- the lack of published data relating to the water management infrastructure and cropping activities within Tandou. Given that this user is one of the largest in NSW, this lack of data is surprising;

- Tandou’s access to inter-valley transfers of water from a property that it owned on the Murrumbidgee. (As far as the auditor is aware, the potential for these transfers existed prior to 1993/94);

- changes to Tandou’s access to off-allocation water which were introduced by NSW in 1997. This may lead to reductions in water diversions after 1997. (Such reductions need to be quantified so their influence on the poor performance of the cap model compared with historical records, can be determined);

- unknown losses incurred in transferring water from the Menindee Lakes system into Tandou’s storages;

- Tandou’s intermittent and special access to unused water in the Menindee Lakes system, which otherwise would have evaporated. On occasions such water was temporarily retained in its on-farm storages (to minimise evaporation that otherwise would have occurred in Lake Cawndilla) and later released to the Anabranch; and

- some lack of agreement between DWE and MDBC concerning the 1993/94 conditions applicable to Tandou and Anabranch.

The auditor has particular concerns with the Lower Darling model given that:

- the standard error quoted in Section 5.5 is 43%. (The Cap Report had a similarly high error of 49%);

- Schedule F requires that special provisions be invoked when the cumulative diversion debit exceeds 20% of the annual average diversion. With standard errors in the model exceeding 40%, conditions under which the special provisions could be invoked, might occur inappropriately; and
Consequently it is the opinion of the auditor that MSM cannot be approved in its present form to simulate diversions in the Lower Darling under cap conditions. Nevertheless, given the Lower Darling’s geographic location and its relatively minor contribution to the overall diversions predicted by MSM, this deficiency in one part of MSM is unlikely to significantly alter MSM’s ability to accurately predict the diversions in the NSW and Victorian Murray Valleys.

5.6 EXPECTED VARIABILITY IN ANNUAL DIVERSIONS PREDICTED BY CAP MODEL

The diversions within a valley can be expected to vary with the prevailing climate and water resource availability. Throughout the twenty-four Designated Valleys of the Basin, some variability in the ‘response’ of diversions to climate and resource availability can be expected.

To provide a measure of the potential variation in annual diversions for the NSW Murray and the Victorian Murray Valleys, Figures 5.2a, 5.2b, 5.3a and 5.3b have been prepared. These figures are under Cap conditions and indicate the potential variability over the range of climatic and resource conditions simulated from May 1891 to April 2006. In respect of the NSW and Victorian Murray Valleys, the information presented in Figures 5.2a, 5.2b, 5.3a and 5.3b indicates (note that the results for the Victorian data are included in brackets below):

- diversions could potentially reduce by 88% (38%) or increase by 36% (23%) from the average annual cap diversion, if similar climate to that of the past 115 years was to reoccur;

- for 32% (58%) of the time, annual diversions should be within ±10% of the average annual cap diversion;

- for 61% (95%) of the time, annual diversions should be within ±20% of the average annual cap diversion; and

- for 92% (100%) of the time, annual diversions should be within ±40% of the average annual cap diversion.

Obviously, if management rules change or the level of development alters, there will be potential for more or less variability to occur than shown in Figures 5.2a, 5.2b, 5.3a and 5.3b.
NSW MURRAY ANNUAL DIVERSION PREDICTED BY CAP MODEL
(JULY 1891 TO JUNE 2006)

Average Annual Cap Diversion 1880 GL (over period July 1891 - June 2006)

Figure 5.2a
VIC MURRAY ANNUAL DIVERSION PREDICTED BY CAP MODEL
(JULY 1891 TO JUNE 2006)

Average Annual Cap Diversion 1660 GL (over period July 1891 - June 2006, excluding Kiewa and Ovens)

Figure 5.2b

Average Annual Cap Diversion 1660 GL (over period July 1891 - June 2006, excluding Kiewa and Ovens)
NSW MURRAY
PROBABILITY OF EXCEEDING AVERAGE ANNUAL DIVERSION UNDER CAP CONDITIONS

Figure 5.3a

Average Annual Cap Diversion 1880 GL (over period July 1891 - June 2006)
Average Annual Cap Diversion 1660 GL (over period July 1891 - June 2006, excl'd Kiewa and Ovens)
5.7 ROBUSTNESS OF MODEL TO OPERATE OUTSIDE CALIBRATION PERIOD

The ability of MSM to accurately simulate diversions outside the calibration period is an important consideration for this audit. This issue however has not been addressed in the Cap Report and in the auditor’s opinion it is difficult to objectively quantify the accuracy of the model outside the calibration period, given the absence of data.

It is noted that the nineteen regression equations which form the basis of the demand estimation within MSM have been based on data up to and including the 1999/2000 season. Verification of the regression equations’ performance over the more recent dry years would provide a better indication of the robustness of the individual demand equations in periods of severe drought. Nevertheless the total demands in each of the NSW Murray and the Victorian Murray still appear to be reasonably replicated in these years (see Figures 5.1a and 5.1b) indicating that the Valley totals are robust. (Note, given the auditor’s comments in Section 5.5, the robustness of the Lower Darling components of MSM will not be discussed further in this section).

In considering other aspects of the robustness of the model, the following subjective comments can be made:

- the model is unable to account for changes in water management resulting from movements in agricultural markets or changes in farm practice that are unrelated to climate or water availability; and

- transmission losses in the model are based on average antecedent conditions. Whilst these losses vary with evaporation and the magnitude of the flow, no account has been taken of antecedent climatic conditions. In general terms, it is likely that in persistently dry or wet months, the predicted losses will generally be under-estimated or over-estimated, respectively.

In conclusion, the robustness of the model to satisfactorily operate outside the climatic conditions represented in the calibration period is not guaranteed, particularly in more extreme climatic conditions. Nevertheless, given the model’s performance in replicating total NSW and Victorian Murray demands over the 2000/01–2005/06 water years, there is some confidence in the robustness of these parts of MSM to operate in conditions dryer than those observed during the calibration period.

5.8 TRIBUTARY INFLOW UPDATES

It is recognised that MSM has a unique status as the principal Cap model in the Basin. It is also the model which utilises either directly or indirectly, the end-of-valley outputs from most of the other Designated Valleys in the Basin. Further, these end-of-valley outputs can be expected to change in the future as additional data becomes available, or revisions to procedures and upstream models are made. The potential for numerous changes to MSM therefore exists.
Consequently, some further procedures relating to MSM and the upstream cap models that provide input to MSM, are considered appropriate. These procedures would be in addition to the QA procedures noted in Section 1.6, and would assist in managing the transfer and use of output data from these other models into MSM.

(Whilst not explicitly described below, these procedures could also be applied to the other methods and models that provide input data to MSM, but are not themselves cap models, e.g. Snowy output or drains data. The procedures could also apply to data used in MSM from valleys where Cap models are awaiting approval, e.g. Murrumbidgee or Barwon-Darling).

Accordingly, it is recommended that the Water Audit Panel (WAP) consider establishment of a register that records the origin and characteristics of the upstream data that is provided as input to MSM. Such a register could include, for example, details of:

(a) location;
(b) type of parameter;
(c) author and jurisdiction;
(d) date received by MDBC and date generated by jurisdiction;
(e) period covered by the data;
(f) MSM Run Number when data first used;
(g) origin and basis of the jurisdiction’s data, including the specific development conditions assumed and other key characteristics; and
(h) some brief statistical analyses of the changes in the data compared to:
    i. previous data which had been entered on the register; and
    ii. data in the approved MSM Cap model.

These analyses might include the changes in the mean annual and mean monthly flows, and details of individual years or months where the means had changed by 10% or more, or other statistics which the WAP decided.

Consequently, the register would assist in clarifying for any MSM Cap or Target model run, the exact status and origin of the input data used.

Further, whilst strictly even a minor change to such input data would require a new approval of MSM under Clause 11(4)(d) of Schedule F, it is suggested that the WAP develop procedures to allow the revised input data to be used on an interim basis in MSM, in lieu of the data used in the approved version of MSM, provided:

(a) average annual flows did not change by more than 5%, or by more than 20% in any one year;
(b) where the data originated from an approved cap model, re-approval of this model was sought within 5 years;

(c) details of the revised input data was included on the register and copies of the register were provided to the jurisdictions;

(d) none of the jurisdictions requested formal approval of the revised MSM or the upstream cap model; and

(e) where formal approval was required, the WAP would oversee this approval themselves, and would only request an independent technical audit where considered necessary.

The WAP might also consider establishing a similar register and applying similar procedures to the Barwon–Darling Cap model in due course.
6. CONCLUSIONS AND RECOMMENDATIONS

Generally the MSM modelling work and its documentation, have been carried out to a high standard.

In respect to the simulation of the NSW and Victorian Murray Valleys (including the Kiewa and Ovens catchments), it is the opinion of the auditor that the model is sufficiently robust and lacks significant bias for it to be used for the simulation of these long-term diversions and their annual targets under Schedule F.

Despite the MDBC expending considerable effort developing a simulation of the Lower Darling diversion system, the auditor does not believe this component of MSM is sufficiently accurate for it to be used to fulfil the requirements of Schedule F. It appears that there is insufficient data available from which to develop an understanding of the 1993/94 levels of development in this system. Further data collection, possibly directly from Tandou Ltd or other sources, might help overcome this problem.

It is recommended that the Lower Darling component of MSM be referred back to the MDBC and NSW for revision and once amended, any impacts to the simulation of the NSW and Victorian Murray diversions, be checked. Should the MDBC and NSW determine that sufficient improvements to the Lower Darling simulation cannot be made, the Water Audit Panel may need to agree that the model sufficiently represents 1993/94 levels of development, despite its inability to replicate the observed diversions.

The following conclusions and recommendations are the key outcomes of this audit:

(a) MSM be approved by the MDBC for use in calculating the long-term diversion cap under Schedule F for the NSW and Victorian Murray Valleys (including the Kiewa and Ovens catchments).

(b) The software used in MSM also be used to determine annual diversion targets under Schedule F for the NSW and Victorian Murray Valleys (including the Kiewa and Ovens catchments).

(c) Approval of the Lower Darling component of MSM be delayed until suitable revisions are made.

(d) In terms of Schedule F, Clause 9(4)(e), the MDBC approve operation of MSM over the 115 year period from May 1891 to April 2006, in respect of the NSW and Victorian Murray Valleys (including the Kiewa and Ovens catchments).

(e) The various improvements which have been identified in Section 5.3 of this report be pursued by the MDBC over the next five years either through developing the new Murray daily model or through revisions to MSM.
(f) A digital copy of the cap model software and input data, once approved under Schedule F, be held at the MDBC office.

(g) Given the numerous tributary inflows to MSM, for which data is obtained from other agencies, the MDBC should establish and maintain a register detailing the source and principal characteristics of the data used in each Cap or Target model run.

(h) The MDBC through its Water Audit Panel, develop procedures to allow the MSM Cap and Target models to be used on an interim basis with inflow data different from those in the approved MSM model.
7. REFERENCES


APPENDIX A

SCHEDULE F — CAP ON DIVERSIONS
MURRAY-DARLING BASIN AGREEMENT
SCHEDULE F

CAP ON DIVERSIONS

Purposes

1. The purposes of this Schedule are:

(a) to establish long-term caps on the volume of surface water used for consumptive purposes in river valleys within the Murray-Darling Basin (including, without limitation, water from waterways and distributed surface waters) in order to protect and enhance the riverine environment; and

(b) to set out action to be taken by the Ministerial Council, the Commission and State Contracting Governments to quantify and comply with annual diversion targets; and

(c) to prescribe arrangements for monitoring and reporting upon action taken by State Contracting Governments to comply with annual diversion targets.

Definitions

2. (1) In this Schedule, except where inconsistent with the context:

"baseline conditions" means:

(a) in the case of New South Wales and Victoria, means the level of water resource development for rivers within the Murray-Darling Basin as at 30 June 1994 determined by reference to:

(i) the infrastructure supplying water; and

(ii) the rules for allocating water and for operating water management systems applying; and

(iii) the operating efficiency of water management systems; and

(iv) existing entitlements to take and use water and the extent to which those entitlements were used; and

(v) the trend in the level of demand for water within and from the Murray-Darling Basin at that date;
(b) in the case of Queensland, means the conditions set out for each river valley in the Resource Operation Plan first adopted by the Government of Queensland in that river valley and published in the Queensland Government Gazette; and

(c) in the case of the Australian Capital Territory, means the conditions proposed by the Government of that Territory and determined by the Ministerial Council on the recommendation of the Commission.

"Cap Register" means the Register referred to in sub-clause 13(7).

"designated river valley" means a river valley or water supply system referred to in, or designated under, sub-clause 3(1).

"diversions", with respect to a river valley, means the volume of surface water used for consumptive purposes determined in accordance with the formula entered in the Diversion Formula Register for that river valley.

"Diversion Formula Register" means the Register referred to in paragraph 40(1)(b).

"historical data" means data relevant to the period from 1 July 1983 to 30 June 1994, or such other period as the Commission may from time to time determine.

"river valley" means a river valley within the Murray-Darling Basin referred to in sub-clause 3(2).

"water year" in relation to a river valley or a water supply system means the relevant 12 month period applicable to the allocation of water entitlements and measurement of diversions in that river valley or water supply system.

(2) In this Schedule:

(a) a reference to the "Government of a State" includes a reference to the Government of the Australian Capital Territory.

(b) a reference to a "State Contracting Government" includes a reference to the Government of the Australian Capital Territory.

(c) a reference to "State" includes Australian Capital Territory.

River Valleys and Designated River Valleys

3. (1) Subject to sub-clause 3(3), the river valleys or water supply systems listed in Appendix 1 are "designated river valleys" for the purposes of this Schedule.

(2) Subject to sub-clause 3(3), the river valleys listed in Appendix 2 are "river valleys" for the purposes of this Schedule.

(3) The Ministerial Council may, from time to time, on the recommendation of the Commission:

(a) amend the description of:

(i) any designated river valley described in Appendix 1; or

(ii) any river valley in Appendix 2;
(b) designate, for the purposes of this Schedule, any river valley or water supply system not referred to in Appendix 1; or

(c) add any river valley to those set out in Appendix 2.

**Diversion Formula Register**

4. (1) The Commission must:

   (a) determine a formula for calculating diversions within each river valley for the purposes of this Schedule; and

   (b) maintain a Diversion Formula Register which records each formula determined under paragraph (a) and the river valley to which the formula relates.

(2) The Commission or States, as may be appropriate, must use the formula entered in the Diversion Formula Register with respect to a river valley for the purpose of:

   developing or approving any analytical model under clause 11;

   making any calculation under clause 12;

   preparing any report required under clause 13; and

   maintaining the Cap Register.

(3) The Commission may from time to time amend:

   any formula determined under paragraph 4(1)(a); and

   any entry in the Diversion Formula Register.

**Long-term diversion cap for New South Wales**

5. (1) The Government of New South Wales must ensure that diversions within each designated river valley in New South Wales do not exceed diversions under baseline conditions in that designated river valley, as determined by reference to the model developed under sub-clause 11(4).

(2) In calculating baseline conditions for the Border Rivers, allowance must be made for such annual volume as the Ministerial Council may, from time to time, determine in view of the special circumstances applying to Pindari Dam.

**Long-term diversion cap for Victoria**

6. (1) The Government of Victoria must ensure that diversions within each designated river valley in Victoria (including the upper River Murray) do not exceed diversions under baseline conditions in that designated river valley, as determined by reference to the model developed under sub-clause 11(4).

(2) In calculating baseline conditions for either or both of the Goulburn/Broken/Loddon water supply system and the Murray Valley water supply system, allowance must be made for an additional 22 GL per year, or such other annual volume as the Ministerial Council may, from time to time, determine in view of the special circumstances applying to Lake Mokoan.
Long-term diversion cap for South Australia

7. (1) The Government of South Australia must ensure that diversions from the River Murray within South Australia:
   (a) for water supply purposes delivered to Metropolitan Adelaide and associated country areas through the Swan Reach-Stockwell, Mannum-Adelaide and Murray Bridge-Onkaparinga pipeline systems do not exceed a total diversion of 650 GL over any period of 5 years;
   (b) for Lower Murray Swamps irrigation do not exceed 94.2 GL per year;
   (c) for water supply purposes for Country Towns do not exceed 50 GL per year; and
   (d) for all other purposes do not exceed a long-term average annual diversion of 449.9 GL.

(2) The Government of South Australia must ensure that:
   (a) no part of any entitlement created in South Australia with respect to the diversion referred to in paragraph 7(1)(a) is either used, or transferred for use, for any purpose other than use in Metropolitan Adelaide and associated country areas; and
   (b) at least 22.2 GL of the diversion referred to in paragraph 7(1)(b) is reserved for environmental purposes and is not transferred, unless the Ministerial Council determines otherwise.

(3) If the Government of South Australia supplies any of the diversions referred to in paragraph 7(1)(d) through the Swan Reach-Stockwell, Mannum-Adelaide and Murray Bridge-Onkaparinga pipeline systems in any year, it must:
   (a) record the volume of water so delivered for that purpose in that year; and
   (b) account for that volume against the long-term average annual diversion referred to in paragraph 7(1)(d), when monitoring and reporting to the Commission under clause13.

Long-term diversion cap for Queensland

8. The Government of Queensland must ensure that diversions from each designated river valley in Queensland do not exceed diversions under baseline conditions in that designated river valley, as determined by reference to the model determined under sub-clause 11(4).

Long-term diversion cap for the Australian Capital Territory

9. The Government of the Australian Capital Territory must ensure that diversions from the designated river valley in the Australian Capital Territory do not exceed diversions under baseline conditions in that designated river valley, as determined by reference to the model developed under sub-clause 11(4).
Power of Commission to alter long-term diversion caps

10. (1) Subject to sub-clause 10(2) the Ministerial Council may, on the recommendation of the Commission, make protocols determining how the Commission may alter any long-term diversion cap referred to in this Schedule.

(2) The Commission, from time to time:
   (a) must alter a long-term diversion cap to reflect the result of transferring water entitlements or allocations within a State or between States, in accordance with any protocols established under Schedule E; and
   (b) may only alter a long-term diversion cap to account for environmental water under Cap in accordance with a protocol made under sub-clause 10(1).

Developing Analytical Models

11. (1) The Commission must develop analytical models for determining the annual diversion targets for the upper River Murray.

(2) Subject to sub-clause 11(1), the Governments of New South Wales, Victoria, Queensland and the Australian Capital Territory must each develop analytical models for determining the annual diversion target for each designated river valley within the territory of that State.

(3) The Government of South Australia must develop analytical models for determining the annual diversion target for diversions referred to in paragraph 7(1)(d).

(4) An analytical model developed under this clause:
   (a) must simulate the long-term diversion cap in the relevant designated river valley; and
   (b) must be tested against relevant historical data to determine the accuracy of the model in estimating the annual diversion; and
   (c) must be approved by the Commission before it is used to determine an annual diversion target under this Schedule; and
   (d) may, from time to time, be modified in such ways as the Commission may approve; and
   (e) must be used to determine the average annual diversion under the conditions of the relevant long-term diversion cap determined under this Schedule for either:
      (i) the period between the start of the 1891 water year and the end of the 1997 water year; or
      (ii) such other period as may be approved by the Commission.

(5) The Commission may only approve an analytical model or a modification to an analytical model if the Commission considers that the model, when approved or modified, will fairly determine the relevant annual diversion target given the climatic conditions experienced in any year.

Calculation of annual diversion targets

12. (1) Within two months after the end of the relevant water year and using the analytical models developed and approved under clause 11:
(a) the Commission must calculate the annual diversion targets for New South Wales and Victoria for that year for the upper River Murray; and

(b) subject to paragraph (a), the Governments of New South Wales, Victoria, South Australia, Queensland and the Australian Capital Territory must, for each designated river valley within the territory of that State, calculate the annual diversion target for that year.

(2) The Commission must promptly inform the Governments of New South Wales and Victoria of the results of every calculation made under paragraph 12(1)(a) with respect to the upper River Murray.

(3) The Government of New South Wales, Victoria, South Australia, Queensland and the Australian Capital Territory, respectively, must each promptly inform the Commission of the results of every calculation made by it under paragraph 12(1)(b).

Monitoring and Reporting

13. (1) Each State Contracting Government must, for each water year and in relation to each river valley specified in Appendix 2 within its territory, monitor and report to the Commission upon:

(a) diversions made within and to; and

(b) water entitlements, announced allocations of water and declarations which permit the use of unregulated flows of water within; and

(c) trading of water entitlements within, to or from, the territory of that State in that water year.

(2) Each State Contracting Government must, for each water year and in relation to each designated river valley within its territory, monitor and report to the Commission upon:

(a) the compliance by that State with each relevant annual diversion target calculated under this Schedule for that water year; and

(b) such actions which the State proposes to take to ensure that it does not exceed the annual diversion targets calculated under this Schedule for every ensuing water year.

(3) For the purpose of sub-clauses 13(1) and (2) the expression "river valley within its territory" in relation to Victoria, includes that portion of the upper River Murray forming the border between Victoria and New South Wales.

(4) A report under sub-clause 13(1) or (2) must be given to the Commission within four months after the end of each relevant water year or by such other time as the Commission may determine.

(5) on the basis of the calculations referred to in sub-clause 12(1) and reports given to it under sub-clauses 13(1) and (2) the Commission:

(a) must, in relation to each State Contracting Government, produce a water audit monitoring report which includes information about that Government's compliance with the annual diversion target calculated for each designated river valley in the territory of that State and for the whole of the State in the relevant water year; and

(b) may publish any such report, or a summary thereof, in such manner as it may determine.
(6) A water audit monitoring report under sub-clause 13(4) must be produced by 31 December following the conclusion of each relevant water year, or by such other time as the Commission may determine.

(7) The Commission must maintain a Cap Register which records:
   (a) for each designated river valley; and
   (b) for each State,

   the cumulative difference between actual annual diversions and the annual diversion targets calculated under this Schedule.

(8) The Cap Register must:
   (a) for New South Wales, Victoria and South Australia, include information for every water year concluding after 1 November 1997; and
   (b) for Queensland, include information about each designated river valley in every water year commencing after the Resource Operations Plan first adopted by the Government of Queensland for that designated river valley is published in the Queensland Government Gazette; and
   (c) for the Australian Capital Territory, include information about its designated river valley in every water year concluding after the Ministerial Council determines the baseline conditions for the Australian Capital Territory; and
   (d) if cumulative actual diversions for any designated river valley or for any State are less than the cumulative annual diversion targets calculated under this Schedule, as the case requires, record the difference as a credit; and
   (e) if cumulative actual diversions for any designated river valley or for any State are greater than the cumulative annual diversion targets calculated under this Schedule, as the case requires, record the difference as a debit.

(9) The Commission must include a report on the operation of this Schedule in any report made to the Ministerial Council under clause 84 of the Agreement.

Appointment of Independent Audit Group

14. The Commission must appoint an Independent Audit Group for the purpose of this Schedule.

Annual audit by the Independent Audit Group

15. (1) The Independent Audit Group must, until 31 December 2009, annually audit the performance of each State Contracting Government in implementing the long-term diversion cap in each water year which concludes on or between 1 June 1999 and 1 November 2009.

   (2) The Commission may direct the Independent Audit Group to audit the performance of any State Contracting Government in implementing the long-term diversion cap in any water year concluding after 1 November 2009.

   (3) The Independent Audit Group must report to the Commission on any audit conducted under this clause.
Power to require a special audit of a designated river valley

16. If, after receiving a report from a State Contracting Government under sub-clause 13(2) for any year, the Commission calculates that either:

(a) the diversion for water supply to Metropolitan Adelaide and associated country areas over the last five years has exceeded 650 GL; or

(b) the diversion in the Warrego, Paroo, Moonie or Nebine designated river valley has exceeded the annual diversion target for that valley, determined under paragraph 12(1)(b); or

(c) the cumulative debit recorded in the Cap Register exceeds 20% of the average annual diversion determined under paragraph 11(4)(e) for a particular designated river valley within that State,

the Commission must direct the Independent Audit Group to conduct a special audit of the performance of that State Contracting Government in implementing the long-term diversion cap in the relevant designated river valley.

Special audit by Independent Audit Group

17. (1) In conducting a special audit under clause 16, the Independent Audit Group must consider:

(a) data on diversions and annual diversion targets recorded on the Cap Register; and

(b) data submitted by the relevant State Contracting Government, including, for example, data about areas under irrigation, storage capacities, crop production, irrigation technology and the conjunctive use of groundwater in the designated river valley; and

(c) the impact that policies implemented by the State Contracting Government may have on the expected pattern of annual diversions; and

(d) whether the diversion for all years on the Cap Register exceeds the diversion expected under the long-term diversion cap for those years, and

(e) any other matter which the Independent Audit Group considers relevant.

(2) The Independent Audit Group must:

(a) determine whether the long-term diversion cap has been exceeded in the designated river valley; and

(b) report to the Commission on the special audit and advise the Commission of its determination within six months after a direction given under clause 16.

Declaration that diversion cap has been exceeded

18. If the Commission receives a report under sub-clause 17(2) which determines that a State has exceeded the long-term diversion cap in a designated river valley, the Commission must:

forthwith declare that the State has exceeded the Murray-Darling Basin diversion cap; and

report the matter to the next meeting of the Ministerial Council.
Advice to Ministerial Council on remedial actions

19. (1) The Government of a State referred to in paragraph 18(a) must report to the next Ministerial Council after a declaration is made under that paragraph, setting out:

(a) the reasons why diversions exceeded the Murray-Darling Basin diversion cap; and

(b) action taken, or proposed to be taken by it to ensure that cumulative diversions recorded in the Cap Register are brought back into balance with the cap; and

(c) the period within the relevant model referred to in clause 11 predicts that the cumulative diversions recorded in the Cap Register will be brought back into balance with the cap.

(2) The Government of a State that has been required to report to the Ministerial Council under sub-clause 19(1) must report to each subsequent meeting of the Ministerial Council on action taken, or proposed to be taken by it to ensure that cumulative diversions recorded in the Cap Register are brought back into balance with the cap, until the Commission revokes a declaration pursuant to sub-clause 19(3).

(3) When the Commission is satisfied that a State in respect of which a declaration has been made under paragraph 18(a) has brought the cumulative diversions recorded in the Cap Register back into balance with the cap and is once more complying with the Murray-Darling Basin diversion cap in all respects, it must:

revoke the declaration; and

report that fact to the next meeting of the Ministerial Council.
APPENDIX 1
DESIGNATED RIVER VALLEYS

1. **New South Wales**

The New South Wales portion of the Border Rivers catchment, excluding the portion of the Gil Gil Creek below the Carole Creek confluence and the Boomi River below the Gil Gil Creek confluence.

The New South Wales portion of the following catchments:

- Moonie, Big Warmambool, the Culgoa/Birrie/Bokhara/Narran, Warrego, Paroo and Nebine.
- Gwydir catchment, including the portion of the Gil Gil Creek below the Carole Creek confluence and the Boomi River below the Gil Gil Creek confluence.
- Namoi catchment.
- The Macquarie/Castlereagh/Bogan catchments.
- The Barwon/Upper Darling river system and the Lower Darling river system, from the furthest upstream reach of the Menindee Lakes to the furthest upstream reach of the Wentworth Weir Pool.
- Lachlan catchment.
- Murrumbidgee catchment excluding that part of the Murrumbidgee River that flows through the Australian Capital Territory, its sub-catchments in that Territory and the Canberra Water Supply System.
- The New South Wales portion of the Murray Valley including the portion of the Lower Darling influenced by the Wentworth Weir Pool.

2. **Queensland**

- The portion of the Condamine and Balonne catchments in Queensland.
- The portion of the Border Rivers catchment in Queensland.
- The portion of the Moonie catchment in Queensland.
- The portion of the Warrego catchment in Queensland.
- The portion of the Paroo catchment in Queensland.
- The portion of the Nebine catchment in Queensland.

3. **Victoria**

- The Goulburn/Broken/Loddon water supply system.
- The Campaspe/Coliban water supply system.
- The Wimmera/Mallee water supply system.
The Victorian portion of the Murray Valley including the Kiewa and Ovens catchments.

4. **South Australia**

The pumps on the Murray within South Australia used to supply Metropolitan Adelaide and associated country areas.

Lower Murray Swamps irrigation.

Country Towns water use.

Water Use for All Other Purposes from the Murray within South Australia.

5. **Australian Capital Territory**

That part of the Murrumbidgee River that flows through the Australian Capital Territory, its sub-catchments in that Territory and the Canberra Water Supply System.
APPENDIX 2

RIVER VALLEYS

1. New South Wales

The portion of the Border Rivers catchment in New South Wales, excluding the portion of Gil Gil Creek below the Carole Creek confluence and the Boomi River below the Gil Gil Creek confluence.

The portion of the Moonie catchment in New South Wales.

The portion of the Big Warmambool catchment in New South Wales.

The portion of the Culgoa/Birrie/Bokhara/Narran catchments in New South Wales.

The portion of the Warrego catchment in New South Wales.

The portion of the Paroo catchment in New South Wales.

That portion of the Nebine catchment in New South Wales.

Gwydir catchment, including the portion of Gil Gil Creek below the Carole Creek confluence and the Boomi River below the Gil Gil Creek confluence.

Namoi catchment.

The Macquarie/Castlereagh/Bogan water catchments.

The Barwon/Upper Darling river system.

Lower Darling river system from the furthest upstream reach of the Menindee Lakes to the furthest upstream reach of the Wentworth Weir Pool.

Lachlan catchment.

Murrumbidgee catchment excluding that part of the Murrumbidgee River that flows through the Australian Capital Territory, its sub-catchments in that Territory and the Canberra Water Supply System.

The New South Wales portion of the Murray Valley including the portion of the Lower Darling influenced by the Wentworth Weir Pool.

2. Queensland

The portion of the Condamine and Balonne catchments in Queensland.

The portion of the Border Rivers catchment in Queensland.

The portion of the Moonie catchment in Queensland.

The portion of the Warrego catchment in Queensland.

The portion of the Paroo catchment in Queensland.

The portion of the Nebine catchment in Queensland.
3. **Victoria**

Kiewa catchment.

Ovens catchment.

Goulburn catchment.

Broken catchment.

Campaspe catchment.

Loddon catchment.

Wimmera/Mallee catchment.

The Victorian portion of the Murray Valley catchment.

4. **South Australia**

The pumps on the Murray within South Australia used to supply Metropolitan Adelaide and associated country areas.

Lower Murray Swamps irrigation.

Country Towns water use.

Water use for All Other Purposes from the Murray within South Australia.

5. **Australian Capital Territory**

That part of the Murrumbidgee River that flows through the Australian Capital Territory, its sub-catchments in that Territory and the Canberra Water Supply System.
APPENDIX B

CONFLICT OF INTEREST — DECLARATION

(This has been provided separately to the MDBC Office)
APPENDIX C

EXTRACT FROM THE MDBC’S
“DIVERSION FORMULA REGISTER FOR THE
MURRAY-DARLING BASIN”

VERSION 2 — 22 APRIL 2008
The purposes of the Diversion Formula Register are twofold:

- qualitative - to define in-principle what a diversion is: and
- quantitative - to provide formulas that define how water diversions from the river system of the Murray-Darling Basin, are to be determined and reported for the purposes of the Murray-Darling Basin Cap on diversions.

This appendix contains a copy of the relevant details from MDBC’s register for the NSW and Victorian Murray Valleys, and for the Valley referred to in Schedule F as the “Barwon/Upper Darling and Lower Darling”.

The Register provides the formulae for calculating diversions for each of the designated river valleys throughout the Murray-Darling Basin defined under Schedule 1 of Schedule F of the Murray-Darling Basin Agreement.

The quantitative formulae are to be used:

- in determining the volume of water diverted in the relevant valley in any given water year (for current, future and for historical diversion records); and
- in the estimation of diversions in analytical models of river systems that have been developed to determine Cap compliance.

In preparing the Register, it was envisaged that the MDBC will change the diversion formulae from time to time as it becomes practical or important to monitor certain items in more detail. For example, in several instances throughout the Register, system returns (return of water diverted back to the river system) have not been explicitly identified. System returns not already included may be in future editions of this Register as the MDBC identifies them as being significant.

The details included here are only for the three valleys which are the subject of this audit and relate to Version 2 of the Register which was approved by the MDBC at Meeting 95 in 22 April 2008.

The Register also contains a description of the infrastructure supporting all transfers of water in and/or out of the Murray-Darling Basin.
DETAILS FOR THE BARWON / UPPER DARLING AND LOWER DARLING VALLEY
(SECTION 2.6 OF REGISTER)

(the Lower Darling catchment extends from the furthest upstream reach of Menindee Lakes to the furthest upstream reach of the Wentworth Weir Pool)

Water year: July to June

Total Diversions = \( \Sigma \) (Barwon / Upper Darling diversions + Lower Darling diversions)

Where:

Barwon/Upper Darling Diversions = \( \Sigma \) (Barwon/Upper Darling Watercourse Diversions + Barwon/Upper Darling Land-surface Diversions)

Lower Darling Diversions = \( \Sigma \) (Diversions from Main Stem of Lower Darling River to supply Regulated Irrigation, Stock, Domestic and Miscellaneous Licences (excluding diversions to supply Tandou) + Diversions from Lake System of Lower Darling River to supply Regulated Irrigation, Stock, Domestic and Miscellaneous Licences (excluding diversions to supply Tandou) + Releases from Lake Cawndilla to supply Anabranch Replenishment (which excludes releases for environmental flushing flows and releases to supply Tandou) + Tandou Diversions)

Barwon/Upper Darling Watercourse Diversions = \( \Sigma \) (Unregulated Irrigation, Stock, Domestic and Miscellaneous Licences + Town & Industrial Supplies)

Barwon/Upper Darling Land-surface Diversions = \( \Sigma \) (Land-surface (Floodwater) Diversion by Licensed Pumpers)

Water course Diversion Components: Barwon/Upper Darling

Unregulated Irrigation, Stock, Domestic and Miscellaneous Licences = The sum of all unregulated licensed diversions in the Barwon and Upper Darling River Valleys. Unregulated diversions are estimated based on metered information (where available) and surveyed information, as officially recorded in the Database system of the responsible state agency.

Town & Industrial Supplies = The sum of all metered licensed diversions for Town & Industrial Supplies in the Barwon and Upper Darling River Valleys, as officially recorded in the Database system of the responsible state agency.
Land-surface Diversion Components: Barwon/Upper Darling

<table>
<thead>
<tr>
<th>Land-surface (Floodwater) Diversion by Licensed Pumpers</th>
</tr>
</thead>
<tbody>
<tr>
<td>= The sum of all the estimated floodplain water harvesting diversions occurring in the Barwon and Upper Darling River Valleys</td>
</tr>
</tbody>
</table>

Diversion Components: Lower Darling

<table>
<thead>
<tr>
<th>Diversions from Main Stem of Lower Darling River to supply Regulated Irrigation, Stock, Domestic and Miscellaneous Licences (excluding diversions to supply Tandou)</th>
</tr>
</thead>
<tbody>
<tr>
<td>= The sum of all regulated licensed diversions from the Main Stem of the Lower Darling from the furthest upstream reach of Menindee Lakes to the furthest upstream reach of the Wentworth Weir Pool (excluding diversions to supply Tandou) and Broken Hill.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Diversions from Lake System of Lower Darling River to supply Regulated Irrigation, Stock, Domestic and Miscellaneous Licences (excluding diversions to supply Tandou)</th>
</tr>
</thead>
<tbody>
<tr>
<td>= The sum of all regulated licensed diversions from the Lakes: Menindee, Cawndilla, Pamamaroo and Wetherill.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Releases from Lake Cawndilla to supply Anabranch Replenishment (which excludes releases for environmental flushing flows and releases to supply Tandou)</th>
</tr>
</thead>
<tbody>
<tr>
<td>= The sum of all releases from Cawndilla Outlet to supply Anabranch Replenishment (which excludes releases for environmental flushing flows and releases to supply Tandou).</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Tandou Diversions</th>
</tr>
</thead>
<tbody>
<tr>
<td>= The sum of all diversions from the following:</td>
</tr>
<tr>
<td>a) Tandou Pumps on the Lower Darling Main Stem;</td>
</tr>
<tr>
<td>b) Releases from Lake Cawndilla to supply Lake Tandou; and</td>
</tr>
<tr>
<td>c) Net diversions from Redbank Creek to supply Lake Tandou at times when water flowing overbank from the Darling River can be diverted.</td>
</tr>
</tbody>
</table>

Diversion Sub-Components: Lower Darling

<table>
<thead>
<tr>
<th>Broken Hill Diversions</th>
</tr>
</thead>
<tbody>
<tr>
<td>= The sum of all Broken Hill licensed pumped diversions.</td>
</tr>
</tbody>
</table>
### DETAILS FOR THE MURRAY (NEW SOUTH WALES) VALLEY
(SECTION 2.9 OF REGISTER)

**Water year:** July to June

| Total Diversions = Σ (Regulated Irrigation, Stock, Domestic and Miscellaneous Licences + Unregulated Irrigation Licences + Town & Industrial Supplies) |

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**Where:**

#### Diversion Components

<table>
<thead>
<tr>
<th>Diversion Components</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Regulated Irrigation, Stock, Domestic and Miscellaneous Licences</td>
<td>The sum of all regulated licensed diversions (Private Irrigation diversions + Irrigation Corporation diversions + Irrigation Trusts and Group Licensed diversions + conjunctive Domestic &amp; Stock diversions) within the NSW portion of the Murray, Edward, Niemur and Wakool Valleys and the Wentworth Weir Pool on the Darling River, officially recorded in the Database system of the responsible state agency.</td>
</tr>
<tr>
<td>Unregulated Irrigation Licences</td>
<td>The sum of all unregulated irrigation licensed diversions in the NSW portion of the Murray River Valley. Unregulated irrigation diversions are estimated based on metered information (where available) and surveyed information, as officially recorded in the Database system of the responsible state agency.</td>
</tr>
<tr>
<td>Town &amp; Industrial Supplies</td>
<td>The sum of all metered licensed diversions for Town &amp; Industrial Supplies within the NSW portion of the Murray, Edward, Niemur and Wakool Valleys and the Wentworth Weir Pool on the Darling River, officially recorded in the Database system of the responsible state agency.</td>
</tr>
</tbody>
</table>

**NB:** Licenses with entitlements < 20 ML are not required to be metered, and usage may be determined by assessment.

#### Diversion Sub-Components

<table>
<thead>
<tr>
<th>Diversion Sub-Components</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Private Irrigation Diversions</td>
<td>The sum of all regulated metered licensed diversions within the NSW portion of the Murray, Edward, Niemur and Wakool Valleys and the Wentworth Weir Pool on the Darling River, officially recorded in the Database system of the responsible state agency.</td>
</tr>
<tr>
<td>Irrigation Corporation Diversions</td>
<td>The sum of all licensed diversions of Murray Irrigation Ltd and Western Murray Irrigation.</td>
</tr>
</tbody>
</table>
### Diversion Sub-Components cont/-

<table>
<thead>
<tr>
<th>Diversion Component</th>
<th>Formula</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Murray Irrigation Ltd Diversions</strong></td>
<td>The sum of Gross Mulwala Canal diversions + Perricoota Pumps – Edward Escape – Wakool Escape – Finley Escape + Wakool Canal diversions – Yallakool escape. Includes all licensed diversions to the following Irrigation Districts: Wakool, Tullakool, Deniboota, Denimein and Berriquin.</td>
</tr>
<tr>
<td><strong>Western Murray Irrigation Diversions</strong></td>
<td>The sum of all licensed diversions to Buronga + Curlwaa + Coomealla.</td>
</tr>
<tr>
<td><strong>Irrigation Trusts and Group Licensed Diversions</strong></td>
<td>The sum of all licensed diversions from Bama, Bringan, Bungumyah/Koraleigh, Glenview, Goodnight, West Cadell, Bullatale, West Corugan, Merran Creek, Moira &amp; Pomona.</td>
</tr>
</tbody>
</table>
KIEWA

Water year: July to June

| Total Diversions = Σ (Unregulated Irrigation Licences + Domestic, Stock Commercial & Industrial Licences and Supplies by Agreement + Urban Bulk Entitlements) |

Where:

**Diversion Components**

| Unregulated Irrigation Licences = | The sum of all diversions to supply unregulated irrigation licences in the Kiewa River Valley, based on meter readings stored on the Database system of the responsible state agency and estimates where unmetered. |
| Domestic, Stock, Commercial & Industrial Licences and Supplies by Agreement = | The sum of all domestic, stock, commercial & industrial licensed diversions and diversions by all Supplies by Agreement direct from streams in the Kiewa River Valley, based on meter readings stored on the Database system of the responsible state agency and estimates where unmetered. |
| Urban Bulk Entitlements (UBE’s) = | The sum of all diversions to supply Unregulated River Urban Bulk Entitlements in the Kiewa River Valley obtained from Urban Water authorities. |

**Diversion Sub-Components**

| Urban Bulk Entitlements (Unregulated River) = | The sum of all diversions for the following urban centres: Kiewa/Tangambalanga, Mt Beauty / Tawonga and Yackandandah. |
OVENS

Water year: July to June

| Total Diversions = Σ (Regulated Irrigation Entitlements + Unregulated Irrigation Licences + Domestic, Stock Commercial & Industrial Licences and Supplies by Agreement + Urban Bulk Entitlements) |

Where:

**Diversion Components**

<table>
<thead>
<tr>
<th>Component</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Regulated Irrigation Entitlements</td>
<td>The sum of all diversions to supply regulated irrigation entitlements in the Ovens River Valley, based on meter readings stored on the Database system of the responsible state agency and estimates where unmetered.</td>
</tr>
<tr>
<td>Unregulated Irrigation Licences</td>
<td>The sum of all diversions to supply unregulated irrigation licences in the Ovens River Valley, based on meter readings stored on the Database system of the responsible state agency and estimates where unmetered.</td>
</tr>
<tr>
<td>Domestic, Stock, Commercial &amp; Industrial Licences and Supplies by Agreement</td>
<td>The sum of all domestic, stock, commercial &amp; industrial licensed diversions and diversions by all Supplies by Agreement direct from streams in the Ovens River Valley, based on meter readings stored on the Database system of the responsible state agency and estimates where unmetered.</td>
</tr>
<tr>
<td>Urban Bulk Entitlements (UBE’s)</td>
<td>The sum of all diversions to supply Regulated River and Unregulated River Urban Bulk Entitlements in the Ovens River Valley obtained from Urban Water authorities.</td>
</tr>
</tbody>
</table>

**Diversion Sub-Components**

<table>
<thead>
<tr>
<th>Component</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Urban Bulk Entitlements (Regulated &amp; Unregulated River)</td>
<td>The sum of all diversions for the following urban centres: Bright, Beechworth, Glenrowan, Harrietville, Moyhu, Myrtleford, Oxley, Porepunkah, Wangaratta and Whitfield.</td>
</tr>
</tbody>
</table>
MURRAY – UPSTREAM OF HUME DAM TO NYAH

Water year: July to June

<table>
<thead>
<tr>
<th>Total Diversions = Σ (Regulated Irrigation Entitlements + Unregulated Irrigation Licences + Domestic, Stock Commercial &amp; Industrial Licences and Supplies by Agreement + Urban Bulk Entitlements)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Where:</td>
</tr>
<tr>
<td>Diversion Components</td>
</tr>
<tr>
<td>Regulated Irrigation Entitlements = The sum of all diversions to supply regulated irrigation entitlements between the Upper Murray and Nyah in the Victorian portion of the Murray River Valley based on hydrographic records, meter readings stored on the Database system of the responsible state agency and estimates where unmetered. These diversions are:</td>
</tr>
<tr>
<td>• Regulated licensed irrigation diversions from the Mitta Mitta River between Lake Dartmouth and Lake Hume, and from the Murray between Lake Hume and Nyah;</td>
</tr>
<tr>
<td>• Net Murray Valley Irrigation Area diversions;</td>
</tr>
<tr>
<td>• Net Torrumberry System diversions; and</td>
</tr>
<tr>
<td>• Diversions to Nyah Irrigation District.</td>
</tr>
<tr>
<td>Unregulated Irrigation Licences = The sum of all diversions to supply unregulated irrigation licences between the Upper Murray (including Mitta Mitta) and Nyah in the Victorian portion of the Murray River Valley, based on meter readings stored on the Database system of the responsible state agency and estimates where unmetered.</td>
</tr>
<tr>
<td>Domestic, Stock, Commercial &amp; Industrial Licences and Supplies by Agreement = The sum of all domestic, stock, commercial &amp; industrial licensed diversions and diversions by all Supplies by Agreement direct from streams between the Upper Murray and Nyah in the Victorian portion of the Murray River Valley, based on meter readings stored on the Database system of the responsible state agency and estimates where unmetered.</td>
</tr>
<tr>
<td>Urban Bulk Entitlements (UBE’s) = The sum of all diversions to supply Regulated River and Unregulated River Urban Bulk Entitlements between the Upper Murray and Nyah in the Victorian portion of the Murray River Valley obtained from Urban Water authorities.</td>
</tr>
</tbody>
</table>
**Diversion Sub-Components**

<table>
<thead>
<tr>
<th>Component</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Regulated Licensed Irrigation Diversions</strong></td>
<td>The sum of all metered and estimated Licensed Irrigation diversions recorded in the following reaches: Upstream of Hume Dam, Hume Dam to Yarrawonga, Yarrawonga to Barmah, Barmah to Torrumbarry, Torrumbarry to Little Murray Effluence, Little Murray Effluence to Nyah and Little Murray Weir (when Fishpoint Weir is open).</td>
</tr>
<tr>
<td><strong>Net Murray Valley Irrigation Area Diversions</strong></td>
<td>The sum of all net diversions (Yarrawonga Main Channel + Murray Valley 1 Pump Station - Yarrawonga Main Channel Outfall - Broken Creek Irrigation Returns as ordered by MDBC) obtained from hydrographic records and the Database system of the responsible state agency.</td>
</tr>
<tr>
<td><strong>Net Torrumbarry System Diversions</strong></td>
<td>Gross Torrumbarry System diversions – Net Torrumbarry System Returns.</td>
</tr>
</tbody>
</table>

*Where:*

<table>
<thead>
<tr>
<th>Component</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Gross Torrumbarry System Diversions</strong></td>
<td>The sum of all diversions recorded at the following locations: National Channel offtake, Ashwins Pumps, Pental Island Pumps, diversions from the Loddon River downstream of Kerang Weir, Woorinen Pump Station, Swan Hill Pumps, Swan Hill Channel 9 diversion (when Fishpoint Weir open), Lake Boga Inflow from Little Murray weir pool (when Fishpoint Weir is open) and obtained from hydrographic records and the Database system of the responsible state agency. (Note: that Gross Torrumbarry Diversions includes private licensed diversions from Little Murray Weir when Fishpoint Weir is closed)</td>
</tr>
<tr>
<td><strong>Net Torrumbarry System Returns</strong></td>
<td>Gross Torrumbarry System Returns – Torrumbarry System Tributary Inflows.</td>
</tr>
<tr>
<td><strong>Gross Torrumbarry System Returns</strong></td>
<td>The sum of flows recorded at the following locations: Gunbower Creek at Koondrook Spillway, Barr Creek downstream of pumps, Loddon River at Kerang Weir, Sheepwash Creek Spill, releases of declared unregulated flows from Gunbower Creek for environmental watering of riverine wetlands, Little Murray weir pool downstream of Little Murray Weir (when Fishpoint Weir closed), 6/7 Channel to Little Murray River (when Fishpoint Weir open) and Lake Boga outflow (when Fishpoint Weir open), obtained from hydrographic records and the Database system of the responsible state agency.</td>
</tr>
</tbody>
</table>
### Diversion Sub-Components

<table>
<thead>
<tr>
<th>Component</th>
<th>Formula</th>
</tr>
</thead>
<tbody>
<tr>
<td>Torrumbarry System Tributary Inflows</td>
<td>The maximum of either: 1) Gross Torrumbarry System Returns – Gross Torrumbarry System diversions; or 2) The sum of the tributary flows recorded at the following locations: Loddon River at Appin South, Mt Hope Creek at Mitiamo, Avoca to Little Murray, Lake Boga Outflow and Barr Creek downstream of pumps, obtained from hydrographic records and the Database system of the responsible state agency.</td>
</tr>
<tr>
<td>Nyah Irrigation District Diversions</td>
<td>The sum of all diversions pumped to the Nyah Irrigation District based on meter readings stored on the Database system of the responsible state agency.</td>
</tr>
<tr>
<td>Urban Bulk Entitlements (Regulated River)</td>
<td>The sum of all diversions for the following urban centres: Barmah, Cobram, Echuca, Koondrook, Nyah, Nyah West, Rutherglen/Wahgunyah, Swan Hill, Wodonga and Yarrawonga.</td>
</tr>
<tr>
<td>Urban Bulk Entitlements (Unregulated River)</td>
<td>The sum of all diversions for the following urban centres: Barnawartha, Bellridge, Chiltern, Corryong, Cudgewa, Dartmouth, Ebden, Tallangatta, and Walwa.</td>
</tr>
</tbody>
</table>
# MURRAY - NYAH TO SOUTH AUSTRALIAN BORDER

**Water year:** July to June

<table>
<thead>
<tr>
<th>Total Diversions</th>
<th>[ \sum (\text{Regulated Irrigation Entitlements} + \text{Unregulated Irrigation Licences} + \text{Domestic, Stock, Commercial} &amp; \text{Industrial Licences and Supplies by Agreement} + \text{Urban Bulk Entitlements}) ]</th>
</tr>
</thead>
</table>

**Where:**

### Diversion Components

<table>
<thead>
<tr>
<th>Component</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Regulated Irrigation Entitlements</strong></td>
<td>The sum of all diversions to supply regulated irrigation entitlements between Nyah and the South Australian Border in the Victorian portion of the Murray River Valley, based on hydrographic records, meter readings stored on the Database system of the responsible state agency and estimates where unmetered. These diversions are:</td>
</tr>
<tr>
<td></td>
<td>• Regulated licensed irrigation diversions between Nyah and the South Australian Border in the Victorian portion of the Murray River Valley including the Lindsay River anabranch;</td>
</tr>
<tr>
<td></td>
<td>• Diversions to Robinvale Irrigation District;</td>
</tr>
<tr>
<td></td>
<td>• Diversions to Red Cliffs Irrigation District;</td>
</tr>
<tr>
<td></td>
<td>• Diversions to Merbein Irrigation District; and</td>
</tr>
<tr>
<td></td>
<td>• Diversions to First Mildura Irrigation Trust.</td>
</tr>
<tr>
<td><strong>Unregulated Irrigation Licences</strong></td>
<td>The sum of all diversions to supply unregulated irrigation licences between Nyah and the South Australian Border in the Victorian portion of the Murray River Valley, based on meter readings stored on the Database system of the responsible state agency and estimates where unmetered.</td>
</tr>
<tr>
<td><strong>Domestic, Stock, Commercial, &amp; Industrial Licences and Supplies by Agreement</strong></td>
<td>The sum of all domestic, stock, commercial &amp; industrial licensed diversions and diversions by all Supplies by Agreement direct from streams (including Milawa Rural District and the Northern Mallee Pipeline) between Nyah and the South Australian Border in the Victorian portion of the Murray River Valley, based on meter readings stored on the Database system of the responsible state agency, and estimates where unmetered.</td>
</tr>
<tr>
<td><strong>Urban Bulk Entitlements (UBE’s)</strong></td>
<td>The sum of all diversions to supply Regulated River and Unregulated River Urban Bulk Entitlements between Nyah and the South Australian Border in the Victorian portion of the Murray River Valley obtained from Urban Water authorities.</td>
</tr>
</tbody>
</table>

### Diversion Sub-Components

<table>
<thead>
<tr>
<th>Component</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Urban Bulk Entitlements (Regulated &amp; Unregulated River)</strong></td>
<td>The sum of all diversions for the following urban centres: Mildura / Irymple / Merbein, Piangil, Red Cliffs and Robinvale.</td>
</tr>
</tbody>
</table>
TOTAL MURRAY – VICTORIA

Water year: July to June

| Total Diversions = Σ (Irrigation Entitlements + Domestic, Stock Commercial & Industrial Licences, Supplies by Agreement and Urban Bulk Entitlements) |

NB: This is the sum of all diversions identified in the previous sections.

Where:

**Diversion Components**

| Irrigation Entitlements = The sum of all diversions to supply Regulated and Unregulated Irrigation entitlements between the Upper Murray and the South Australian Border in the Victorian portion of the Murray River Valley. |
| Domestic, Stock Commercial & Industrial Licences, Supplies by Agreement and Urban Bulk Entitlements = The sum of all diversions to supply Domestic, Stock Commercial & Industrial Licences, Supplies by Agreement and Urban Bulk Entitlements between the Upper Murray and the South Australian Border in the Victorian portion of the Murray River Valley. |
### GLOSSARY

<table>
<thead>
<tr>
<th>Term</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>ACTEW</td>
<td>Australian Capital Territory Electricity &amp; Water Corporation Ltd</td>
</tr>
<tr>
<td>anabranch</td>
<td>A diverging branch of a river which re-enters the main stream</td>
</tr>
<tr>
<td>announced allocation</td>
<td>The percentage of water entitlement declared available for diversion from a regulated water course in a season</td>
</tr>
<tr>
<td>Annual allocation</td>
<td>The annual volume of water available for diversion from a regulated water course by an entitlement holder</td>
</tr>
<tr>
<td>authorised use</td>
<td>Total of the water allocated in the valley plus off-allocation and water harvesting use plus unregulated stream use not in allocation and system losses not in allocation</td>
</tr>
<tr>
<td>bulk entitlement (BE)</td>
<td>A perpetual entitlement to water granted to water authorities by the Crown of Victoria under the Water Act 1989</td>
</tr>
<tr>
<td>conjunctive domestic &amp; stock diversions</td>
<td>The domestic and stock diversion component of a regulated irrigation license</td>
</tr>
<tr>
<td>diversion</td>
<td>Diversions are all forms of consumptive water use which may affect surface water flows.</td>
</tr>
<tr>
<td>diversion licence</td>
<td>specified licences issued for a specified annual volume of water and diversion rate</td>
</tr>
<tr>
<td>end-of-valley flows</td>
<td>The flow regime at the end of a valley</td>
</tr>
<tr>
<td>Floodplain harvesting or floodplain diversion</td>
<td>The term used in NSW for a component of land-surface diversions to refer to the diversions from the floodplain (extending to 1 in 100 year flood line) of the water that originated as overflow from the main channel or from upstream floodplain</td>
</tr>
<tr>
<td>FMIT</td>
<td>First Mildura Irrigation Trust</td>
</tr>
<tr>
<td>GMW</td>
<td>Goulburn-Murray Rural Water Authority</td>
</tr>
<tr>
<td>GR</td>
<td>Grid Reference</td>
</tr>
<tr>
<td>gravity districts</td>
<td>districts which use gravity to divert the flow of water from the river</td>
</tr>
<tr>
<td>high security entitlement</td>
<td>An entitlement which does not vary from year to year and is expected to be available in all but the worst droughts</td>
</tr>
<tr>
<td>IAG</td>
<td>Independent Audit Group for the Cap</td>
</tr>
<tr>
<td>Irrigation</td>
<td>Supplying land or crop with water by means of streams, channels or pipes</td>
</tr>
<tr>
<td>Land surface</td>
<td>Any location away from the bed and banks of a watercourse or a lake/billabong. This includes areas where runoff or overland flows could be ponding or flowing (comprising both designated floodplains and upland areas);</td>
</tr>
<tr>
<td>Land-surface diversions</td>
<td>All forms of surface water diversions for the purpose of consumptive use, that occur from beyond the beds and banks of surface water courses,(eg rivers, lakes, billabongs). Floodplain harvesting, overland flow take, overland flow harvesting, rainfall runoff harvesting, interception by hillside farms dams or by commercial tree plantations are different components of land-surface diversions</td>
</tr>
<tr>
<td>MDBC</td>
<td>Murray-Darling Basin Commission</td>
</tr>
<tr>
<td>MDBMC</td>
<td>Murray-Darling Basin Ministerial Council</td>
</tr>
<tr>
<td>Term</td>
<td>Description</td>
</tr>
<tr>
<td>------------------------------------------</td>
<td>-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Overland flow harvesting</td>
<td>The term used in NSW for a component of land-surface diversions to refer to the diversions from land surfaces located beyond 1 in 100 year flood line</td>
</tr>
<tr>
<td>Overland flow take</td>
<td>The term used in Queensland to refer to the diversion of water that runs across the land after rainfall, either before it enters a watercourse, after it leaves a watercourse as floodwater, or after it rises to the surface naturally from underground. This is very close to the term land-surface diversions that refers to all surface water diversions for consumptive purposes, which occur outside the beds and banks of surface water sources (eg rivers, lakes, billabongs).</td>
</tr>
<tr>
<td>Private diverters</td>
<td>Licensed to operate privately owned water pumps or diversion channels; includes river pumpers and diverters as well as town water supplies</td>
</tr>
<tr>
<td>Rainfall Run-off harvesting or rainfall harvesting</td>
<td>The term used in NSW for a component of land-surface diversions to refer to diversions or interception of rainfall run-off from the areas that have been developed for irrigation</td>
</tr>
<tr>
<td>Regulated diversions</td>
<td>Diversions from a regulated stream or waterway</td>
</tr>
<tr>
<td>regulated streams/waterways</td>
<td>Streams and waterways where users are supplied by releases from a storage. A water licence for a regulated stream or waterway specifies a base water entitlement defining the licence holder’s share of the resources from a water course</td>
</tr>
<tr>
<td>SA Water</td>
<td>South Australia Water Corporation</td>
</tr>
<tr>
<td>Sunraysia</td>
<td>Sunraysia Rural Water Authority</td>
</tr>
<tr>
<td>Tail-water</td>
<td>Excess irrigation water that may be collected and returned to the On-Farm Storages.</td>
</tr>
<tr>
<td>UBE</td>
<td>Urban Bulk Entitlement</td>
</tr>
<tr>
<td>unregulated diversions</td>
<td>Diversions from unregulated streams</td>
</tr>
<tr>
<td>unregulated streams/waterways</td>
<td>Streams and waterways that are not controlled or regulated by releases from major storages</td>
</tr>
<tr>
<td>utilisation</td>
<td>The amount of water available for diversion that is actually diverted</td>
</tr>
<tr>
<td>WRP</td>
<td>Water Resources Plan (Queensland) determines what part of the flow regime should be preserved for environmental flows, and what part can be made available for consumptive use</td>
</tr>
<tr>
<td>Watercourse diversion</td>
<td>The diversion of water for consumptive purposes from within the beds and banks of surface water courses eg rivers, lakes and billabongs</td>
</tr>
<tr>
<td>water entitlement</td>
<td>The legal right of a user to access a specified amount of water in a given period</td>
</tr>
<tr>
<td>water harvesting</td>
<td>This term is sometimes used in Queensland to refer to diversion of water from unregulated river systems This term is sometimes used in NSW to describe the combination of floodplain harvesting and rainfall runoff harvesting</td>
</tr>
</tbody>
</table>
# WATER TRANSFER INFRASTRUCTURE IN AND/OR OUT OF THE MURRAY-DARLING BASIN

## SUMMARY OF INTER-BASIN WATER TRANSFER INFRASTRUCTURE

<table>
<thead>
<tr>
<th>DIVERSION SCHEME</th>
<th>LOCATION</th>
<th>TRANSFER DIRECTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tantangara Reservoir to Lake Eucumbene</td>
<td>NSW</td>
<td>Out of the MDB</td>
</tr>
<tr>
<td>Tumut Pond Reservoir ⇔ Lake Eucumbene</td>
<td>NSW</td>
<td>In &amp; Out of the MDB</td>
</tr>
<tr>
<td>Lake Jindabyne to Geehi Reservoir</td>
<td>NSW</td>
<td>Into the MDB</td>
</tr>
<tr>
<td>Fish River Scheme to Lithgow, Blue Mountains</td>
<td>NSW</td>
<td>Out of the MDB</td>
</tr>
<tr>
<td>Moora Moora Reservoir to Brimpaen/Laharum</td>
<td>Victoria</td>
<td>Into the MDB</td>
</tr>
<tr>
<td>Lake Jindabyne to Geehi Reservoir</td>
<td>Victoria</td>
<td>Out of the MDB</td>
</tr>
<tr>
<td>Mt. Cole Reservoir to Ararat City</td>
<td>Victoria</td>
<td>Out of the MDB</td>
</tr>
<tr>
<td>First &amp; Second Wannon Creeks to Lake Bellfield</td>
<td>Victoria</td>
<td>Into the MDB</td>
</tr>
<tr>
<td>Toolondo Reservoir to Lake Taylor</td>
<td>Victoria</td>
<td>Into the MDB</td>
</tr>
<tr>
<td>Silver &amp; Wallaby Creeks to Yan Yeann Reservoir</td>
<td>Victoria</td>
<td>Out of the MDB</td>
</tr>
<tr>
<td>Newlyn Reservoir to Bacchus Marsh</td>
<td>Victoria</td>
<td>Out of the MDB</td>
</tr>
<tr>
<td>Coghlills Creek to Lake Learmonth</td>
<td>Victoria</td>
<td>Out of the MDB</td>
</tr>
<tr>
<td>Campaspe Reservoir to Woodend</td>
<td>Victoria</td>
<td>Out of the MDB</td>
</tr>
<tr>
<td>Morgan to Whyalla</td>
<td>South Australia</td>
<td>Out of the MDB</td>
</tr>
<tr>
<td>Swan Reach to Stockwell</td>
<td>South Australia</td>
<td>Out of the MDB</td>
</tr>
<tr>
<td>Mannum to Metropolitan Adelaide</td>
<td>South Australia</td>
<td>Out of the MDB</td>
</tr>
<tr>
<td>Murray Bridge to Onkaparinga</td>
<td>South Australia</td>
<td>Out of the MDB</td>
</tr>
<tr>
<td>Tailem Bend to Keith</td>
<td>South Australia</td>
<td>Out of the MDB</td>
</tr>
<tr>
<td>Perseverance Creek Dam to Toowoomba</td>
<td>Queensland</td>
<td>Into the MDB</td>
</tr>
</tbody>
</table>
APPENDIX D

MDBC’S RESPONSE TO “REQUEST FOR DATA” RECEIVED ON 20 JUNE 2007
Drew Bewsher

My responses to your request are as below. Tuesday is fine with me and Andy. If you could confirm it asap I would block it in our diaries. Also if you could let me know in advance any other information needed that could facilitate the discussions on Tuesday.

1. Model Description
   File with information to assist filling up Table 2.1 is attached.

2. Auditor’s Assessment
   I would email you an EXCEL file with data requested by Friday evening.

3. Standard Questionnaire
   The only request I am not sure of your expectations are is the Request for Data Part A. I have written the report keeping this request in mind and I was more inclined to include my responses as refer to Section *** or Table ** etc. I would try to send my response to Part A before Tuesday but can't make that promise yet.

Part B data request is completed and is attached.

4. Copy of the Software
   We had posted an installation CD with program and all data files and result files for installation on your computer a day after sending the report. Could you please confirm that you have not received the CD and we should send another one.

5. Copy of Report
   Report titled Generation of Diversion Demands for MSM*, MDB 2003 is attached. But as you would have read in my report, I have re-derived the demand equations. This report is referred to only in the context of “Trend” estimates and methodology description.

6. Register of MSM Input Files
   The emails with data received from State are stored on our database and our document storage system (TRIM). However, it is not as elaborate as requested by you ie we don't get details of location, parameter type, author, date received, date generated, origin/basis of the data etc. I am hoping that once all models are accredited, we may have to revisit Murray Cap estimates and at that Stage may be a complete documentation on the lines proposed in your email should become part of the standard practice for data exchange.

7. The Murray Daily Model
   Mention of the daily model in the report is only in the context of further improvement possible for estimating operational losses or rain rejection. I think we should keep the issue of Daily Model outside of the MSM Accreditation for Cap unless, there are serious reservations about the current model capabilities for Cap purposes. If there are any serious reservations, I would like to address them. The time frames of the Daily Model project are dependent on rate of progress by E-Water CRC so it is not possible for me to put any time frames.

8/01/2008
8. Visit to Canberra

Yes, Tuesday is fine with me.

Cheers

Pradeep Sharma
Sr. Modelling Engineer
Murray-Darling Basin Commission
GPO Box 409, Canberra, ACT 2601, Australia
Email: pradeep.sharma@mdbc.gov.au
Tel No: (02) 6279 0105
Fax No: (02) 6230 6005

Unless explicitly attributed, the opinions expressed are personal not those of the Murray-Darling Basin Commission.

-----Original Message-----
From: Drew Bewsher [mailto:drew@bewsher.com.au]
Sent: Tuesday, 19 June 2007 10:14 PM
To: Pradeep Sharma; Andy Close
Subject: MSM Cap Model Audit - Request for Further Information

Hallo Pradeep and Andy

Thanks for the report. I can see you have put a lot of work into it.

To progress the audit of the model, would you please provide the following additional information:

1. Model Description

In reporting on the audit of each cap model, I have included a standard table which summarises typical information about the model structure (and all previous models that have been audited). I have attached a copy of an earlier version of this table (ie Table 2.1) so you can see its structure. Can you assist by providing the relevant information so I can create a new column for the NSW Murray + Vic Murray + Lower Darling? (Note that you don’t need to provide the information in yellow).

2. Auditor’s Assessment

In each audit report, I’ve also prepared three graphs which look at the ability of the model to reproduce the historical diversions, amongst other things. (This usually requires me carrying out some trend adjustment to normalise these recorded diversions to 1993/94 conditions). An example of the three graphs is provided in the attachment (see Figures 7.1, 7.3 and 7.4).

To assist me in the preparation of these graphs for each of the NSW Murray, Vic Murray and Lower Darling (ie a total of nine graphs), would you please provide the following:

(A) A time series (Excel) of the following annual values from the cap model, for each water year for each of the NSW Murray, Vic Murray and Lower Darling
   a. Annual diversions predicted by the cap model. These should be the cap diversions so if I average them I should get the same long term cap diversion that you quote in the report.
   b. Combined Hume+Dartmouth+Lake Victoria+Menindee Lakes volumes at the beginning of October each year
   c. Some sort of weighted rainfall value which is indicative of annual rainfall over the irrigated areas for that year.

In summary, the file you send me should have about 100 rows and seven columns (water year, diversion for NSW Murray, diversion for Vic Murray, diversion for Lower Darling, combined storage volume, rainfall). Note that the storage volumes and rainfalls are only used to provide the climatic and storage indices quoted on Figure 7.1. The methodology you use to prepare the rainfall value doesn’t need to be too precise as it’s only a general indicator of rainfall in the irrigation areas.

8/01/2008
For those years for which you have historical diversions recorded, would you also please provide the annual historical diversions for each of the NSW Murray, Vic Murray and Lower Darling. These values should comprise exactly the same diversion components that are included in the cap model values referred to in item (A)a above. Please provide all the annual historical diversion data that is available.

3. Standard Questionnaire

Each model audit has commenced with a standard questionnaire. This questionnaire is contained in the two attached files (Word):

- Request For Data - Part A - Version 1.doc
- Request For Data - Part B - Version 1.doc

When completed, the questionnaire will be bound into the rear of the audit report. If not already done so, would you please complete this questionnaire (you may reference sections of your cap report where appropriate).

4. Copy of the Software

Would you please provide a copy of the software and the input+output data files so that the model can be run in our office to reproduce the long-term cap diversions quoted in the report, and the output files you provide.

5. Copy of Report

Could I please have a copy of the report “Generation of Diversion Demands for MSM”, MDBC 2003 referred to in Section 4.1.3 of the cap report.

6. Register of MSM Input Files

Do you have a system for recording the source/status of those files/data which originate from the jurisdictions (or those you have estimated on their behalf)? For example, location, parameter type, author, date received, date generated, origin/basis of the data, development condition assumed, period covered by data, etc. If you have such a beast could I have a copy please of the entries for the cap and target models?

7. The Murray Daily Model

There seemed to be an inference in the report that the Commission will be going to a Murray daily model at some time in the future and that this will become the new cap model. Could you provide a brief statement about this which I could use in my report? Further if you could provide details of how any deficiencies in MSM would be addressed in the new model, that would also be useful. Is there a timeline for implementation that you can tell me about?

8. Visit to Canberra

I would hope to visit your office one day next week (Tuesday?) and meet with you to go through model issues and to help me better understand what is in the model. What days next week might you (Pradeep?) be available say for a two hour session in the morning and another in the afternoon.

Any chance you could get me the above information ahead of that visit?

Regards

Drew Bewsher
Bewsher Consulting Pty Ltd
P O Box 352 Epping NSW 1710 Australia

Ph: 02 9868 1966
Fax: 02 9868 5759
Mob: 0418 473 222
Email: drew@bewsher.com.au
Web: www.bewsher.com.au

8/01/2008
The Murray-Darling Basin Commission office is now located on Levels 3 and 4, 51 Allara Street, Canberra ACT 2601. Our postal address, phone numbers and fax numbers all remain the same.

DISCLAIMER:

This message, and any attachments, is intended for the addressee(s) named and may contain confidential or privileged information. If you are not the intended recipient please immediately delete this email, and any attachments, and notify the sender. This email is subject to copyright and no part of it may be used without the express written permission of the copyright holder(s). The views expressed in this message may be those of the individual sender and are not necessarily the views of the Murray-Darling Basin Commission ("the Commission"). To the extent permitted by law the Commission does not represent or guarantee that the email and any attachments are free of errors, viruses or defects. The Commission accepts no liability for loss or damage arising from the use of this email or any attachments.
TABLE 1: TYPES OF MODEL USED TO COMPLY WITH SCHEDULE F (as agreed at WAWG Meeting on 14 August 2001)

<table>
<thead>
<tr>
<th>MODEL</th>
<th>SIMULATION PERIOD</th>
<th>WATER DEMANDS, INFRASTRUCTURE AND MANAGEMENT RULES</th>
<th>STARTING STORAGE VALUES AND OTHER INITIAL CONDITIONS</th>
<th>CLIMATIC INPUTS</th>
<th>TRIBUTARY INFLOWS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cap Model Used to determine the long term diversion cap</td>
<td>From 1891/92 to 1997/98, or supposedly a period starting earlier and/or finishing later</td>
<td>As for the 1993/94 levels of development, or other conditions agreed with the IAG/MDBC</td>
<td>Actual if available, otherwise synthetic data.</td>
<td>Recorded if available, otherwise synthetic data.</td>
<td>Inflow data adjusted to represent 93/94 levels of development on the tributary. Otherwise, recorded or synthetic data is used.</td>
</tr>
<tr>
<td>Target Model Used to determine the annual diversion targets</td>
<td>From July 1997 until the current year</td>
<td>As for the Cap Model</td>
<td>Recorded values as at beginning of July 1997</td>
<td>Recorded values</td>
<td>As for the Cap Model. Where data after the end of the cap model is required, this is derived using procedures identical to those for the Cap Model.</td>
</tr>
<tr>
<td>Calibration Model Used to calibrate model parameters so that the Cap Model replicates 1993/94 levels of development</td>
<td>From 1983/84 to 1993/94, or other period if this better represents 1993/94 conditions.</td>
<td>As for the Cap Model (or varying with time where established using a trend analysis)</td>
<td>Recorded values</td>
<td>Recorded values</td>
<td>Recorded values</td>
</tr>
</tbody>
</table>

The term “model” is used to refer to:
- software; and
- all input data, ie:
  - parameters specifying irrigation levels and management rules
  - climatic data including rainfall, evaporation, etc
  - tributary inflow data
  - initial conditions at start of simulation

It is assumed that the same software is used for the Cap, Target and Calibration Models.
### TABLE 2: SUMMARY DESCRIPTION OF MODELS USED TO COMPLY WITH SCHEDULE “F” FOR VICTORIAN MURRAY, NSW MURRAY AND LOWER DARLING VALLEYS

<table>
<thead>
<tr>
<th>MODEL</th>
<th>SIMULATION PERIOD</th>
<th>WATER DEMANDS, INFRASTRUCTURE AND MANAGEMENT RULES</th>
<th>STARTING STORAGE VALUES AND OTHER INITIAL CONDITIONS</th>
<th>CLIMATIC INPUTS</th>
<th>TRIBUTARY INFLOWS</th>
</tr>
</thead>
</table>
| Cap Model  
Used to determine the long term diversion cap | From 1891/92 to 2005/06 | 1993/94 level of development for Water demands, infrastructure and management rules | Synthetic data corresponding to total storage in the system being about 65% of full storage capacity. However, initial conditions are not an issue in the Murray and Lower Darling System as all storages spill in September 1891 due to flood flows and 1891/92 is a full allocation year. | Recorded values. Any gaps in data were filled and extended to cover the simulation period. | Inflows for 1993/94 development conditions for the tributaries where development has occurred before 1993/94. For catchments upstream of Hume - natural flow except for Snowy which take in to account Snowy operations. |
| Target Model  
Used to determine the annual diversion targets | From May 1989 to April 2006 | As for Cap Model | Recorded values as at beginning of June 1989. This is to take in to account continuous accounting which started from June 1989. | Recorded values. Any gaps in data were filled and extended to cover the simulation period. | As for Cap model. |
| Calibration Model  
Used to calibrate model parameters so that the Cap Model replicates 1993/94 levels of development | From May 1983 to April 2006 | Changing with time to reflect infrastructure and management rules at the time. | Recorded values | Recorded values | Recorded values |
APPENDIX E

COMMENTS RECEIVED FROM NSW
Drew,

Apologies for the delay in replying. Attached is a short summary of comment on the sections you have highlighted below. Please call me to discuss when you have had a chance to consider these comments.

Regards

Paul

Paul Simpson
Manager, Interstate Program Performance
Water Management Division
Department of Water and Energy
Ph. 9895 7480
Fax 9895 7756
Mob. 0414 332 380

>>> "Drew Bewsher" <drew@bewsher.com.au> 20/06/2007 13:34 >>>

To: Barry James (Vic), Paul Simpson (NSW) and Jarrod Eaton (SA)

The MSM Cap Model for the NSW Murray, Vic Murray and the Lower Darling has been referred to me for auditing. As part of the audit, the attached cap model report has been provided by the Commission office.

I presume that the report has been vetted by the Water Audit Panel before being sent on to me. Nevertheless, there are various statements in the report about State operational practices that need to be verified. Whilst I have some knowledge of water management practice along the Murray River, there are many gaps in my knowledge and I would be pleased if you would confirm that from a cap modelling perspective, there are no major flaws in the material presented in relation to your state (or elsewhere).

To assist in this task, I have prepared an index of key statements for you to refer to.

I’ll ring to discuss this with you shortly. I was hoping that I might have your reply within 5 working days as this will assist me in preparing a timely response. Will this be possible?

Thanks

Drew Bewsher
Bewsher Consulting Pty Ltd
NSW Comments for Drew Bewsher on MSM Cap calibration report

Section 2.7: Water Trading

Comment provided from NSW to MDBC on draft report:

“NSW does not agree that inter-valley trade should be set to zero for the Cap scenario, as described on p.11. This has been discussed at WAP meetings previously, and a paper was presented by NSW outlining an analysis which suggests that the major reason why trade was so low until 1994/95 was the very wet climate and high allocation levels observed at that time. It is recognized that there are practical difficulties in simulation of such activities, and there is a need to ensure all Cap models (Bidgee, Murray and Lower Darling) are consistent in their approach to this. Maybe this could be recognised as an issue and included as a recommendation for future work.”

(Paper presented at Wollongong Hydrology Symposium on inter-valley trade also attached)

Drainage Flows

Not clear why Box Creek drain at Conargo is included in the MSM inputs list (Table 6), as this is a drain into the Forest Creek (part of the Yanco-Billabong Creek system) in the Murrumbidgee Valley?

NSW Allocations

The estimated inflow until the end of May at specified risk level. NSW uses minimum flows and Victoria till 2002/03 season was using 99%ile inflow from any month of the current season to the end of the following irrigation season in May. However, since 2002/03, “Recession Inflow” from the current flow are being used instead of 99%ile to avoid any business risk mainly during sub-water right allocation periods; In the MSM set up for the Cap condition, expected inflows are computed using serially correlated minimum flows until the end of November and minimums for the rest of the water year.

MIL Loss/Conveyance Entitlements

The entitlements in the report in Table 7 and Table 26 are at odds. Below is the advice provided by NSW to the MDBC:

“There was no formal Conveyance entitlement for irrigation channel systems in 1993/94, and an allowance was set aside by the State to manage such losses. This allowance varied from 200 GL at 40% GS allocations, to 290 GL at 100% GS allocations. GS allocations below 40% at that time were unknown, and the allowance for MIL losses remained undefined at those levels. It seems likely that NSW would have used an allowance of 150 GL at 0% GS allocation (as we do now), had the appropriate circumstances arisen prior to 1993/94.”
Barma-Millewa Forest EWA
Only 20 GL???

Tandou Water Availability
There has been some debate about whether Tandou diversions have grown since 1993/94. The discussion in the last paragraph of p53 is critical to this. NSW has some concern that the Cap model includes neither the “ad-hoc” allocations to Tandou from the NSW 125 GL entitlement, nor the increased inter-valley trade (estimated by the MDBC at approximately 6 GL/year) that is likely to have replaced it from 1994 onwards.

Menindee Target Storage Volumes
As mentioned in the text of the report, the target storage volumes are not always followed. A good example of this is in Table 23, which requires that Pamamaroo be filled to over 200 GL of capacity whilst keeping Wetherell empty.
APPENDIX F

COMMENTS RECEIVED FROM VICTORIA
From: Barry.James@dse.vic.gov.au
Sent: Tuesday, 17 July 2007 6:30 PM
To: Drew Bewsher
Cc: Seker.Mariyapillai@dse.vic.gov.au
Subject: Update on MSM Cap Model Audit - State Water Management Practice

Attachments: Statements About State Water Management Practices - Vic comments.doc

Drew

There are 2 outstanding issues that I hope to resolve tomorrow. I will then send you our final comments. To let you know where we are up to, the attached file contains our comments with the 2 outstanding issues in red text.

regards
Barry James

Water Resource Policy,  
Office of Water,  
Department of Sustainability and Environment 
Level 10, 8 Nicholson St. East Melbourne 3002
Ph. +61-3-96379980 Fax +61-3-96378119
Email Barry.James@dse.vic.gov.au

"Drew Bewsher" <drew@bewsher.com.au>
16/07/2007 12:49 PM
To <Barry.James@dse.vic.gov.au>
cc Subject RE: MSM Cap Model Audit - State Water Management Practice

Hi Barry

Just wondering how your response to this is going? Any chance I could have it today or by noon tomorrow?

Drew

---------------------------------------------------------------------
--------------------------------------------
From: Drew Bewsher [mailto:drew@bewsher.com.au] On Behalf Of Drew Bewsher
Sent: Wednesday, 20 June 2007 1:29 PM
To: Barry.James@dse.vic.gov.au; Paul Simpson; Eaton.Jarrod@saugov.sa.gov.au
Subject: MSM Cap Model Audit - State Water Management Practice

To: Barry James (Vic), Paul Simpson (NSW) and Jarrod Eaton (SA)

The MSM Cap Model for the NSW Murray, Vic Murray and the Lower Darling has been referred to me for auditing. As part of the audit, the attached cap model report has been provided by the Commission office.

I presume that the report has been vetted by the Water Audit Panel before being sent on to me. Nevertheless, there are various statements in the report about State operational practices that need to be verified. Whilst I have some knowledge of water management practice along the Murray River, there are many gaps in my knowledge
and I would be pleased if you would confirm that from a cap modelling perspective, there are no major flaws in the material presented in relation to your state (or elsewhere).

To assist in this task, I have prepared an index of key statements for you to refer to.

I’ll ring to discuss this with you shortly. I was hoping that I might have your reply within 5 working days as this will assist me in preparing a timely response. Will this be possible?

Thanks

Drew Bewsher
Bewsher Consulting Pty Ltd
P O Box 352 Epping NSW 1710 Australia
Ph: 02 9868 1966
Fax: 02 9868 5759
Mob: 0418 473 222
Email: drew@bewsher.com.au
Web: www.bewsher.com.au

<M
<table>
<thead>
<tr>
<th>TOPIC</th>
<th>REPORT SECTION</th>
<th>REPORT PAGE</th>
<th>REFERRED FOR COMMENT TO</th>
<th>VICTORIAN COMMENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Snowy Scheme Operation</td>
<td>2.4</td>
<td>7 &amp; 8</td>
<td>Y</td>
<td></td>
</tr>
<tr>
<td>Water Trading</td>
<td>2.7 &amp; 3.4.5</td>
<td>10 &amp; 27</td>
<td>Y</td>
<td></td>
</tr>
<tr>
<td>Daily Tributary Inflow File</td>
<td>3.3</td>
<td>17</td>
<td>Y</td>
<td></td>
</tr>
<tr>
<td>Unregulated Catchment Flow File</td>
<td>3.3</td>
<td>17 &amp; 18</td>
<td>Y</td>
<td></td>
</tr>
<tr>
<td>Daily Drainage Flow File</td>
<td>3.3</td>
<td>20 &amp; 21</td>
<td>Y</td>
<td></td>
</tr>
<tr>
<td>Resource Assessment</td>
<td>3.4 &amp; 3.5.8 &amp;</td>
<td>22-25 &amp; 61-</td>
<td>Y Y Y</td>
<td></td>
</tr>
<tr>
<td>Special Accounting</td>
<td>3.4.4</td>
<td>26 &amp; 27</td>
<td>Y Y</td>
<td></td>
</tr>
<tr>
<td>SA Entitlements</td>
<td>3.4.6</td>
<td>27 &amp; 28</td>
<td>Y</td>
<td></td>
</tr>
<tr>
<td>Operation of Storages</td>
<td>3.4.7</td>
<td>28-31</td>
<td>Y Y Y</td>
<td></td>
</tr>
<tr>
<td>Menindee Lakes Operation</td>
<td>3.4.8</td>
<td>31</td>
<td>Y</td>
<td></td>
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<tr>
<td>Barmah Millewa Forests</td>
<td>3.4.10 &amp; 5.5.4</td>
<td>32 &amp; 59</td>
<td>Y Y</td>
<td></td>
</tr>
<tr>
<td>Lower Darling Demands</td>
<td>3.4.11</td>
<td>32-34</td>
<td>Y</td>
<td></td>
</tr>
<tr>
<td>Murray Irrigation Demands and</td>
<td>4.3.3</td>
<td>44</td>
<td>Y</td>
<td></td>
</tr>
<tr>
<td>Measurement Accuracy</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Losses in the Barmah Millewa Forest</td>
<td>Figure 6</td>
<td>46</td>
<td>Y Y</td>
<td></td>
</tr>
<tr>
<td>Tandou and Anabranch Operation</td>
<td>4.6.2 &amp; 5.5.7</td>
<td>53, 54 &amp; 61</td>
<td>Y</td>
<td></td>
</tr>
<tr>
<td>Menindee Lakes Parameters</td>
<td>5.5.1</td>
<td>58</td>
<td>Y</td>
<td></td>
</tr>
<tr>
<td>Lake Victoria Operation</td>
<td>5.5.2</td>
<td>58</td>
<td>Y</td>
<td></td>
</tr>
</tbody>
</table>

These are complex rules which are described in detail in other references such as Snowy Water Licence. However, the report provides an adequate interpretation for the purposes of Cap modelling.

Note that in 1993/4 Victorian entitlements included an ability to take off-quota water in times of declared surplus flow. This has since been replaced with an advance water arrangement.

The material presented is adequate.

The material presented is adequate.

The material presented is adequate.

The material presented is adequate.

Table 10: 2nd Column: Yarrawonga Channel Capacity seems too high. It should be about 96 GL/month not 425 GL/month as stated.

It is unclear which lake is filled last and emptied first. Lake Wetherell see p31 or Menindee/Cawndilla Lake see p58

Fig6: The shape of the curve which produces a small negative loss (gain) for flow rates around 1000 GL/month is strange. If there is a physical explanation it should be documented.
<table>
<thead>
<tr>
<th>Minimum Flows</th>
<th>5.5.3 &amp; Table 25</th>
<th>59 &amp; 60</th>
<th>Y</th>
<th>Y</th>
<th>The material presented is adequate.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Audit Run</td>
<td>6.3 &amp; Table 31</td>
<td>68 &amp; 69</td>
<td>Y</td>
<td>Y</td>
<td>Table 31: Column 1 Title should be “Year <strong>Starting</strong> June” not ending June</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td><strong>Outstanding issue:</strong> The long term average Cap increased after model recalibration but the cumulative Cap credits have reduced significantly (ie 600 GL less). We need to understand the changes to the model configuration since last update to understand the reasons for the change.</td>
</tr>
<tr>
<td>Tributary Data</td>
<td>Appendix B</td>
<td>81-90</td>
<td>Y</td>
<td>Y</td>
<td>The material presented is adequate.</td>
</tr>
<tr>
<td>Drains Data</td>
<td>Appendix C</td>
<td>91-92</td>
<td>Y</td>
<td>Y</td>
<td>The material presented is adequate.</td>
</tr>
<tr>
<td>History of Changes in Operational Practices</td>
<td>Appendix E</td>
<td>98-114</td>
<td>Y</td>
<td>Y</td>
<td>The material presented is adequate.</td>
</tr>
<tr>
<td>Diversion Definitions and MSM Output</td>
<td>Appendix K</td>
<td>159-162</td>
<td>Y</td>
<td>Y</td>
<td>The material presented is adequate.</td>
</tr>
<tr>
<td>Other Comments</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td><strong>Outstanding issue:</strong> Appendix L: MSM Parameters a) P 171, The table of Victorian entitlements and loss allowances are mostly from the Murray Bulk Entitlements in 2000 but Murray Valley &amp; Torrumbarry losses and utilisation factors have been adjusted to make the resulting curve match the one used in 1993/94. We are a little concerned that the actual numbers do not apply to 1993/94 but realise that the resulting allocation curve is the important final “parameter” used by the model. We are waiting on additional information from Pradeep to verify that the curve does match the curve used in 1993/94.</td>
</tr>
</tbody>
</table>