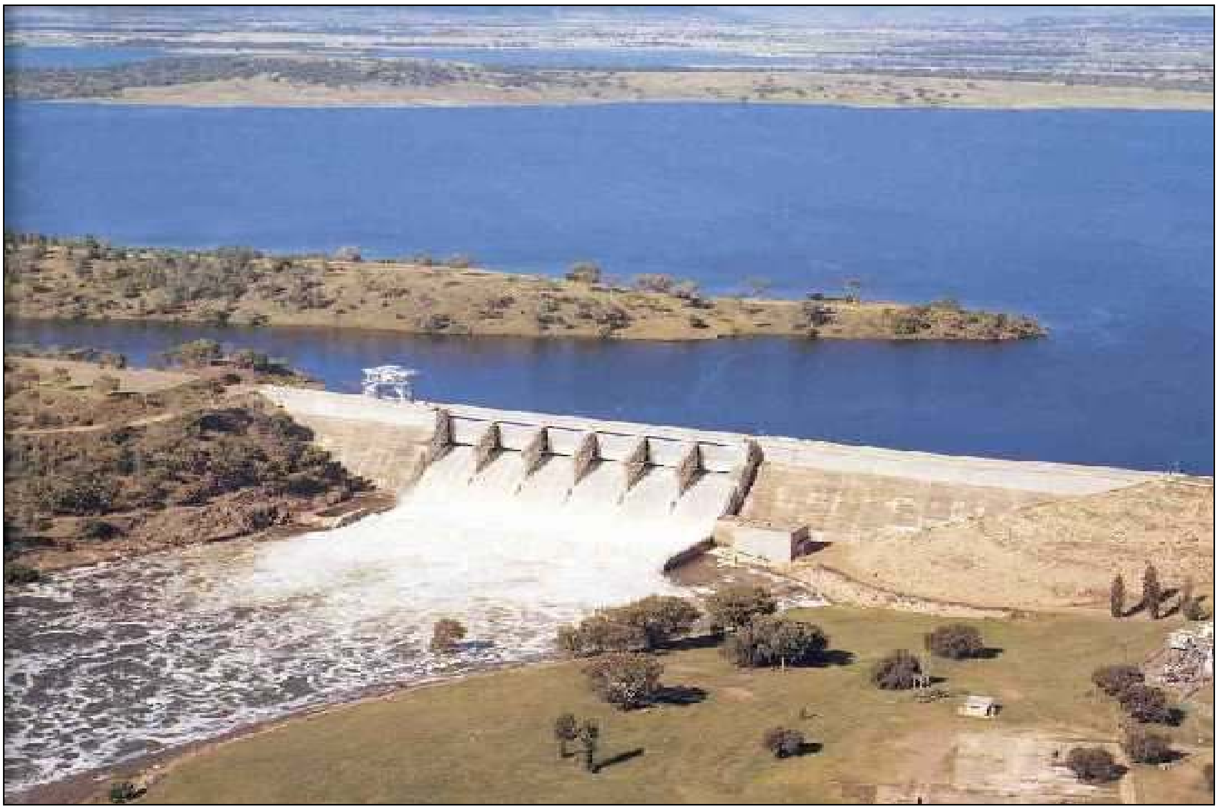
Department of
Infrastructure, Planning and Natural Resources

Namoi River Valley



IQQM Cap Implementation Summary Report

Issue: Final

March 2005

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Chris Ribbons
Andrew Brown
Shahadat Chowdhury

Project conducted in collaboration with Water Management Division and the Barwon Region

Advice and Comments

Geoff Podger	– Principal Scientists Unit
Robert O'Neill	– Surface and Groundwater Processes Unit
Daren Barma	– Water Management Division
Paul Simpson	– Water Management Division
Derek Everson	– Water Management Division
Peter Christmas	– Regional Operations

Acknowledgments

The authors wish to thank past and present staff in the DIPNR's:
Surface and Groundwater Processes Unit, Hydrographic Section,
River Operations Section, Licensing Section and Policy Section.

Published by:
Surface and Groundwater Processes Unit
Centre for Natural Resources
New South Wales Department of Infrastructure Planning & Natural Resources
Parramatta

March 2005

ISBN
CNR2003.072

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Executive Summary

What has initiated the work?

The Murray Darling Basin Ministerial Council Cap required that NSW develop a suitable planning tool to enable review of water use and sharing arrangements in the Namoi River Valley. The tool accepted as suitable for the purpose is a calibrated water balance model that includes all relevant important features on and in the system. Such a model is called an Integrated Quantity Quality Model or IQQM for short.

Scope of this report summarises the Namoi –IQQM status

This report summarises and documents the IQQM calibration and model use for provisional Cap runs

Purpose is to prove model suitability as a Cap estimation tool and present Cap modelling results

The primary purpose of this IQQM summary report is to that the developed of the Namoi IQQM includes all of the important features in the system, and closely replicates records of flow and water extraction behaviour. The secondary purpose is to demonstrate that the model can be successfully used to determine long term diversions under 1993/94 Cap conditions as well as auditing diversions under Schedule F of the Murray Darling Basin Agreement.

Model construction includes all important features

Chapter 2 describes the main physical and management features included in the model. The availability and extent of time series data is also described in this chapter, as well as decisions on the number, type and arrangement of the nodes and links used to construct the Namoi Valley IQQM.

Calibration and validation over the 1983-1998 period demonstrates model suitability

Chapter 3 describes the model calibration and validation results. Comparison is made between time series observed data and time series model simulated data. Quality ratings were applied to the model calibration. The modelled water diversions were generally a close match to the observed water diversions. Model end-of-system flows were of an "adequate" quality for comparison of alternate management options. Model storage behaviour had a "high" quality rating. Overall, the model achieved a "high" quality rating, demonstrating the model's suitability for the intended purposes.

Statement of model adequacy for comparing management options

The Namoi River Valley IQQM can now be accepted as calibrated and validated to a satisfactory degree. The model is suitably robust for 100+ year scenario running and for comparison of impacts from alternative management scenarios.

1993/94 Cap scenario run

In Chapter 4 the newly upgraded model was used to carry out a 1993/94 Cap scenario run. This involved fixing development conditions in the model to 1993/94 planted areas and licence volumes, configuring appropriate operating rules, and running the model for the 100+ year period from 1892 to 2002 inclusive. The results show NSW not to be in breach of the Cap over both the short and longer term for the current level of development.

1999/00 Development Scenario run	Chapter 5 outlines the 1999/00 development condition model that NSW has developed to test current strategies needed to manage Cap conditions. The results show both the 1998 Environmental Flow Rules and the proposed Water Sharing Plan will keep Namoi Valley diversions below the Cap at 1999/00 levels of development.
Improvements	Chapter 6 lists a series of potential short and long term model improvements that have been identified.
Submission of report to MDBC for Auditing	This report is submitted to the MDBC for auditing under Schedule F of the Murray Darling Agreement. A preliminary draft report was submitted and reviewed independently. Several comments and improvements resulting from the independent review have been incorporated in this final report.

Glossary of Terms

Allocation Level – Allocation level or announced allocation is the percentage of the licensed entitlement volume that general security irrigators can divert in the current water year during on allocation periods. The first allocation level for the forthcoming irrigation season is announced at the beginning of water year and is not reduced from this announcement, noting however that it can be increased. NSW announce increased allocation levels from time to time during the irrigation season.

Allocation Sub-system – Allocation sub-system is a number of river sections that represents a group of water users who are all treated the same in terms of determining allocation levels.

Allocation System – An allocation system is a group of allocation sub-systems that have the same announced allocation announcement. The allocation level for an allocation system is defined as the minimum of the allocation levels for all the allocation sub-systems under it. This applies when irrigator groups have access to only one dam's resources but their announced allocation level is determined by another dam's resource criteria.

Cap – The Murray Darling Basin Ministerial Council Cap on extractions for consumptive users at the level that would have occurred under 1993/94 development levels and management rules.

Cap Scenario – An IQQM that has been configured for the long-term simulation of 1993/94 development conditions and management rules.

Cap Audit Scenario – An IQQM that has been configured for the simulation of 1993/94 development conditions and management rules. The model commences simulation in 1997/98 and provides estimates of the annual water diversions that would have occurred under Cap (1993/94) development conditions.

Coefficient of Determination – A statistical term that describes the degree of correlation between two data sets (usually observed and simulated data points). Its value is always expressed as a decimal less than 1.0, such that the closer its value is to 1.0, the better the correlation. The symbol $\mathbf{r^2}$ is often used to represent the coefficient of determination.

DIPNR – NSW Department of Infrastructure Planning and Natural Resources.

DLWC – Department of Land and Water Conservation (replaced by DIPNR in 2003).

d/s – Downstream.

ECA – Environmental Contingency Allowance; a volume of water set aside in storage for environmental purposes.

Farmer's Risk – See irrigator behaviour.

FPH - Flood Plain Harvesting is water obtained by pumping or direct inflows of water off the flood plain. This water has not been monitored to date, and is generally considered to be that water which fills spare capacity in an on farm storage, but not via on allocation or off allocation diversions. Conceptually flood plain harvested water includes water:

- Pumped from the floodplain to the on farm storage (ie during large floods), using secondary lift pumps which are not metered.
- Entering the on farm storage because flood levels spill directly into the on farm storage.

General Security Licences – Licences that are supplied with water after high security licence needs are fully satisfied. These licences cover the great majority of irrigation licences both in terms of number and annual entitlements. In an annual accounting system announced allocations are made each year to indicate the percentage of annual licence entitlement volume that can be supplied. A annual accounting system was in place for the Namoi Valley under the 1993/94 Cap scenario.

High Security Licences – Licenses that provide the highest reliability of water supply. Generally these licences are for (relatively) small amounts of water for town water supplies and permanent plantings (orchards, vineyards etc). In announcing allocation entitlements high security licences are fully satisfied prior to any allocation for general security licences.

Hot-start – To configure the model with the correct boundary or initial conditions (ie, river flows, storage volumes, soil moisture levels and releases for water orders), the model is started several weeks before the commencement of the analysis period. The purpose of this is to minimise the effect of initial assumptions on results produced by short term scenario runs.

Irrigator Behaviour (also called farmer's risk) – This relates to the irrigator's decision making process when deciding on the amount of area to plant. For example, given a drought period with dry antecedent climatic conditions, low on farm storage volume, and low announced allocation, an irrigator who plants the same area as in wet years (ie years when storages are full) is taking a higher than previous risk. That is, there is an increased likelihood that the irrigator will run out of water supplies unless additional streamflows or rainfall occurs.

Licensed Entitlement Volume – The volume of water that a licence holder on a regulated stream/river can draw on during a 100% allocation announcement. The amount drawn may be subject to other licence conditions.

Link – The stretch of river in the model between two nodes. This may or may not represent a real length, noting that a link can be used to separate two processes at the same location.

MDBC – Murray Darling Basin Commission, a joint interstate/federal commission with responsibility for managing the operation of the Murray River system and coordinating water management issues in the Murray Darling Basin.

MDBMC – Murray Darling Basin Ministerial Council, a body composed of the relevant state and federal ministers which oversees the management of the Murray Darling Basin Commission.

ML/d – The units used to express rate of flow, in terms of megalitres (ie millions of litres) per day.

Node – A model node is used to represent a point on a river system where certain processes occur. The node type identifies the rules and parameters that are used by the model to simulate the relevant processes at a given location.

OFA - Off Allocation extraction is the volume of water extracted by the irrigator during an off allocation period.

Off Allocation Period – A period when the river flow is in excess of the anticipated demands of the downstream users by a specified amount. The announcement of off-allocation periods may be subject to a number of other conditions such as equity, ease of access or environmental requirements. The amount of water drawn during off-allocation periods is not debited from the allocated portion of the irrigator's water entitlement for the water year.

OFS – On Farm Storage, usually referring to a large private storage constructed on an irrigator's property to store water.

ONA - On Allocation extraction is water diverted by the irrigator from regulated flows to satisfy the irrigator's crop needs or future management needs, debited against the announced allocation volume (ie allocation level times licensed volume entitlement) of the irrigator. The water supplied to the irrigator may be directly released from the dam release or by d/s tributaries, or by a combination of both.

Pump capacity – The maximum extraction rate for an irrigation node (ML/d).

Rainfall-runoff model - (see Sacramento model)

Rainfall harvesting – Is water obtained from local rainfall runoff on the land holders property that is caught and diverted into on farm storage filling. Existing water recycling systems are usually expanded to catch runoff from the planted and/or developed area of a property.

Reach – A defined length of river.

Regulated River – The section of river that is downstream from a major flow regulation storage that supplies water to irrigators.

Residual Catchment – This is an ungauged catchment existing between known upstream and downstream river gauges. It can include ungauged creeks or rivers as well as areas of land adjacent to the main streams between the gauges. The outflow from this catchment is simulated in the model as the difference between the flow of upstream and downstream gauges taking into consideration river losses and diversions.

Resource Assessment – The process of calculating announced allocation levels based on the current and predicted water resource availability and water requirements of all water users.

River Section – see river *Reach*.

Sacramento Model – A rainfall-runoff model used to estimate long term streamflows at gauging stations where there are short period of records or gaps in the flow data. The model tries to represent the physical processes that impact on runoff and it uses local rainfall and evaporation data as well as catchment details. The model was developed by *Burnash et al (1973)*, in Sacramento California.

Storage Reserve – The amount of storage volume reserved or set aside for next year to ensure high security needs are met. The storage reserve is taken into account when calculating this year's allocation announcement.

Tributary – A stream that contributes its flow to a larger stream or water body.

Tributary utilisation – The proportion of the flow from the tributary that can be used to meet water orders.

Unregulated River – A river with no major storages by which flows could be regulated.

u/s – Upstream.

Water Year – A continuous twelve-month period starting from a specified month for water accounting purposes. In the Namoi Valley the water year commences on the 1st October and concludes on the 30th September.

1. Introduction

1.1. BACKGROUND TO IQQM

Prior to 2001 a monthly time step computer model of the Namoi Valley had been constructed, calibrated, and used to investigate various policy and water sharing initiatives. This model was used to develop the initial environmental flow rules for the Namoi in 1998.

In 1986 the first daily time step modelling software, called the WARAS model, was developed by Lyall and Macoun (consultants) and applied to the Lachlan valley. Building on the concepts in the WARAS model, DIPNR proceeded to develop a more generalised and complete modelling tool, in the form of the IQQM software. During the 1990's a large number of developments occurred in both water policy and IQQM. The MDBC cap and the river flow objectives required a much greater level of model complexity, where the short term variability of flows became increasingly more important. IQQM's have now been developed for all of the major inland regulated river systems (except the Murray River).

A full description of IQQM, including details about model structure, algorithms, processes that can be modelled and assumptions are described in the *IQQM Reference Manual (DLWC, 1995).*

1.2. AIM OF IMPLEMENTING IQQM IN THE NAMOI RIVER SYSTEM

Namoi IQQM has been implemented from the headwaters of Split Rock and Keepit Dams to the outlet of the Namoi River into the Barwon River at Walgett, and the regulated sections of the Pian /Gunidgera Creek system. A separate Peel Valley IQQM is currently being developed to estimate inflows into the Namoi River for a range of different development conditions in the Peel Valley. IQQM will provide a tool that is capable of simulating daily hydrologic processes over a 100+ year period of varying climatic conditions from 1892 to the present.

The model presented in this study only simulates the behaviour of the regulated part of the Namoi Valley. Irrigation practices in the unregulated part of the valley are not specifically modelled. However, all land use changes in a particular unregulated tributary are reflected in the gauged outflow from the tributary system.

The aims of implementing the model are:

(a) DIPNR requires a tool capable of examining a range of river basin management policies and catchment development scenarios. This includes the need to assess the impact of the options on processes such as stream flows at various locations; irrigation behaviour; allocation reliability; storage behaviour and water quality. IQQM will quantify the effects of changes in policies and development conditions on all of the above processes by comparing the results from various scenarios.

(b) Under the Murray Darling Basin Ministerial Council Cap, DIPNR is required to audit and assess compliance of the Cap with modelling tool. The Namoi IQQM will be the tool used by DIPNR to audit Cap compliance in the Namoi Valley.

1.3. STATUS OF IQQM IMPLEMENTATION

The development and use of the Namoi IQQM has covered the following main steps:

- Build and calibrate the IQQM.
- Establish the 1993/94 development condition baseline model run for MDBC CAP.
- Establish 1999/00 development conditions
- Examine 1998 Environmental Flow Rules and proposed Water Sharing Plan Rules.
- Define and compare alternative future management option proposals.

All model calibration, validation, 1993/94 development and 1999/00 development steps have now been completed and documented in this report.

1.4. AIM AND OBJECTIVE OF THIS REPORT

The aim of this report is to summarise the main findings and conclusions of the model calibration and development of the Cap scenario. Preparation of this report is a requirement of Schedule F of the Murray Darling Basin Agreement.

1.5. SCOPE OF THIS REPORT

The scope of work covered in this report includes:

- Building the system model (Chapter 2).
- Calibrating IQQM (Chapter 3).
- Establishing an agreed Cap (1993/94) development run (Chapter 4).
- Establish a 1999/00 development run with current management conditions (Chapter 5)
- Outlining model improvements (Chapter 6).
- Outlining climatic and streamflow stations (Appendix A).
- Outlining model configuration (Appendix B)
- Node link diagram (Appendix C)
- Outlining irrigator planting decision (Appendix D)
- Describing quality assessment guidelines (Appendix E)
- Outlining 1993/94 Cap development conditions and management rules (Appendix F)
- Outlining 1999/00 development conditions and management rules (Appendix G)

1.6. QUALITY ASSESSMENT SYSTEM

Sets of quality assessment guidelines (Appendix E) have been used to evaluate and report on the model's calibration against observed data. There are five categories of quality assessment:

- Very high confidence;
- High confidence;
- Moderate confidence;
- Low confidence; and
- Very low confidence.

2. The Namoi River Valley

2.1. CATCHMENT DESCRIPTION

The Namoi Valley is shown in Figure 2.1. The Namoi River Valley, located in north western NSW, occupies around 43,000 km^2 or about 5% of NSW. The eastern part of the catchment has higher elevations of around 1200 m near the headwaters of the McDonald River and contributes most of the flow to the river via the Peel, McDonald, and Manilla Rivers. About 75% of the valley is flat, having slopes less than 3 degrees.

Since the early 1960s, irrigation activities have increased rapidly and according to recent data, some 75,000 ha is currently used for planting crops such as cotton, cereals, and oilseeds. Most of the summer crops (cotton) need irrigation, whereas the winter crops generally get most of their required moisture from rain.

The regulated Namoi River system is dominated by major irrigation developments in the area around Wee Waa. DIPNR operational management defines Keepit Dam as the main reservoir in the Namoi River System. Split Rock Dam is operated to supply all requirements as far as Keepit Dam, then Keepit Dam is operated to supply all requirements downstream to the Barwon River junction near Walgett. In case of low Keepit Dam storage levels, transfers are made from Split Rock Dam to Keepit Dam to meet projected demands.

The major diversion weirs are Mollee Weir located downstream from Narrabri and Gunidgera Weir located at Wee Waa. Mollee Weir is operated as a re-regulating structure and Gunidgera Weir provides head for diverting water into the Pian & Gunidgera Creek effluent system. The operation of Mollee Weir is simulated in the model, however Gunidgera Weir is not. Table 2.1 summarises the capacities of the major storages.

Figure 2.1: Namoi Valley boundary

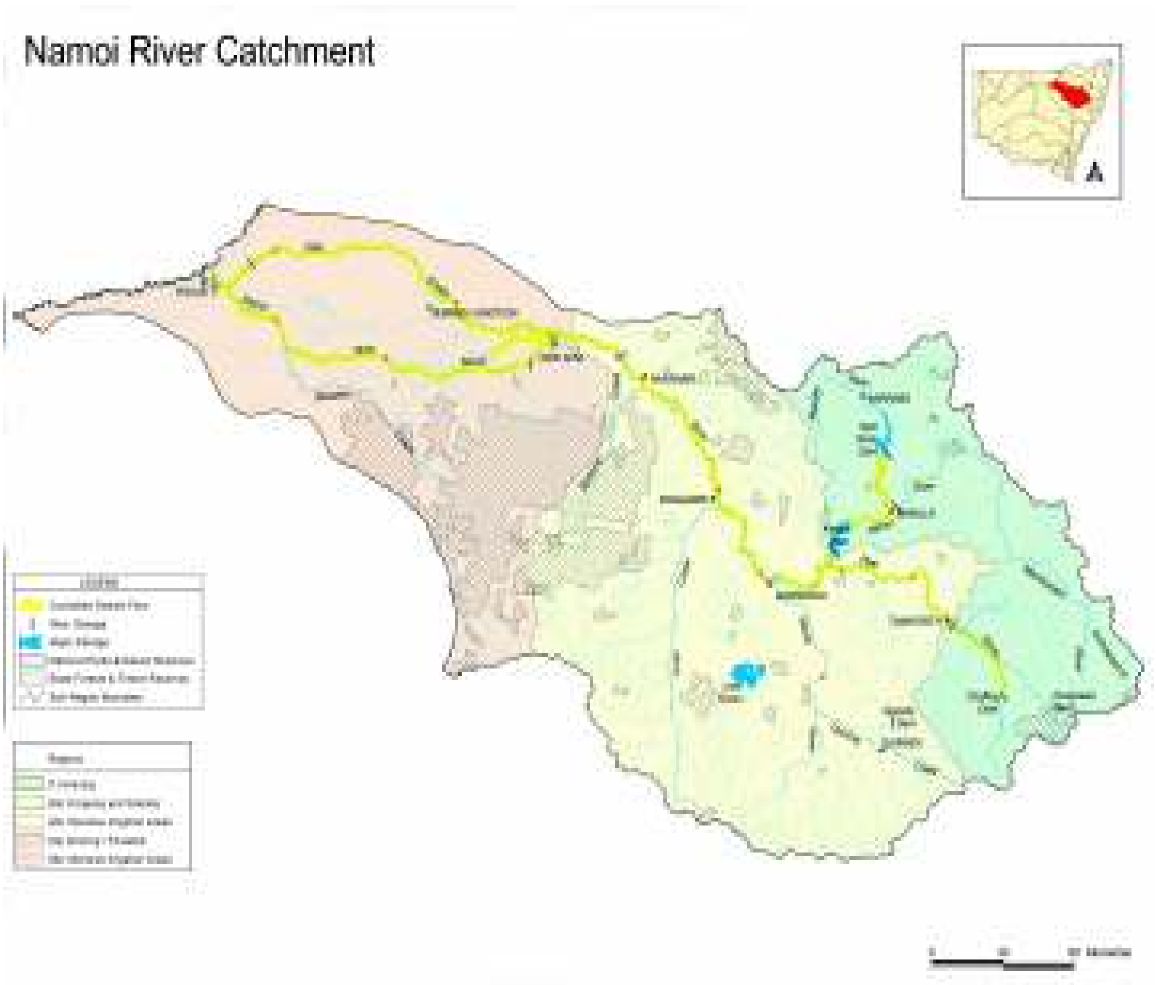


Table 2.1: Storage capacities

Storage	Total Capacity (ML)	Useable Capacity (ML)
Keepit Dam	425,510	418,960
Split Rock Dam	397,370	394,210
Mollee Weir	2,500	
Gunidgera Weir	About 1500 ML	

2.2. CLIMATIC DATA

The climatic data used to configure the model was obtained from the Bureau of Meteorology. Every effort has been made to collate the best available data to configure and calibrate the model.

2.2.1. Rainfall

Rainfall data is required by IQQM as input to the soil moisture accounting module (Section 3.4), for computing the rainfall onto reservoir storage volumes (Section 3.6) and onto river reaches (Section 3.4). Rainfall data is also required for generating catchment inflows using rainfall-runoff modelling (Section 2.3.4).

Annual average rainfall varies over the Namoi Valley, from a maximum of 1000 mm over the high ground in the east to a minimum of less than 500 mm near the junction of Namoi and Barwon Rivers. An extensive network of daily read rain gauges covers the Namoi River catchment. Statistical correlation techniques were used to fill any gaps in the observed data at the main sites. Observed rainfalls at surrounding sites were used in the correlation. Figure 2.2 show the location of the main rainfall sites.

Of the available rainfall stations in the valley, the following criteria are used to select an appropriate sub-set to use in the Namoi IQQM:

- adequate representation of spatial variability of the rainfall;
- availability of long term records to cover not just the intended calibration period, but also the intended long term modelling period;
- continuity and quality of data; and
- availability of nearby gauging stations that could be used to substitute missing data and/or disaggregate accumulated records.

Table A1 details the main rainfall sites used in the model. Rainfall data is also used in the generation of catchment inflows using the Sacramento rainfall runoff model. Further details of the rainfall data are presented in report “Rainfall, Evaporation & Streamflow Data for Namoi IQQM” (DIPNR 2005).

Figure 2.2: Rainfall gauge locations

2.2.2. Evaporation

Evaporation data is used in IQQM to estimate the evapotranspiration from crops (Section 3.5), for computing evaporation losses from reservoirs (Section 3.5) and for evaporation losses from river reaches (Section 3.5). Evaporation data is also used for generating catchment inflows using Sacramento rainfall-runoff modelling (Section 2.3.4).

Evaporation potential, as measured in Class A pans, substantially exceeds average rainfall throughout the whole catchment. Annual average evaporation ranges from around 1250 mm a year at Tamworth, around 1500 mm at Wee Waa, to around 1750 mm at Walgett.

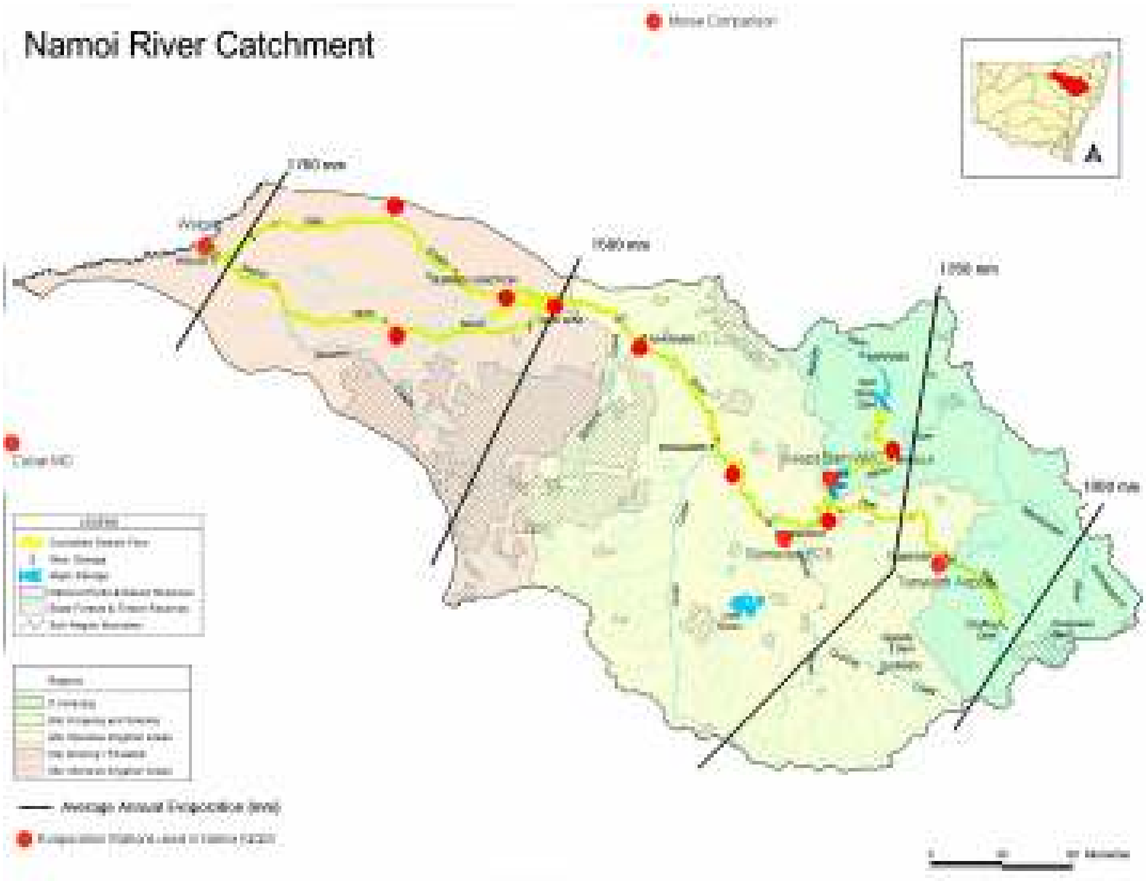
Only five evaporation sites were found in the Namoi Valley with long enough records to allow evaporation estimates to be made:

- Tamworth Airport (055054)
- Keepit Dam (055276)
- Gunnedah SCS (055024)
- Walgett (055026)

- Cobar (048027)

Because of the limited number of daily observed evaporation sites it was necessary to generate daily evaporation data at a number of sites to ensure adequate distribution of evaporation data. The following list details the sites that were generated; Manilla PO; Carroll (The Ranch); Boggabri; Narrabri Bowling Club; Wee Waa PO; Pillega PO and Rowena (Myall Plains). Figure 2.3 shows both the evaporation sites for the observed and generated data. Further details of the evaporation data are presented in report "Rainfall, Evaporation & Streamflow Data for Namoi IQQM" (DIPNR 2005).

Figure 2.3: Evaporation gauge locations



2.3. STREAMFLOW DATA

Streamflow data is used for model calibration and for model simulations. Time series flow data was extracted from the Department's HYDSYS database. In the model calibration phase, streamflow data is required for all major tributaries represented in the model and at all key main stream gauging stations. The tributary inflows are used to achieve mass balance within each river reach, whereas the main stream gauges are used to derive losses and flow routing parameters for each river reach. In the model simulation phase, only the tributary inflows need to be provided as inputs.

2.3.1. Main stream gauging stations

Streamflow data for gauging stations along the Namoi River were used for model calibration and no processing was carried out for this data and any gaps due to missing data were left as such. Selection of appropriate gauges to use in the Namoi IQQM is discussed in Section 3.3 with a full listing of the gauges selected provided in Table A.2. The location of main stream gauging stations has been shown in Figure 2.4.

2.3.2. Gauged tributary inflows

The principal flow contributing tributaries of the Namoi River (Peel River, Mooki River and Coxs Creek) enter the river upstream of Narrabri. Streams below Narrabri make little or no contribution to Namoi River flow except in wet periods. During localised rainfall there can be significant floods flowing out of the Piliga Region of the Namoi Valley. Namoi IQQM includes all the major tributary inflows and they have been estimated for both the model calibration period and the anticipated longer period required for model simulation runs.

The tributary gauges usually did not have a long enough period of record to cover the full period of intended model simulation (from the 1890's to date). However there was generally sufficient climate data to allow the use of the Sacramento rainfall runoff models to extend the tributary flow data. The gauged tributaries inflows that were represented in the Namoi IQQM are listed in Table A.3 and their locations are shown in Figure 2.4.

2.3.3. Inflow into Dams

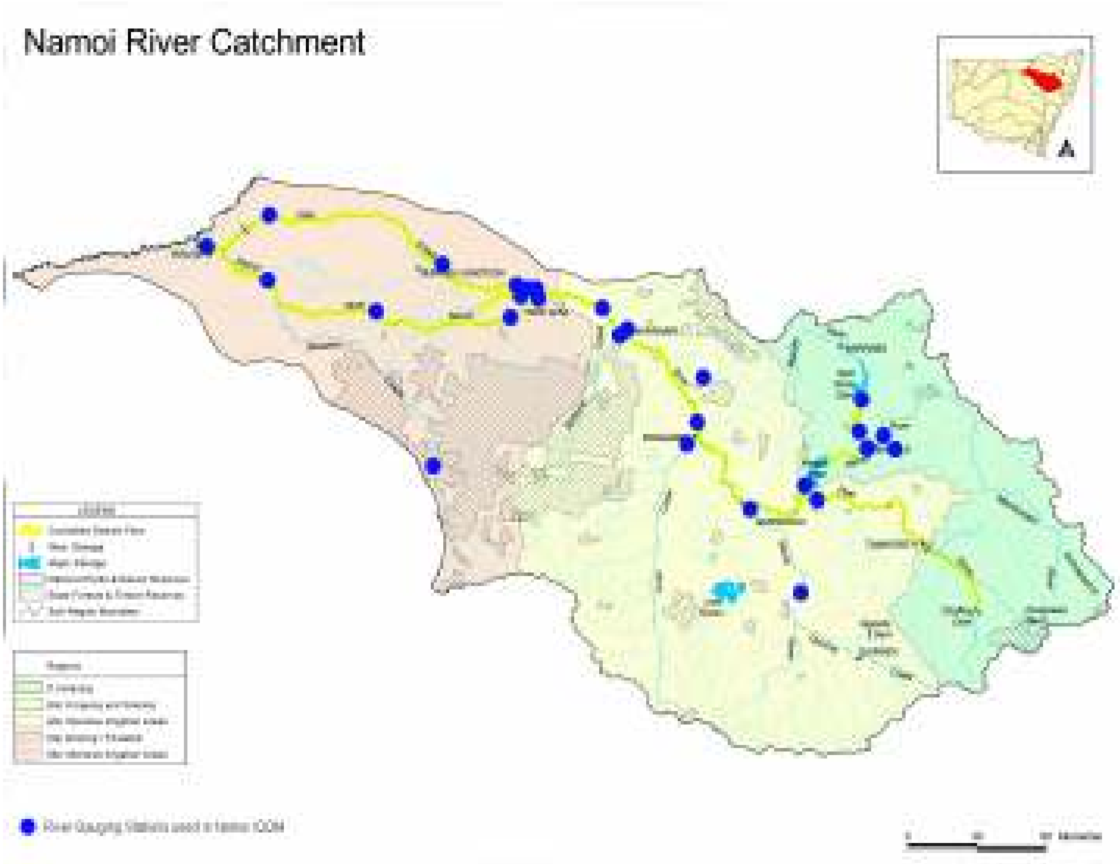
Inflows to Keepit and Split Rock Dams were required for the purposes of model calibration and model simulation. Daily Keepit Dam and Split Rock Dam inflows for the period of dam operation were estimated using back-calculation procedures (ie *Inflow = Change in Storage + Releases + Spills + Losses - Direct Rain*). For the periods prior to dam construction, Sacramento models were used to estimate inflows. It should be noted that Keepit Dam inflows result from the releases from the upstream dam, Split Rock Dam, plus any tributary inflows between the two dams.

2.3.4. Ungauged tributary inflows

Gauging stations on the tributaries are generally located some distance upstream from the confluence with the main river, resulting in large areas of ungauged catchment. There are also some ungauged contributions from smaller streams and local area runoff. Namoi IQQM makes allowances for the inflows from these ungauged catchments by the estimation of what is termed "residual" catchment inflows.

The flows contributing from ungauged catchment were estimated by mass balance calculations for the various river reaches along the river. The river was divided up into 17 river reaches for modelling purposes, details of the 17 river reaches given in Appendix B. For 12 of these river reaches the ungauged or "residual" catchment inflows were estimated and are listed in Table A.4. Further details of the streamflow data are presented in report "Rainfall, Evaporation & Streamflow Data for Namoi IQQM" (DIPNR 2005).

Figure 2.4: Streamflow gauge locations



2.4. IRRIGATION INFORMATION

2.4.1. Irrigation licenses

Irrigators in Namoi IQQM were represented as clustered groups, broken up to match the division of the river into the 17 gauged reaches (see Appendix B).

DIPNR records of total on allocation, off allocation diversions, crop areas and crop mixes were generally available for the calibration period, at the individual irrigator level. The information was collated into the irrigator groupings. Table 2.2 lists the irrigator groups used in the model.

Table 2.2: Irrigator groupings used in Namoi IQQM

Model Reach	Location	Number of Irrigators	Percentage of Valley Licenced Entitlement (%)	Percentage of Valley area irrigated (%)
1	Split Rock Dam to Brabri Gauge	32	2	2
2	Brabri Gauge to Manilla Gauge	15	1	0
3	Manilla Gauge to Keepit Dam	27	1	1
4	Keepit Dam to Gunnedah Gauge	19	2	1
5	Gunnedah Gauge to Boggabri Gauge	24	2	1
6	Boggabri Gauge to Narrabri Gauge	45	4	3
7	Narrabri Gauge to Mollee Gauge	15	2	2
8	Mollee Gauge to Gunidgera Gauge	38	34	35
9	Gunidgera Gauge to Weeta Gauge	11	9	6
10	Weeta Gauge to Duncans Gauge	8	2	1
11	Duncans Gauge to Bugilbone Gauge	13	6	6
12	Bugilbone Gauge to Goangra Gauge	8	4	4
13	Goangra Gauge to Walgett Gauge	13	3	3
14	D/S Gunidgerra Weir to Pian Cutting (Gunidgera Creek)	12	10	8
15	Pian Cutting to Namoi River return (Gunidgera Creek)	6	3	2
16	Pian Cutting to Rossmore Gauge (Pian Creek)	24	14	19
17	Rossmore Gauge to Dempsey's Bridge Gauge (Pian Creek)	10	1	7

2.4.2. Irrigator pump capacity, storage infrastructure and entitlement

Extensive pump infrastructure exists in the valley, with DIPNR surveys indicating a maximum overall installed capacity of around 14,000 ML/d. Table 2.3 summarises the pump capacity information taken from DIPNR's licensing information and Regional surveys.

Table 2.3: Namoi valley installed pump capacity

Water Year (Oct to Sept)	Installed Pump Capacity (ML/day)
1988/89	11587
1989/90	12126
1990/91	12649
1991/92	12225
1992/93	11574
1993/94	9103
1994/95	14030
1995/96	11385
1996/97	11545
1997/98	10609
1998/99	10694
1999/00	10683
2000/01	11014

Significant volumes of on farm storage have been built in the Namoi Valley. Early records of volumes are sparse with the first detailed survey undertaken in 1987/88. Surveys of storage volumes were initially collected intermittently, however, they are now collected generally twice a season. Table 2.4 outlines the volumes of on farm storages in the Namoi Valley.

Table 2.4: On farm storage volumes

Water Year (Oct to Sept)	Estimated on farm storage capacity (ML)
1987/88	33022
10/11/92	98474
24/09/93	117933
08/08/96	144400
23/08/97	145091
11/12/97	147631
02/06/98	156795
30/11/98	160300
07/10/99	177190
31/02/00	179315
25/10/00	187185
06/04/01	189825
16/11/01	191526
21/5/02	197920
13/11/02	198440
21/03/03	201490

The licences supplied with water by Keepit and Split Rock Dams were converted from area-based licences to volumetric licences at the commencement of the 1981/82 season. There has been an administrative embargo on the issuing of new licences (with the exception of stock, domestic, industrial and town water supplies) since 1980. This became a statutory embargo in 1982. The historic data on licensed irrigation volumes and licence types was analysed and separated into high security and general security licence portions. This data is summarised below in Table 2.5.

Table 2.5: Licensed Entitlements

Water Year (Oct to Sept)	General Security irrigation entitlement (ML)	High Security entitlements (ML)	Total (ML)
1988/89	254 083	4 422	258 505
1989/90	247 398	4 486	251 884
1990/91	255 792	4 524	260 316
1991/92	256 598	7 713	264 311
1992/93	256 478	7 872	264 350
1993/94	256 425	8 040	264 465
1994/95	256 429	8 035	264 464
1995/96	256337	8 035	264372
1996/97	256336	8 035	264371
1997/98	256336	8 035	264371
1998/99	256335	8 035	264370
1999/00	256335	8 035	264370
2000/01	256335	8 035	264370

2.4.3. Irrigation extraction data

DIPNR has historic records of on allocation, off allocation usage and high security diversions for the Namoi River Valley and they are summarised in Table 2.6. Historically the data has not always been collected at regular monthly intervals and Region has estimated the monthly usage in some circumstances. The monthly totals were disaggregated to daily totals during flow calibration.

Table 2.6: General security water diversions and high security diversions

Water Year (Oct to Sept)	General Security On allocation (ML)	General Security Off allocation (ML)	Total General Security Diversions (ML)	High Security (ML)
1988/89	97 848	119 912	217 760	na
1989/90	169 734	48 883	218 617	na
1990/91	181 586	81 734	263 320	274
1991/92	189 588	15 652	205 240	0
1992/93	134 449	48 830	183 279	583
1993/94	72 877	93 112	165 991	1472
1994/95	17 419	23 182	40 601	1638
1995/96	39 467	93 818	133 285	1834
1996/97	229 603	5 615	285 940	2396
1997/98	146522	57057	203579	1407
1998/99	194866	37281	232147	1344
1999/00	213295	24463	237758	2686
2000/01	205139	47484	252623	1394
2001/02	254689	957	255646	2721

2.4.4. Crop areas and crop mixture

Cotton irrigation is the dominant crop in terms of irrigated water use in the Namoi Valley and constitutes the majority of irrigated summer crop area. In contrast irrigated winter crop areas have generally been significantly lower than irrigated summer crop areas.

Historic records of total planted areas and crop type for regulated licence holders were available from the DIPNR licensing database from the early 1980's. The data collected in the 1980's was generally obtained by a mail out process with percentage returns varying and limited follow up. In more recent times there has been a concerted attempt to improve the collection of good data on areas irrigated.

The Namoi Valley has a significant amount of irrigated cropping from groundwater and unregulated water sources. In particular, use by conjunctive groundwater/surface water licenses has been significant. Many of the irrigators in the valley have a number of types of licences including, regulated river, unregulated river, conjunctive use and groundwater only. There has been only one system reporting area irrigated and it is not known to what degree, groundwater or unregulated water resources might be contributing to these reported areas. In this modelling process it is assumed that all water resources available to the irrigator are being used to irrigate the area reported planted. Figure

2.5 and Tables 2.7 shows details of historical areas planted for the total regulated part of the Namoi Valley. Table 2.8 outlines the crop mixture over the period of record

Figure 2.5: Historical crop areas

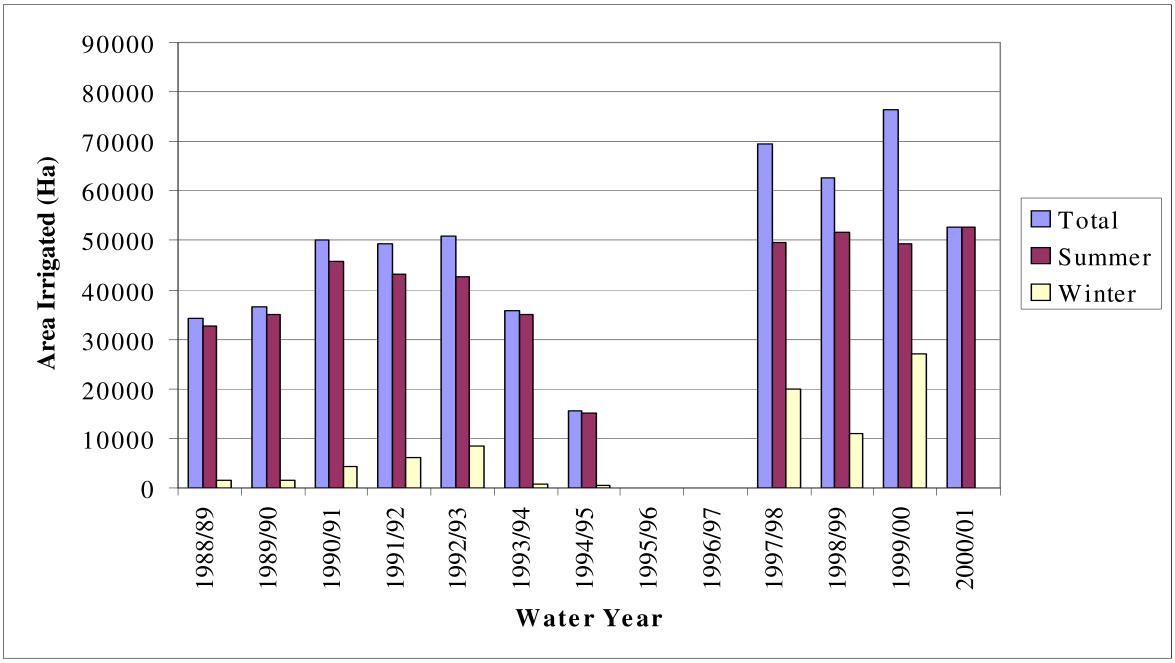


Table 2.7: Total area planted

Water Year (Oct to Sept)	Total Area (Ha)	Summer Area (Ha)	Winter Area (Ha)
1988/89	34,307	32,657	1,650
1989/90	36,530	35,019	1,511
1990/91	50,156	45,706	4,450
1991/92	49,309	43,246	6,064
1992/93	50,988	42,613	8,375
1993/94	35,861	35,063	798
1994/95	15,555	15,058	497
1995/96	na	na	Na
1996/97	na	na	Na
1997/98	69,583	49,707	19,876
1998/99	62,662	51,722	10,940
1999/00	76,538	49,365	27,173
2000/01	75,492	52,552	22,940
2001/02	52,907	52,010	897

Table 2.8: Percentage crop mix

Water Year	Cotton %	Lucerne %	Summer Cereal %	Summer Oil %	Summer Pasture %	Wheat %	Winter Cereal %	Winter Pasture %
1988/89	81	1	2	10	1	4	0	0
1989/90	89	2	1	2	2	4	0	0
1990/91	84	1	2	2	2	7	1	1
1991/92	79	2	3	2	3	9	1	1
1992/93	76	2	3	1	2	14	1	1
1993/94	91	3	2	1	1	0	2	0
1994/95	84	6	3	0	4	0	3	0
1997/98	68	1	0	2	0	0	29	0
1998/99	80	0	1	2	0	0	17	0
1999/00	59	0	1	5	0	0	35	0
2000/01	67	0	1	2	0	0	30	0
2001/02	76	1	14	8	0	0	1	0

2.4.5. Transfer market

A scheme permitting the temporary transfer of water entitlements is allowed in the Namoi Valley. In IQQM this cannot be modelled explicitly. However, IQQM does assume full activation of entitlements within a irrigation node but no transfer of water entitlement from node to node.

2.5. TOWN WATER SUPPLY

Town water demands are an extremely small component of the total water use in the valley, generally less than 0.1% of the total water use, and their demands less variable and influenced to a lesser extent by climate. The demands represented by a fixed annual demand with a monthly pattern of use. In the regulated sections of the Manilla and Namoi Rivers, two towns were identified and represented in the model, Manilla and Walgett and they have an annual high security entitlement of 35 ML and 2271 ML respectively. These two towns are represented in the model for resource assessment and their water use has been set at historical levels. Table 2.9 summarises high security usage.

2.6. STOCK AND DOMESTIC REQUIREMENTS

The stock and domestic (S&D) users fall into two categories, those with a S&D licence only and those who have both a S&D licence and general security licence. The total licensed entitlement for stock and domestic purposes in the Namoi Valley is about 2.4 GL. These S&D water users are recognised in the model when doing resource assessment and their historical use has been included into the model. Table 2.9 summarises high security usage

2.7. INDUSTRIAL AND MINING EXTRACTIONS

DIPNR licencing records indicate entitlements for industrial and mining licences in the Namoi Valley of about 3.4 GL. However water diversion records indicate only a small amount of this entitlement is ever diverted. They have been accounted for in resource assessment and their historical use included into the model. Table 2.9 summarises high security usage.

Table 2.9: Summary of High Security Usage 1990 to 2000

Water Year	1990/91 (ML)	1992/93 (ML)	1993/94 (ML)	1994/95 (ML)	1995/96 (ML)	1996/97 (ML)	1997/98 (ML)	1998/99 (ML)	1999/00 (ML)
Horticulture			13	20				53	24
Industry			19		12	110	86	126	118
Recreation			90	72	31		37	66	40
Stock & Domestic	222	583	776	826	581	807	104	314	856
Sand & Gravel	12				31	39			
Stock	40		313	83	61	207	20	20	62
Town Water Supply			259	634	118	1216	1161	765	1586
Domestic			2	2		16			
Total	274	583	1472	1637	1834	2396	1408	1344	2686

2.8. GROUNDWATER ACCESS

Extensive groundwater supply bores exist throughout the irrigated areas and they are often used to supplement regulated river water. Traditionally surface water irrigators have turned to groundwater to balance shortfalls in surface water allocations. Irrigators have in the past had access to two types of groundwater licences; Conjunctive use licence (the licence allows surface water users to supplement their surface water entitlement with groundwater) and Groundwater only licences that are completely independent of surface water allocations.

Table 2.10 details observed water extraction data from conjunctive groundwater licences. There is generally no data available on the area grown from these groundwater resource and it has been assumed that these diversions contribute to the crop areas reported for regulated surface water users (see Section 2.4.4).

Table 2.10: Conjunctive Groundwater Usage

YEAR	Conjunctive Groundwater Use (ML)	Surface water allocation at 1st of December
1984/85	13,919	100%
1985/86	18,147	100%
1986/87	19,020	100%
1987/88	24,683	75%
1988/89	29,881	100%
1989/90	31,564	100%
1990/91	27,355	100%
1991/92	32,033	100%
1992/93	66,398	20%
1993/94	95,697	27%
1994/95	117,723	0%
1995/96	47,172	10%
1996/97	21,149	100%
1997/98	20,342	100%
1998/99	19,917	100%

The Namoi IQQM incorporates groundwater use for the regulated river pumpers that have conjunctive use groundwater licences. In 2000/2001 conjunctive use groundwater licences were converted to groundwater only licences with a new entitlement and conjunctive use licences ceased to exist. The Namoi IQQM modelling post 1999/00 assumes the new groundwater only licence entitlements are still accessible to the regulated river pumpers to plant their areas.

The conjunctive groundwater licence rules allowed for increased groundwater use with decreasing surface water entitlement. Two different conjunctive use rules applied for the Namoi River (areas above and below Narrabri) and they were based on the authorised area attached to the licence. The authorised area being that area used when volumetric conversions was introduced into the Namoi Valley in the mid 1980’s at an conversion rate of 6 ML/ha.

In the Namoi River above Narrabri the conjunctive use rules allowed for a direct one for one replacement of the ML/ha lost by reduced allocation plus a minimum use (1.5 ML/ha) from the bore. In the Namoi River below Narrabri the minimum use of 1.5 ML/ha was maintained, however for each 4 ML/ha lost due to reduced allocation, only 1.5 ML/ha was supplemented by the conjunctive use licence. The following table summarises the rules.

Table 2.11: Conjunctive use entitlement – Namoi River above Narrabri

Surface Water Announced allocation %	100	90	80	70	60	50	40	30	20	10	0
Equivalent Surface water entitlement ML/ha	6.0	5.4	4.8	4.2	3.6	3.0	2.4	1.8	1.2	0.6	0.0
Replacement Conjunctive use entitlement ML/ha	0.0	0.6	1.2	1.8	2.4	3.0	3.6	4.2	4.8	5.4	6.0
Minimum Conjunctive use entitlement ML/ha	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
Conjunctive use entitlement ML/ha	1.5	1.5	1.5	1.8	2.4	3.0	3.6	4.2	4.8	5.4	6.0

Table 2.12: Conjunctive use entitlement – Namoi River below Narrabri

Surface Water Announced allocation %	100	90	80	70	60	50	40	30	20	10	0
Equivalent Surface water entitlement ML/Ha	6.0	5.4	4.8	4.2	3.6	3.0	2.4	1.8	1.2	0.6	0.0
Replacement Conjunctive use entitlement ML/Ha	0.0	0.22	0.45	0.67	0.9	1.12	1.35	1.57	1.8	2.02	2.25
Minimum Conjunctive use entitlement ML/Ha	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
Conjunctive use entitlement ML/Ha	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.6	1.8	2.0	2.2

Applying the entitlements outlined in Tables 2.11 and 2.12 would establish the quantities of groundwater that could be diverted to river pumpers. However, the observed data shown in Table 2.10 is only a small fraction of this potential diversion. The limited observed data suggests a base conjunctive use plus an "as needed" conjunctive use depending on the amount of surface water allocation available. To simulate the conjunctive use diversions consistent with observed data, a regression relationship between historical conjunctive use and the surface water allocation was used. See section 3.5.3.

2.9. RESOURCE ASSESSMENT

Under a volumetric allocation scheme all licences are issued with an annual entitlement volume. In any irrigation season, the amount of water available for general security irrigation is the announced allocation percentage times the annual entitlement volume. The allocation announcement is the result of a resource assessment process that takes into account:

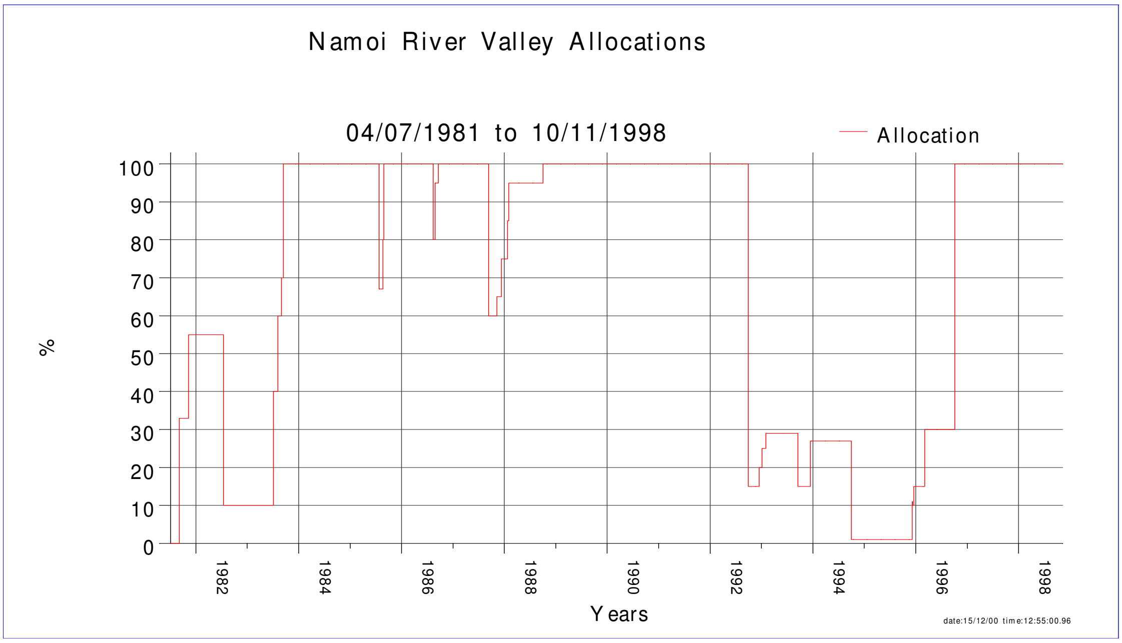
- all available water resources at that time
- water resources expected to become available for the remainder of the water year and
- an allowance for essential requirements to meet high security supplies, environmental and other reserves and expected losses

After these calculations are undertaken the remaining resources are then declared available for general security irrigation use and are expressed as a percentage of the total general security entitlement. The estimate of expected water resources is conservative and uses the driest recorded inflow and tributary sequence to estimate expected resources for the remainder of the water year.

Some of the items used in the resource assessment process are subject to change over time for a variety of reasons. From time to time transmission losses estimated under drought conditions are be reviewed or reserves for essential supplies or environmental purposes may be reassessed.

The allocation assessments are made at the beginning of the water year (1st October for Namoi Valley), and may be updated when there is significant inflow to Keepit Dam. The historical allocation announcements for the Namoi Valley are presented in Figure 2.6.

Figure 2.6: Historical announced allocations



2.10. RIVER AND STORAGE OPERATION

The Namoi River system is operated to ensure that maximum conservation of resource is achieved during regulated operation, and that flows in excess of the target at the end of the system are kept to a minimum. During normal regulated operations, flows in excess of requirements usually occur as a result of:

- tributary inflows below the storage being in excess of requirements;
- rainfall on crops reducing extraction of ordered water in transit; and
- errors in forecasting system requirements.

2.10.1. Tributary utilisation

When making releases from storage to satisfy consumptive requirements, the river operator forecast inflow contributions they expect from downstream tributaries and adjusts the releases from the major storage(s) accordingly. In practice a range of factors influence the river operator's decision, including recent weather and the most recently observed inflows from the various downstream tributaries. When releases are made from Keepit Dam, flows entering from the Peel River, Mooki River and Coxs Creek are considered. IQQM representation and calibration of tributary utilisation is discussed further in Section 3.6.

2.10.2. Operational surpluses

Operational surpluses result from errors in forecasting demands for irrigation and transmission losses, both of which can be quite variable, as well as general over-ordering by irrigators. The Namoi River regulated system is operated under a water order debiting system where any water ordered by a irrigator is debited against account, regardless of whether or not the water was actually extracted. IQQM representation and calibration of over-ordering is discussed further in Section 3.6.

2.10.3. Split Rock to Keepit Dam transfers

Keepit and Split Rock Dams are operated under the principle of managing the two major storages to maximise the potential to catch runoff, whilst ensuring that adequate head is maintained in Keepit Dam to permit the peak daily demand to be released through the outlet valves.

In general this is achieved by holding Split Rock Dam as full as possible, whilst also keeping the water level in Keepit Dam high enough to permit gate operations if needed (around 110GL). Keepit Dam is often unable to release the peak summer demands just using the valves (2 valves and hydroelectric station). Due to flow constraints in the Manilla River (determined during test transfers from Split Rock to Keepit Dam), operators are required to predict the peak demand on Keepit Dam, and the seasons usage, and transfer the water down to Keepit Dam before summer begins.

2.10.4. Flood mitigation releases

Keepit Dam does not have specific flood mitigation storage, however, the dam has achieved some reductions in downstream flooding on occasions. This was largely due to the volume of the flood being contained within the available empty dam storage volume. Careful operation of the spillway gates can also reduce flooding downstream. Keepit Dam is operated according to standard DIPNR procedures for gated storages during flood events. These procedures seek to delay and minimise peak outflows consistent with the protection of the dam infrastructure. Flood operation of Keepit Dam is not included in the Namoi IQQM.

2.11. SURPLUS FLOW ACCESS

Off allocation periods may be announced in the regulated Namoi River downstream of Keepit Dam when flows are in excess of demands (surplus flows). Surplus flows may comprise operational excess flows, tributary inflows and spill releases from Keepit Dam. During these off allocation periods water may be extracted without debit to their entitlement. The volume of water available is usually announced as a percentage of licensed entitlement. Smaller surpluses are occasionally made available only to selected river reaches for ease of administration. Declarations are usually made to ensure equity of access to surplus flows where possible.

Records of monthly off allocation extraction volumes were available. Also available were the off allocation announcements with specified shares and access areas. Announcements for access to off allocation water are generally made on a section by section basis, depending on the amount of surplus flow available, the expected demand and the access that each section has previously received. Namoi IQQM calibration of off allocation is discussed further in Section 3.5.2.

2.12. RIVER FLOW REQUIREMENTS

2.12.1. Minimum flow

2.12.1.1 Flow at Goangra (gauge 419026)

A target flow of 40 ML/day existed at Goangra. During calibration it was noted that the target was active only during irrigation periods. It was also noted that the target was often not met. For the purposes of the model, a 40 ML/day target is set in the model over the period 1st October to 31st March.

2.12.1.2 Keepit Dam minimum release target

A minimum Keepit Dam release of 10 ML/day has been set in the model.

2.12.1.3 Split Rock Dam minimum release target

A minimum Split Rock Dam release of 6 ML/day from 1st October to 31st March, and 5 ML/day from 1st April to 30th September has been set in the model

2.12.2. Flow constraints

2.12.2.1 Gunidgera Creek channel capacity

Gunidgera Weir diverts water into the Gunidgera/Pian Creek system. At normal Gunidgera Weir operating levels, around 800-900 ML/day can be diverted and in times of peak demand, the weir pool level can be raised and around 1250 – 1300 ML/day can be diverted into Gunidgera Creek. Uncontrolled outflow down Gunidgera Creek commences at about 15000 ML/day in the Namoi River.

These limitations on flows down Gunidgera Creek have resulted in irrigators on the Gunidgera/Pian Creek system altering their water diversion practices to allow for these restrictions. The irrigators have tended to construct on farm storages where they can store ordered water in advance of their crop water needs. This pre-ordering of water will reduce demands on the channel system during peak summer demand times. The offtake capacity limitation has also seen the Department adopt a rostering system with off allocation diversions to try any equally distributing available off allocation supplies.

The Gunidgera Weir diversion limits are not included in Namoi IQQM. IQQM is not capable of reproducing this type of behaviour with irrigation scheduling and irrigators pre-ordering water early and storing the water for peak demand periods.

2.12.2.2 Pian Creek/Cutting channel capacity

The old Gunidgera-Pian cutting had a channel capacity of about 800 ML/day. B&B channel was constructed parallel to the old cutting with a capacity of about 600 ML/day. Generally these two channels have adequate capacity to meet the water diversions needs of users on Pian Creek, however, if channel capacity problems arise then rostering arrangements are put in place to ensure adequate water is supplied when needed. This limit is not include in the Namoi IQQM model.

2.12.3. Replenishments

A 14,000 ML allowance is made for 2 stock & domestic replenishments of lower Pian Creek each year. The aim of these replenishments is to fill all the waterholes and billabongs down to the end of Pian Creek. These replenishments are usually met from surplus flows. If these surplus flows are insufficient, water is released from Keepit Dam at either the beginning or end of the irrigation season.

3. Model Calibration and Validation

3.1. MODEL CONFIGURATION

The Namoi regulated river was configured in IQQM using input data as described in Chapter 2. The number and types of nodes and links were selected in accordance with the aims of the modelling detailed in Section 1.2. The Namoi IQQM model contains over 200 nodes and 41 links with hydrologic routing. Details of the model set-up and presentation of the node-link diagram are contained in Appendix B and Appendix C.

Inflows were estimated for Split Rock Dam, 7 gauged tributary and 13 ungauged catchment inflows as described in Section 2.3. General security irrigators were represented in 28 groups based on river reaches and access to on farm storage.

Daily rainfall data was obtained from the Bureau of Meteorology and 9 sites were selected to represent 17 river reaches. Daily evaporation data was generated for the 17 river reaches using 5 evaporation sites available (see Section 2.2.2) and the gap-filled rainfall records. The 15 flow sites selected to calibrate the IQQM are listed in Table A.1.

3.2. LIMITATIONS AND EXCLUSIONS

A number of processes were not modelled either due to insignificance or lack of data or beyond the scope intend. Some processes were modelled in a simplified form.

Unregulated licence cropping and usage have not been represented explicitly in the model. The exception is one licence in the lower Namoi River. This property has made extensive use of an unregulated licence on a tributary and this has impacted on use of the regulated river licence over time. Unregulated licences and crops have not been explicitly modelled due to a lack of suitable information to allow model calibration. The effects of unregulated licence activity will be present to some degree in the flow records used to produce inflows to the regulated system, especially in more recent years. No adjustment of inflows for changes in unregulated licence activity has been made.

No high security irrigation was modelled, however, if high security irrigation diversions are incorporated in general security then high security irrigation is implicitly included. High security stock and domestic usage is modelled as fixed rate diversion independent of climatic condition. Other high security entitlement, including town water supply, are modelled for resource assessment purpose with historical usage included in the model as a fixed demand that does not vary from year to year.

Some groundwater use was represented. The volumes available through conjunctive use licenses, and their corresponding converted ground water only licences are used. Existing groundwater only licences were not considered due to insufficient data to allow model calibration.

Resource assessments (announced allocations) were forced to observed values during the calibration process because there are often changes in policy and reassessment of estimated parameters, making it difficult to produce a generic resource assessment that reproduced announced allocations across the whole calibration period.

3.3. NAMOI IQQM COVERAGE OF THE REGULATED AND UNREGULATED RIVER SYSTEMS

The Namoi IQQM detailed in this report and submitted for accreditation under Schedule F of the Murray Darling Basin Agreement comprises the regulated parts of the Manilla and Namoi Rivers. Parts of the Namoi Valley not modelled in the Namoi IQQM are the regulated part of the Peel River and all of the unregulated parts of the Namoi Valley.

The inflows from the unregulated parts of the Namoi Valley and the regulated Peel River have been included in the Namoi IQQM to correctly represent water sharing and to estimate water diversions in the regulated parts of the Manilla and Namoi Rivers. The inflows from the Peel River and unregulated parts of the Namoi Valley are taken into consideration in the Namoi IQQM by:

- Inflows from the regulated Peel River are a direct input to the Peel IQQM. Historical flows from the Carrol Gap gauging station (419006) have been supplemented for the early years of the long-term simulation by estimated flows using a preliminary Peel IQQM (representing current conditions)

- Inflows from the unregulated Namoi Valley are input to Namoi IQQM as gauged or ungauged tributaries.

3.4. CALIBRATION OVERVIEW

Calibration of IQQM involves the adjustment of the processes and the variables in the model until the model satisfactorily reproduces historical data over a selected period of time. IQQM is a complex model and there are a number of different parameters that are used to represent the major river valley processes. For this reason, a calibration process has been developed to proceed sequentially, progressively eliminating unknowns. The sequential process adopted in the Namoi Valley involves four major steps. Each step estimates a specific parameters for the step, whilst forcing all other parameters to observed data. At the end of the four stage process, all the estimated parameters are brought together to see how well the overall model calibration reproduces historical information. The four steps are summarised below, with an indication of which parameters are calibrated during each one:

- Flow calibration - to reproduce the observed flow hydrographs at key locations, given observed storage releases, tributary inflows and water extractions. For this process, irrigation and other water extractions are fixed to those observed historically. Routing parameters and transmission losses are calibrated.
- Irrigation diversion (demand) calibration - to reproduce observed irrigation extractions from the river, given observed crop areas and crop mix. Crop factors and irrigation efficiency are calibrated.
- Storage calibration - to reproduce the observed volumes in the four major storages, throughout the calibration period. This involves calibration of the processes relating to irrigation ordering and river operation and off allocation.

- Area planting decision - calibrates an irrigator's decision making process to reproduce observed crop planted areas. Maximum and minimum area, crop mix and farmers planting decision process are calibrated.

These steps were repeated whenever a later step identified significant problems with earlier parts of the calibration process.

The selection of the calibration and validation periods was constrained by the availability of data, especially for irrigation data such as diversions, areas and crop mixes. Within this constraint, the calibration period was chosen to be representative of as wide a range of climatic conditions as possible. The crop data prior to 1988 (not reliable) and for 1995/96 and 1996/97 (not collected) were not used for calibration.

The periods chosen for the various stages of the calibration process varied depending on data availability. These are shown in Table 3.1 and summarised below:

- Flow calibration – different for various reaches, ranging from 1/5/1965 up to 31/12/1997.
- Diversion calibration – from 1/10/1989 to 30/9/1995 (1988/89 was available but not used because of poor quality).
- Area planting decision – This step was done twice. The calibration period of 1/10/88 to 30/09/95 was used to represent 93/94 conditions. The period from 1/10/97 to 30/09/01 was used to represent 99/00 conditions.
- Storage behaviour calibration – from 1/10/1989 to 30/9/1995
- Overall model validation – 1/10/1997 to 30/9/2000

Table 3.1: Calibration periods used for different components

SUBJECT	Period definition from	Period definition to
Flow calibration	see	below
Namoi River		
Reach 1 to Brabri	01/10/1972	31/10/1997
Reach 2 to Manilla Railway Bridge	01/11/1965	30/09/1997
Reach 3 to Keepit Dam	01/10/1983	30/09/1997
Reach 4 to Gunnedah	01/10/1983	30/09/1997
Reach 5 to Boggabri	01/10/1983	30/09/1997
Reaches 6 & 7 Mollee weir	01/10/1983	30/09/1997
Reach 8 to Gunidgera gauge	01/10/1983	30/09/1997
Reach 9 to Weeta Weir	01/10/1983	30/09/1997
Reaches 10 & 11 to Bugilbone	01/10/1983	30/09/1997
Reach 12 to Goangra	01/10/1983	30/09/1997
Reach 13 to Walgett	01/10/1983	30/09/1997
Gunidgera Creek		
Reach 14 to Knights Weir	15/12/1956	30/09/1968
Reach 15 to Namoi Return	01/07/1970	30/06/1982
Pian Creek		
Reach 16 to Rossmore	01/04/1952	31/12/1970
Reach 17 to Waminda	01/04/1956	31/05/1965
Diversion calibration	01/10/1988	30/09/1995
Crop area calibration	01/10/1988	30/09/2000
Storage calibration	01/10/1989	30/09/1995
Overall model validation	01/10/1997	30/09/2000

3.5. FLOW REPLICATION

The objective of this step is to calibrate the river system flows module over the calibration period (DLWC, 1998[c]). All known components of the water balance within the river valley are forced to the observed data. Known system inflows (gauged tributaries and reservoir inflows (DLWC, 1998[g]) are used as inputs to the model. Irrigation demands are extracted from river reaches as per the observed data. Town water is extracted from river reaches as per fixed patterns. The remaining unknowns (river routing (DLWC, 1998[k]), residual catchment inflows (DLWC, 1998[h]) and transmission losses (DLWC, 1998[e]) are calibrated by trial and error to achieve the best overall match to mainstream gauges (DLWC, 1998[d]).

Streamflow data is required at all key main stream gauging stations and for all major tributaries represented in the model over the calibration period. An extensive network of streamflow gauging stations represents the main river flows in the Namoi River catchment. The following criteria was used to select an appropriate sub-set to use in calibration of the main stream flows:

- limit the length of river reaches;
- isolation of key features such as tributary inflows and effluent outflows;
- availability of good quality records to cover the intended calibration period, with a minimum number of missing periods.

After a review of the available main stream gauging stations and consideration of these criteria, there were seventeen gauging stations selected for use in the model, thus creating fifteen flow calibration reaches in the Namoi systems (Table 3.1 and Table B1). Duncan's gauge (419082), and the two

Narrabri gauges (419002 & 419003) were dropped from the initial selection when problems were identified with flow representation.

There were also streamflow gauging stations located on four of the major tributary inflows in the Namoi River catchment. Of these available gauging stations, the following criteria are used to select an appropriate sub-set to represent the tributary flow contributions:

- significance of flow contribution;
- maximise gauged coverage of the contributing catchments;
- availability of good quality records to cover the intended calibration period and long term model simulation period;
- availability of nearby long term stream flow stations to be used to gap-fill and extend the stream flow data set;
- availability of nearby rainfall and evaporation stations that could be used to set-up rainfall-runoff models to gap-fill and extend the stream flow data set.

Streamflow data for gauging stations along the main river was used to compare the model results with the observed records, therefore, no processing was carried out for this data and any gaps due to missing data were left as such. Rainfall and evaporation onto the river surface were modelled explicitly by giving each reach an average width.

Presented below in Figure 3.1 to 3.8 are the results obtained from the final calibrated assembled model for river flow replication at three gauging locations. Objective measures of the quality of model fit achieved are presented in Table 3.2 based on the quality assessment guidelines described in Appendix E.

Figure 3.1: Namoi River at Gunnedah – Flow frequency

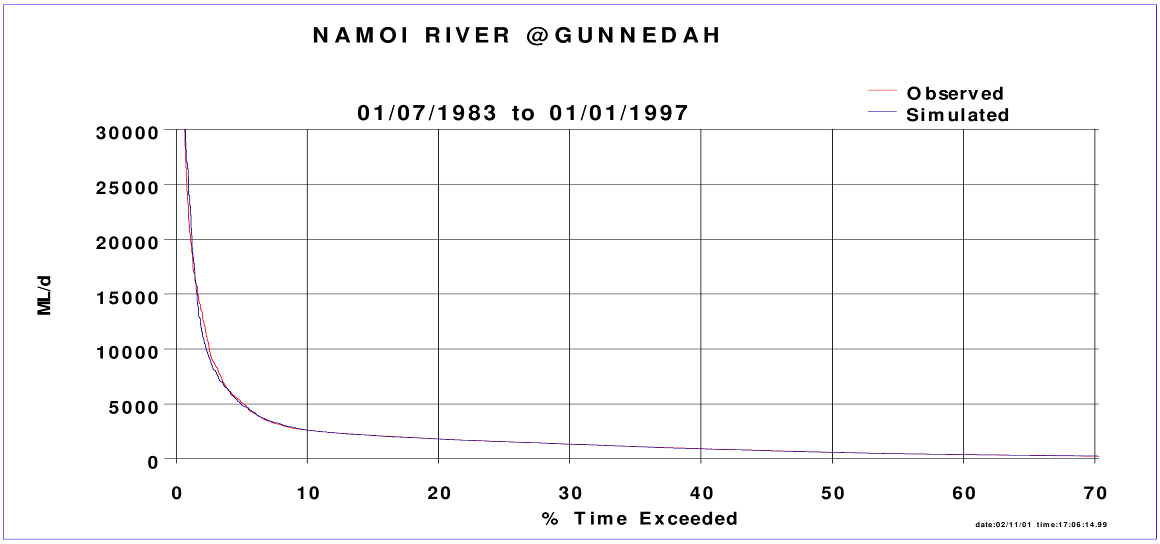


Figure 3.2: Namoi River at D/S Mollee Weir – Flow frequency

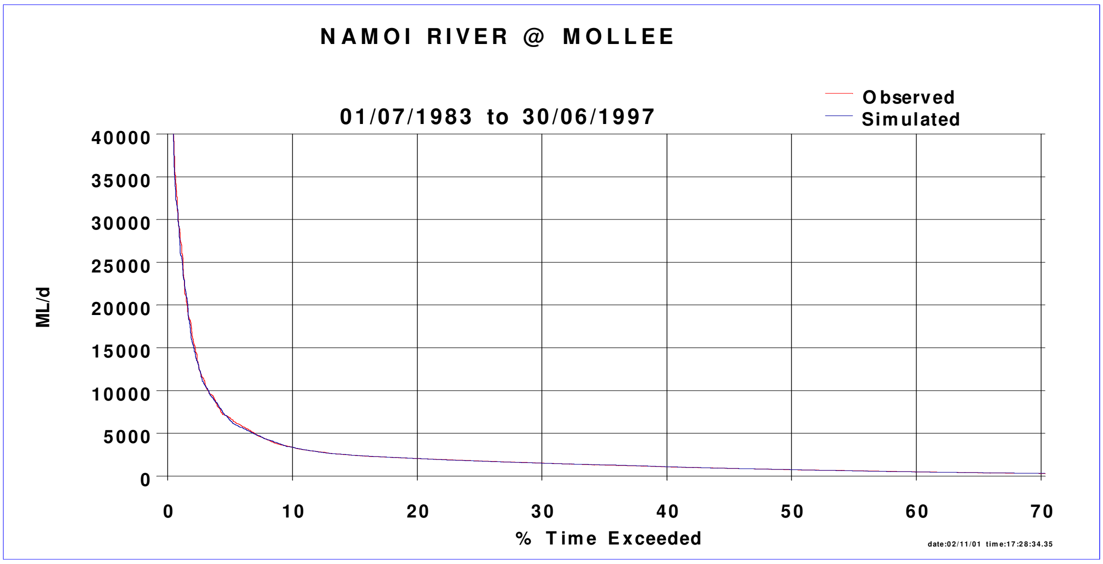


Figure 3.3: Namoi River at Goangra – Flow frequency

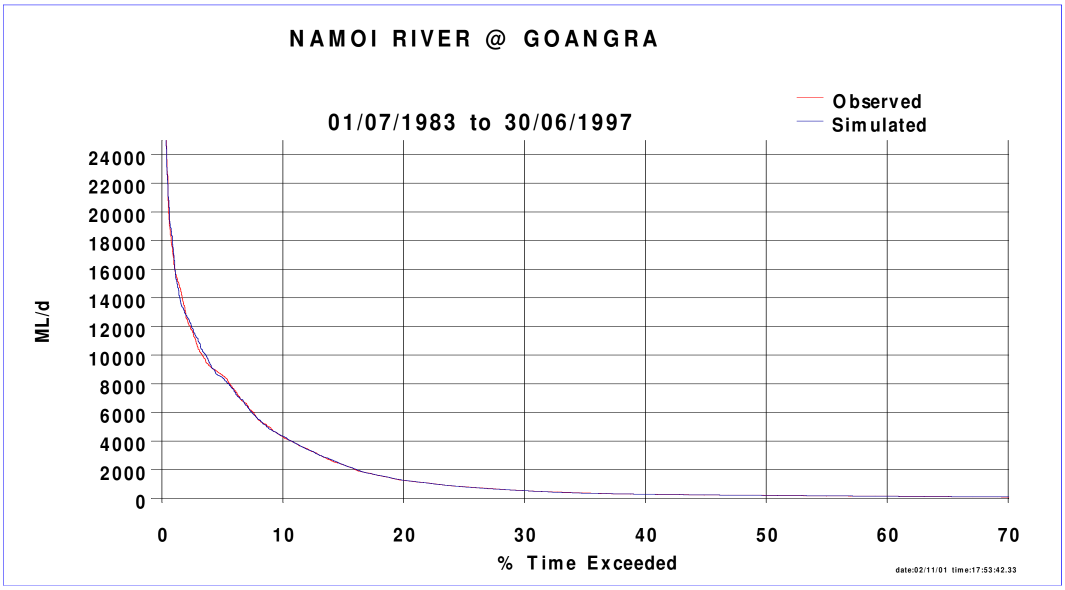


Figure 3.4: Namoi River at Gunnedah – Annual flow volume comparison

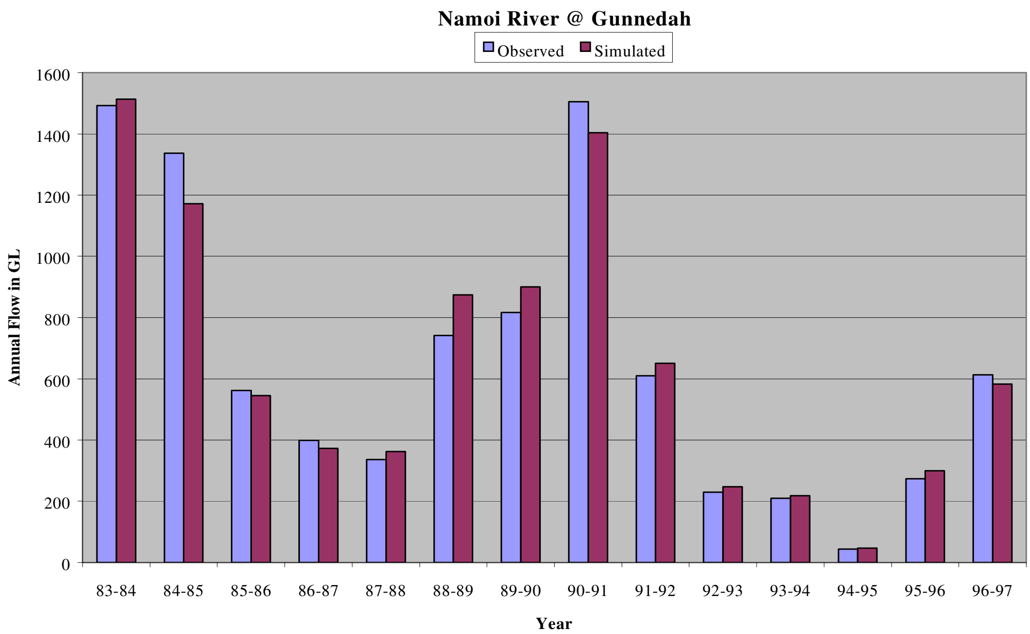


Figure 3.5: Namoi River at Mollee – Annual flow volume comparison

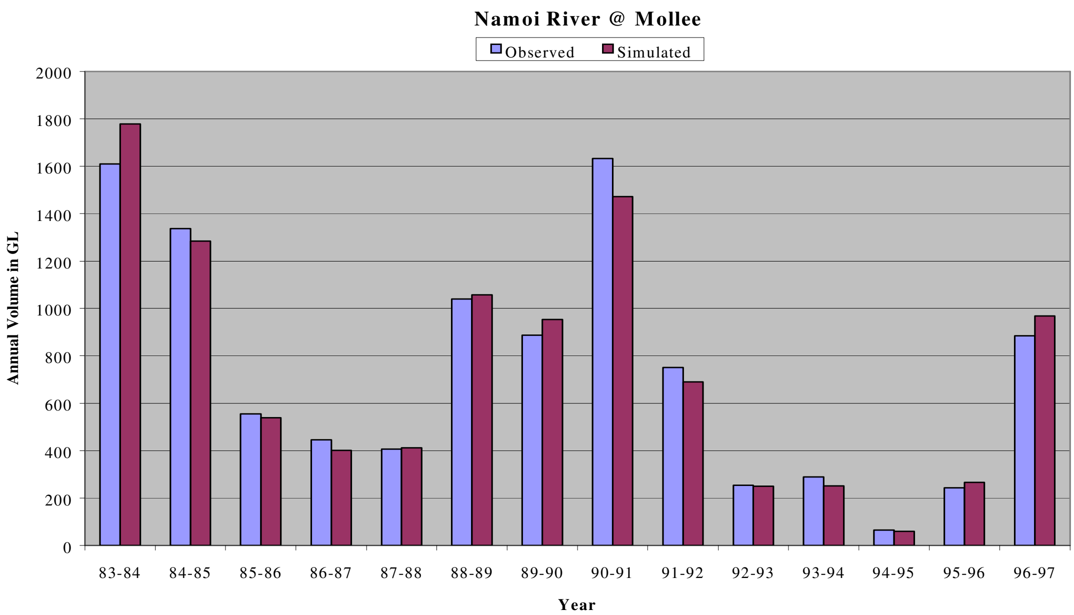


Figure 3.6: Namoi River at Goangra – Annual flow volume comparison

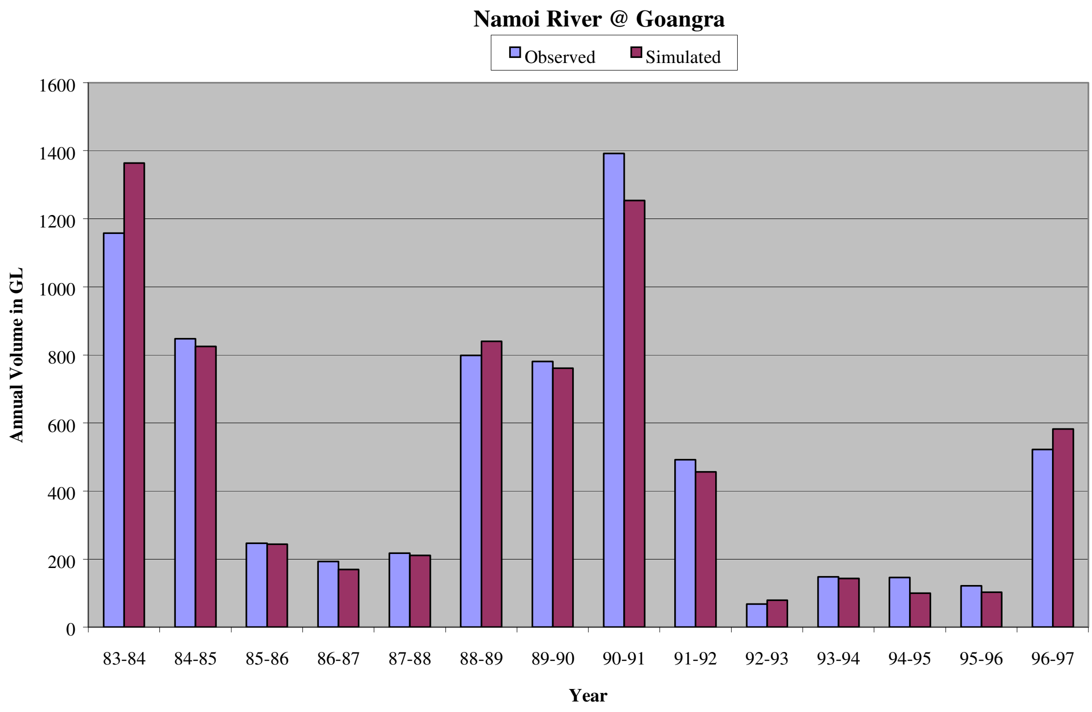


Figure 3.7: Namoi River at Mollee – Driest year in period

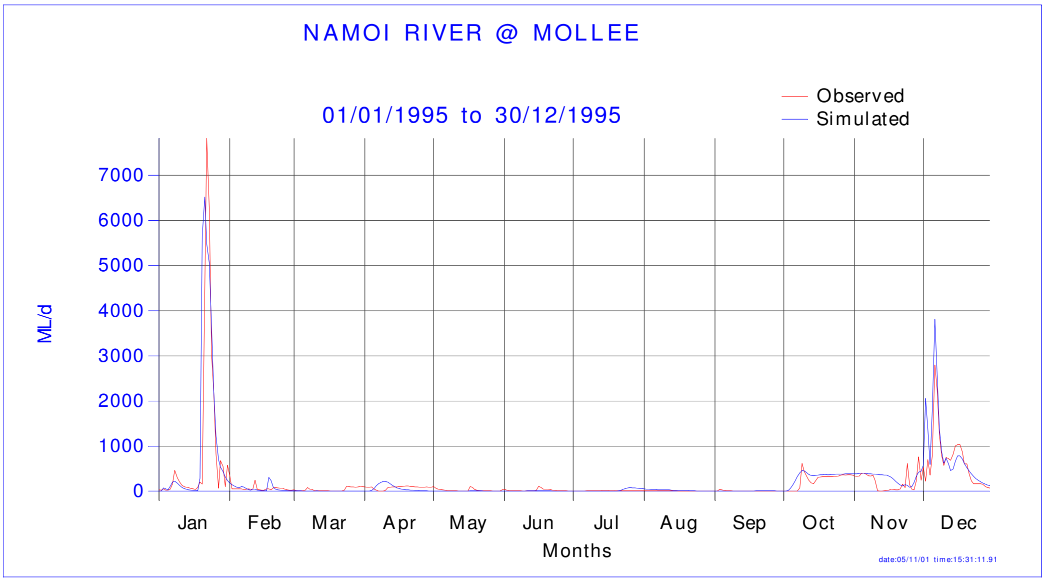


Figure 3.8: Namoi River at Mollee – Wettest year in period

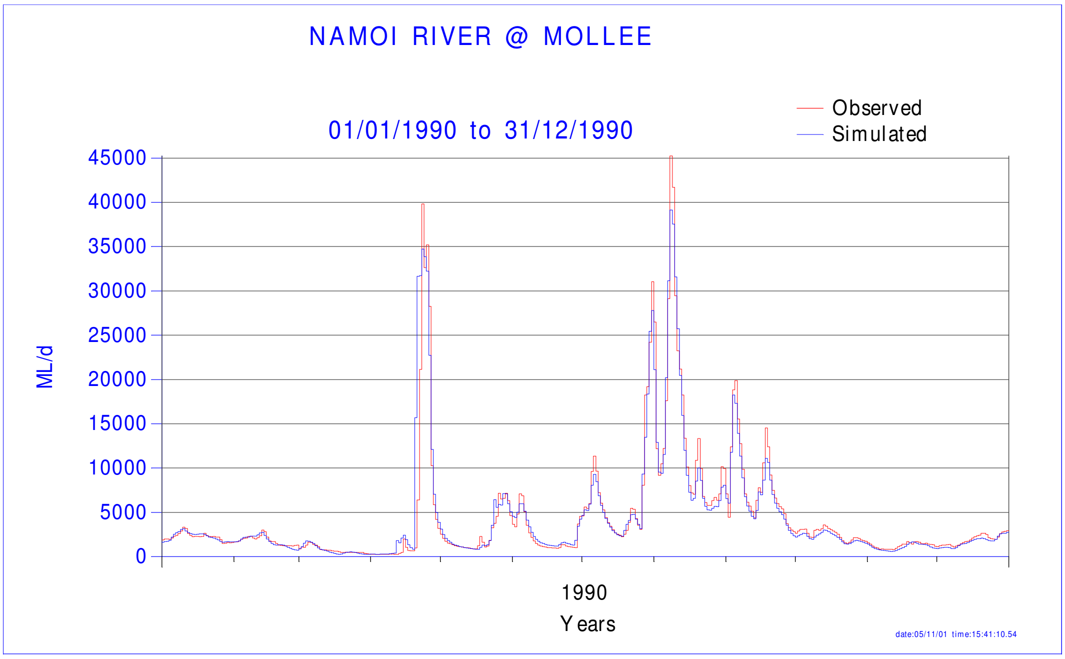


Table 3.2: River flow replication quality

SUBJECT		FLOW FREQUENCY: VOLUME RATIO %'s (#)				TIME SERIES MATCH	
Comparison point	Aspect Reported	Whole Range	Low Range	Mid Range	High Range	"1-r²"	CMAAD
Namoi River @ Gunnedah	Observed GL:-	8837	51	3251	5537	-	-
	Simulated GL:-	8889	49	3221	5622	-	-
	Appar't Error:-	0.6%	-4.3%	-0.9%	1.5%	8%	7.8%
	Rating:-	V. High	High	V. High	V. High	High	High
Namoi River @ Mollee	Observed GL:-	10168	41	3182	6926		
	Simulated GL:-	10150	37	3190	6902		
	Appar't Error:-	-0.2%	-8.1%	0.3%	-0.3%	5%	7.2%
	Rating:-	V. High	Moderate	V. High	V. High	High	High
Namoi River @ Goangra	Observed GL:-	6967	50	850	6069		
	Simulated GL:-	6967	50	845	6073		
	Appar't Error:-	0%	0%	-0.6%	0.1%	6%	8.9%
	Rating:-	V. High	V. High	V. High	V.High	High	High

(#) Gunnedah for period from 1/07/1983 to 01/01/1997, high flows > 10%, low flows < 80%
Mollee for period 01/07/1983 to 30/06/1997, high flows > 15%, low flows < 85%
Goangra for period 01/07/1983 to 30/06/1997, high flows > 20%, low flows < 70%

3.6. DIVERSION VOLUME REPLICATION

3.6.1. Background and methodology

IQQM uses a soil moisture accounting model and estimated crop evapotranspiration to generate irrigation demands. The model takes into account crop areas and different crop types, crop factors to estimate evapotranspiration from pan evaporation, rainfall, evaporation, irrigation efficiency and active licence factors (DLWC, 1998[b]).

The objective of this step is to calibrate the crop water demand module over the calibration period (DLWC, 1998[c]). The parameters calibrated during flow calibration (routing, losses and residuals) are used, crop areas and types and off-allocation extractions are forced to observed data. Appropriate rainfall and evaporation data is selected to drive the crop demand module, which is then calibrated to replicate the observed diversions based on the observed areas planted. The IQQM modeller estimates the potential crop factors (Allen, et. al., 1998) to actual factors, with the unknowns being the size of the average effective soil moisture store, rainfall interception loss for each irrigator group and the crop watering efficiency for each crop type. Values for these parameters are adjusted until the simulated crop water demands best match the observed data (DLWC, 1998[d]). Table A1 details the climatic data that was used to estimate crop water requirements.

Crop factors for crops other then cotton, such as lucerne and cereals were estimated from guidelines published by the United Nations Food and Agriculture Organisation (Allen, et. al., 1998). Crop Factors for cotton are based on values derived at Myall Vale Cotton research as publish in AGFACTS (1984). These base factors were adjusted to suit evapotranspiration. The crop factors used for different crops are presented in Table B2. Irrigation efficiency parameters derived during the calibration process are shown in Table B3.

A number of other factors also impact on the calibration, these are:

- The pump capacities used in each of the irrigation nodes that are based on the total of the estimated installed pump capacities of irrigators in that reach.
- The development of large on farm storages.
- The considerable variation in off allocation announcement thresholds.
- The number of one off events such as overdraws and carryovers.
- Complications associated with irrigators access to significant quantities of water from other sources such as groundwater only licences, conjunctive use licences, floodplain harvesting, and on farm rainfall-runoff harvesting.

3.6.2. On allocation replication

Calibration of the model crop water requirements and on farm water management results in the irrigators placing orders for water. These orders are supplied to the irrigator and debited against their account. These diversions are known as on allocation diversions and the model is calibrated to reproduce observed data. Factors such as soil moisture, crop area, crop type, irrigation watering schedules and on farm water management, including groundwater, rainfall runoff and on farm storage volumes impact on irrigators water order. The observed data was used to calibrate on allocation diversions.

3.6.3. Off allocation replication

The surplus flow announcements were often made on an event by event basis during the calibration period. There was a large degree of variation in the triggers used to declare access to surplus flows from event to event.

Discussion with the river operator show that off allocation volumes were declared based on the demand from irrigators (determined by faxed expressions of interest), equalising opportunity to pump between irrigators, channel delivery constraints, and replenishment or end of system flow requirements.

IQQM models off-allocation periods using defined off-allocation reaches, that have surplus flow thresholds above which off-allocation is made available. As flows in excess of downstream requirements exceed the threshold level for a reach, off-allocation is made available to that off-allocation reach.

A set of thresholds were developed by calibrating to match as best as possible the recorded days of off allocation and the off allocation volumes diverted. Table F5 shows the off allocation thresholds derived during the calibration and these were adopted for 1993/94 development conditions.

3.6.4. On farm storage operation rules

For irrigators with on farm storages the sequences of on and off allocation diversions can be influenced by how their on-farm storages are operated. There is no specific information about on-farm storage operation and anecdotal information and some discussions with irrigators were used to derive the starting operation rules. Operation rules were fine-tuned during the model calibration process to match observed on and off allocation diversions.

On-farm storages were assumed to have both a reserve and airspace. The reserve volume in the on-farm storage is generally maintained at about one watering to cover unforseen circumstances. A reserve of 1 ML/Ha of irrigated area was assumed initially. The airspace in on-farm storages is generally maintained to allow the first flush from rainfall runoff to be kept within the property boundary because of water quality issues. An airspace of 15% of total volume was assumed initially.

The on farm storage is also the location where water diverted from floodplain harvesting and local rainfall runoff harvesting is stored. Therefore the availability /timing of on farm storage volumes has a significant impact on the volumes of floodplain and local rainfall runoff harvesting that can be diverted.

3.6.5. Estimation of other diversions

As discussed above, the calibration process was complicated by irrigators having access to significant quantities of other water including groundwater only licences, conjunctive use licences, floodplain harvesting and on farm rainfall-runoff harvesting. For these potentially significant quantities of water only the conjunctive use volumes were recorded and only in annual quantities. The following assumptions were followed in the model calibration process to account for water diversions from these unmeasured sources:

Groundwater only water – Not modelled, assuming this water was not used to irrigate the crop areas returned from the river pumpers;
Conjunctive use water – The processes was included in the model to recognise the use of this water by river pumpers. A regression relationship between historical conjunctive use and surface water allocation was derived, it took the following form:

Total Groundwater Use = Base Groundwater Use + (Max allocation - allocation) * factor

The factor was derived such that the historical use observed in 1994/95 was representative of a 0% allocation year (year of maximum conjunctive use). No attempt was made to fine tune the regression. Table 3.3 shows calibrated volumes verses those reported.

Floodplain harvesting – The process was included in the model to recognise the use of this water by users. The river flow rate for commencement of floodplain harvesting was estimated at a level such that over bank flooding would be significant and it is assumed the event is significant enough to fill the on-farm storage. Floodplain harvesting together with on farm rainfall-runoff harvesting was fine tuned to ensure off allocation diversions calibrated. No historical data exists on floodplain harvesting volumes.
On-farm rainfall runoff harvesting – The process was included in the model to recognise the use of this water by users. A volume of on-farm rainfall runoff capacity was initially estimated by relating rainfall to cropped areas. The "Best Management Practice Manual" from the Australian Cotton Industry suggests capturing 15 mm per hectare. Floodplain harvesting together with on farm rainfall-runoff harvesting was fine tuned to ensure off allocation diversions calibrated. No historical data exists for on-farm rainfall runoff harvesting.

Table 3.3: Simulated conjunctive groundwater use

YEAR	Observed Conjunctive Groundwater Use (GL)	Simulated Conjunctive Groundwater Use (GL)
1988/89	30	34
1989/90	32	23
1990/91	27	12
1991/92	32	16
1992/93	66	38
1993/94	96	70
1994/95	118	66

3.6.6. Results

Figures 3.9 to 3.11 shows the modelled and observed total diversion volumes over whole valley. Table 3.4 summarises the calibration using the quality guidelines outlined in Appendix E.

Figure 3.9: Namoi Valley - Observed and simulated on allocation diversions

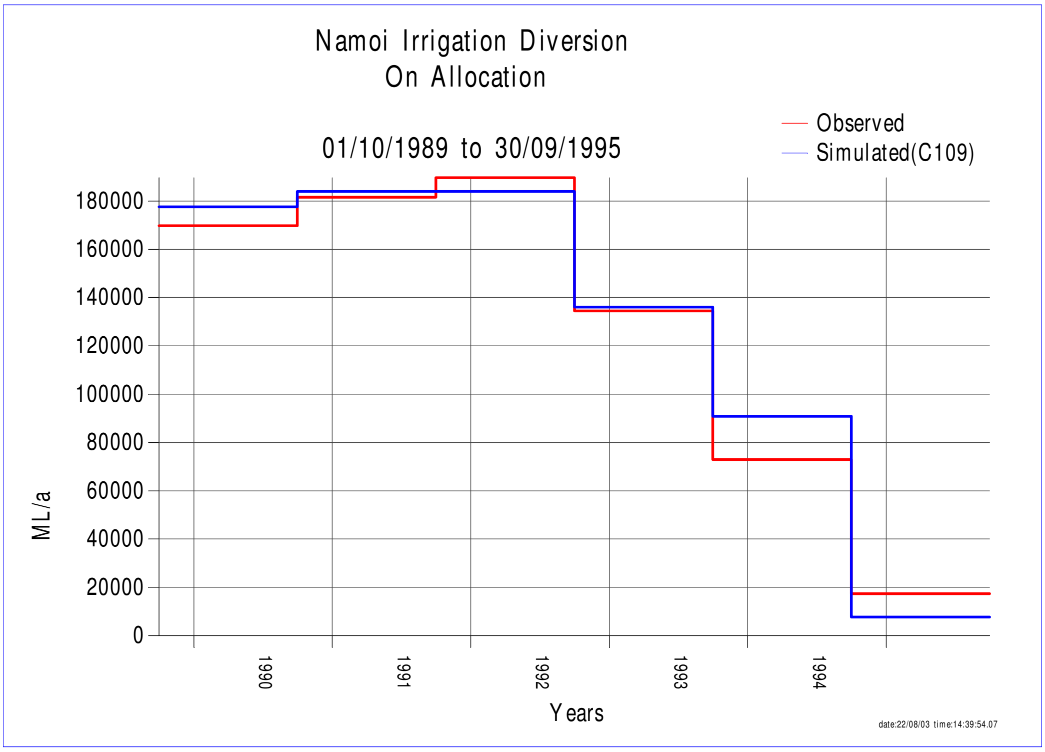


Figure 3.10: Namoi Valley - Observed and simulated off allocation diversions

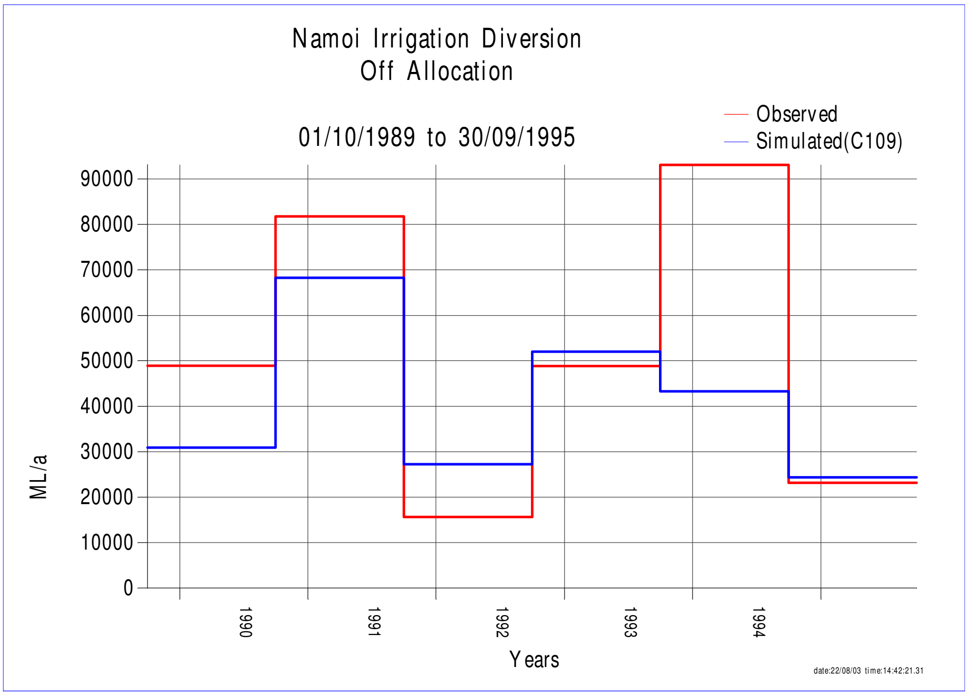
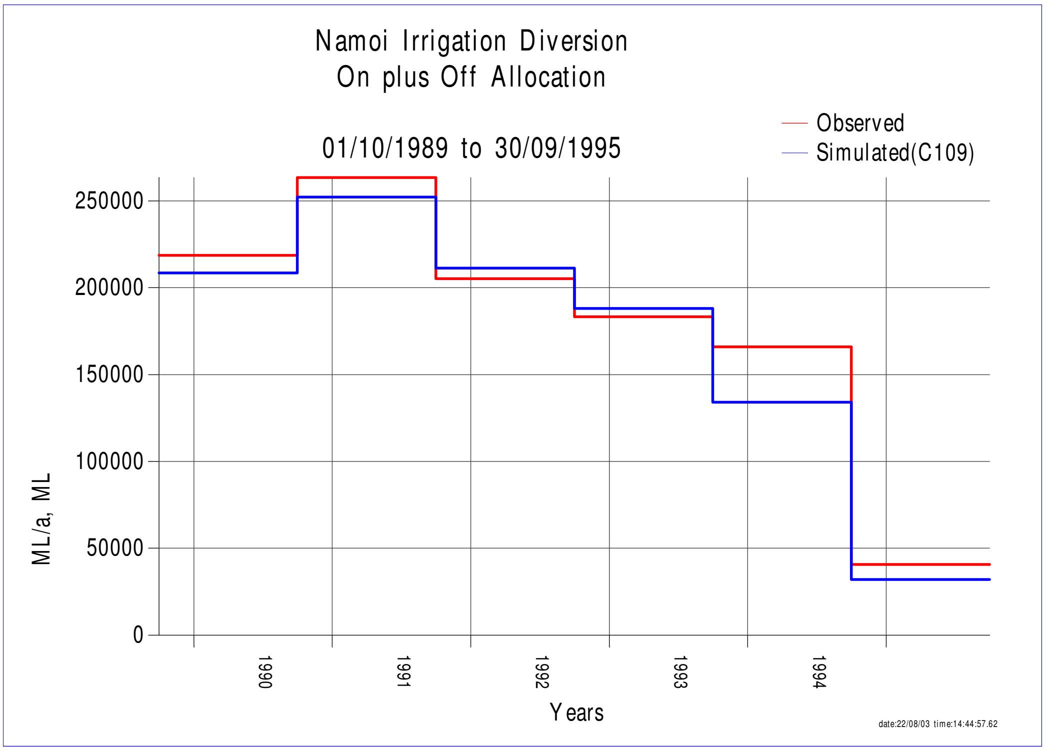


Figure 3.11: Namoi Valley - Observed and simulated total diversions



The worst model calibration was is in 1993/94 were the modelled total diversions were less -24% less than observed. On allocation diversions were +20% and off allocation diversions –50% compared to observed diversions. The model during this calibration phase is planting the observed area. The major difference was caused by the -50% reduction in off allocation diversions, the model is trying to compensate for this by increasing on allocation diversions. The off allocation thresholds calibrated in IQQM were selected to achieve average off allocation diversions over the full range of climatic conditions during the calibration period. Historically during drought times (such as 1992 to 1994) the Department was more lenient allowing greater access to off allocation access more frequently with the aim of allowing more off allocation water to be used. These results are reflected in the quality rating of low (Table 3.4) for off allocation diversions.

Table 3.4: Diversion calibration quality achieved

Diversion Type	Volume Ratio	Apparent Err	Quality Rating	CMAAD	Quality Rating
On Allocation	102%	2%	Very High	6%	Very High
Off Allocation	79%	21%	Low	31%	Very Low
Total	95%	5%	High	7%	Very High
Run No C109, Period 1.10.1989 to 30.9.95 1. Apparent Error = 100 ~ Volume Ratio 2. CMAAD = Σ (Simulated ~ Observed)/ ΣObserved, in annual scale					

3.7. STORAGE BEHAVIOUR REPLICATION

Storage behaviour replication by the model provides the best numerical check of the model's overall performance. All elements of the system contribute to the pattern of draw down and releases in the dam behaviour.

A number of model parameters are calibrated in the storage calibration process (DLWC, 1998[c]). To calibrate these parameters, the calibrated parameters from flow and demand calibration are used, while the crop areas and off-allocation extractions are still forced to observed data. The river operation parameters are then adjusted until the simulated storage behaviour, storage releases and end-of-system flows best match the observed data. The following details the different processes in storage calibration.

3.7.1. Inflow to dams

For the calibration of storage behaviour, dam inflows must first be derived. This is done using a back-calculation procedure (DLWC, 1998[g]) based on information obtained from dam Officer in Charge (OIC) sheets (DLWC, 1940-2000). The back-calculation technique is based on a water balance of dam inputs and outputs as follows:

```
Inflow  = Change in Storage + Releases + Spills + Losses – Direct Rainfall
```

After a review of the available rainfall and evaporation stations and consideration of the criteria outlined in Section 3.4.1, the rainfall and evaporation stations listed in Table A.1 were selected to drive the storage behaviour in the model. Daily OIC sheets were obtained (Keepit Dam = 1983 to 1999; Split Rock Dam = 1988 to 1999) and were used to estimate dam inflows. These inflows were used for calibrating the storage behaviour.

3.7.2. Tributary utilisation

The forecast of the expected flow from a tributary on a future day is modelled as a fixed fraction of the known flow on the current day (i.e. a recession assuming no rainfall). Tributary utilisation is generally quoted in terms of the river operator's adopted *tributary recession factor*. The number of days in the future for which the prediction is required is equal to the travel time from the storage (where the release is being computed for the current day) to the tributary. Releases from the storage to meet downstream demands are reduced to allow for this predicted tributary inflow.

Typically, the tributary recession factors reduce progressively down the main river because of the increasing uncertainty with predicting further into the future. In reality, the factors are not fixed, but they vary with time and recent climatic conditions. The river operator advised us that flows from the Peel and Mooki Rivers as well as Cox's Creek are considered useful for meeting regulated demands when making dam releases. The fixed tributary utilisation factors that produce the best calibration of storage behaviour over the calibration period are presented in Table B.4.

3.7.3. Operational surplus

IQQM represents operational surplus by applying a fixed *over-order factor* to the orders placed by each of the irrigation groups. As the orders are passed upstream they are multiplied by the over ordering factor to increase dam release.

Typically, the over-order factors increase progressively down the main river because of the increasing uncertainty in transmission losses and greater flow attenuation with increased travel distance. For the Namoi IQQM, the fixed over-order factor of 1.0 produced the best calibration of storage behaviour over the calibration period. This was consistent with advice received from the river operator.

3.7.4. Dams transfers

Keepit and Split Rock Dams are operated as a combined storage. Water orders for irrigators below Keepit Dam are supplied from Keepit Dam and water orders for irrigators between Split Rock Dam and Keepit Dam are supplied from Split Rock Dam. Water is released from Split Rock Dam to inflow into Keepit Dam whenever Keepit Dam does not have sufficient volume to meet projected peak daily demands.

Water is held preferentially in Split Rock Dam to maximise the systems ability to capture inflows. The water level in Keepit Dam is maintained high enough to meet the expected peak demand. This is normally just high enough to use the spillway gates.

During the calibration period, a number of test transfers occurred, as well as some other one-off events. The adopted transfer rules in the model are the best interpretation of the official rules and the way the dams are expected to be operated over the long term.

3.7.5. Results

The following Figures 3.12 to 3.14 show the storage calibration for each of the major storages. Table 3.5 summarises the calibration results in terms of the quality guidelines outlined in Appendix E.

Figure 3.12: Keepit Dam – Observed and simulated storage volume

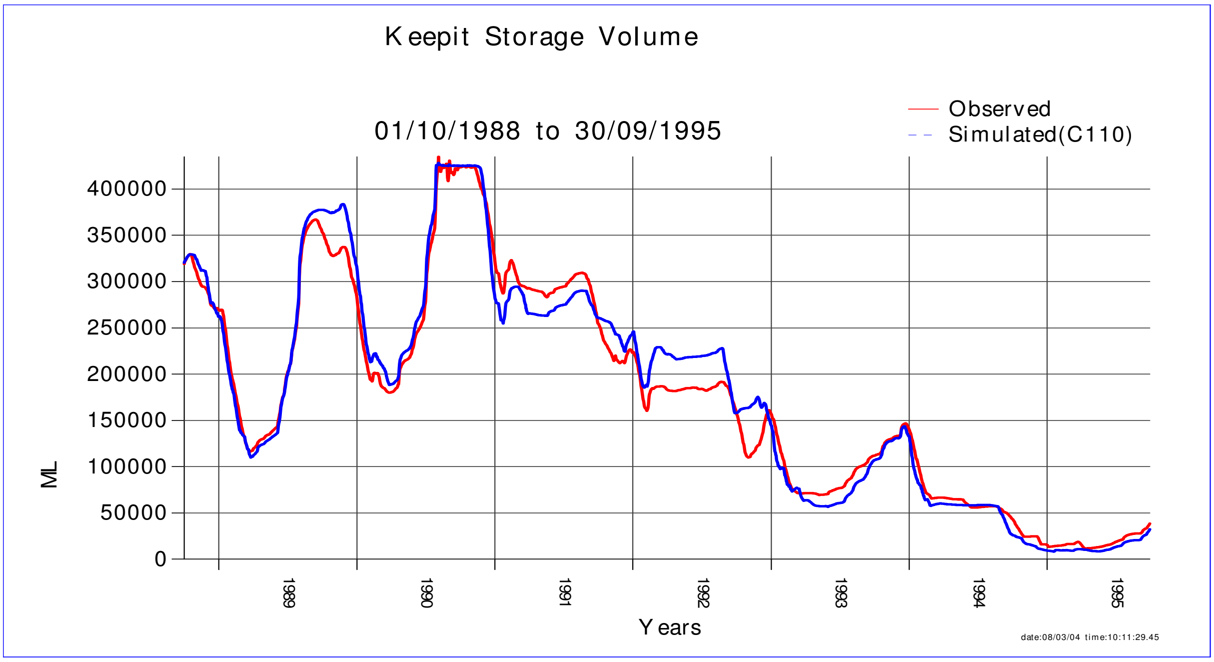


Figure 3.13: Split Rock Dam – Observed and simulated storage volume

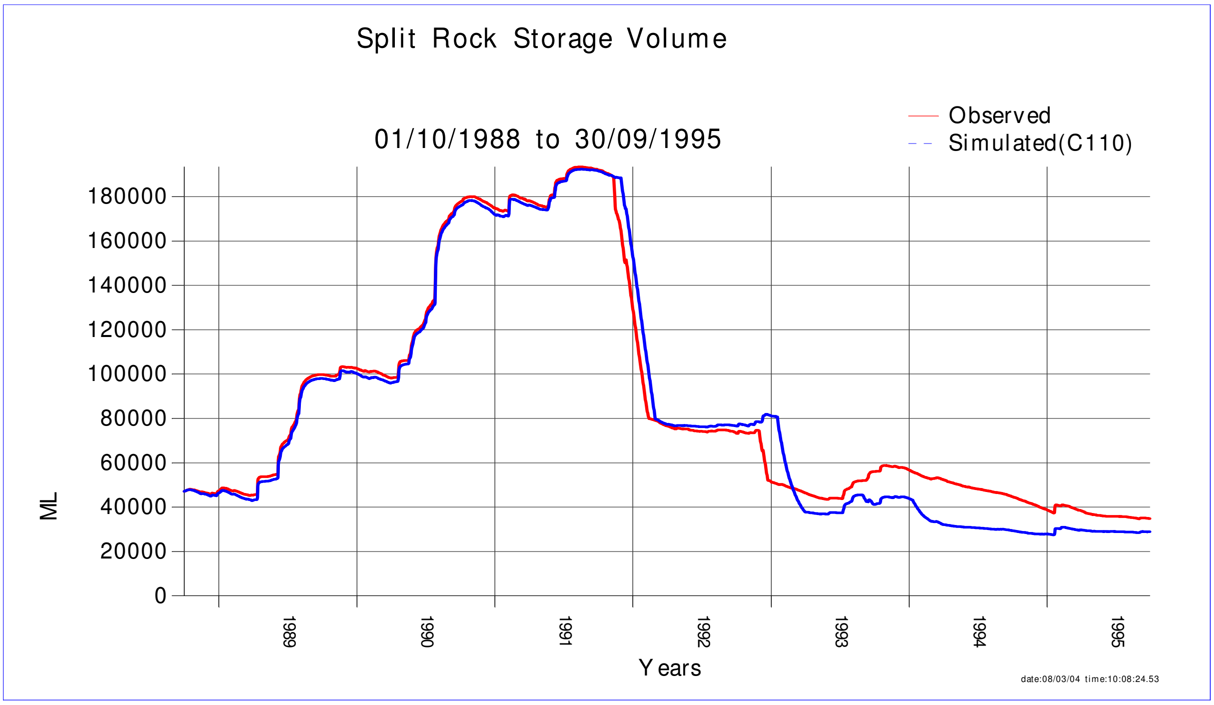
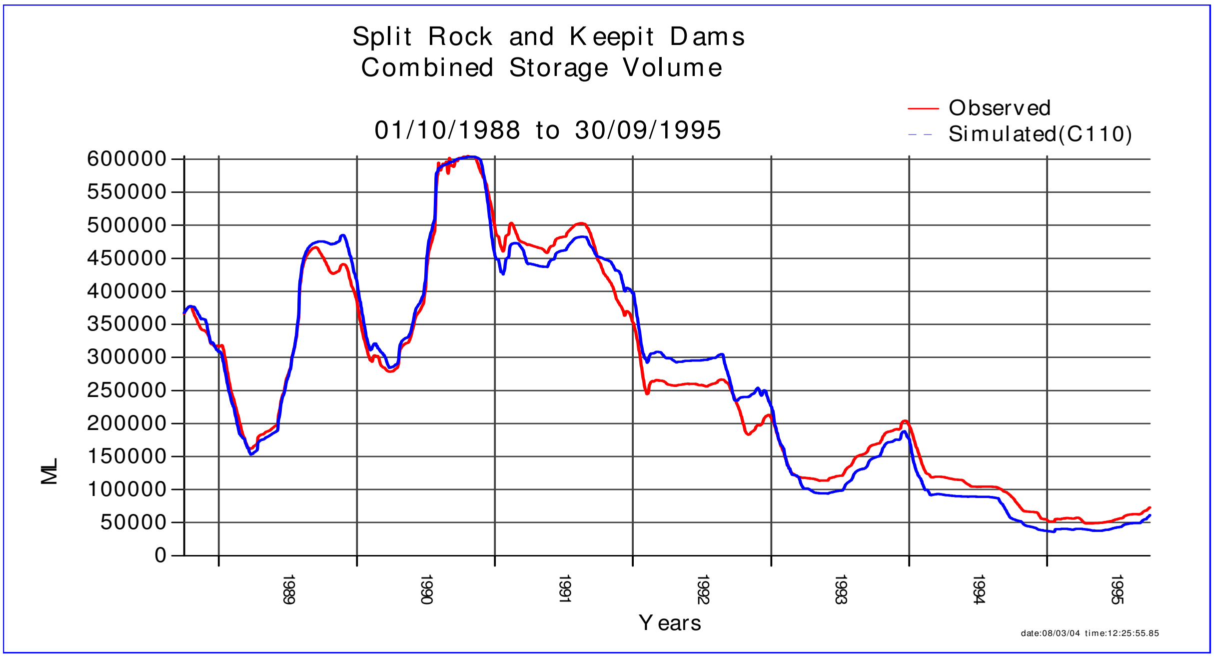


Figure 3.14: Combined Dams – Observed and simulated storage volume



The major difference between the simulated and observed storage behaviour occurred in the 1992/93 water year were the simulated model released more water from Split Rock Dam than observed, however, the combined Dam simulated volume was under estimating compared to observed. At the time of first calibrating the model the reason for this difference was not clear. However with more recent data available from the 2001 to 2003 drought conditions the same model characteristic was observed. Following detailed investigation it was revealed the river operators have adopted a more efficient practices to minimise river losses in the Split Rock to Keepit Dam section. Model losses were fine tuned to match behaviour, however, as mentioned previously the model simulates average losses to ensure long term model behaviour is correct. In individual years during times of extreme dry or wet climatic conditions the model losses will likely not simulate observed losses.

Table 3.5: Storage calibration quality achieved

SUBJECT		Apparent Error (C101)	QUALITY RATING
Irrigator Group	Quality Indicator		
Keepit	CMASDD	2%	Very High
Split Rock	CMASDD	2%	Very High
TOTAL	CMASDD	2%	Very High

CMASSD: Coefficient of mean absolute Storage Drawdown Deviation

3.8. PLANTED AREA REPLICATION

The area planted during the calibration and validation periods usually changes as a result of a number of factors including climate, development in the valley and market conditions. Therefore area planted is usually forced during the calibration phase, however, the data is analysed to understand the farmers planting behaviour. Hence the ability of IQQM to reproduce the farmers planting decision is not really a calibration process but rather a input algorithm to the model to simulate farmers planting behaviour for particular development levels. It was decided to adopt a planted area function based on a ML/ha relationship combined with minimum and maximum areas. Separate functions were derived to represent 93/94 conditions and 99/00 conditions due to observed behavioural changes.

The Namoi Valley experienced growth in planted area during the calibration period. This limits the representativeness of a single planting decision function. Namoi irrigators also have access to groundwater and significant quantities of water stored on farm that further complicates the decision making process. Very little data was available to quantify the impacts of this additional water. The effects of external factors such as commodity prices, financial status, and weather conditions are also not considered.

When developing the farmers planting decision it is appropriate to use data from a range of climatic and resource available years. During the Namoi IQQM calibration period of 1988 to 1995 there were a range of wet and drought years. This variation in climatic conditions should make the minimum and maximum areas highly representative of the true values. Appendix D discusses the approaches used to develop the farmers planting decision. Section 4 discusses the particular parameters derived for 93/94 conditions.

3.8.1. Results

The farmers planting decision is derived for a particular development condition. As a check on the correctness of the planting decision it is usually checked against observed farmer behaviour during the years around the development year. Figure 3.15 show the results from the 1993/94 development conditions compared to the observed areas actually planted in the surrounding years. The results are generally quite good and show farmer behaviour responding to the drought conditions from 1993 to 1995. Table 3.6 applies the quality criteria to assess quality rating for the adopted planting decisions.

Figure 3.15: Observed and simulated planted area

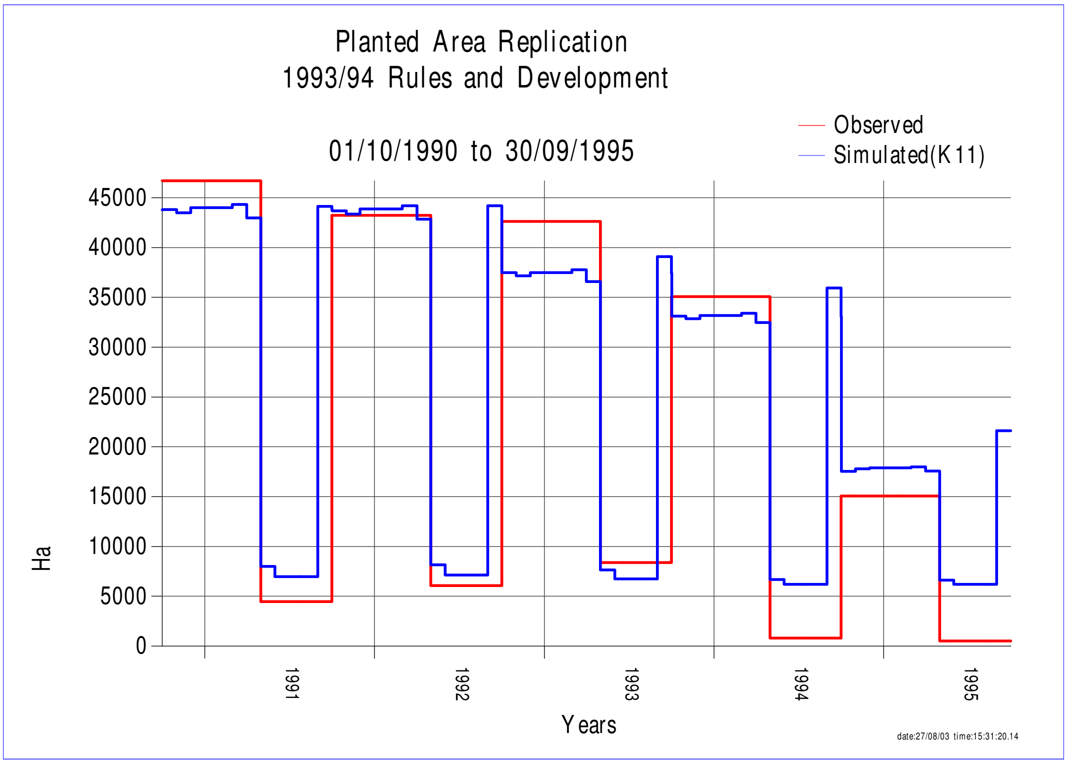


Table 3.6: Planted area quality achieved

SUBJECT				Apparent Error	QUALITY RATING
Irrigator Group	**Period**	**Season**	**Quality Indicator**		
Whole of Valley	93/94	Summer	Area Ratio	1.5%	Very High
			CMAAD	11.5%	Very High
		Winter	Area Ratio	-23.6%	Low
			CMAAD	36%	Very Low
	99/00	Summer	Area Ratio	-0.4%	Very High
			CMAAD	1.8%	Very High
		Winter	Area Ratio	1.7%	Very High
			CMAAD	20.9%	Moderate

3.9. RESOURCE ASSESSMENT

Resource assessment involved the Department assessing how to distribute the available water resources to all water users. Current and future needs of high security user are provided for initially and then remaining resources are allocated to general security users. The Departments operation of the system and any environmental needs are taken into consideration during this process. Up until the

1997/98 water year the Namoi Valley was operated on a annual accounting system. From 1998/99 onwards the resource assessment of the Namoi has been undertaken on a continuous accounting basis.

The following factors are generally taken into consideration in IQQM resource assessment:

- current volume available in the dam; and any downstream weirs;
- minimum expected inflow to the dam;
- minimum expected useful tributary inflow downstream of the dam;
- expected evaporation and transmission losses over the remainder of the irrigation season;
- all the essential requirements placed on the dam.

In consultation with the regional operators, the above information was analysed to identify what operating rules and decision processes had been used in the past. Rules have been setup in IQQM to represent the resources assessment process undertaken for the 1993/94 development conditions (see Section 4).

3.10. OVERALL MODEL CALIBRATION

The overall model calibration quality has been assessed using a combination of selected key indicators (see Appendix E). The results of applying this evaluation process are summarised in Table 3.7.

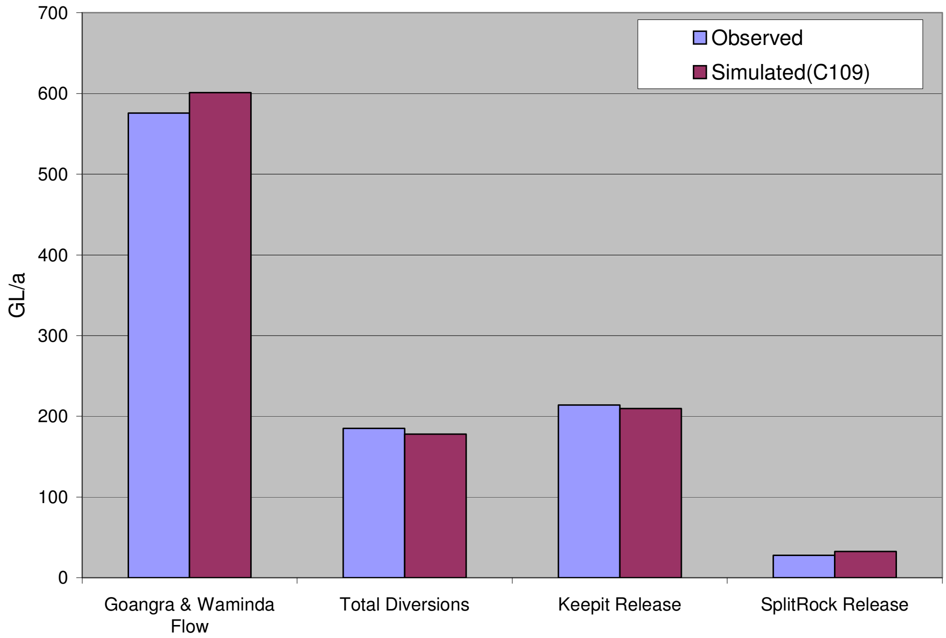
Table 3.7: Overall model quality rating

(Run C109)

ITEM	GS Irrigation		Flow at Mollee		End of System		Storage
Apparent error in :	V Ratio	CMAAD	V Ratio	CMAAD	V Ratio	CMAAD	CMASD
Indicator Value I	5%	7%	5%	6%	4%	8%	2%
Quality Rating of I (QI)	High	V High	High	V High	High	V High	V.High
Lower limit of QI: LL	2	0	2	0	2	0	0
Upper limit of QI : UL	5	10	5	10	5	10	2
Std lower limit of QI: SL	5	0	5	0	5	0	0
Std upper limit QI: SU	10	5	10	5	10	5	5
Standarised indicator: SI	10	3.5	10	3	8.3	4	5
Average Std Indicator: AI	6.3		No of Calibration Year: NY			7	
OVERALL QUALITY INDICATOR			5.3	HIGH			

Another way of viewing the overall calibration is to look at the main indicators of mass balance in the system, as show below in Figure 3.16.

Figure 3.16: Average annual water balance in Namoi River system (1988/89 to 1994/95)



4. 1993/94 Development Conditions (Cap) Scenario

The Namoi River Valley is a designated river valley under Schedule F of the Murray-Darling Basin Agreement (MDBMC, 2000), and is consequently required to be managed to ensure that diversions do not exceed those expected under 1993/94 levels of irrigation infrastructure and management rules (ie the MDBMC Cap). DIPNR will use the Namoi IQQM to estimate this diversion limit and provide an indication of the valley's compliance with the MDBMC Cap.

The previous chapters of this report have outlined how the IQQM has been configured, calibrated and validated for the Namoi Valley. This chapter outlines how the IQQM has been further developed to perform a simulation of the valley with 1993/94 levels of development and long term climatic conditions (ie the *Cap scenario)*. This chapter also outlines how the Cap scenario has been used for short term Cap auditing, ie the *Cap audit scenario*.

Licenced water users extracting water from unregulated streams have not been included in the Namoi Valley IQQM. To date these licences have been operating on the basis of a maximum authorised irrigable area and a commence to pump and/or cease to pump limit for pumping (usually a visible flow at the pump site or the nearest flow gauging station). Past operation of these licences has not been closely monitored and there has generally been very little data collected on water extractions and cropping by these licences. Consequently, the Cap benchmark described in this report only relates to the regulated system. It is intended that, if sufficient information should become available, the model would be expanded to represent unregulated licences.

It should also be noted that the tributary inflows used in the Namoi Valley IQQM have been calibrated using observed streamflow at gauging stations for the periods of their records. Inherent in the stream flow data is the effect of extractions by unregulated licences that are outside influence of regulated flows from Keepit and Split Rock Dams. For the purposes of determining the Cap for the regulated Namoi system, this effect has been deemed to be negligible.

4.1. CAP IN BRIEF

The Namoi River IQQM was used over the 108 year period from 1892 to 2000 to determine long term average annual diversions. For Cap auditing purposes under Schedule F, the model has been run for the 1997/98, 1998/99, 1999/2000 and 1999/2001 water years. The following assumptions were used to represent Cap conditions:

- Keepit and Split Rock Dams infrastructure and operation policy as per 1993/94 conditions;
- Pump capacity as installed in the 1993/94 irrigation season;
- On-farm storage capacity as installed in the 1993/94 irrigation season;
- The crop mix based on observed data up to the 1993/94 irrigation season;
- Maximum planted areas based on observed data up to 1993/94 irrigation season (note the missing crop data for 1995/96 and 1996/97 do not provide continuous data before and after the designated Cap (a drought year) year of 1993/94 to adopt another approach);
- Management rules applicable in the 1993/94 irrigation season.

4.2. CLIMATIC DATA

4.2.1. Rainfall

For the long term simulations, the rainfall stations selected were extended and gap-filled to cover the intended simulation period (Table A1).

4.2.2. Evaporation

For the long term simulations, the evaporation data is generated based on a relationship between monthly evaporation totals and number of rain days in the month. As explained in Section 2.2.2, nine long-term rainfall stations were used for generation of evaporation data for the seventeen river reaches (Table A.1).

4.3. FLOW DATA

4.3.1. Streamflows

The observed data for the tributary gauging stations selected for use in the model (Table A.3) were collated, gap-filled and extended using Sacramento rainfall-runoff models such that they covered the intended simulation period.

The ungauged catchment contributions were then derived based on applying the methodology outlined in Table A.4 to the long-term gauged tributary inflows.

Peel River inflows are based on observed inflows that have been extended using a preliminary Peel IQQM. This preliminary IQQM has been configured to represent XXXX conditions.

4.3.2. Inflows into the dams

To derive the required long-term inflow sequence to Split Rock Dam, the OIC sheet mass balance approach could no longer be sufficient (as these records only begin once the storage has been built about 1987). Therefore, to derive the long-term inflow sequences; a single Sacramento model calibration was prepared for gauge 419043 (Manilla River @ Tarpoly) for the period prior to Split Rock dam construction. This model was then used to extend the pre 1987 back-calculated inflows (DLWC, 1998[a]).

Inflows to Keepit Dam were not estimated directly because they are the resultant of Split Rock Dam outflows and tributary inflows between Split Rock Dam and Keepit Dam.

4.4. IRRIGATION INFORMATION

Where possible, observed data was used to configure the model for physical infrastructure including pump capacities and on-farm storages (Section 2.4).

Parameters such as crop irrigation efficiencies and tributary utilisation factors have been determined during calibration and validation periods. A full listing of parameters describing the Namoi IQQM Cap scenario is included in Appendix F.

4.4.1. Irrigation licences

The regulated irrigation entitlement observed in 1993/94 was used for the 1993/94 Cap scenario (Section 2.4.2 and Appendix F). The 1993/94 Cap scenario described in this report only relates to the regulated system at present. It is intended that, if sufficient information should become available, the model would be expanded to represent unregulated licences explicitly.

4.4.2. Irrigation extraction and storage infrastructure

The pump capacities and on-farm storage volumes observed for the 1993/94 irrigation season were used for 1993/94 Cap scenario (Section 2.4.2 and Appendix F).

4.4.3. Crop areas (planting decision determination)

An examination of historical planted areas suggested that the area planting decision taken by irrigators was reasonably constant (considering climatic condition) over time. Cotton is always the dominant summer crop, however, there have been some variations in winter cropping. Part of the model calibration included developing farmer planting decisions for summer and winter. Further discussion of the planting decision process in IQQM, and its development, are presented in Appendix D.

4.4.3.1 Crop mix

Even if the economic and social conditions remain unaltered, the need to rotate land on the farms and the variations in local climate affecting soil moisture at the planting decision date will lead to some changes in crop areas and mix from year to year. It was decided to investigate the crop mix over a few years around 1993/94 before determining the best crop mix to represent 1993/94 Cap conditions.

Table 2.8 show the crop mix leading up to 1993/94 was reasonably consistent. It was also recognised that 1993/94 was a drought year in the Namoi Valley. A crop mix based on the average of the years 1990/91, 1991/92, and 1992/93 (reach by reach) was adopted as being most representative of 1993/94 long term development conditions. Table F4 shows the final crop mix adopted for 1993/94. The adopted crop mix for each irrigation node is constant for the duration of the simulation.

4.4.3.2 Maximum area

The calibration period contains a number of years of 100% allocation and reasonable off allocation supplies. The maximum area was determined on a reach by reach basis, and should be highly representative of the actual maximum area. The maximum planted area specified in IQQM is planted when there are sufficient resources available.

Table 2.7 shows the area planted for the valley. There is a general trend of increasing area even taking into consideration the drought years and years of missing data. An maximum summer and winter area based on the average of years 1990/91, 1991/92, and 1992/93 (reach by reach) was adopted as being most representative of 1993/94 development conditions. Table F2 shows the final maximum areas adopted for 1993/94. The adopted maximum area for each irrigation node is held constant for the duration of the simulation.

4.4.3.3 Minimum area

In resource constrained years there is likely to be a minimum area planted. Using observed irrigation area data particularly including the 1994/95 irrigation season. An estimate was made of the total minimum area that would be planted in the Valley for the Cap scenario in resource constrained years.

The 1994/95 year was the worst year of an extended drought sequence. There was 0% allocation, and little or no opportunity to store or harvest water from other sources. This year should be highly representative of severely resource constrained planting for the purposes of the Namoi IQQM model. The total minimum planted area for the Namoi IQQM Cap scenario is approximately 13,300 Ha. The estimated minimum areas are based around the 1994/95 year, however, no minimum areas were assumed for river reaches above Keepit Dam (reaches 1, 2 and 3) or the winter areas. Table F2 details the minimum areas used for the 1993/94 development conditions.

4.4.3.4 Planting decision determination

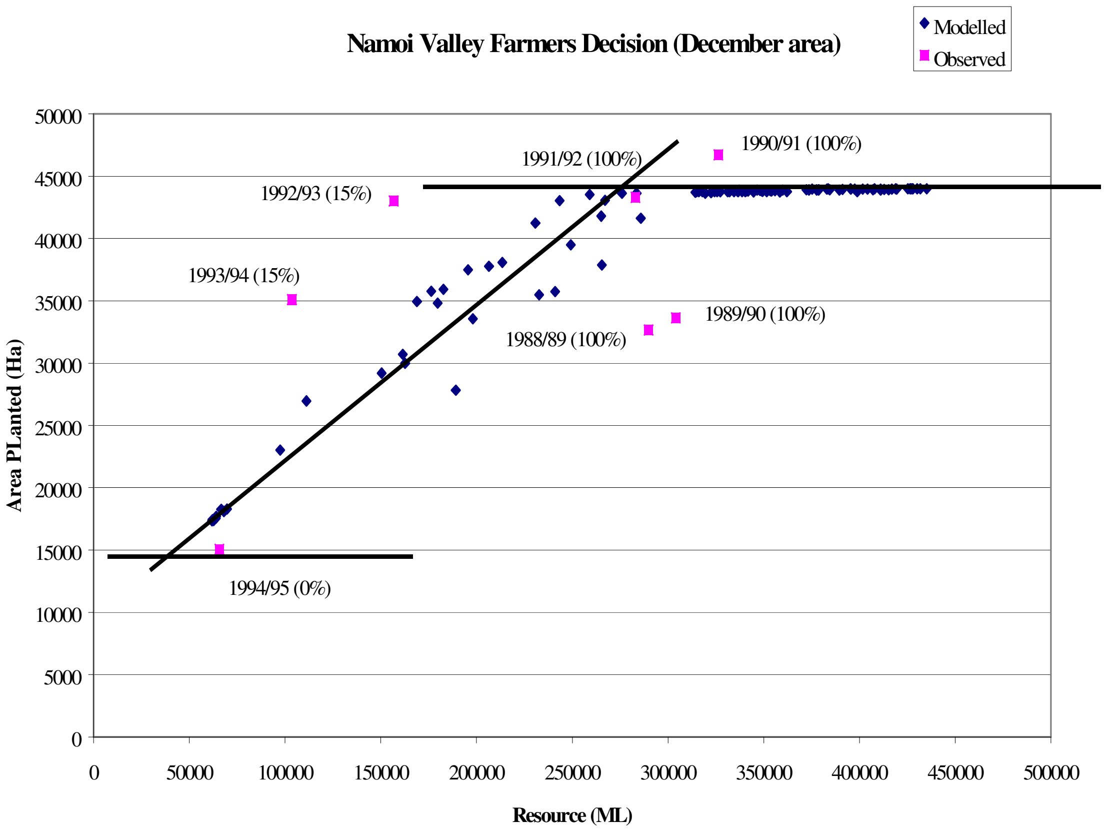
To determine a planting decision that covered the full range of resource availability, the following points were taken into consideration:

- A summer minimum area of about 13,300 ha that will be planted.
- A summer and winter maximum area of about 45,000 ha, and 6,000 ha.
- In the model it is assumed that irrigators may take some risk in medium years. This means that crops are planted based on the water that is available at planting date (including any estimates for transfer water) and a risk factor allowing for increases in allocation or access to off allocation.
- When allocating water for summer and winter crops it was assumed that priority was given to summer crops. This means that summer crops were planted on the basis of using as much of the entitlement as was required to plant maximum summer area. The balance remaining at the winter decision date was used to determine the area to plant in winter.
- Planting decisions are based on the amount of water an irrigator has available. In the case of the Namoi Valley this would include the sum of on allocation water, water in on-farm storage and any water available under conjunctive water use.

Based on the above observations, a function was derived for total valley summer planting behaviour and is shown in Figures 4.1. Following the example shown in Figure 4.1, a summer planting behaviour was estimated for each irrigation reach based on the area planted and estimated resources available to the irrigation node during the period 1988/89 to 1994/95. Plotting these values and assessing the slope of the line allowed an apparent application rate to be derived for each irrigation node. The apparent application rates used for each node are detailed in Table F3.

There was little information available to estimate a winter planting decision. A maximum winter area was set at about 6,000 ha with no minimum area. Reviewing the cropping data indicated an application rate of about 4 ML/ha for winter cropping. This application rate was used for all irrigation nodes to estimate the area planted within the maximum and minimum area boundaries.

Figure 4.1 Total Namoi Valley summer planting decision



4.4.4. End-of-year diversions

The Namoi Valley has significant on farm storages, and the observed diversion data shows evidence of ordering of on allocation water in September and this water being stored in the on farm storages. There appear to be a number of reasons for this irrigator behaviour:

- A use-it-or-loose it mentality developed under the old annual accounting system;
- Pre-water for the coming irrigation season or;
- Priming of on farm storage volumes ready for the coming irrigation season.

Irrespective of the reason for the on farm filling in September it is a common practice of irrigators and has been included in the Namoi IQQM. All irrigators that have an on farm storage will order water to fill their on farm storage until their account balance is gone, or the on farm storage reaches 90% of its maximum capacity.

4.4.5. Transfer market

Temporary trading of water is assumed within irrigation nodes that allow full entitlement to be used. IQQM has not been setup for any trading between irrigation nodes. The significance of temporary trade in the Namoi Valley on water availability has not been investigated.

4.4.6. High security irrigation

No high security irrigators are modelled in Namoi IQQM.

4.4.7. Unregulated use

The unregulated licences have not been included explicitly in the Namoi IQQM. Consequently, the 1993/94 Cap scenario described in this report only relates to the regulated system.

It is important to note, however, that the tributary inflows used in the Namoi IQQM have been estimated using observed streamflow at gauging stations over a variety of periods. Inherent in the observed streamflows is the effect of extractions by unregulated licences that are upstream of the gauging stations. For this reason, some of the unregulated extractions have been included implicitly in the model. For the purposes of determining the Cap for the regulated Namoi system, this effect has been deemed to be negligible.

It is intended that, if sufficient information should become available, the model would be expanded to represent unregulated licences explicitly, as discussed in Chapter 5.

4.5. TOWN WATER SUPPLY

Town water supply is modelled by Namoi IQQM, the high security entitlement is considered during resource assessment and a use is included in the model to represent 1993/94 development. The high security town water supply entitlement of 2,300 ML was used for the Cap run and usage was set at 1993/94 diversion levels (see Table 2.9).

4.6. STOCK AND DOMESTIC

Stock and domestic supply is modelled by Namoi IQQM, the high security entitlement is considered during resource assessment and use is included in the model to represent 1993/94 development. The high security stock and domestic entitlement of 2,600 ML was used for the Cap run and usage was set at 1993/94 diversion levels (see Table 2.9).

There is an additional 200 ML of entitlement for such activities as horticulture, pecans, pisciculture and recreation uses that has been added into this category.

4.7. INDUSTRIAL AND MINING EXTRACTIONS

Industrial and mining supply is modelled by Namoi IQQM, the high security entitlement is considered during resource assessment and use is included in the model to represent 1993/94 development. The high security industrial and mining entitlement of 3,400 ML was used for the Cap run and usage was set at 1993/94 diversion levels (see Table 2.9).

4.8. GROUNDWATER ACCESS

In the IQQM calibration process allowance was made for conjunctive use of groundwater resources and the combined use of those resources together with on allocation water, off allocation water and on farm storage water to meet crop water requirements. The conjunctive use parameters estimated during the calibration period (Section 3.5.3) were applied to the Cap run.

4.9. RESOURCE ASSESSMENT

The typical information required to make resource assessments for the Namoi Valley was determined and the model configured appropriately. The main features of the resource assessment system that were in place for the 1993/94 season are listed below:

- Keepit and Split Rock Dams operated together.
- Water transferred from Split Rock Dam to Keepit Dam to maintain volume in Keepit Dam at about 105 GL.
- Annual accounting
- Maximum allocation of 100%
- No carryover of unused allocation
- No borrow from the following year's allocation;
- Storage reserve is a function of total storage, Split Rock Dam ranges from 30 GL at empty storage to 84.7 GL at full storage and Keepit Dam ranges from 10 GL at empty storage to 57.5 GL at full storage.

A full listing of parameters used can be found in Appendix F.

4.10. RIVER AND STORAGE OPERATION RULES

4.10.1. Tributary utilisation

Tributary utilisation in terms of meeting orders generated by water users is 100% utilisation of tributary flow from Peel, Mooki and Coxs Rivers/Creeks.

4.10.2. Operational surplus

For the Namoi IQQM, the fixed over-order factor of 1.0 produced the best calibration of storage behaviour over the calibration period. The same factors are adopted for the Cap scenario as well.

4.11. SURPLUS FLOW ACCESS (OFF-ALLOCATION)

The off allocation threshold developed in calibration and described in Table F5 were adopted for the Cap scenario.

4.12. RIVER FLOW REQUIREMENTS

4.12.1. Minimum flows

Table 4.1 shows the adopted minimum flow requirements at various locations for the Cap case.

Table 4.1: Minimum flow requirements

Location	Minimum flows
Split Rock Dam	5 to 6 ML/d
Keepit Dam	10 ML/d
Goangra	40 ML/d (October to March)

4.12.2. Stock & Domestic replenishment

An allowance of 14,000 ML is set aside for 2 stock and domestic replenishments down Pian Creek (Section 2.12.13).

4.13. FLOODPLAIN HARVESTING

The parameters derived during model calibration for floodplain harvesting were used in the Cap scenario. Table G.6 details the flow thresholds used in the Cap development model.

4.14. RAINFALL RUNOFF HARVESTING

The parameters derived during model calibration for rainfall runoff harvesting were used in the Cap scenario. Table G.6 details the potential rainfall runoff volume irrigators can utilise in the Cap development run.

4.15. COMPARISON WITH 1989/90 TO 1994/1995 PERIOD

To assess the robustness of the Cap scenario, a simulation was performed over the period where irrigation development was closest to Cap conditions. Just using the irrigation seasons around 1993/94 was not feasible because of drought conditions in the Namoi. The drought started in the 1992/93 irrigation season and finished during the 1995/96 irrigation season. The 1989/90 to 1994/95 seasons was chosen to test the 1993/94 development conditions to provide a range of climatic conditions.

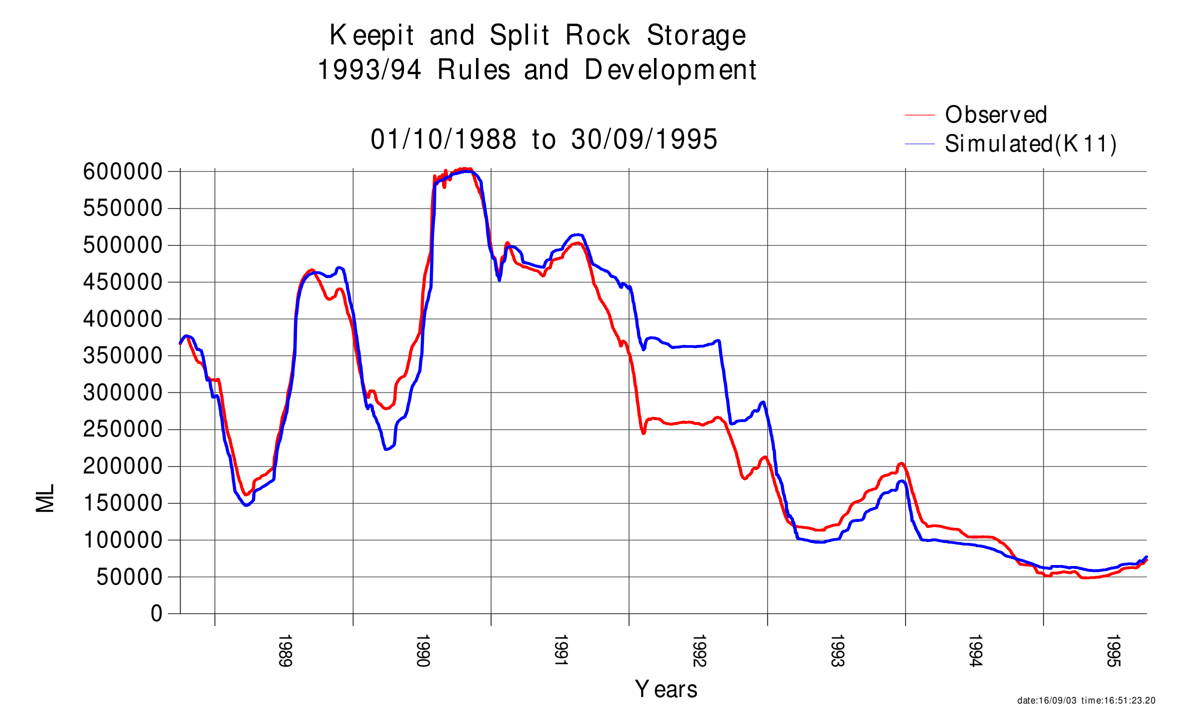
The storage volumes in Keepit and Split Rock Dams at the commencement of the 1989/90 water year were selected from observed data. The starting storage volumes in the on-farm storages were estimated from a combination of reported volumes and observed river flows. Information suggested that is was highly likely that on-farm storages were full at the start of the 1989/90 water year.

The observed and simulated results were compared for a number of processes including announced allocations, planted areas, diversions, storage behaviour and end-of-system flows. The results are presented in Table 4.2. The Keepit plus Split Rock Dam storage behaviour for the 1990-95 period is shown in Figure 4.2.

Table 4.2: Key observed verses modelled parameters for 1989/90 – 1994/95

Parameter		*1989/90*	*1990/91*	*1991/92*	*1992/93*	*1993/94*	*1994/95*
Announced Allocation (%)							
October	Modelled	100	100	100	35	5	0
	Observed	100	100	100	15	15	0
Areas (Ha)							
Total	Modelled	50,400	51,000	51,100	38,700	39,100	22,700
	Observed	36,500	52,200	49,300	51,400	35,800	15,500
	Difference	+38%	-2%	+4%	-25%	+9%	+46%
Summer (Ha)	Modelled	44,000	44,000	43,900	37,500	33,200	17,900
	Observed	35,000	46,700	43,200	43,000	35,000	15,000
	Difference	+25%	-6%	+2%	-13%	-5%	+19%
Winter (Ha)	Modelled	6,600	6,900	6,800	6,800	6,200	6,200
	Observed	1,500	4,500	6,100	8,400	800	500
	Difference	+440%	+53%	+11%	-19%	+775%	+1240%
Diversions (GL)							
Total	Modelled	274	262	229	199	104	23
	Observed	219	263	205	184	166	40
	Difference	+25%	-1%	+12%	+8%	-37%	-42%
On allocation	Modelled	215	166	181	137	68	0
	Observed	170	182	190	134	73	18
Off allocation	Modelled	59	94	47	61	35	21
	Observed	49	82	15	49	93	23
Application Rate (ML/Ha)							
	Modelled Observed	5.4 6.0	5.0 5.0	4.5 4.2	5.1 3.6	2.6 4.6	1.1 2.6
Flows (GL)							
Keepit releases	Modelled	472	199	215	160	88	16
	Observed	471	241	258	154	100	33
	Difference	0%	-17%	-17%	+4%	-12%	-52%
End-of-system: (Goangra* + Wamindra[#])	Modelled Observed	1322 1412	644 744	454 400	165 140	145 77	235 151
	Difference	-7%	-13%	+13%	+18%	+88%	+56%

Figure 4.2: Keepit plus Split Rock Dam Combined Storage



4.15.1. Comment on modelled and observed allocations

The observed and modelled announced allocations are exactly the same for the first three years (1989/90, 1990/91 and 1991/92) when allocations were 100%. In 1992/93 the Department allowed a one off, valley carryover of 80 GLs from 1991/92 on allocation water into the 1992/93 water year. The carryover had to be used up within he first 3 months of 1992/93. The announced allocation of 15% plus the 80 GL (about 30% of entitlement) equates well with the modelled allocation of 35%. 1992/93 to 1994/95 were drought years in the Namoi Valley and the system was not operated "on average". Considering this behaviour the simulated allocation levels still match observed allocation levels well.

4.15.2. Comments on modelled and observed areas

When comparing the observed and modelled planted areas, over the 1989/90 to 1994/95 validation period, there are three major factors that affect the results, these are:

- the differences between observed and simulated allocation announcements will produce an expected difference in the planted areas;
- the irrigator's risk function in the model will for different total water resources plant different areas;
- the adopted maximum area in the model places a ceiling on the area planted irrespective of the water resources available.

The following comments are made on the year by year behaviour:

- The modelled summer areas for 1989/90 to 1991/92 are at their maximum of 44,000 Ha. There is a difference in 1989/90 where the valley was less developed than that assumed for 1993/94 development conditions and the model plants an additional 9,000 Ha.
- The observed and modelled summer areas for 1990/91 to 1991/92 match well (before the drought).
- The modelled summer area for 1992/93 was less (-25%) that that observed. This season had the one off 80 GL carryover that would have likely impacted on the way irrigators planted. Also this was the first year of the 3 years of drought and it appears irrigators may have been over optimistic with their areas planted.
- The modelled summer areas for 1993/44 and 1994/95 compare well with the observed areas.
- The modelled winter areas generally exceed the observed winter areas. The model area planted in winter has been set at a level representative of plantings during a good to average water availability year. During the drought years of 1993 to 1995 the irrigators chose to not plant winter areas. The winter area is not particularly critical to total water diversions because winter crops generally rely on water from rainfall.

4.15.3. Comments on modelled and observed diversions

When comparing the observed and modelled diversions over the 1989/90 to 1994/95 validation period, there are three major factors that need to be considered:

- the differences between observed and modelled planted areas will flow onto differences in the water diversions;
- the available volume in on-farm storages and how irrigators utilise floodplain harvesting, on farm rainfall-runoff harvesting and their access to groundwater all impact on diversions from the river. It should be notes that on-farm storage volumes increased from about 80 GL's to about 120 GL's during this validation period and no year by year records were available.

The following comments are made on the year by year behaviour:

- The comparison between modelled and observed diversions between 1989/90 and 1994/95 was overall very well, however, in individual years there were errors. Therefore any differences in diversions cannot be attributed only to calibration inadequacies.
- In 1989/90 the modelled planted area was greater (+38%) then observed and therefore modelled diversions are greater (+32%) then observed diversions.
- In 1990/91 and 1991/92 modelled areas and diversions match observed areas and diversions well.
- In 1992/93 the modelled planted area is less (-25%) then observed but the modelled diversions are greater (+7%) then observed diversions. Also for an effective allocation of around 45% (15% announced allocation and about 30% carryover) the irrigators planted a total area equivalent to that planted in previous years when 100% allocation was announced. The modelled diversions and observed diversions match well because there was likely only a limited amount of water available to be used and the model made all of that water available.
- In 1993/94 the modelled diversions were less (-37%) compared to observed but the modelled area planted was greater (+9%) then observed. The modelled and observed areas planted are close enough to suggest something else was causing the difference in diversions. When you look at the

break down of diversions, the major difference was about a -60% reduction in off allocation diversions. The off allocation thresholds calibrated in IQQM were selected to achieve average off allocation diversions over the full range of climatic conditions during the calibration period. Historically during drought times the Department was more lenient with greater access to off allocation access more frequently with the aim of allowing more off allocation water to be used.

- In 1994/95 the modelled diversions were less (-25%) compared to observed but the modelled area planted was greater (+46%) then observed. Here the break down of diversions showed the modelled on allocation diversions to be zero (as expected with a 0% allocation) while the observed on allocation diversions were some 18 GL's. Again, historically during drought times, the Department has where possible supplied water to irrigators

4.15.4. Comments on modelled and observed storage behaviour

The dam storage behaviour is the major indicator of how well the model assumptions compares to the observed behaviour. However, many of the processes in the river system including on allocation diversions, off allocation diversions, water orders, river losses, tributary utilisation and estimated streamflow impact on the dam releases which in turn impact on dam behaviour. For example Figure 4.2 show the result of the model over the 1989/90 to 1994/95 period where the model calculated area planted and announced allocation using the Cap scenario conditions. However, if you force the model to use the observed planted areas and the observed announced allocations over the 1989/90 to 1994/95 period the combined storage behaviour would be different, see Figure 3.14.

4.16. 1993/94 CAP MODEL RESULTS

4.16.1. Long term Cap annual diversions

Table 4.3 summarises the model results for the 1993/94 development condition Cap model being run over the long term of 1892/93 to 1999/00.

The storage volumes in Keepit Dam, Split Rock Dam and the on-farm storages were initially set as being full or substantially full. Experience and initial model runs showed that it was irrelevant what starting conditions were put in the model, there was so much water around in the early 1890's that the dams quickly filled. It is also clear that the long-term average diversions do not vary significantly with changes to the assumed starting conditions when the period of model simulation is over 100 years. Sensitivity testing of the staring conditions was not considered worthwhile.

Table 4.3: Summary of the 1993/94 development condition simulation run

Summary Aspect	*Sub-aspect*	*Long term average*
System file		NamoB023.sqq
Water usage	General security on allocation	174 GL
	General Security off allocation	76 GL
	Floodplain harvesting	19 GL
	High security/stock & domestic/town water supply	1.5 GL
	Total	270 GL
	Rainfall runoff harvesting	45 GL
	Groundwater	27 GL
Crop model	Average general security planted area (summer and winter)	29300 Ha
	Maximum general security planted area (summer)	44,000 Ha
River flows	Namoi River at Goangra plus Pian Creek at Wamindra	624 GL

Namoi Reliability on 01/10	100%	75%	50%	5%
(% of years that achieved ≥ stated % allocation)	65%	71%	79	92%

4.16.2. 2001/02 Cap audit (Schedule F accounting simulation)

To assess Cap performance in each valley designated in Schedule F of the Murray-Darling Basin Agreement (MDBMC, 2000), annual Cap simulations using the relevant IQQM are performed. In the Namoi Valley, the Cap simulation commenced at the start of the 1997/98 water year (October), with storage levels initialised at observed values. The IQQM then simulates continuously through subsequent water years using the observed climatic data as input and development and management rules fixed at 1993/94 levels.

To commence the Cap audit scenario, IQQM is started several weeks before the commencement of the 1997/98 water year, to allow for the river system to fill with water and to provide a better starting soil moisture store. Storage levels are set such that, at the commencement of the 1997/98 water year, they are equivalent to observed levels. This is known as *hot-starting* the model for the 1997/98 water year. At the commencement of the simulation, IQQM will plant an area based on the resources available at that time.

The annual Cap simulation results for the 1997/98 to 2001/2002 irrigation seasons are presented in Table 4.4, with a comparison to the observed data. These results show for the Namoi Valley, at the end of the 2002/03 water year, that cumulative observed diversions are 20 GL's in excess of the diversions predicted by the model. Given that cumulative observed diversions are allowed to exceed the modelled diversions by 20% of the long term average annual Cap diversions (ie 48 GL) then the Namoi Valley is not in breach of Schedule F of the MDBMC Cap.

Table 4.4: Namoi Valley preliminary Schedule F account

Water year	Total diversions (GL)	Cap estimate from IQQM (GL)	Difference (GL)	Cumulative Difference
1997/98	209	235	+26	+26
1998/99	233	228	-5	+21
1999/00	258	252	-6	+15
2000/01	265	243	-22	-7
2001/02	266	250	-16	-23
2002/03	194	160	-34	-57
Cumulative total	1425	1368		
Long-term average Cap estimate:			250	
20% of Long-term average Cap estimate:			50	
Cumulative Cap performance:			Above Cap	

5. Management of Cap with 1999/2000 Development Conditions

As outlined in Section 4 the Namoi River Valley is a designated river valley under Schedule F of the Murray-Darling Basin Agreement (MDBMC, 2000). This requires the valley to be managed to ensure that diversions do not exceed those expected under 1993/94 levels of irrigation infrastructure and management rules (ie the MDBMC Cap). As also outlined in Chapter 4 DIPNR will use the Namoi IQQM to estimate this diversion limit and therefore provide an indication of the valley's compliance with the MDBMC Cap.

DIPNR has proposed to manage water diversions by the introduction of management and/or environmental flow rules that keep long tern water diversions under the 1993/94 Cap conditions. To test these environmental flow rules or management practices to manage the MDBMC Cap, a model with current conditions needs to be used. This would include current development conditions, current irrigator practices as well as current water management policies. This chapter outlines the model DIPNR has set up for 1999/2000 development condition to examine Cap management with current development and new management rules.

5.1. 1999/2000 DEVELOPMENT CONDITIONS IN BRIEF

Since 1993/94 development conditions there has been growth in irrigation area planted, increases in on-farm storage volumes and changes to on farm water management practices. Irrigators have better utilised both floodplain harvesting and rainfall runoff harvesting resources and there have been changes to groundwater management. The following highlights the major changes in the Namoi Valley that have occurred in water use and management since the 1993/94 development conditions.

- Table 2.7 shows total area planted has grown from a maximum of 50,988 Ha in 1992/93 (before the drought) to a new maximum of 76,538 Ha in 1999/00 (50% increase). Summer areas have increased from 45,706 Ha to 52,552 Ha (15% increase) while winter areas have increased from 8,375 Ha to 27,173 Ha (320% increase). Some of these figures may be isolated good or bad years, however, the trend shows overall increasing area.
- Table 2.4 shows on farm storage volumes have increased from around 118,000 ML to nearly 190,000 ML (60% increase).
- Some data and anecdotal information suggests greater use of floodplain harvesting and local rainfall runoff harvesting.
- Conjunctive use groundwater licenses have been converted to groundwater only licenses.
- DIPNR introduced environmental flow rules into the Namoi Valley in 1998.
- The valley has switched from an annual accounting system to continuous accounting in 1999/2000.
- It is proposed to commence the Namoi Valley Water Sharing Plan in January 2004.

5.2. UPDATES TO CLIMATIC DATA & STREAMFLOW DATA

The selected rainfall and evaporation stations used in the model have been extended and gap filled to cover the simulation period of 1892 to 2002. The observed data for the tributary gauging stations used in the model were collated, gap-filled and extended using Sacramento rainfall-runoff models such that they covered the intended simulation period. Inflows to Split Rock Dam have been updated using back-calculated inflows. Inflows from residual catchments have been updated following previous practices.

5.3. IRRIGATION INFORMATION

Where possible, observed data was used to configure the model for physical infrastructure including pump capacities and on-farm storages. A full listing of parameters describing the Namoi IQQM 1999/00 scenario is included in Appendix G.

5.3.1. Irrigation licences

The regulated irrigation entitlement observed in 1999/00 was used for this scenario (Section 2.4.2 and Appendix G). The 1999/00 development scenario described in this report only relates to the regulated system.

5.3.2. Irrigation extraction and storage infrastructure

The pump capacities and on-farm storage volumes observed for the 1999/00-irrigation season were used for 1999/00 development scenario (Section 2.4.2 and Appendix G).

5.3.3. Crop areas (planting decision determination)

With more updated information some fine tuning of the farmers planting decision applied to the 19993/94 development conditions have been updated for 1999/00 development..

5.3.3.1 Crop mix

Table 2.8 show the crop mix leading up to 1999/00. A crop mix based on the average of the years 1997/98, 1998/99, and 1999/90 (reach by reach) was adopted as being most representative of 1999/00 long term development conditions. Table G.4 shows the final crop mix adopted for 1999/00. The adopted crop mix for each irrigation node is constant for the duration of the simulation.

5.3.3.2 Maximum area

Table 2.7 shows the area planted for the valley. There is a general trend of increasing area even taking into consideration the drought years and years of missing data. An maximum summer and winter area based on the average of years 1997/98, 1998/99, and 1999/90 (reach by reach) was adopted as being most representative of 1999/00 development conditions. Table G.2 shows the final maximum areas adopted for 1999/00. The adopted maximum area for each irrigation node is held constant for the duration of the simulation.

5.3.3.3 Minimum area

In resource constrained years there is likely to be a minimum area planted. Using observed irrigation area data particularly including the 1994/95 irrigation season. An estimate was made of the total minimum area that would be planted in the valley for the 1999/00 scenario in resource constrained years. The estimated minimum areas are based around the 1994/95 year, however, with more recent data and some newer grouping of licences, there were some minor adjustments. Table G.2 details the minimum areas used for the 1999/00 development conditions.

5.3.3.4 Planting decision determination

To determine a planting decision that covered the full range of resource availability, the following points were taken into consideration:

- A summer minimum area of about 11,100 ha that will be planted.
- A summer and winter maximum area of about 51,000 ha, and 19,000 ha.
- In the model it is assumed that irrigators may take some risk in medium years. This means that crops are planted based on the water that is available at planting date (including any estimates for purchasing transfer water) and a risk factor allowing for increases in allocation or access to off allocation.
- When allocating water for summer and winter crops it was assumed that priority was given to summer crops. This means that summer crops were planted on the basis of using as much of the entitlement as was required to plant maximum summer area. The balance remaining at the winter decision date was used to determine the area to plant in winter.
- Planting decisions are based on the amount of water an irrigator has available. In the case of the Namoi Valley this would include the sum of on allocation water, water in on-farm storage and any water available from groundwater (formerly conjunctive water use).

A summer planting behaviour was estimated for each irrigation reach based on the area planted and estimated resources available to the irrigation node during the period 1988/89 to 1999/00. Plotting these values allowed an maximum area, minimum area and apparent application rate to be derived for each irrigation node. The apparent application rates used for each node are detailed in Table G.3.

There was little information available to estimate a winter planting decision. A maximum winter area was set at about 19,000 ha with no minimum area. Reviewing the cropping data indicated an application rate of about 4 ML/ha for winter cropping. This application rate was used for all irrigation nodes to estimate the area planted within the maximum and minimum area boundaries.

5.3.4. End-of-year diversions

See section 4.3.4 for details. Information suggests this practice is still operating in the valley and has been modelled for 1999/00 development conditions.

5.3.5. Transfer market

For 1999/00 development the trading market is assumed to be working effectively and all available water resources are utilised within each irrigator node. In practice there will be some temporary transfer of water between irrigator nodes. This option is not available in the current IQQM.

5.3.6. High security irrigation

There is no high security irrigator entitlement in the Namoi IQQM.

5.3.7. Unregulated use

The unregulated licences have not been included explicitly in the Namoi IQQM. Consequently, the 1999/00 development scenario described in this report only relates to the regulated system at present.

5.4. TOWN WATER SUPPLY

The input for the 1993/94 Cap model run with the high security town water supply entitlement (2,300 ML) and usage was used for the 1999/00 development run.

5.5. STOCK AND DOMESTIC

The input for the 1993/94 Cap model run with the high security stock and domestic entitlement (2,600 ML) and usage was used for the 1999/00 development run.

5.6. INDUSTRIAL AND MINING EXTRACTIONS

The input for the 1993/94 Cap model run with the high security industrial and mining entitlement (3,400 ML) and usage was used for the 1999/00 development run.

5.7. GROUNDWATER ACCESS

The conjunctive use licences were converted to groundwater use only licences in the late 1990's. The groundwater entitlement of those users with conjunctive use licences is now 111,000 ML and this has been used for the 1999/00 development run.

5.8. RESOURCE ASSESSMENT

The Namoi Valley moved to continuous accounting in the late 1990's. This allowed individual irrigators to operate their own water accounts as they saw fit including carry over from one season to the next. The main features of continuous accounting included in the 1999/00 development run are listed below:

- Individual irrigator accounts are operated with a maximum account limit of 200%.
- Individual irrigators are allowed to use up to 100% of their entitlement during a water year (1998 EFR)
- Individual irrigators are allowed to use up to 125% of their entitlement during a water year with the three year rolling average not to exceed 100% (Water Sharing Plan).

DIPNR operates the continuous accounting system under the following general rules.

- Keepit and Split Rock Dams operate together
- Water transferred from Split Rock to Keepit Dam to maintain volume in Keepit Dam at about 105 GL.
- Individual accounts are maintained for each irrigator.
- A separate account is maintained for transmission and operation losses. Thirty percent of the volume in the general security irrigation accounts is set aside for these losses.
- Essential supplies are maintained in the dams to cover a 2 year period from the date of assessment. An amount of 68 GL is included in the Keepit Dam storage reserve.
- Storage loss is the volume of water lost due to evaporation and is projected ahead for 2 years. An amount of 38.5 GL is included in the Keepit Dam storage reserve and 39.5 GL in the Split Rock Dam reserve.

A full listing of parameters used can be found in Appendix G.

5.9. RIVER AND STORAGE OPERATION RULES

5.9.1. Tributary utilisation

As for the 1993/94 Cap run, the tributary utilisation is 100% from Peel, Mooki and Coxs Rivers/Creeks.

5.9.2. Operational surplus

For the Namoi IQQM, the fixed over-order factor of 1.0 produced the best calibration of storage behaviour over the calibration period. The same factors are adopted for the 1999/00 run.

5.10. SURPLUS FLOW ACCESS (OFF-ALLOCATION)

The off allocation threshold described in Table G.5 and G.6 were adopted for the 1999/00 development run.

5.11. RIVER FLOW REQUIREMENTS

5.11.1. Minimum flows

Table 5.1 shows the minimum flow requirements at various locations for the 1999/00 development case.

Table 5.1: Minimum flow requirements

Location	Minimum flows
Split Rock Dam	5 to 6 ML/d
Keepit Dam	10 ML/d
Walgett (Water Sharing Plan)	June 21 ML/d, July 24 ML/d & August 17 ML/d

5.11.2. Stock & Domestic replenishment

An allowance of 14,000 ML is set aside for 2 stock and domestic replenishments down Pian Creek (Section 2.12.3).

5.12. FLOODPLAIN HARVESTING

The floodplain harvesting thresholds derived during model calibration was generally used for the 1999/00 development run. Some fine tuning of thresholds was undertaken given the extra years of diversion data. Given there is no data on floodplain harvesting volumes the adjustments were more intuitive given the objective of better matching observed off allocation diversions. Table F.7 details flow thresholds used in the 1999/00 development run.

5.13. RAINFALL RUNOFF HARVESTING

During the validation of this model during the 1997/98 to 1999/00 period, it was very difficult for the model diversions to match the observed off-allocation diversions. After a number of trials and based on anecdotal information it was concluded that irrigators were likely making greater use of rainfall runoff volumes than originally calibrated in the 1990 to 1995 period. Again there is not data to physically confirm this information. The volumes of water that could potentially be harvested from rainfall runoff were increased in the model until the model better reproduced observed off allocation diversions. Table F.7 details the potential rainfall runoff volume irrigators can utilise in the 1999/00 development run

5.14. COMPARISON WITH 1997/98 TO 2001/02 PERIOD

To assess the robustness of the 1999/00 scenario, a simulation was performed over the period where irrigation development was closest to 1999/00 conditions. The observed and simulated results were compared for a number of processes including: announced allocations, planted areas, diversions, storage behaviour and end-of-system flows. The results are presented in Table 5.2 and Figure 5.1, 5.3 and 5.3 show the modelled and observed diversions, area planted and storage behaviour.

Table 5.2: Key observed verses modelled parameters for 1997/98 – 2001/02

	1997/98		1998/99		1999/00		2000/01		2001/02	
	obs	sim	obs	sim	obs	sim	obs	sim	obs	sim
On allocation diversions (GL)	147	172	195	200	213	219	205	201	255	244
Off allocation diversions (GL)	57	52	37	26	24	18	47	34	2	2
High security diversions (GL)	0.2	1.5	0.9	1.5	1.7	1.5	6.5	1.5	2.1	1.5
Total diversions (GL)	204	226	233	227	239	238	259	237	259	248
Summer area (Ha)	49700	51300	51800	51300	49500	51300	52600	51300	55000	51300
Winter area (Ha)	20000	19300	11000	18500	27300	18000	22900	18100	900	15600
Conjunctive groundwater (GL)	20	20	18	14	na	20	na	20	na	20
Max OFS volume (GL)	na	177	na	168	na	120	na	138	na	85
Keepit releases (GL)	600	693	278	318	216	217	219	148		300

Figure 5.1: Total Irrigation Diversions 1997/98 – 2001/02

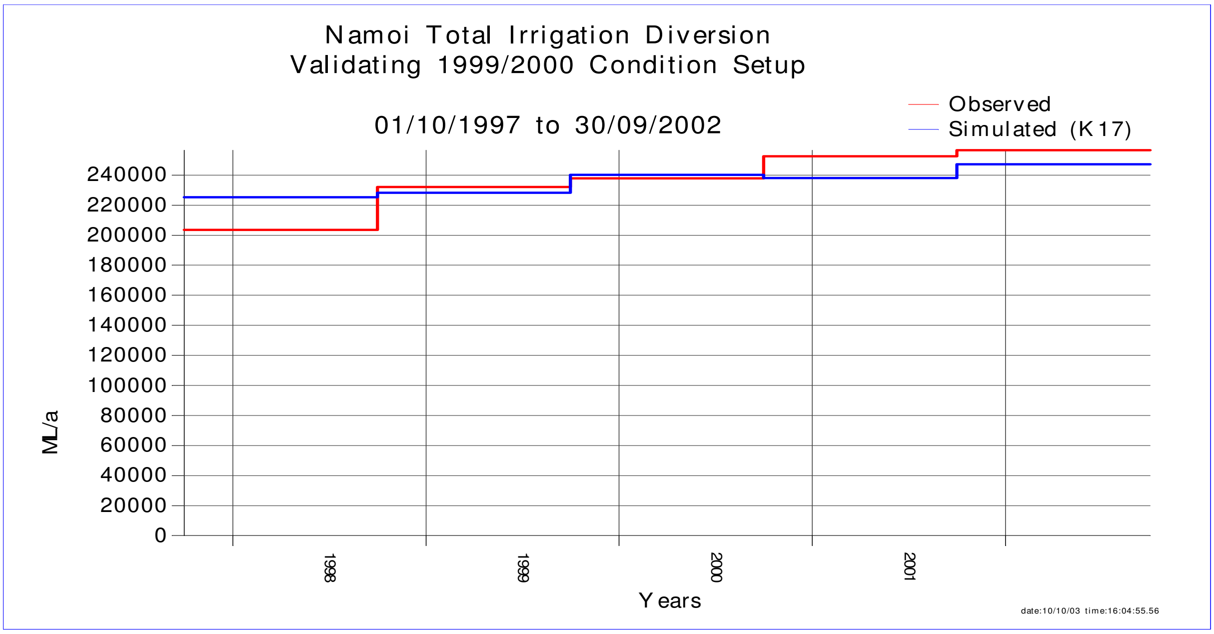


Figure 5.2: Area Planted for 1997/98 – 2001/02

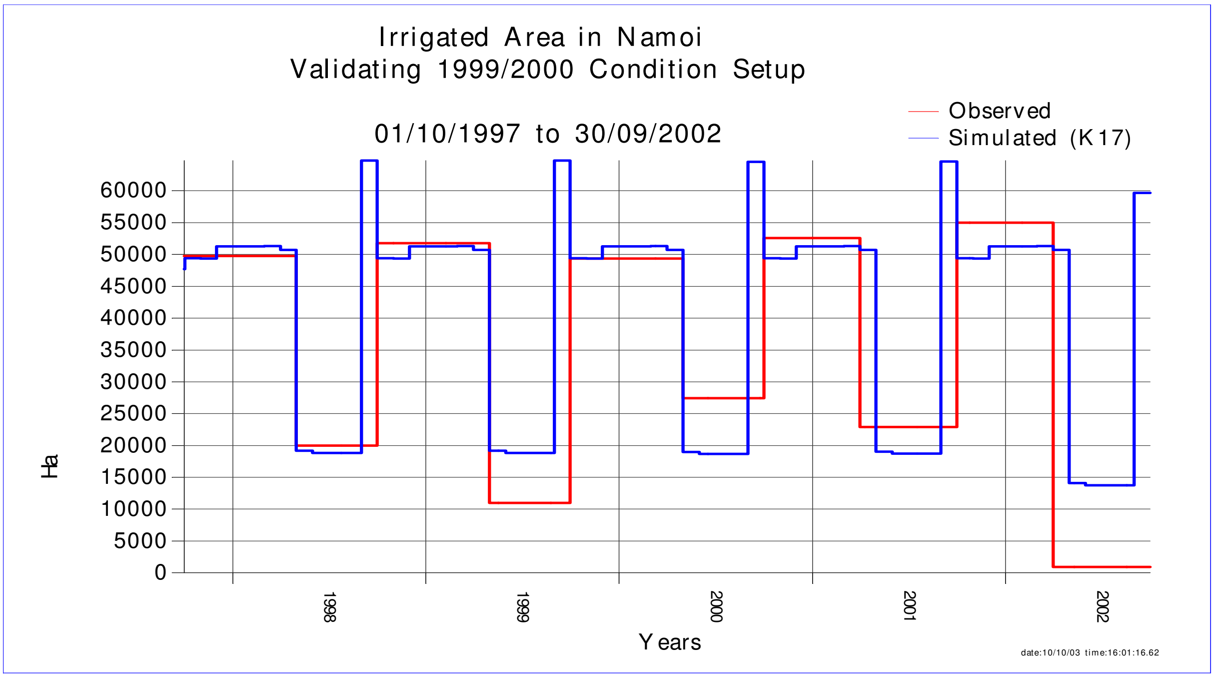
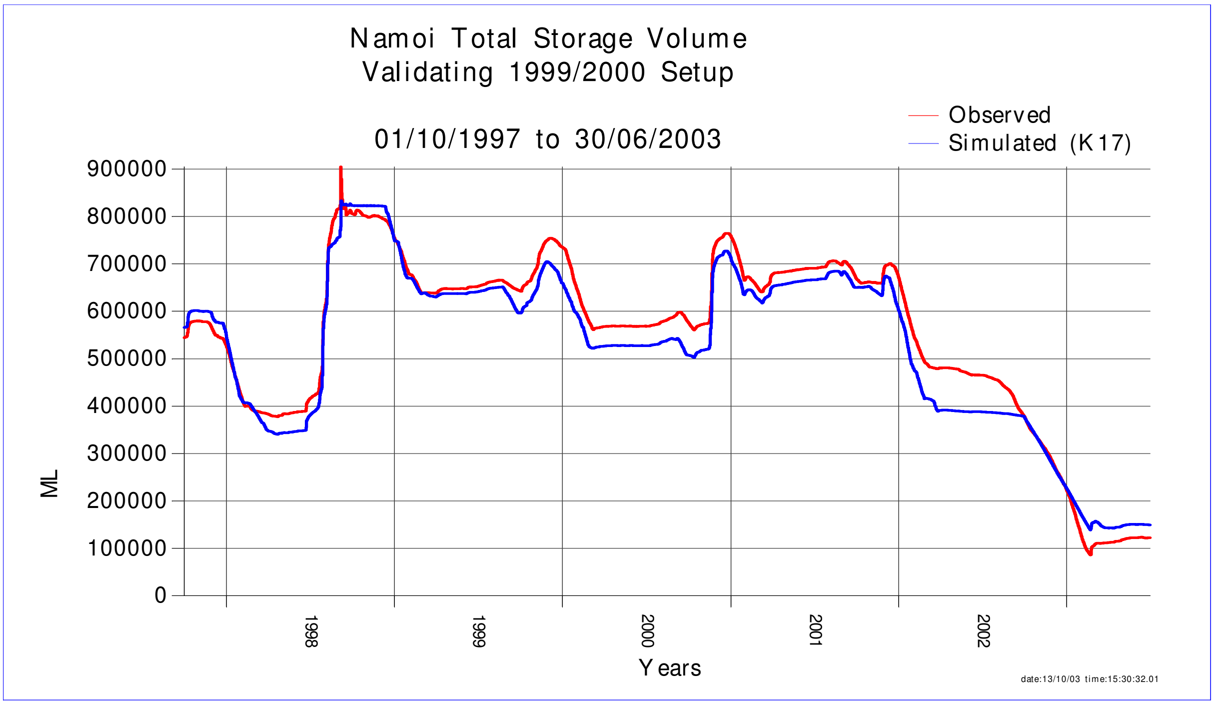


Figure 5.3: Keepit plus Split Rock Dam storage behaviour



5.14.1. Comments on modelled and observed areas

The model is reproducing the observed summer area planted well for the 1997/98, 1998/99, 1999/00 and 2000/01 water years well accounting for some small under and over estimates. However the 2001/02 observed summer area is significantly under estimated. The data available is not of sufficient duration to identify this as a one off event or part of a long term trend.

The modelled winter area planted varies significantly from observed on a year to year comparison, however, over the years between 1997 and 2001 the averages are about the same. The year 2002 winter area were impacted by the drought and the minimum winter areas predicted by the model were not planted. The results from the drought period may result in a lower minimum area for future modelling.

5.14.2. Comments on modelled and observed diversions

The model diversions compare well with observed diversions over the 5 years with about a 1% difference. The trends of the 2 data sets are similar with the possible exception of the model slightly under estimating diversions. This is linked to the model under planting area.

5.14.3. Comments on modelled and observed storage behaviour

The model storage behaviour and observed compare well in trend apart from the model results producing consistently lower storage volumes.

5.15. LONG TERM DIVERSIONS FOR 1999/00 DEVELOPMENT AND MANAGEMENT POLICIES

5.15.1. Long term annual diversions for Management under 2000/01 development with 1998 Environmental Flow Rules

When the 1998 Environmental Flow Rules were introduced to the Namoi Valley one of the objectives was to maintain long term water diversions below the Cap level. Table 5.3 summarises the model results for the 1999/00 development condition with 1998 EFR's and shows that long term average diversions are about 4% below Cap diversions.

Table 5.3: Summary of the 1999/00 development condition with 1998 EFR's simulation run

Summary Aspect	*Sub-aspect*			*Long term average*
System file				NamoP004.sys
Water usage	General security on allocation			196 GL
	General Security off allocation			49 GL
	Floodplain harvesting			15 GL
	High security/stock & domestic/town water supply			1.5GL
	Total			262 GL
	Rainfall runoff harvesting			66 GL
	Groundwater			26 GL
Crop model	Average general security planted area (summer and winter)			36,500 Ha
	Maximum general security planted area (summer)			51,300 Ha
River flows	Namoi River at Goangra plus Pian Creek at Wamindra			695 GL
Namoi Reliability on 01/10	100%	75%	50%	5%
(% of years that achieved ≥ stated % allocation)	60%		82%	

5.15.2. Long term annual diversions for Management under 2000/01 development with proposed 2004 Water Sharing Plan Rules

It is proposed to introduce the Water Sharing Plan into the Namoi Valley in 2004 and one of the objectives is to maintain long term water diversions below the Cap level. Table 5.4 summarises the model results for the 1999/00 development condition with Water Sharing Plan and shows that long term average diversions are about 7% below Cap diversions.

Table 5.4: Summary of the 1999/00 development condition with WSP simulation run

Summary Aspect	*Sub-aspect*	*Long term average*
System file		Namo9088.sys
Water usage	General security on allocation	202 GL
	General Security off allocation	35 GL
	Floodplain harvesting	15 GL
	High security/stock & domestic/town water supply	1.5 GL
	Total	254 GL
	Rainfall runoff harvesting	79 GL
	Groundwater	37 GL
Crop model	Average general security planted area (summer and winter)	35,600 Ha
	Maximum general security planted area (summer)	51,300 Ha
River flows	Namoi River at Goangra plus Pian Creek at Wamindra	703 GL

Namoi Reliability on 01/10	100%	75%	50%	5%
(% of years that achieved ≥ stated % allocation)	58%		78%	

6. Improvement Plans

Maintenance is a dynamic process and covers updating the model to account for:

- New model capabilities
- Improvements to existing model capabilities
- Further information becoming available to facilitate improved calibration
- More time and resources to refine calibration

In the development of the IQQM software, every effort has been made to ensure that all aspects of the software are operational as intended. However, should it become apparent that any part of the software is not operating appropriately, and resolution of the problem causes any change to the results of Cap simulation, the Commission will be informed of the changes to the results, and the reason why the changes occurred.

For the Namoi Valley the following points outline the future enhancements that have been identified should further information, time or data become available.

1. The Gunidgera Creek offtake at Gunidgera Weir has a outlet capacity that prevents on allocation ordered water being supplied when needed and off allocation water being equally shared between the Pian/Gunidgera system and the Lower Namoi. In practical operation sense these problems are overcome by pre-ordering on allocation water and rostering of off allocation water. The Namoi IQQM does not represent this behaviour at present assuming no outlet capacity problems at the Gunidgera Creek offtake. Enhancements to the IQQM code would have to be made to simulate actual conditions. Re-calibration of the model would be required.

2. Data suggests the farmers without on-farm storages utilise off allocation water to fill up their soil moisture store. This process has been simulated by dummy on-farm storages in the model. Code improvements could be made to IQQM to correctly model the process.

3. Because the Peel Valley IQQM has not been completed, the model uses observed streamflow at Carrol Gap to simulate tributary inflow from the Peel River. Prior to observed data, output from a preliminary Peel IQQM was used to extend observed streamflow. In the future the Peel IQQM will be run for the appropriate development scenario to estimate the correct tributary inflow from the Peel River, for the appropriate development condition in the Namoi Valley.

4. The Mooki River tributary has been modelled as observed stream flow at Breeza. In recent years there has been major unregulated irrigation development between Breeza and the Namoi River confluence. The unregulated irrigator practices should be correctly modelled to simulate Mooki River tributary inflows.

5. The Namoi IQQM has not been setup or calibrated to best represent valley inflow to the Barwon/Darling River system. Enhancements to the model could be made when better information is available on Namoi Valley inflow required to achieve mass balance in the Barwon/Darling River.

Depending on the purpose, it may be appropriate to use different end of system sites for different purposes.

6. Both floodplain harvesting and rainfall runoff harvesting appear to be major water resources used by some Namoi Valley irrigators. Calibration of the Namoi IQQM could not be achieved using plausible parameters without some floodplain and rainfall runoff modelling within IQQM. When better information and/or data becomes available on floodplain harvesting and rainfall harvesting techniques used by irrigators then better modelling of these processes could be included into the Namoi IQQM.

7. Because Namoi IQQM performs a dual role for long term simulation and short term MDBC Cap auditing, only long term rainfall sites were calibrated into the model. Investigations should be undertaken to see if shorter term rainfall site details provide the spatial variability to explain variations in observed and simulated irrigation crop requirements.

8. There is little streamflow data to support modelling techniques used for estimating runoff from the Pilliga area. When more data becomes available better simulation of this process might be achieved.

9. Irrigation practices on the Pian/Gunidgera Creek systems use of pump pools to allow sufficient volumes of water to be diverted rather than just run of the river volumes. Enhancements could be made to the model to better simulate these processes.

10. Better data on on-farm storages, irrigation crop area and crop mixtures and on-farm water use could improve Namoi IQQM modelling of these processes.

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Appendix A. Climatic and Streamflow Stations

Table A.1: Geographic zones for rainfall and evaporation records

River Reach	Geographic zone	Primary Rain Gauge (Name) and Evaporation Site (observed or generated)	Primary Gauge-Number
1	Split Rock to Brabri	Manilla Post Office	055031
2	Brabri to Manilla	Manilla Post Office	055031
3	Manilla to Keepit	Manilla Post Office	055031
4	Keepit to Gunnedah	Carroll (The Ranch)	055055
5	Gunnedah to Boggabri	Boggabri (Milchengowrie)	055034
6	Boggabri to Narrabri	Narrabri Bowling Club	054120
7	Narrabri to Mollee	Narrabri Bowling Club	054120
8	Mollee to Gunidgera	Wee Waa Post Office	053044
9	Gunidgera to Weeta	Wee Waa Post Office	053044
10	Weeta to Duncan	Wee Waa Post Office	053044
11	Duncan to Bugilbone	Pilliga Post Office	052023
12	Bugilbone to Goangra	Walgett Post Office	052026
13	Goangra to Walgett	Walgett Post Office	052026
14	Gunidgera Creek from Offtake to Cutting	Wee Waa (Penndennis)	053034
15	Gunidgera Creek below Cutting	Wee Waa (Penndennis)	053034
16	Pian Creek from the Cutting to Rossmore	Wee Waa (Penndennis)	053034
17	Pian Creek from Rossmore to Waminda	Rowena (Myall Plains)	052021

Table A.2: Streamflow stations used for instream model calibration

Gauge Number	Gauge Name
419043	Manilla River @ Tarpoly (Split Rock Dam inflow prior to dam construction)
419020	Manilla River @ Brabri
419022	Namoi River @ Manilla Railway Bridge
419007	Namoi River @ Keepit
419001	Namoi River @ Gunnedah
419012	Namoi River @ Boggabri
419039	Namoi River @ Mollee
419059	Namoi River @ Gunidgera Weir
419068	Namoi River @ Weeta Weir
419021	Namoi River @ Bugilbone
419026	Namoi River @ Goangra
419091	Namoi River @ Walgett
419061	Gunidgera Creek @ Regulator
419079	Gunidgera Creek @ Knights
419049	Pian Creek @ Waminda

Comments on gauges with problems:

- 419003: The Narrabri Creek gauge was dropped from flow calibration because its low flow measurement appeared to be unreliable. This is possibly due to the channel being wide and shallow at this point. We note that the rating has been fixed in recent times.
- 419082: The Duncan gauge appeared to be missing flow. A short conversation with the river operator confirmed this and we excluded the gauge.
- 419072: The sandy bed in Baradine Creek makes the reliability of this gauge suspect, but there were no realistic alternatives, so it has been used anyway.
- Most of the gauges on Pian and Gunidgera creek are operational gauges. The data used is predominantly daily read and has some gaps. Also, due to the limited channel size and difficulties gauging high flow, high flow measurements are probably not good.

Table A.3: Streamflow stations used for gauged inflow to model

Gauge Number	Gauge Name	Comment
419043	Manilla River @ Tarpoly	Extended with Split Rock inflows and Sacramento modelling.
419005	Namoi River @ North Cuerindi	Extended with Sacramento modelling
419029	Halls Creek @ Ukolan	Extended by correlation with 419005
419006	Peel River @ Carrol Gap	Extended by Peel IQQM flow model
419027	Mooki River @ Breeza	Extended with Sacramento modelling
419051	Maules Creek @ Avoca East	Extended with Sacramento modelling
419032	Cox's Creek @ Boggabri	Extended with Sacramento modelling
417072	Baradine Creek @ Kienbri No.2	Extended with Sacramento modelling

Table A.4: Ungauged inflow to model

Reach	Inflow Estimate	Comment
Reach 1 Split Rock Dam to Brabri Gauge	419053 + 419029	We had lots of problems with this one. Many options were tried.
Reach 2 Brabri Gauge to Manilla Gauge	0.671 * 419029	Based on catchment area ratio.
Reach 3 Manilla Gauge to Keepit Dam	2.0 * 419029	Initially based on catchment area, but it had to be increased to get mass balance.
Reach 4 Keepit Dam to Gunnedah	3.0*(419027*0.65 + 419006*0.13)	Initially based on multiple regression analysis, but problems were found, so increased to get mass balance.
Reach 5 Gunnedah to Boggabri	1.0*419032	The gauge was selected because the catchments are quite similar. The multiplier was found by trialing different values.

Reach	Inflow Estimate	Comment
Reach 6 & 7 Boggabri to Mollee	(2.23*419051 + 0.24*419032) + 3.1*419072	The first part was based on a regression analysis for the section from Boggabri to Narrabri. The last term is an area ratio. 419072 was chosen because its catchment is most similar to Bohena creek.
Reach 8 Mollee to Gunidgera	1.0 * 419032 lagged by 2 days	We had lots of problems with this one. Flow is entering during floods, possibly overland from Bohena creek.
Reach 9 Gunidgera to Weeta	0.5*419072	Based on catchment area ratio.
Reach 10 &11 Weeta to Bugilbone	Sacramento modelling & a main stream flow mass balance	Also difficult. The main problems were floods, significant flows enter from Pilliga via Coghill, Bullerawa, Talluba etc creeks.
Reach 12 Bugilbone to Goangra	4.19*419072	Based on catchment area ration. This is the only local gauge.
Reach 13 Goangra to Walgett	1.02*419072	Based on catchment area ratio. See above.
Reach 14,15,16 &17 Pian Creek	1.0*419072	Severe data problems prevent accurate estimation of the ungauged inflows.

Comments on Pilliga Inflows

- The ungauged inflows that enter the Namoi River from Pilliga region are very difficult to quantify and to model. The inflow estimates described above are the best that we have been able to come up with within the constraints imposed by data availability and time.
- We know the estimated inflows are representative of the volumes which enter the Namoi river (measured by the river gauges), however we suspect that a large amount of water may come out of Pilliga during floods, that is not measured by the main channel gauges.
- In the future, the gauges that have been installed on Bohena Creek and Brigalow Creek should provide a better representation of Pilliga inflows. We are waiting for sufficient data to develop a Sacramento model from both these gauges.

Appendix B. Model Configuration

Table B.1: Functional elements represented in IQQM

Element Type	*Number of Items*	*Description of Items*
Direct tributary inflows	8	• Split Rock Dam inflows from back-calculation • Gauge at 419029 – Halls Creek @ Ukolan • Gauge 419005 – Namoi River @ Cuerindi • Gauge 419006 – Peel River @ Carroll Gap • Gauge 412027 – Mooki Creek @ Breeza • Gauge 419032 – Coxs Creek • Gauge 419051 – Maules Creek • Gauge 419072 - Baradine Creek
Residual catchment inflows	13	• Reach 1 – Split Rock Dam to Brabri Gauge • Reach 2 – Brabri Gauge to Manilla Gauge • Reach 3 – Manilla Gauge to Keepit Dam • Reach 4 – Keepit Dam to Gunnedah Gauge • Reach 5 – Gunnedah Gauge to Boggabri Gauge • Reach 6 – Boggabri Gauge to Narrabri Gauge • Reach 7 – Narrabri Gauge to Mollee Weir • Reach 8 – Mollee Weir to Gunidgera Gauge • Reach 9 – Gunidgera Gauge to Weeta Weir • Reach 10 & 11 – Weeta Weir to Bugilbone Gauge • Reach 12 – Bugilbone Gauge to Goangra Gauge • Reach 13 – Goangra Gauge to Walgett Gauge • Reach 14, 15 ,16 & 17 – Pian Creek
Mainstream river flow calibration reaches	13	• Reach 1 – Split Rock Dam to Brabri Gauge 419020 • Reach 2 – Brabri Gauge to Manilla Gauge 419022 • Reach 3 – Manilla Gauge to Keepit Dam • Reach 4 – Keepit Dam to Gunnedah Gauge 419001 • Reach 5 – Gunnedah Gauge to Boggabri Gauge 419012 • Reach 6 – Boggabri Gauge to Narrabri Gauge 419002 & 003 • Reach 7 – Narrabri Gauge to Mollee Weir 419039 • Reach 8 – Mollee Weir to Gunidgera Gauge 419059 • Reach 9 – Gunidgera Gauge to Weeta Weir 419068 • Reach 10 & 11 – Weeta Weir to Bugilbone Gauge 419021

		• Reach 12 – Bugilbone Gauge to Goangra Gauge 419026 • Reach 13 – Goangra Gauge to Walgett Gauge 419091 & 419057 • Reach 14, 15 ,16 & 17 – Pian Creek 419061 to 419049
Storages	2	• Split Rock Dam • Keepit Dam
Loss points	17	• Reach 1(1) losses • Reach 1(2) losses • Reach 2 losses • Reach 3 losses • Reach 4(1) losses • Reach 4(2) losses • Reach 5 losses • Reach 6 & 7 losses • Reach 8 losses • Reach 9 losses • Reach 10 & 11 losses • Reach 12 losses • Reach 13 losses • Reach 14 losses • Reach 15 losses • Reach 16 losses • Reach 17 losses
General security Irrigator Group extractions	29	• Reach 1 irrigation • Reach 2 irrigation • Reach 3 irrigation • Reach 4 irrigation • Reach 5 irrigation no OFS • Reach 5 irrigation with OFS • Reach 6 irrigation no OFS • Reach 6 irrigation with OFS • Reach 7 irrigation no OFS • Reach 7 irrigation with OFS • Reach 8 irrigation no OFS • Reach 8 irrigation with OFS • Reach 9 irrigation no OFS • Reach 9 irrigation with OFS • Reach 10 irrigation no OFS

		• Reach 10 irrigation with OFS • Reach 11 irrigation no OFS • Reach 11 irrigation with OFS • Reach 12 irrigation no OFS • Reach 12 irrigation with OFS • Reach 13 irrigation no OFS • Reach 13 irrigation with OFS • Reach 14 irrigation no OFS • Reach 14 irrigation with OFS • Reach 15 irrigation no OFS • Reach 16 irrigation no OFS • Reach 16 irrigation with OFS • Reach 17 irrigation no OFS • Reach 17 irrigation with OFS
High security Irrigator Group extractions	0	Nil
Stock and Domestic (subsistence) extractions	17	Stock & Domestic demands are positioned in each river reach, however they have not been activated.
Wetland replenishments	0	Nil
TWS extractions	2	TWS extractions for Manilla & Walgett have been included in the model however they are not active.
Industrial & Recreational	15	A range of industrial and recreational nodes has been included in the model however none are active.
Effluent off takes	3	• Gunidgera Creek offtake from the Namoi River into Gunidgera Creek • Pian Creek offtake from Gunidgera Creek into Pian Creek • Flood flow from Namoi River above Gunidgera Weir returning downstream of Weeta Weir
Effluent off takes that don't return	0	Nil
Confluences	10	
Off-allocation reaches	15	
Minimum Flow control nodes	4	• D/s of Split Rock Dam • D/s of Keepit Dam • Pian Creek Summer replenishment • Pian Creek Winter replenishment

Table B.2: Crop factors

Crop	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Maize	1.20	1.07	0.27	0	0	0	0	0	0	0.16	0.41	1.02
Lucerne	0.57	0.57	0.47	0.32	0.24	0.24	0.24	0.24	0.34	0.50	0.57	0.57
Cotton	0.70	0.69	0.55	0.19	0	0	0	0	0	0.10	0.29	0.63
W Pasture	0	0	0.24	0.28	0.44	0.56	0.57	0.57	0.51	0.33	0	0
Wheat	0	0	0	0	0.42	1.06	1.15	1.08	0.49	0	0	0
S Pasture	0.56	0.57	0.31	0.24	0.07	0	0	0	0	0.25	0.57	0.57
Soybeans	1.01	1.15	1.09	0.31	0	0	0	0	0	0	0	0.45
Canola	0	0	0	0	0.19	0.52	1.05	1.15	1.13	0.75	0.14	0
Orchid	0.82	0.63	0	0	0	0	0.57	0.70	0.84	0.90	0.90	0.90

Table B.3: Irrigation efficiency

Reach	Efficiency	Reach	Efficiency
1	0.80	11 no OFS	0.80
2	0.88	11 with OFS	0.80
3	0.92	12 no OFS	0.70
4	0.65	12 with OFS	0.75
5	0.75	13 no OFS	0.65
6 no OFS	0.75	13 with OFS	0.75
6 with OFS	0.65	14 no OFS	0.60
7 no OFS	0.67	14 with OFS	0.75
7 with OFS	0.75	15 with OFS	0.75
8 no OFS	0.68	16 no OFS	0.73
8 with OFS	0.70	16 with OFS	0.58
9 no OFS	0.78	17 no OFS	0.90
9 with OFS	0.75	17 with OFS	0.75
10 no OFS	0.66		
10 with OFS	0.75		

Table B.4: Tributary utilisation factors

Dam	Tributary utilisation
Keepit orders	100% Peel River 100% Mooki River 100% Coxs Creek 0% for all remaining inflows

Appendix C. Namoi Node Link Diagram

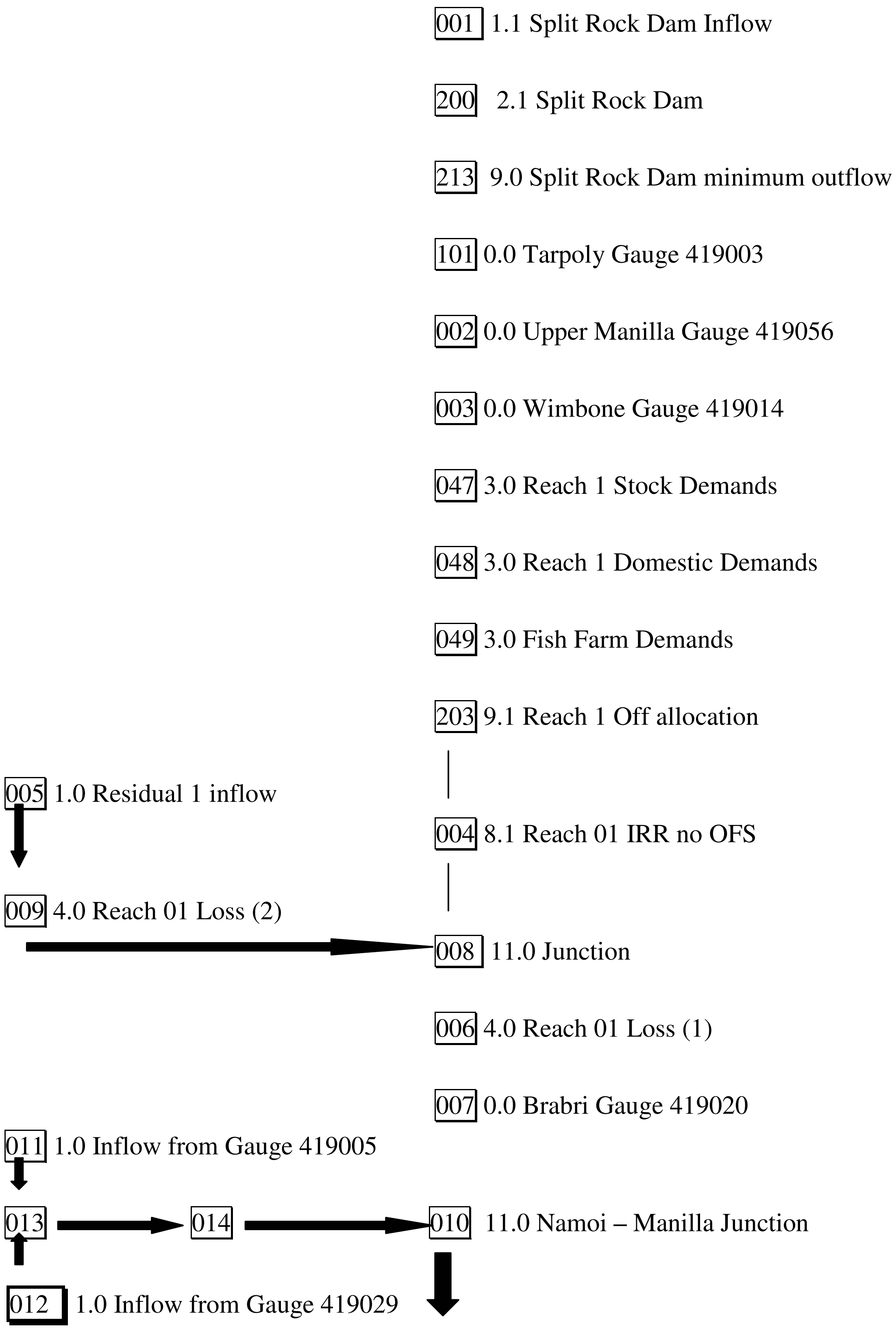
Key

Each node is labelled as follows

Node No "Node type" "Description of node"

Node type	Node name	Main purpose of the node
0.0	Straight	Dummy nodes used to output simulated flows at selected locations.
0.3	Straight	Dummy node used for regulated flow lag time
1.0	Tributary inflow	Tributaries joining the main river.
1.2	Pumped inflow	Allows water pumped from Nodes 3.2, 3.3, 3.4 or 3.5 nodes to inflow into a river section.
2.0	On-river storage (un-gated)	On-river storage (uses storage routing procedure during flood operation); un-met orders are passed to next storage upstream.
2.1	Head-water storage (un-gated)	As above, except no upstream storage to pass un-met water orders to.
3.0	Fixed demand	Fixed pattern of demands (daily or monthly), for town water supplies, industrial demands, etc.
3.1	Demand	Fixed demand constrained by flow requirements. May be pumped to a Node 1.2.
4.0	Effluent off-take	Diversion of flows into an effluent channel, as a function of river flow.
4.1	Regulated effluent off-take	Diversions of regulated flow into an effluent channel to meet demands
5.0	Effluent return	Return of unregulated effluent flows to the river
5.1	Regulated effluent return	Return of regulated effluent flows (specified at Node 4.1) to the top of a separate river section
8.0	Irrigation demand	Irrigation demands, ordering and diversion calculations for normal security licenses under water use debiting scheme.
8.1	Irrigation demand	Same as Node 8.0, except for irrigators with water order debiting scheme.
8.3	Irrigation demand	Irrigation demands from unregulated streams.
9.0	Minimum flow	Orders water for maintaining minimum flows.
9.1	Minimum flow	As for Node 9.0, except also sets the boundaries for off-allocation reaches.
10.0	Wetland	Wetland requirement calculations based on irrigation allocations for the year.
10.2	Wetland	Wetland demands are input as a pattern.
11.0	Confluence	Confluence of two river sections.

Namoi Valley Node Link Diagram Page 1



Namoi Valley Node Link Diagram Page 2

012 1.0 Trib Inflow from Gauge 419029

015 1.0 Reach 2 residual inflow

204 9.0 Reach 2 & 3 Off allocation

050 Reach 02 Stock Demands

051 Reach 02 Domestic Demands

053 3.0 Pecan Nut Farm

016 8.1 Reach 02 IRR no OFS

201 3.0 Manilla TWS Demand

017 4.0 Reach 02 Losses

018 0.0 Manilla Gauge 419022

019 1.0 Reach 03 Residual Inflow

054 3.0 Reach 03 Stock Demand

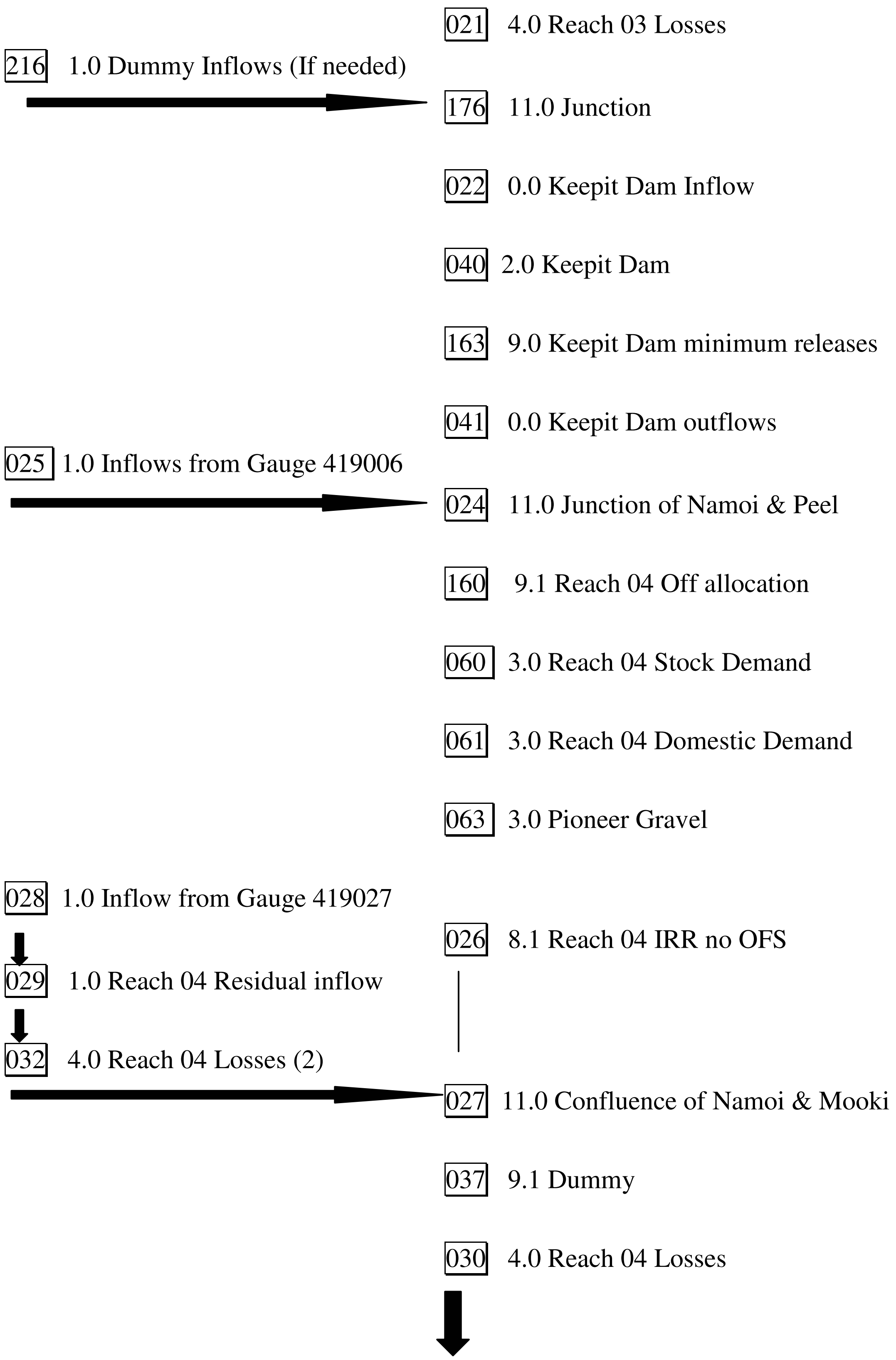
055 3.0 Reach 03 Domestic Demand

058 3.0 Fish Hatchery

059 3.0 Sport & Rec Centre

020 8.1 Reach 3 IRR no OFS

Namoi Valley Node Link Diagram Page 3



Namoi Valley Node Link Diagram Page 4

052 0.0 Gunnedah Gauge 419001

198 9.1 Reach 05 Off allocation

056 1.0 Trib inflow from Coxs Creek 419032

057 1.0 Reach 05 Residual Inflow

065 3.0 Reach 05 Stock Demands

066 3.0 Reach 05 Domestic Demands

067 3.0 Namoi Mining

062 8.1 Reach 05 IRR no OFS

261 8.1 Reach 05 IRR with OFS

064 4.0 Reach 05 Losses

071 0.0 Boggabri Gauge 419012

199 9.1 Reach 06 Off Allocation

072 1.0 Tributary Inflow from Maules Creek 419051

073 1.0 Reach 06 Residual Inflow

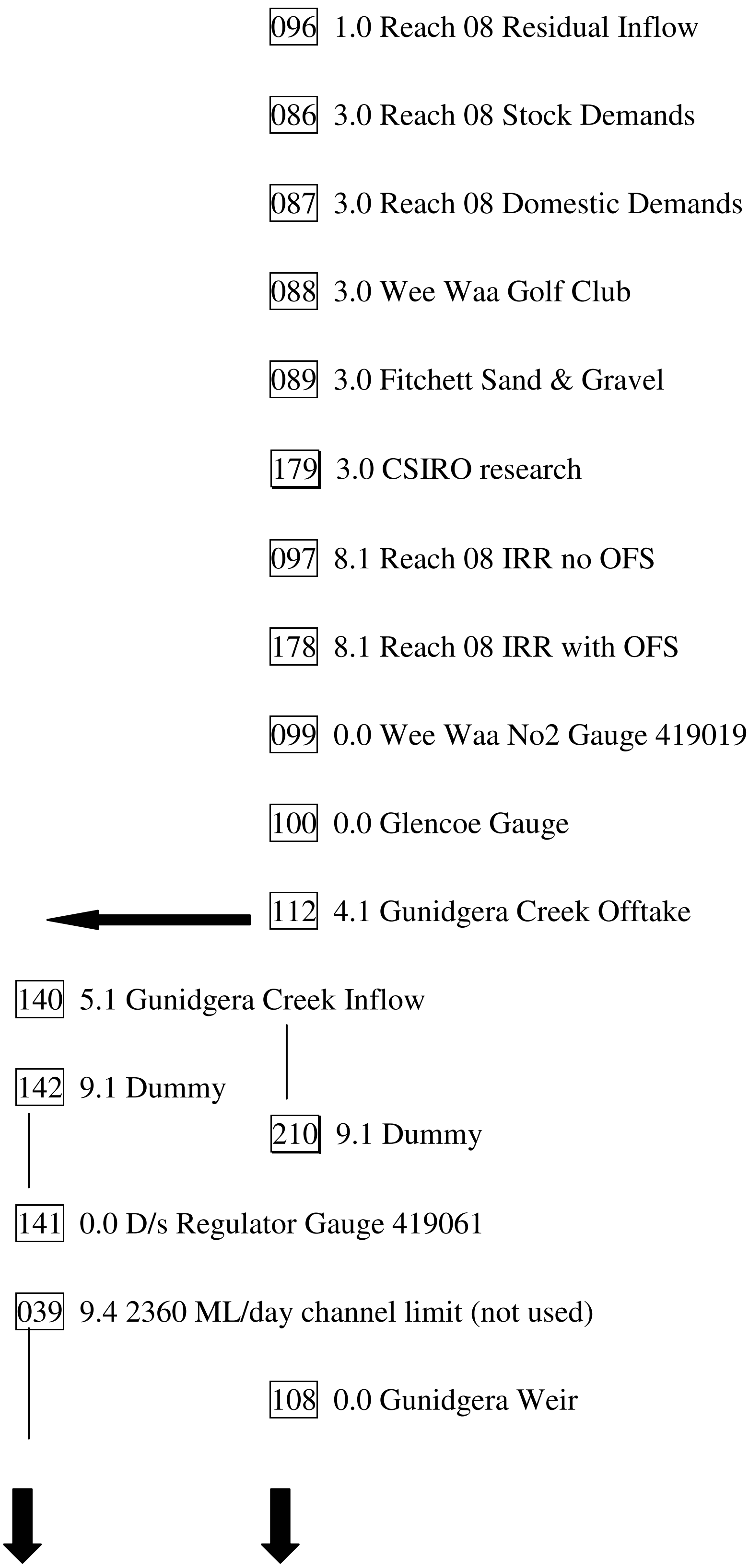
068 3.0 Reach 06 Stock Demands

069 3.0 Reach 06 Domestic Demands

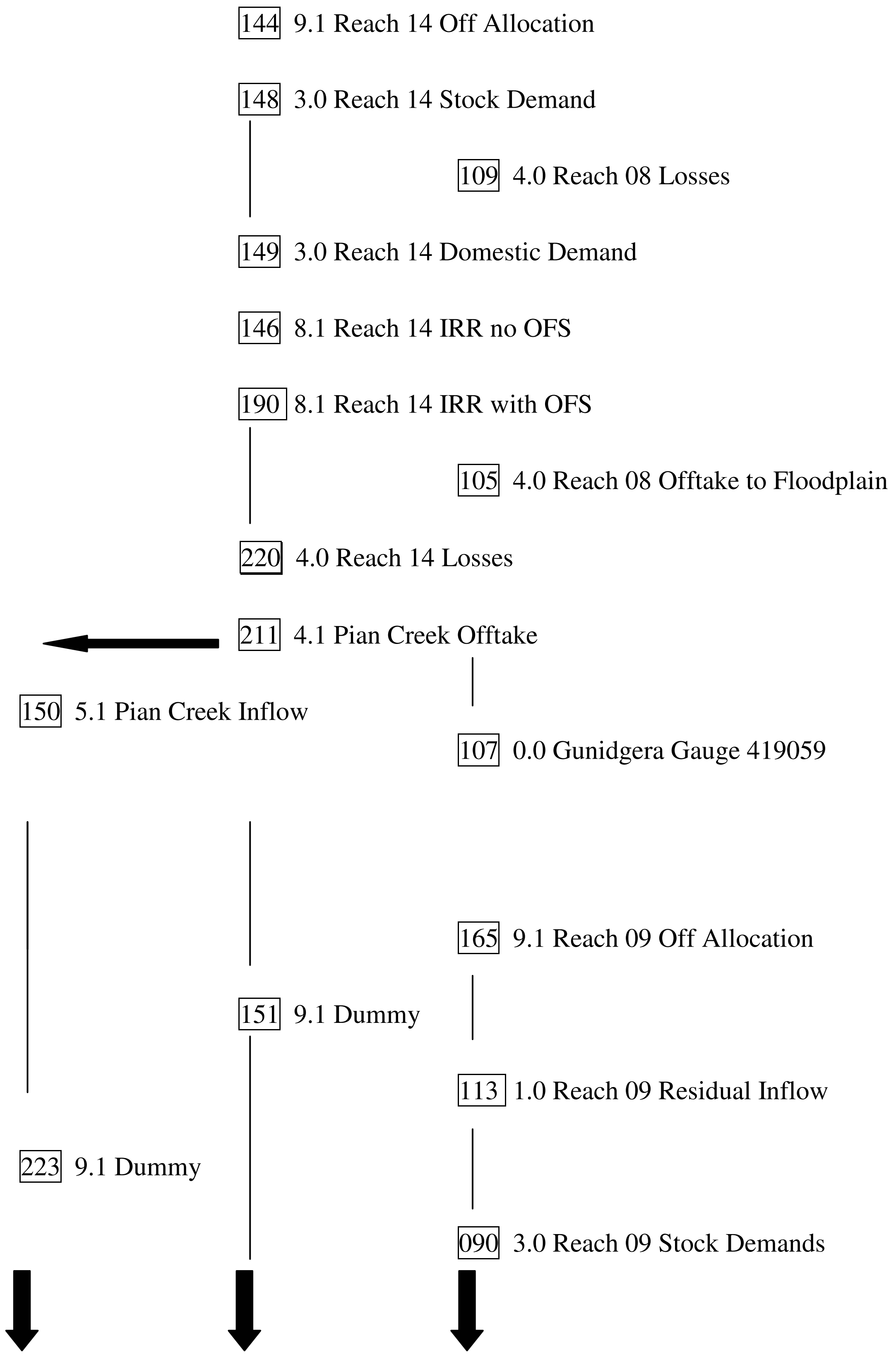
Namoi Valley Node Link Diagram Page 5

070	3.0 Hogarth & Brett
074	8.1 Reach 06 IRR no OFS
075	8.1 Reach 06 IRR with OFS
031	3.0 Novacoal Aust
076	0.0 Narrabri Gauge 419002 & 419003
205	9.1 Reach 07 Off Allocation
079	1.0 Reach 07 Residual Inflow
077	3.0 Reach 07 Stock Demands
078	3.0 Reach 07 Domestic Demands
084	3.0 Narrabri Golf Club
085	3.0 Boral & Williams
080	8.1 Reach 07 IRR no OFS
177	8.1 Reach 07 IRR with OFS
081	4.0 Reach 06 & 07 Losses
082	0.0 Mollee Weir
083	0.0 Mollee Gauge 419039
164	9.1 Reach 08 Off Allocation

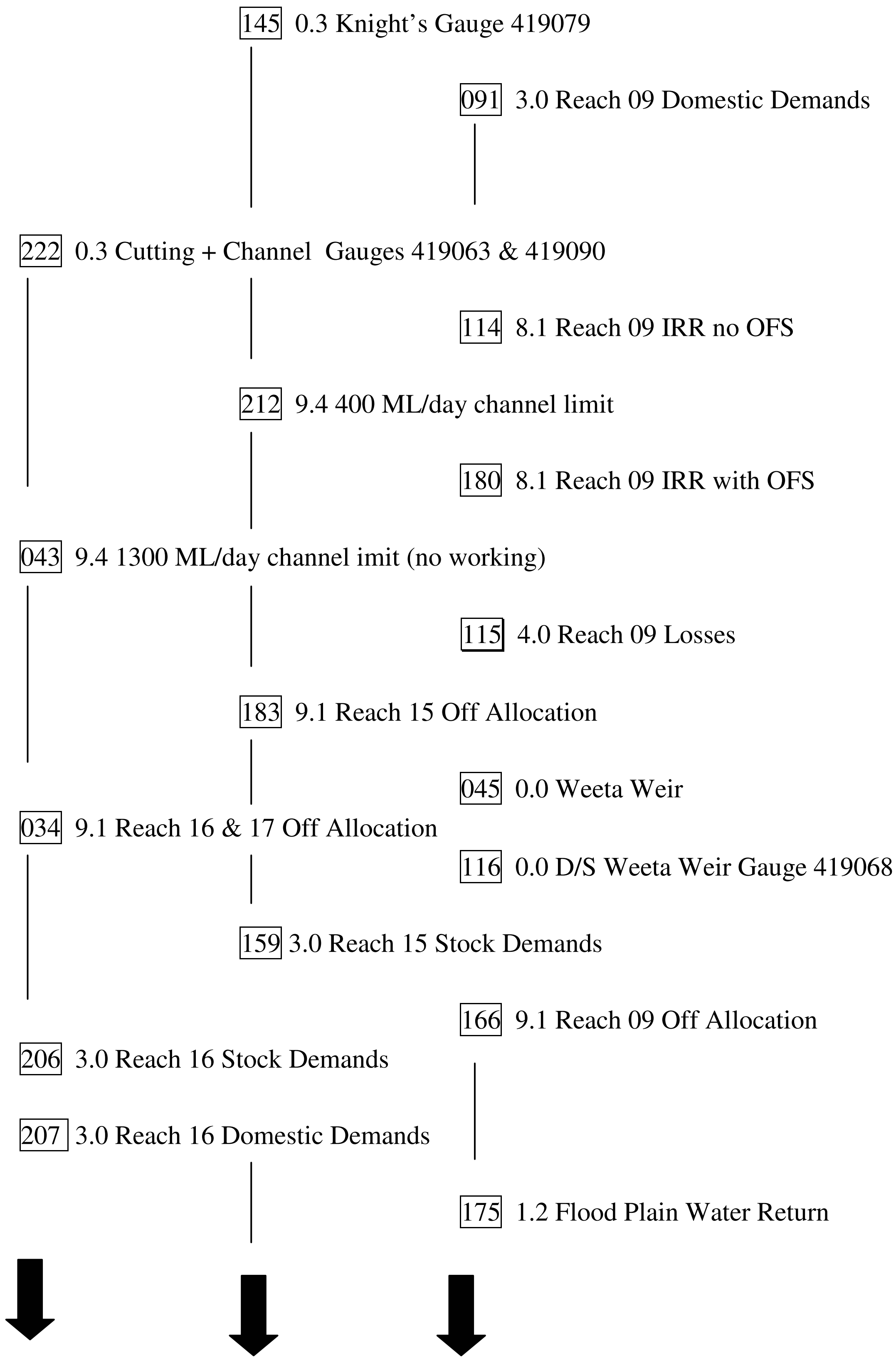
Namoi Valley Node Link Diagram Page 6



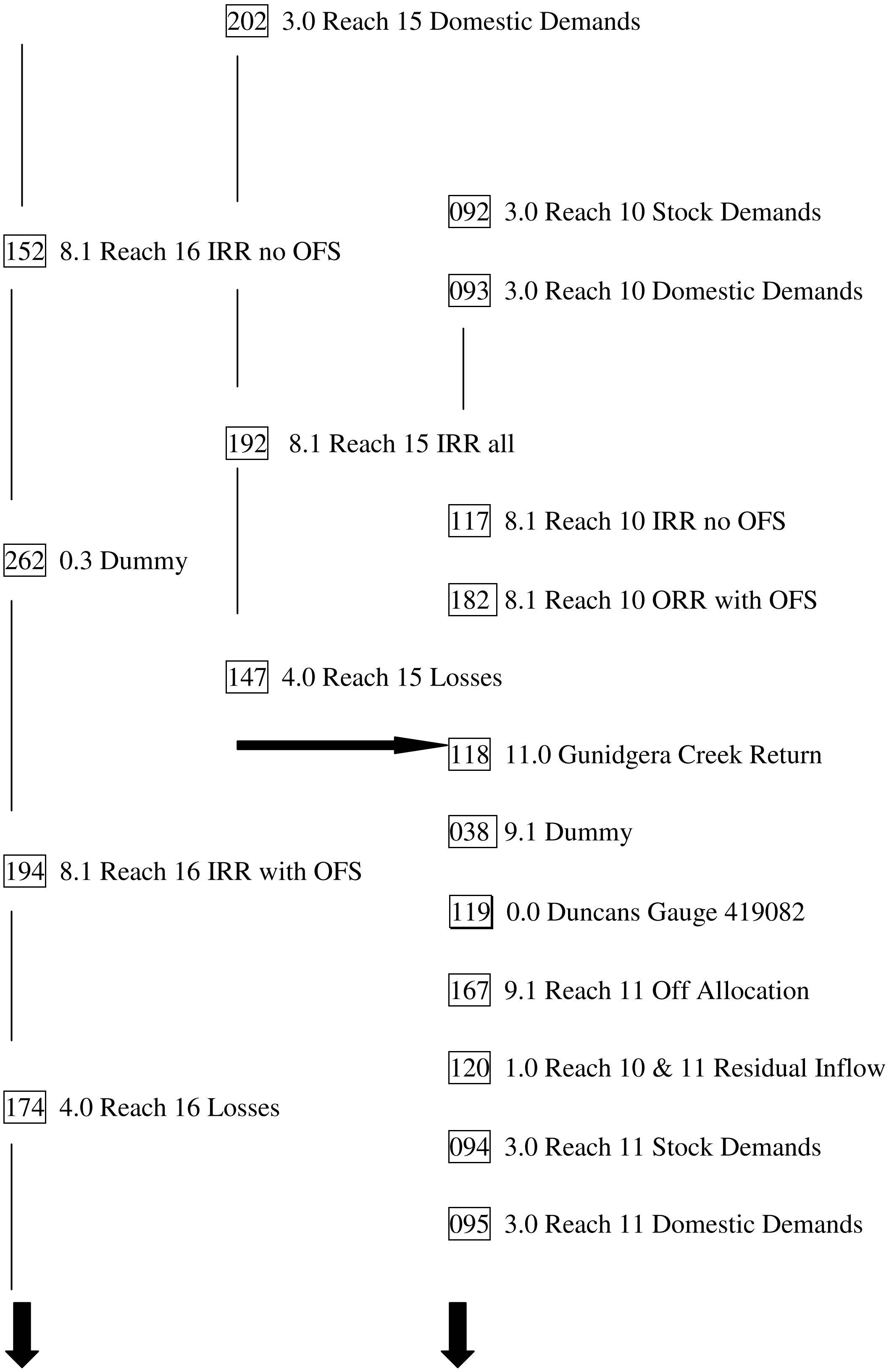
Namoi Valley Node Link Diagram Page 7



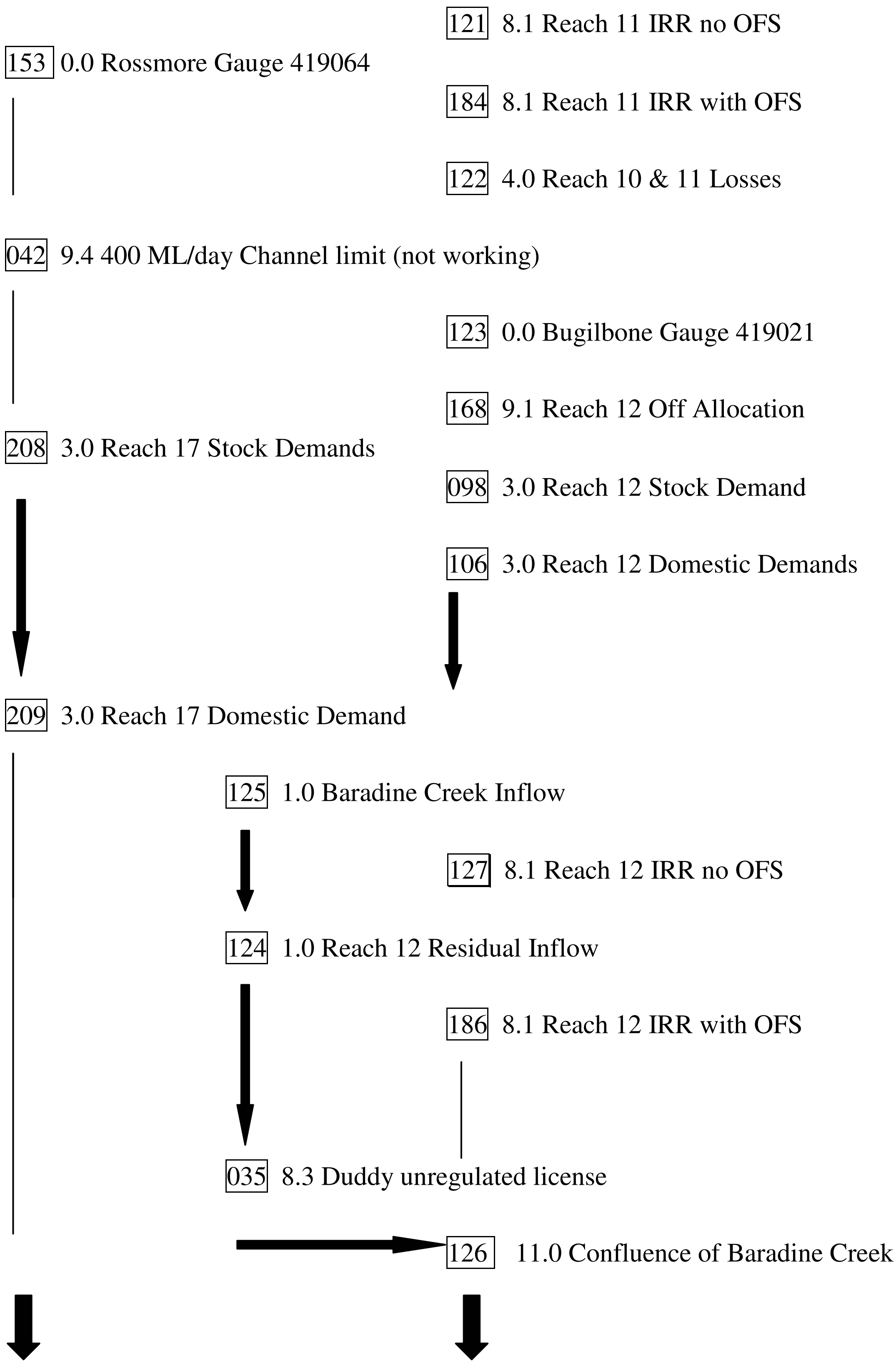
Namoi Valley Node Link Diagram Page 8



Namoi Valley Node Link Diagram Page 9



Namoi Valley Node Link Diagram Page 10



Namoi Valley Node Link Diagram Page 10

154 8.1 Reach 17 IRR no OFS

196 8.1 Reach 17 IRR with OFS

155 1.0 Pain Creek Residual Inflow

156 4.0 Pian Creek Losses

033 10.2 Spring Replenishment

044 10.2 Autumn Replenishment

157 0.0 Dempsey's Gauge 419089

158 0.0 Waminda Gauge 419049

046 9.1 Dummy

129 4.0 Reach 12 Losses

130 0.0 Goangra Gauge 419026

023 9.0 40 ML/day target flow (not working)

258 9.1 Reach 13 Off Allocation

131 1.0 Reach 13 Residual Inflow

111 3.0 Reach 13 Stock Demand

128 3.0 Reach 13 Domestic Demand

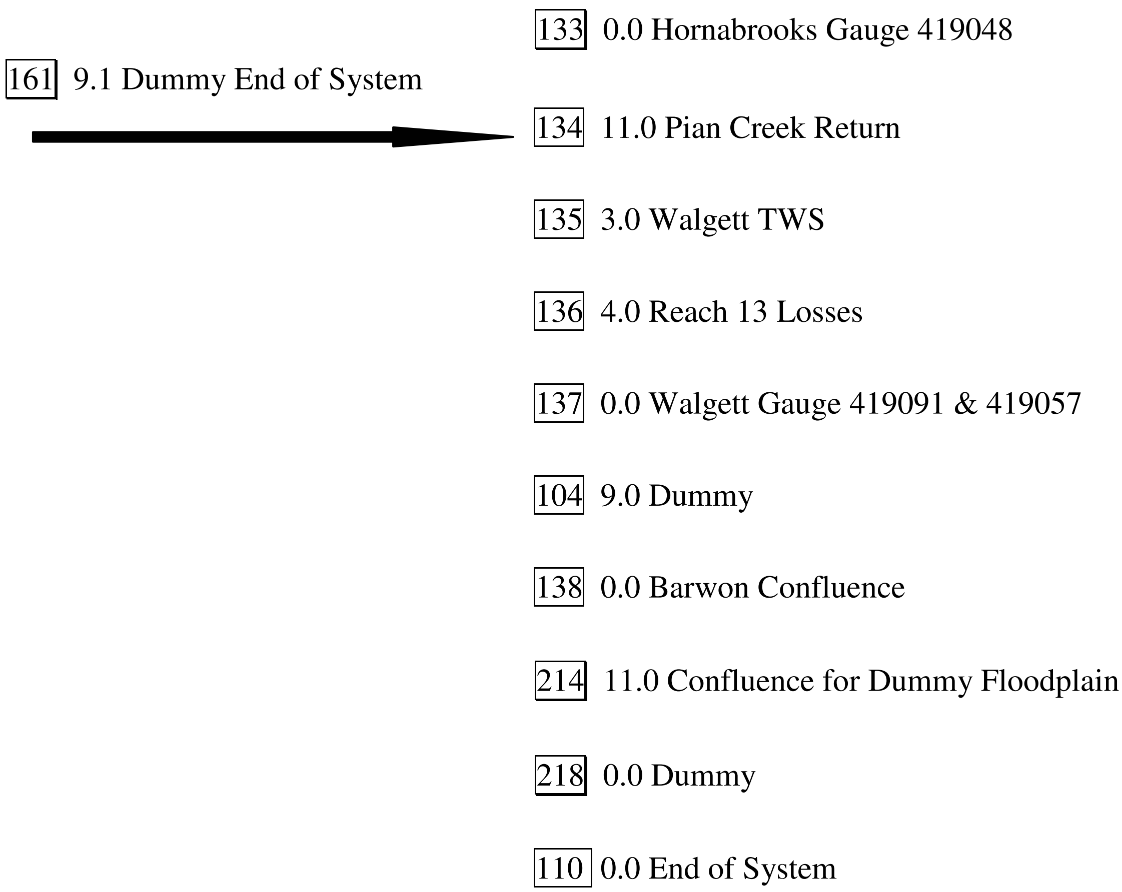
139 3.0 Walgett Sports

143 3.0 Narella Park

132 8.1 Reach 13 IRR no OFS

188 8.1 Reach 13 IRR with OFS

Namoi Valley Node Link Diagram Page 10



Appendix D. Modelling the Planting Decision

6.1. IQQM PLANTING DECISION

IQQM is capable of simulating a planted area for each irrigation node, based upon water availability, for a summer and winter crop each year. Each crop type that is specified is modelled separately as either a summer crop (generally configured to commence in October) or a winter crop (generally configured to commence in March), and has a series of monthly crop factors and crop watering efficiency factors.

Analysis of irrigator behaviour has indicated that there is a complex inter-relationship between numerous climatic, economic and social influences and the decision to plant particular areas of various crop types. To attempt to represent all of these influences is considered too complex to model within IQQM. To develop the IQQM planting decision, some fundamental assumptions regarding irrigators' behaviour as a group have been made, based on observed behaviour and numerous discussions with irrigation representatives.

It has been assumed that irrigators would generally seek to plant some maximum area for a notional level of development and set of economic and social conditions, given sufficient water availability. As resources are constrained due to climatic variability, they would respond by planting smaller areas based on an apparent application rate. This apparent application rate would represent a number of influences not specifically modelled within IQQM. At some point of resource constraint, irrigators would seek to plant a minimum area based on possible future resources becoming available, economic pressures and the need to maintain perennial crops. Overall this process is called the irrigators planting risk.

The irrigators' planting risk will reflect the influence of a number of factors including commodity prices, individual farm finances, antecedent climatic conditions and water availability in recent seasons. However, the ability to represent these influences explicitly within IQQM has not been developed yet, in part due to a lack of reliable information. It is clear, however, that the available water at the planting decision date is the most influential variable on the area planting decision. Consequently, a relationship between the planted area and water availability only has been adopted.
The total area to be planted is determined by the following relationship:

Total Area = Function (Current Water Available and Irrigators' Planting Risk)

The total area is bounded by a maximum and minimum planted area, where:

Current Water Available = Current Announced Allocation * Licensed Entitlement (with annual accounting) + Water in Storage on Farm + Water available from groundwater

Irrigators' Planting Risk = An apparent application rate based on the Total Area and the Current Water Available at the planting decision date. This apparent application rate will reflect a number of influences including: the actual crop water requirements, expectations that the irrigators may have in regard to further increases in announced allocation, future access to off-allocation, rainfall on the crop during the growing season and a range of economic considerations.

An irrigator's planting decision is generally regarded as being specific to a particular model scenario (eg 1993/94 or 1999/00 development), and is selected as part of the scenario development. The selection of a calibration period for a model scenario is based on the assumption that irrigator behaviour (including climatic, social and economic influences) will remain constant. Therefore, the further away from the chosen calibration period the data used to base the IQQM planting decision, the less likely the assumption regarding stability with regard to the external influences is to remain true.

The mix of crop types that make up the total area and their relative portion of the total area are also selected from the calibration period and area specified as input for a given scenario and remain unchanged for the entire simulation period.

6.2. SELECTION OF PLANTING DECISION FACTORS

As mentioned above, the area planting decision in IQQM can be performed separately for both the summer and winter crops. When selecting the planting decision, parameters derived in earlier calibration stages are used. The main objective of selecting the correct farmers planting decision is to generate the planted areas over a period of time that is appropriate for the scenario in which it will be used. Consequently, the planting decision is intended to be calibrated/selected such that it is appropriate for each scenario run.

There are several important factors that need to be considered in selecting the planting decision factors, including:

- The effects of growth in utilisation of entitlement;
- Changes to the crop mix and area planted;
- Availability of water resources during the calibration period;
- Effects of trade on available water at each irrigation node; and
- The representation of irrigator behaviour under resource constrained conditions.

Periods in which substantial growth is occurring will have ever increasing maximum areas (and could well have a different level of irrigators' risk in each season) and are generally considered inappropriate for planting decision calibration. Similarly, varying crop mixes will also affect the relationship between the total planted area and water availability within IQQM. For example, the total planted area in a valley may decrease for the same water availability, but this may not indicate a decrease in risk if the crop mix is changing from a low water use crop to a high water use crop.

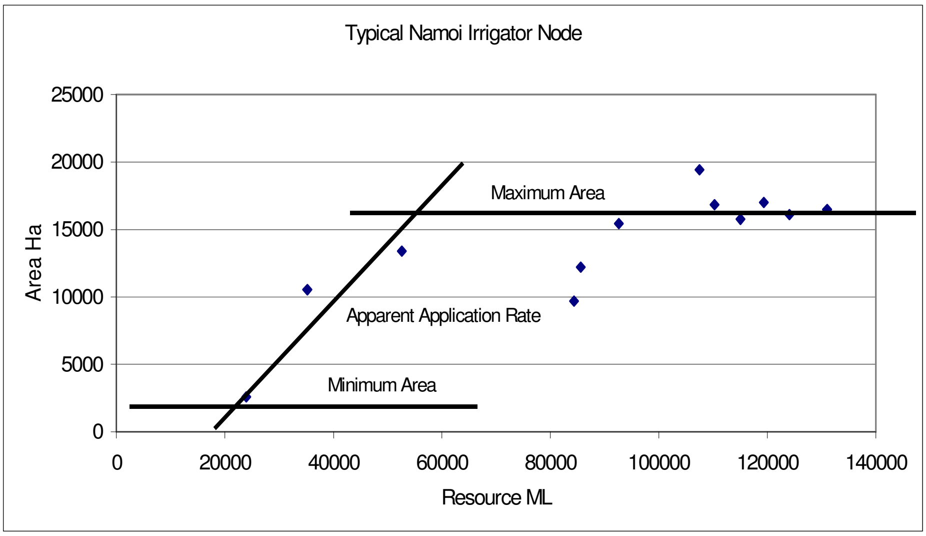
6.3. IRRIGATORS' PLANTING DECISION FACTORS IN THE NAMOI

As resources are constrained due to climatic variability, it is assumed that irrigators would respond by planting smaller areas based on an apparent application rate. This application rate would represent a number of influences not specifically modelled within IQQM. Clearly, the major factor is resource availability, and it is upon this variable that IQQM makes its planting decision. The available data on current water available and area planted was used to estimate the maximum area, minimum area and apparent application rate for each irrigator mode.

Each irrigator group in the model was considered separately to derive their planting risk. Over the period planting records were available, observed area planted and water availability was plotted to derive a representative planting decision.

Details of the historical irrigation information are outlined in Section 2.4. Figure D.1 shows an example of typical data used to derive the maximum area, minimum area and apparent application rate for a irrigation node in the Namoi IQQM.

Figure D.1: Example farmers planting decision for Namoi IQQM



6.4. MAXIMUM AREA

The maximum planted area specified is planted in IQQM every time there are sufficient resources available to do so. In practice, it is observed that this is not the case and that there will be some variation from year to year, even if economic conditions remain largely unaltered. This is thought to be due to the need to rotate land on the farms, and variations in local climate affecting soil moisture at the planting decision dates.

For the Namoi IQQM, for each irrigator group the maximum area was estimated by two methods with the minimum of the two values being used in the model. The historical information is used as outlined above in Figure D.1. Also the historical maximum area for the representative years leading up to the designated development point were averaged to determine the maximum area planted for each irrigator group. For 1993/94 development the 1990/91, 1991/92 and 1992/93 years were used, for the 1999/00 development the 1997/98, 1998/99 and 1999/00 years were used.

6.5. MINIMUM AREA

The concept of a minimum planted area is based on the notion that, at some point of severe resource constraint, irrigators will not continue to reduce their planted areas. This is assumed to be the result of a number of factors which include the need to keep perennial crops such as lucerne alive, the costs associated with replacing them, and an attempt to maintain a minimal amount of production from opportunistic resource availability to provide cash flow.

In the Namoi IQQM the drought of 1993 to 1995 was used to estimate minimum area planted for each of the irrigator nodes.

6.6. APPARENT APPLICATION RATE

The concept of an apparent application rate is based on the notion that a certain ML/Ha will be needed at the pump site to meet the crop water requirements. This application rate plus current water in any on-farm storage plus any groundwater resources, together with expected rainfall and surplus water during the growing season, will in total meet the crop water needs.

In the Namoi Valley the observed area planted and estimated water resources were plotted to derive an estimated apparent application rate (see Figure D1).

6.7. EFFECTS OF TEMPORARY TRADE

Currently IQQM is not capable of modelling the temporary trade activities of irrigators explicitly. However, the impacts of this trade still need to be considered as temporary trading between irrigation groups may be important to the sustainability of the observed planted areas. To ensure that irrigation groups within IQQM are not artificially constrained to plant less than their maximum area due to the lack of trade representation within IQQM, appropriate adjustments to irrigation group entitlements are made. These adjustments reflect the degree of temporary trade occurring.

In the Namoi IQQM it was assumed that full entitlement was active within the valley. Temporary trading of water would ensure that the full resources are generally utilised within the valley. No attempt was made to track the movement of the trading and manually adjust entitlements within IQQM to reflect water transfers around the valley.

Appendix E. Quality Assessment Guidelines

This Appendix describes the latest draft practice notes for assessing the quality of model calibration or validation – as outlined in Section 1.6.

They are based on rating the confidence that the model can be used to closely replicate both the time series and statistical distribution behaviour of the real system, under a specified set of development conditions. These quality rating guidelines are presented for each significant quality indicator identified by senior modelling and operational staff.

The five categories used for expressing the quality rating of a particular indicator, or of the model as a whole, are:-

- Very high confidence
- High confidence
- Moderate confidence
- Low confidence
- Very low confidence

The *apparent error* associated with each quality indicator is calculated and placed within one of the five quality ranges, to define the calibration quality in that indicator. The primary quality indicator used is generally the percentage (ratio) of the model simulated volume or area versus the actual recorded volume or area, over the entire period analysed. Supplementary to this indicator but of equal importance, is a new indicator of time series variability, called the *coefficient of mean absolute annual differences* (CMAAD) as described below:-

```
CMAAD    =  ∑Absolute value(Simulated-Observed) / ∑Observed                  %
```

Where the Simulated and Observed volumes or areas refer to the total amounts relevant to a particular water year or other time period.

There is a further variation of this indicator used to assess the apparent error associated with storage volume time series, call the *coefficient of mean absolute storage drawdown deviation* as described below:

```
CMASDD   =  ∑Absolute value(SMDS-OMDS) / (Max Observed Drawdown * No months)      %

Where       SMDS =  Simulated monthly change in storage volume
            OMDS =  Observed monthly change in storage volume
```

To define an overall model confidence, the quality of the observed data needs to be considered. However, as noted at the end of Chapter 1, objective means of determining measurement uncertainty and climatic representativeness are not readily available. In the interim period prior to such means being developed, these guidelines have incorporated the effects of these two sources of uncertainty by:

- Using record length as a surrogate for climatic representativeness;

- Formulating quality rating tolerance bands relevant to the known greater or lesser measurement uncertainty of the observed data. As an example planted area uncertainty's moderate confidence rating is for simulated areas within ±15% of observed, whereas to achieved the same confidence rating in diversion replication a match to within ±10% must be achieved – indicating the greater inherent measurement uncertainty allowed for in the planted area data.

6.8. FLOW CALIBRATION QUALITY INDICATORS AND RATINGS

Set out below are the latest draft practice notes for assessing the quality of model calibration or validation achieved – as outlined at the end of Chapter 1.

They are based on rating the confidence that the model can be used to closely replicate both the time series and statistical distribution behaviour of the real system, under a specified set of development conditions. These quality rating guidelines are presented for each significant quality indicator identified by senior modelling and operational staff.

The five categories used for expressing the quality rating of a particular indicator, or of the model as a whole, are:

- Very high confidence
- High confidence
- Moderate confidence
- Low confidence
- Very low confidence

The *apparent error* associated with each quality indicator is calculated and placed within one of the five quality ranges, to define the calibration quality in that indicator. The primary quality indicator used is generally the percentage (ratio) of the model simulated volume or area versus the actual recorded volume or area, over the entire period analysed. Supplementary to this indicator but of equal importance, is a new indicator of time series variability, called the *coefficient of mean absolute annual differences* (CMAAD) as described below:-

```
CMAAD    =  ∑Absolute value(Simulated-Observed) / ∑Observed                   %
```

Where the Simulated and Observed volumes or areas refer to the total amounts relevant to a particular water year or other time period.

There is a further variation of this indicator used to assess the apparent error associated with storage volume time series, call the *coefficient of mean absolute storage drawdown deviation* as described below:

```
CMASDD   =  ∑Absolute value(SMDS-OMDS) / (Max Observed Drawdown * No months)      %

Where       SMDS= Simulated monthly change in storage volume
            OMDS= Observed monthly change in storage volume
```

To define an overall model confidence, the quality of the observed data needs to be considered. However, as noted at the end of Chapter 1, objective means of determining measurement uncertainty and climatic representativeness are not readily available. In the interim period prior to such means being developed, these guidelines have incorporated the effects of these two sources of uncertainty by:

- Using record length as a surrogate for climatic representativeness;
- Formulating quality rating tolerance bands relevant to the known greater or lesser measurement uncertainty of the observed data. As an example planted area uncertainty's moderate confidence rating is for simulated areas within ±15% of observed, whereas to achieve the same confidence rating in diversion replication a match to within ±10% must be achieved – indicating the greater inherent measurement uncertainty allowed for in the planted area data.

Table E.1: Comparing actual gauged with model simulated flows over a period

PRIMARY FOCUS	*QUALITY INDICATOR*	*SUB-ASPECT (see note 2)*		*QUALITY RATING GUIDELINES (See note 1)*
		Definition	*Apparent Error (AE)*	
FLOW FREQUENCY REPLICATION (ranked daily flows)	VOLUME RATIO (vr) Where "vr" = 100 * (Simulated / Observed) Expressed as a %	Whole flow range	AE = ("vr" – 100)	Very High: AE within ±2% High: AE within ±5% Moderate: AE within ±15% Low: AE within ±30% Very Low: AE within ±40%
		Low flow range from X%ile to 100%ile (see note 4)	AE = ("vr" – 100)	Very High: AE within ±3% High: AE within ±7% Moderate: AE within ±20% Low: AE within ±35% Very Low: AE within ±45%
		Mid flow range from Y%ile to X%ile (see note 4)	AE = ("vr" – 100)	Very High: AE within ±2% High: AE within ±5% Moderate: AE within ±15% Low: AE within ±30% Very Low: AE within ±40%
		High flow range from 0%ile to Y%ile (see note 4)	AE = ("vr" – 100)	Very High: AE within ±4% High: AE within ±10% Moderate: AE within ±25% Low: AE within ±40% Very Low AE within ±50%
FLOW TIME SERIES REPLICATION	Daily flow time series – line of best fit: r^2	"r^2" coefficient of determination, (or the degree of scatter around the line of best fit)	AE = 100 * (1- r^2)	Very High: AE within 5% High: AE within 10% Moderate: AE within 25% Low: AE within 40% Very Low: AE within 50%
	Annual flow time series: Individual reach calibration stage CMAAD	CMAAD – Coefficient of Mean Absolute Annual Differences	AE = CMAAD (see note 3)	Very High: AE within 5% High: AE within 10% Moderate: AE within 15% Low: AE within 20% Very Low: AE within 25%
	Annual flow time series: Assembled reach calibration stages: CMAAD	CMAAD – Coefficient of Mean Absolute Annual Differences	AE = CMAAD (see note 3)	Very High: AE within 10% High: AE within 15% Moderate: AE within 20% Low: AE within 25% Very Low: AE within 30%

Notes:-

1. Where range specifications are not mutually exclusive, the range conforming to the maximum quality rating should be adopted
2. Unless explicitly stated, all indicator values should be calculated in absolute value terms
3. CMAAD = 100* ∑Absolute value(Simulated annual – Observed annual) / ∑ (Observed annual values)
4. The "X%ile" and "Y%ile" points should be defined from examination of the ranked flow-duration plot of daily flows over the calibration period. The "X%ile" point should be identifiable as the point of convexity on a log-scale plot, where the lower flow region of the curve starts to turn downwards (usually around the 70 to 90%ile zone). The "Y%ile" point should be similarly identifiable as the point of concavity on a log-scale plot, where the higher flow region of the curve starts to turn upwards (usually around the 5 to 10%ile zone).

6.9. STORAGE CALIBRATION QUALITY INDICATORS AND RATINGS

Table E.2: Comparing actual gauged with model simulated storage over a period

PRIMARY FOCUS	*QUALITY INDICATOR*	*SUB-ASPECT (see note 2)*		*QUALITY RATING GUIDELINES (see note 1)*
		Definition	*Apparent Error (AE)*	
STORAGE VOLUME REPLICATION (time series of storage volumes)	Storage volume time series CMASDD	CMASDD – Coefficient of Mean Absolute Storage Drawdown Deviation	AE = CMASDD (see note 3)	Very High: AE within ±2% High: AE within ±5% Moderate: AE within ±8% Low: AE within ±10% Very Low: AE within ±15%

Notes:-
1. Where range specifications are not mutually exclusive, the range conforming to the maximum quality rating should be adopted
2. Unless explicitly stated, all indicator values should be calculated in absolute value terms
3. CMASDD = 100* ∑Absolute value(SMDS – OMDS) / (Observed maximum drawdown*Number of months)

6.10. DIVERSION CALIBRATION QUALITY INDICATORS AND RATINGS

Table E.3: Comparing actual gauged with model simulated diversions over a period

(applicable for ONA, OFA and TOTAL diversions)

PRIMARY FOCUS	*QUALITY INDICATOR*	*SUB-ASPECT (see note 2)*		*QUALITY RATING GUIDELINES (see note 1)*
		Definition	*Apparent Error (AE)*	
Whole of Valley , and irrigator groups	VOLUME RATIO "vr" based on Total period diversion Where "vr" = 100 * (Simulated / Observed) Expressed as a %	ONA total	AE = ("vr" – 100)	Very High: AE within ±2% High: AE within ±5% Moderate: AE within ±15% Low: AE within ±30% Very Low: AE within ±40%
		OFA total	AE = ("vr" – 100)	Very High: AE within ±3% High: AE within ±7% Moderate: AE within ±20% Low: AE within ±35% Very Low: AE within ±50%
		Total Diversions	AE = ("vr" – 100)	Very High: AE within ±2% High: AE within ±5% Moderate: AE within ±15% Low: AE within ±30% Very Low: AE within ±40%
	Annual diversion time series comparison (ONA, OFA and Total): CMAAD	CMAAD – Coefficient of Mean Absolute Annual Differences	AE = CMAAD (see note 3)	Very High: AE within 10% High: AE within 15% Moderate: AE within 20% Low: AE within 25% Very Low: AE within 30%

Notes:-
1. Where range specifications are not mutually exclusive, the range conforming to the maximum quality rating should be adopted
2. Unless explicitly stated, all indicator values should be calculated in absolute value terms
3. CMAAD = 100* ∑Absolute value(Simulated annual – Observed annual) / ∑ (Observed annual values)

6.11. PLANTED CROP AREA CALIBRATION QUALITY INDICATORS AND RATINGS

Table E.4: Comparing actual recorded with model simulated planted crop areas

PRIMARY FOCUS	*QUALITY INDICATOR*	*SUB-ASPECT (see note 2)*		*QUALITY RATING GUIDELINES (see note 1)*
		Definition	*Apparent Error (AE)*	
Whole of Valley, and irrigator groups	AREA RATIO Whole period total area ratio (ar): Where "ar" = 100 * (Simulated / Observed)	Overall % (ar)	AE = ("ar" – 100)	Very High: AE within ±3% High: AE within ±7% Moderate: AE within ±20% Low: AE within ±35% Very Low: AE within ±50%
	Annual cropped area time series comparison CMAAD	CMAAD – Coefficient of Mean Absolute Annual Differences	AE = CMAAD (see note 3)	Very High: AE within 15% High: AE within 20% Moderate: AE within 25% Low: AE within 30% Very Low: AE within 35%

Notes:-

1. Where range specifications are not mutually exclusive, the range conforming to the maximum quality rating should be adopted
2. Unless explicitly stated, all indicator values should be calculated in absolute value terms
3. CMAAD = 100* ∑Absolute value(Simulated annual – Observed annual) / ∑ (Observed annual values)

6.12. REPRESENTATIVENESS OF CALIBRATION PERIOD

As noted in Chapter 1, the observed data quality should ideally be based on a combination of measurement uncertainty of the data, and the representativeness of the calibration period. At this stage, however, only record length is readily available, as an indicator of climatic representativeness, as presented in Table E.5.

Table E.5: Climatic representativeness classification guideline

PRIMARY FOCUS	*QUALITY INDICATOR*	*SUB-ASPECT*		*QUALITY RATING GUIDELINES*
		Definition	*Ideal value*	
RECORD LENGTH	Available "valid" data record length	Length for IQQM calibration (L)	10 years	Very High: L > 10 years High: 5.0 < L< 10.0 years Moderate: 2.0 <L< 5.0years Low: 1.0 <L< 2.0 years Very Low L < 1 year

Another aspect that should be considered by the modeller/analyst is whether or not the period adequately represents the degree of development that will be represented in the model for long term simulation purposes. For example does it include 1993/94, if the model is to be used for CAP simulation purposes. At this stage no explicit allowance for this aspect has been made, but it is mentioned here for completeness.

6.13. OVERALL MODEL QUALITY RATING

There are a number of methods for evaluating the overall quality of a model calibration. The evaluation of a calibration should take into account the intended use of the model and appropriate indicators should be chosen. Given that the major use of IQQM to date is CAP compliance and scenario comparisons the following indicators have been chosen:

1) Total diversion for the valley (Volume ratio and CMAAD)

2) End of system flows (Volume ratio and CMAAD)
3) Combined storage behaviour (CMASDD)
4) Key gauge site (Mid range volume ratio and CMAAD)

These criteria have been chosen on the basis that they represent the major components of the model that will be used for evaluating various options. The first three criteria give a reasonable assessment of the mass balance validity of the model while the fourth criteria gives an indication of the suitability of the model for assessing environmental flow options. As each of these criteria is of equal importance they have been given an equal weighting in the overall assessment of the model.

Each of the eight indicators has an associated quality guideline that is described in the preceding tables. Each of the guidelines has five sets of confidence limits of various magnitudes. To be able to combine these criteria with equal weighting these indicators need to be transformed into a standard rating system as follows:

1) Very High 0%<=x<=5%
2) High 5%<x<= 10%
3) Moderate 10%<x<=15%
4) Low 15%<x<=20%
5) Very low 20%<x<=30%

The transformation is carried out as follows:

```
SI       =  (I-LL)*(SU-SL)/(UL-LL) + SL

Where    SI   =  Standardised indicator
         I    =  Indicator for selected criteria
         UL   =  Upper limit of the confidence band that I lies between
         LL   =  Lower limit of the confidence band that I lies between
         SU   =  Standardised upper confidence limit of equivalent indicator
                 confidence limit
         SL   =  Standardised lower confidence limit of equivalent indicator
                 confidence limit
```

To obtain an overall quality indicator (OI) each of the eight indicators are standardised and averaged (AI). That is, AI = $\sum$ SI,s / 8. This average quality indicator is then adjusted for climatic representativeness of the calibration period on the following basis:

OI = AI * 3.0 * $NY^{-0.65}$

```
Where    OI   =  Overall quality indicator
         AI   =  Average standardise quality indicator
         NY   =  Number of years model is calibrated over
```

The adjustment for climatic representativeness takes into account that indicators in the preceding tables have been formulated assuming a calibration period of approximately five years. This adjustment allows for a decrease in confidence with a shorter calibration period and an increase in confidence with a longer calibration period. However, it should be noted that calibration period length is a surrogate for climatic representativeness, and that if this period does not contain dry and wet periods then this adjustment may not be appropriate.

The overall quality indicator gives an indication of what the model may be used for.

- **"OI" quality of high to very high**: can be used for detailed concept design new weirs or storage structures, or to design modifications to existing structures, or to determine CAP conformance for a particular year.
- **"OI" quality of low to moderate**: useful for comparing alternative improvement options or development scenario impacts, eg for Hydro-power feasibility studies, and for long term CAP determination.
- **"OI" quality of very low** indicates that the model requires further calibration before it can be relied upon.

Appendix F. MDBMC Cap Development Conditions and Management Rules

Table F.1: 1993/94 infrastructure & development parameters

ITEMS	DESCRIPTION	
GENERAL		
Simulation Period	1 October 1892 to 30 September 2000	
Water Year	October to September	
CATCHMENT INFORMATION		
Storages modelled	Keepit & Split Rock Dams	
Storage Volumes *(ML)*	Dead Storage	Capacity
Keepit	6550	425510
Split Rock	3160	397370
FLOW INFORMATION		
Storage Inflows *(GL/yr)*	Average annual inflow Split Rock Dam = 75 GL Keepit Dam = 357 GL (including Split Rock Dam releases and tributary inflow)	
Lateral inflows *(GL/yr)*	Split Rock Dam to Keepit Dam = 419 GL Downstream Keepit Dam = 1379 GL	
IRRIGATION INFORMATION		
General Security (GS) licence volume *(GL)*	Split Rock Dam to Keepit Dam = 9.7 GL Downstream Keepit Dam = 247 GL	
High Security (HS) licence volume *(GL)*	Nil	
Accounting system	Annual accounting with water order debiting	
Maximum irrigable area *(Ha)*	Summer = 44555 Ha Winter = 6200 Ha See Table F2	
On-farm storage capacity *(GL)*	120433 ML	
Pump capacity *(ML/d)*	9103 ML	

Active licence factor *(%)*	100%
Irrigators' carry over *(%)*	Nil
On-farm storage operation	Flood plain harvesting = yes End-of-year diversions = yes Rainfall runoff harvesting = yes Airspace = yes Reserve = yes
Average crop mix *(%)*	See Table F3
OTHER EXTRACTIONS	
Town water supply *(ML/yr)*	2300 ML entitlement (combined diversions for TWS, S&D and Industrial equals 1.5 GL/year)
Stock & domestic *(ML/yr)*	2600 ML entitlement (combined diversions for TWS, S&D and Industrial equals 1.5 GL/year)
Industrial / mining/other *(ML/yr)*	3400 ML entitlement (combined diversions for TWS, S&D and Industrial equals 1.5 GL/year)
Groundwater access *(ML/yr)*	Surface water licence holders with conjunctive use licences were modelled. (1) Conjunctive users upstream of Narrabri have any reduction in surface water allocation directly replaced by groundwater entitlement. (2) Conjunctive users downstream of Narrabri have any reduction in surface water allocation replaced by groundwater on a 4:1 ration. With a minimum allocation of 1.5 ML/ha. (see Section 2.8)
RESOURCE ASSESSMENT	
Storage Reserve *(GL)*	Split Rock Dam = ranges from 30000 ML at empty storage to 84700 ML at full storage. Keepit Dam = ranges from 10000 ML at empty storage to 57551 at full storage
Transmission / operation loss *(GL)*	Ranges from 76928 ML in October to 8847 ML in September
Minimum storage inflows *(ML)*	Nil
Minimum tributary inflows	Ranges from 7918 ML in October to 0 ML in

(ML)	September
System development factor *(%)*	100%
Maximum allocation *(%)*	100%
RIVER AND STORAGE OPERATING RULES	
Transfer rules (Split Rock Dam to Keepit Dam)	Transfer water from Split Rock Dam to Keepit Dam if during the irrigation season dam water levels impact on maximum outlet valve capacity (approximately below 105 GL's in Keepit Dam)
Tributary recession factors *(%)*	100% for Peel, Mooki, Coxs tributaries
Over order allowances *(%)*	All reaches = 0
Off-allocation Cap *(GL/yr)*	110 GL
SURPLUS FLOW ACCESS	
Off-allocation thresholds	See Table F.5.
RIVER FLOW REQUIREMENTS	
Minimum flow requirements *(ML/d)*	Split Rock Dam = 5 to 6 ML/day Keepit Dam = 10 ML/day Goangra = 40 ML/day (October to March)
Pian replenishment	14000 ML set aside for 2 stock and domestic replenishments down Pian Creek

Table F.2: Estimation of maximum and minimum area for 1993/94 development

Reach	Maximum Area (Ha) for 1993/94 development (Average of 90/91,91/92,92/93)		Minimum area Planted (Ha) 1993/94	
	Summer	Winter	Summer	Winter
1	722	129	0	0
2	85	20	0	0
3	310	78	0	0
4	366	101	154	0
5	790	100	45	0
5 ofs	0	0	0	0
6	490	85	174	0
6 ofs	929	22	88	0
7	108	56	0	0
7 ofs	665	41	262	0
8	1174	290	0	0
8 ofs	16035	2153	2344	0
9	164	13	54	0
9 ofs	2936	129	650	0
10	142	13	0	0
10 ofs	394	99	115	0
11	54	78	0	0
11 ofs	2266	324	1426	0
12	356	34	0	0
12 ofs	1066	169	600	0
13	275	192	128	0
13 ofs	428	157	413	0
14	0	0	0	0
14 ofs	4141	453	1348	0
15	1340	1940	175	0
16	772	82	0	0
16 ofs	5027	770	4000	0
17	91	0	0	0
17 ofs	2959	476	1519	0
Total	44555	6200	13296	0

Table F.3: Apparent application rate for 1993/94 development

Reach	Apparent application rate ML/Ha
Summer Planting	
1	4.8
2	5.0
3	3.7
4	3.8
5	1.9
5 ofs	na
6	7.1
6 ofs	2.4
7	4.5
7 ofs	5.9
8	5.9
8 ofs	4.8
9	11.1
9 ofs	5.0
10	7.7
10 ofs	4.8
11	5.3
11 ofs	14.3
12	6.6
12 ofs	2.3
13	2.6
13 ofs	2.0
14	3.8
14 ofs	5.6
15	3.6
16	6.7
16 ofs	3.3
17	1.2
17 ofs	0.5
Summer average	4.9
Winter Planting	4.0

Table F.4: Crop mix details for 1993/94 development conditions

Reach	Percentage of crop (%)							
	Lucerne	Summer Cereal	Summer Pasture	Winter Cereal	Winter Pasture	Cotton	Summer Oil	Wheat
1	48	6	32	8	6			
2	60	4	19	14	3			
3	54	13	13	18	2			
4	13	12	46		21	8		
5	15	20	17		5	13	20	10
5 ofs	nil	nil	nil	nil	nil	nil	nil	nil
6	9	13	21	2	11	37	5	2
6 ofs	1	13				83		2
7	14	18	32	4	15			17
7 ofs						91		9
8		1				71	8	20
8 ofs		1				85	2	12
9						89		11
9 ofs						96		4
10	4	10				67		19
10 ofs		10	2		2	71		15
11		47		53				
11 ofs			3			85		12
12		9				83		8
12 ofs						86		14
13		11	3	32	3	35		16
13 ofs						78	4	18
14	nil	nil	nil	nil	nil	nil	nil	Nil
14 ofs		5				85		10
15			2			85		13
16		2	2			88		8
16 ofs			2			84	2	12
17		35	33	22	10			
17 ofs						87	7	6

Table F.5: Adopted surplus flow thresholds for 1993/94 development conditions

River Reach	Ml/d
Keepit Dam to Gunnedah	800
Gunnedah to Boggabri	1050
Boggabri to Narrabri	1050
Narrabri to Mollee	1050
Mollee to D/S Gunidgera	1300
D/S Gunidgera to D/S Weeta	900
D/S Weeta to Duncans	780
Duncans to Bugilbone	1030
Bugilbone to Goangra	1490
Goangra to Walgett	1490
Gunidgera Ck from regulator to Knights Gauge	165
Gunidgera Ck below Knights Gauge	30
Pain Creek	140

Table F.6: Adopted factors for floodplain harvesting and rainfall runoff harvesting

Note:
1. Floodplain Harvesting factor is a flow threshold at which on-farm storage is filled.
2. Rainfall runoff harvesting factor is the volume of runoff that can be stored and diverted to the on-farm storage.

Reach	Floodplain Harvesting Threshold Flow	Rainfall Runoff volume that can be harvested
	ML/day	ML
1		
2		
3		
4		
5		
5 ofs		
6		
6 ofs	25000	
7		
7 ofs	68000	
8		
8 ofs	25000	2000
9		
9 ofs	25000	
10		
10 ofs	24000	450
11		
11 ofs	30000	450
12		
12 ofs	20000	
13		
13 ofs	20000	300
14		
14 ofs	10000	2000
15	10000	
16		
16 ofs	10000	6000
17		
17 ofs	10000	
Total		

Appendix G. 1999/2000 Development Conditions and Environmental Flow Management Rules

Table G.1: 1999/00 infrastructure & development parameters

ITEMS	DESCRIPTION
GENERAL	
Simulation Period	1 October 1892 to 30 September 2002
Water Year	October to September
CATCHMENT INFORMATION	
Storages modelled	Keepit & Split Rock Dam
Storage Volumes *(ML)*	Dead Storage / Capacity
Keepit	6550 / 425510
Split Rock	3160 / 397370
FLOW INFORMATION	
Storage Inflows *(GL/yr)*	Average annual inflow Split Rock Dam = 75 GL Keepit Dam = 357 GL (including Split Rock Dam releases and tributary inflow)
Lateral inflows *(GL/yr)*	Split Rock Dam to Keepit Dam = 419 GL Downstream Keepit Dam = 1379 GL
IRRIGATION INFORMATION	
General Security (GS) licence volume *(GL)*	Split Rock Dam to Keepit Dam = 9.7 GL Downstream Keepit Dam = 246 GL
High Security (HS) licence volume *(GL)*	Nil
Accounting system	Continuous accounting with maximum account at 200% of entitlement and water order debiting
Maximum irrigable area *(Ha)*	Summer = 51580 Ha Winter = 19350 Ha
On-farm storage capacity *(GL)*	178815 ML

Pump capacity *(ML/d)*	10683 ML
Active licence factor *(%)*	100%
Irrigators' carry over *(%)*	Continuous accounting
On-farm storage operation	Flood plain harvesting = yes End-of-year diversions = yes Rainfall runoff harvesting = yes Airspace = yes Reserve = yes
Average crop mix *(%)*	See Table G2
OTHER EXTRACTIONS	
Town water supply *(ML/yr)*	2300 ML entitlement (combined diversions for TWS, S&D and Industrial equals 1.5 GL/year)
Stock & domestic *(ML/yr)*	2600 ML entitlement (combined diversions for TWS, S&D and Industrial equals 1.5 GL/year)
Industrial / mining/other *(ML/yr)*	3400 ML entitlement (combined diversions for TWS, S&D and Industrial equals 1.5 GL/year)
Groundwater access *(ML/yr)*	Surface water users who had conjunctive use licences have been converted to groundwater only licences. It is assumed this water is still accessible for use. (see Section 2.8)
RESOURCE ASSESSMENT	
Storage Reserve *(GL)*	Split Rock Dam =39500 ML Keepit Dam = 106500 ML
Transmission / operation loss *(GL)*	Transmission and operation loss account allowed for at 30% of the general security irrigation account volume.
Minimum storage inflows *(ML)*	Nil
Minimum tributary inflows *(ML)*	Nil
System development factor *(%)*	100%
Maximum allocation *(%)*	Irrigators allowed to use up to 100% of entitlement during water year (1998 EFR) Irrigators allowed to use up to 125% of entitlement daring water year but must have an average of 100% over any 3 year period (Water

	Sharing Plan)
RIVER AND STORAGE OPERATING RULES	
Transfer rules ***(Split Rock Dam to Keepit Dam)***	Transfer water from Split Rock Dam to Keepit Dam if during the irrigation season dam water levels impact on maximum outlet valve capacity (approximately below 105 GL's in Keepit Dam)
Tributary recession factors *(%)*	100% for Peel, Mooki, Coxs tributaries
Over order allowances *(%)*	All reaches = 0
Off-allocation Cap *(GL/yr)*	110 GL
SURPLUS FLOW ACCESS	
Sharing of surplus flow	• During a period of surplus flow the water is shared 50% to the environment and 50% to irrigators (1998 EFR) • During the months of September, October, November & December the surplus flows are shared 90% to the environment and 10% to the irrigators. During all other months the surplus flow is shared 50% to the environment and 50% to the irrigators (Water Sharing Plan).
Off-allocation thresholds	See Table G.5 & G.6.
RIVER FLOW REQUIREMENTS	
Minimum flow requirements *(ML/d)*	Split Rock Dam = 5 to 6 ML/day Keepit Dam = 10 ML/day Walgett = June 21 ML/d, July 24 ML/d& August 17 ML/d (Water Sharing Plan)
Pian replenishment	14000 ML set aside for 2 stock and domestic replenishments down Pian Creek

Table G2: Estimation of maximum and minimum area for 1999/00 development

Reach	Maximum Area (Ha) for 1999/00 development (Average of 97/98,98/99,99/00)		Minimum area Planted (Ha) 1999/00	
	Summer	Winter	Summer	Winter
1	722	129	0	0
2	85	20	0	0
3	310	78	0	0
4	483	186	154	0
5	308	510	45	0
5 ofs	436	121	0	0
6	267	48	120	0
6 ofs	1775	606	88	0
7	0	0	0	0
7 ofs	751	232	262	0
8	403	74	0	0
8 ofs	16263	6308	0	0
9	110	0	54	0
9 ofs	4071	1294	650	0
10	0	0	0	0
10 ofs	1295	241	120	0
11	54	67	0	0
11 ofs	2804	1203	1440	0
12	0	0	0	0
12 ofs	2296	480	600	0
13	0	0	128	0
13 ofs	1421	158	413	0
14	0	0	0	0
14 ofs	2993	1675	1378	0
15	1192	466	179	0
16	69	18	0	0
16 ofs	10697	4621	4000	0
17	0	0	0	0
17 ofs	2577	1023	1500	0
Total	51584	19356	11131	

Table G.3: Apparent application rate for 1999/00 development

Reach	Apparent application rate ML/Ha
Summer Planting	
1	4.8
2	5.0
3	3.7
4	3.8
5	8.3
5 ofs	na
6	2.5
6 ofs	1.8
7	6.7
7 ofs	5.6
8	10.0
8 ofs	6.7
9	9.1
9 ofs	4.8
10	7.7
10 ofs	3.5
11	5.3
11 ofs	14.3
12	6.6
12 ofs	4.2
13	2.6
13 ofs	5.0
14	3.8
14 ofs	5.6
15	3.1
16	3.1
16 ofs	5.6
17	1.2
17 ofs	3.2
Summer Average	5.3
Winter Planting	4.0

Table G.4: Crop mix details for 1999/00 development conditions

Reach	Percentage of crop (%)							
	Lucerne	Summer Cereal	Summer Pasture	Winter Cereal	Winter Pasture	Cotton	Summer Oil	Wheat
1	48	6	32	8	6			
2	60	4	19	14	3			
3	54	13	13	18	2			
4	25	10		28		35	2	
5	3	7		63		13	14	
5 ofs				22		78		
6	23	5		15		55	2	
6 ofs				26		66	8	
7	nil	nil	nil	nil	nil	nil	nil	Nil
7 ofs				24		76		
8		7		16		77		
8 ofs		7		27		68	4	
9						100		
9 ofs				24		72	4	
10	nil	nil	nil	nil	nil	nil	nil	Nil
10 ofs				16		84		
11				55		45		
11 ofs				30		69	1	
12	nil	nil	nil	nil	nil	nil	nil	Nil
12 ofs				17		81	2	
13	nil	nil	nil	nil	nil	nil	nil	Nil
13 ofs		4		10		83	3	
14	nil	nil	nil	nil	nil	nil	nil	Nil
14 ofs				36		63	1	
15		1		30		68	1	
16				20		68	12	
16 ofs				30		68	2	
17	nil	nil	nil	nil	nil	nil	nil	Nil
17 ofs				28		72		

Table G5: Surplus flow thresholds for 1999/00 development conditions (allocations > 35%)

River Reach	Start (ML/day)			End (ML/day)		
	Jan	Feb to July	Aug to Dec	Jan	Feb to July	Aug to Dec
Keepit Dam to Gunnedah	3294	1832	4084	1832	919	2648
Gunnedah to Boggabri	3370	1720	4250	1720	780	2580
Boggabri to Narrabri	3772	1856	4807	1856	879	2841
Narrabri to Mollee	4000	2000	5000	2000	1000	3000
Mollee to D/S Gunidgera	3994	1991	4890	1991	966	2998
D/S Gunidgera to D/S Weeta	4000	2000	4000	2000	1000	2500
D/S Weeta to Duncans	2000	1500	3000	1500	1000	2000
Duncans to Bugilbone (1)	315	315	315	315	315	315
Bugilbone to Goangra (1)	450	450	450	450	450	450
Goangra to Walgett (1)	450	450	450	450	450	450
	Jan to Feb	Mar to Apr	May to Aug	Sep to Oct	Nov to Dec	
Gunidgera Ck from regulator to Knights Gauge (2)	30	290	30	290	30	
Gunidgera Ck below Knights Gauge	30	30	30	30	30	
Pian Ck	1000	1000	1000	1000	1000	

(1) – These thresholds were selected to produce 200 ML/day at Walgett assuming average calibration losses

(2) – These thresholds are higher in some months to satisfy the rule that replenishment flows have first call on off allocation water in the Gunidgera & Pian systems.

Table G6: Surplus flow thresholds for 1999/00 development conditions (allocation < 35%)

River Reach	Start (ML/day)			End (ML/day)		
	Jan	Feb to July	Aug to Dec	Jan	Feb to July	Aug to Dec
Keepit Dam to Gunnedah	444	444	444	444	444	444
Gunnedah to Boggabri	360	360	360	360	360	360
Boggabri to Narrabri	432	432	432	432	432	432
Narrabri to Mollee	500	500	500	500	500	500
Mollee to D/S Gunidgera	512	512	512	512	512	512
D/S Gunidgera to D/S Weeta	500	500	500	500	500	500
D/S Weeta to Duncans	500	500	500	500	500	500
Duncans to Bugilbone (1)	315	315	315	315	315	315
Bugilbone to Goangra (1)	450	450	450	450	450	450
Goangra to Walgett (1)	450	450	450	450	450	450
	Jan to Feb	Mar to Apr	May to Aug	Sep to Oct	Nov to Dec	
Gunidgera Ck from regulator to Knights Gauge (2)	30	290	30	290	30	
Gunidgera Ck below Knights Gauge	30	30	30	30	30	
Pian Ck	1000	1000	1000	1000	1000	

(1) – These thresholds were selected to produce 200 ML/day at Walgett assuming average calibration losses

(2) – These thresholds are higher in some months to satisfy the rule that replenishment flows have first call on off allocation water in the Gunidgera & Pian systems.

Table G7: Adopted factors for floodplain harvesting and rainfall runoff harvesting

Reach	Floodplain Harvesting Threshold Flow	Rainfall Runoff volume that can be harvested
	ML/day	ML
1		
2		
3		
4		
5		
5 ofs	25000	200
6		
6 ofs	25000	2000
7		
7 ofs	68000	800
8		
8 ofs	22500	30000
9		
9 ofs	25000	2000
10		
10 ofs	20000	100
11		
11 ofs	18000	2000
12		
12 ofs	8000	200000
13		
13 ofs	20000	3000
14		
14 ofs	10000	0
15	10000	500
16		
16 ofs	10000	20000
17		
17 ofs	5000	600000