REPORT FOR MDBC REVIEW

NSW Government

DEPARTMENT OF NATURAL RESOURCES

Gwydir River Valley

IQQM Cap Implementation Summary Report

November 2005

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Cover photo:

– Copeton Dam spillway releasing water

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Specifically, readers should be aware that the Murray-Darling Basin Cap and the associated models have been superceded by Sustainable Diversion Limits under the Murray-Darling Basin Plan and the associated models.

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Acknowledgments

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

Published by:
Water Resource Management Performance Unit
Water Reform & Innovation Branch
New South Wales Department of Natural Resources
Parramatta

November 2005

Contents

Page

Figures .

Page

Tables .

Executive Summary

What has initiated the work?

The MDBMC Cap requires that NSW develop a suitable planning tool to enable review of water use and sharing arrangements in the Gwydir River Valley. The tool accepted as suitable for this purpose is a calibrated water balance model that includes all relevant important features on and in the system. The adopted model is called the Integrated Quantity/Quality Model (IQQM).

Scope of this report summarises the Gwydir IQQM status

This report summarises and documents the IQQM calibration, validation and model use for representation of Cap conditions in the regulated sections of the Gwydir River.

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 demonstrate to the reader that the developed model includes <u>all</u> of the important features in the system, and <u>closely</u> replicates records of flow and water extraction behaviour. The secondary purpose is to demonstrate that the model can be successfully used to define the 1993/94 diversion Cap.

Model configuration includes all important features

Chapter 3 describes inclusion of the main physical and management features in the model. The availability and extent of time series data is also described in this chapter.

Calibration to 1988/89 – 2003/04 configures the model parameters

Chapter 3 also describes the model calibration procedure and results. Comparison is made between time series observed data and time series model simulated data using time series model parameters to determine appropriate values for use in scenario runs. Quality ratings were applied to the components of the model calibration as follows:

- Flow calibration: overall "High" CMAAD rating;
- Diversion calibration: ONA "High" CMAAD rating; SW "High" CMAAD rating;
- Storage behaviour calibration: overall "V. High" CMASDD rating;
- Planted area calibration: overall "High" CMAAD rating;

The Overall quality of the model calibration was also assessed based on the quality of the individual calibrations and the length of the calibration period. The model achieved a "V. High" rating.

Statement of model adequacy

The overall quality of the Gwydir River Valley IQQM calibration suggests that it is suitably robust for Cap Auditing, 100+ year scenario running and for comparison of impacts from alternative management scenarios.

Validation for the 1993/94 scenario

Chapter 4 describes the 1993/94 development conditions and management rules. These are configured into what DNR is defining as the 1993/94 Cap scenario. Presented are the model validation results over the 1989/90 to

1994/95 period using the static 1993/94 Cap scenario parameters. Comparison is made between time series observed data and time series model simulated data. Analysis and discussion of the model's performance over this period is presented.

Simulation of the 1993/94 Cap benchmark scenario

Chapter 4 also describes the use of the Gwydir IQQM to simulate the 1993/94 Cap scenario. Results are presented for:

- the 113 year period from 1892 to 2004 inclusive, to estimate the long term Cap scenario average annual diversions;
- the 1997/98 to 2004/05 period, to produce estimates of the Cap for auditing under the provisions of Schedule F of the Murray-Darling Basin Agreement.

Improvement suggestions

Chapter 5 lists a series of short and long term improvement plans, categorised as upgrades to flow, demand, storage behaviour and other general upgrades. These suggestions are not intended to reduce the credibility of the current model, but should be viewed as part of DNR's quality assurance process, which promotes continuous improvement to its key planning tools and products.

Glossary of Terms

ACF	Australian Cotton Foundation.
Agrecon	Agricultural Reconnaissance Technologies Pty Ltd
account balance	This is the current amount of water an irrigator has access to for irrigation. It is calculated differently depending on whether the system uses annual accounting or continuous accounting. In annual accounting, it is a function of their water share, the AWD and the amount of water they have already diverted. In continuous accounting their balance is continuously updated based on inflow sharing and water diverted.
allocation level	See “AWD”.
available water determination (AWD)	Available water determination (AWD) was previously known as allocation level or announced allocation. This is the percentage of their water share volume that general security irrigators can divert in the current water year during on-allocation periods. The first AWD for the coming irrigation season is announced at the beginning of the water year and is not reduced from this announcement, noting however that it can be increased during the irrigation season as a result of dam inflows.
allocation system	An allocation system is a group of river sections that have the same AWD. The AWD for an allocation system is defined as the minimum of the AWD’s for all the allocation sub-systems under it. This applies when irrigator groups have access to only one dam’s resources but their AWD is determined by another dam’s resource criteria.
annual accounting	An annual accounting system is where general security water users get an AWD of water each year. This system can be without carryover, where unused water at the end of the year gets re-socialised and distributed evenly between all users. Alternatively, it can be with carryover, where unused water at the end of the year remains in an irrigator’s water share (up to a certain limit).
Cap	The Murray Darling Basin Ministerial Council Cap on extractions for consumptive users at the level that would have occurred under 1993/94 development conditions and management rules over a long term period of varying climatic conditions [MDBMC, 1996].
Cap Audit scenario	An IQQM that has been configured for the simulation of 1993/94 development conditions and management rules, commencing in 1997/98, to provide a cumulative target for the diversions that would have occurred

	under Cap conditions.
Cap scenario	An IQQM that has been configured for the simulation of 1993/94 development conditions and management rules, commencing around 1892, to provide an estimate of the long term average diversions that would have occurred over the last 100+ years under these rules.
coefficient of determination	See "r^2".
coefficient of mean absolute annual differences (CMAAD)	A comparative statistic developed by DNR to assess the match between simulated and observed annual values for model calibration. Further details are provided in (Appendix E.1).
coefficient of mean absolute monthly differences (CMAMD)	A comparative statistic developed by DNR to assess the match between simulated and observed monthly values for model calibration. Further details are provided in (Appendix E.2).
coefficient of mean absolute storage drawdown deviation (CMASDD)	A comparative statistic developed by DNR to assess the match between simulated and observed daily storage behaviour for model calibration. Further details are provided in (Appendix E.3).
continuous accounting	In a continuous accounting system water users have individual accounts that build up as inflows are shared and reduce as water diversions are debited against the account. The accounts are operated continuously overlapping water years with no need for AWD's. There are usually limits on the maximum amount the accounts can build up to and limits on the amount that can be used in a water year. DNR maintains separate accounts to manage year to year high security needs and transmission/operation losses. In addition a storage reserve is usually set aside to provide longer term security for high security water use. The Gwydir Valley went to a continuous accounting system in the 1999/00 water year.
DIPNR	see "DNR".
DLWC	see "DNR".
DNR	NSW Department of Natural Resources. Previously known as the NSW Department of Infrastructure, Planning and Natural Resources (DIPNR), the Department of Land and Water Conservation (DLWC) and the Department of Water Resources (DWR) before that.

DWR	see “DNR”.
d/s	Downstream.
ECA	Environmental Contingency Allowance: a volume of water set aside in Copeton Dam and used for environmental purposes.
entitlement	See “water share”.
Environmental Flow Rules (EFR)	A set of the river management/operation rules aimed at increasing the environment’s share of river flows. The EFR’s were first triggered in the 1995/96 irrigation season and included options such as a 25 GL ECA.
floodplain harvesting (FPH)	Water obtained by irrigators through pumping or direct inflows of water off the flood plain. This includes water: • Pumped from the floodplain into spare OFS capacity (ie during floods from higher up in the catchment), using secondary lift pumps; and • Gravity fed from the floodplain into spare OFS capacity (ie during large floods from higher up in the catchment). This water is not metered and hence there is no good quality historical FPH data available.
general security (GS) licenses	Licenses that are supplied with water after high security license needs are fully satisfied. These licenses cover the great majority of irrigation licenses both in terms of number and annual water share volume. In an annual accounting system AWD’s are made each year to indicate the percentage of annual water share volume that can be supplied. In a continuous accounting system the annual water share volume is a function of usage in previous years and shared inflows this year.
high security (HS) licenses	Licenses that provide the highest reliability of water supply. Generally, these licenses are for (relatively) small amounts of water for town water supplies and permanent plantings (orchards, vineyards etc). Requirements for high security licenses are fully satisfied prior to any water being made available for general security licenses.
hot-start	To configure IQQM with the correct boundary or initial conditions (ie, river flows, storage volumes, soil moisture levels and releases for water orders), it 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, such as the Cap Audit scenario.
irrigator behaviour function	This relates to the irrigator’s area planting decision and the main factors affecting this decision. For example, given a drought period with dry antecedent climatic conditions, low on-farm storage volume and low

	AWD, 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.
IQQM	An integrated quantity/quality river basin simulation model developed by DNR since the early 1990's. It is a tool that can be used to investigate water resources management issues in large river basins, with complex combinations of water regulation for irrigation and environmental requirements. It operates on a daily time-step. Further information is contained in the IQQM Reference Manual [DLWC, 1995].
irrigators' planting risk	see "irrigator behaviour".
license volume	See "water share".
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 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	Units of flow rate, 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.
off-allocation (OFA) extraction	See "supplementary water".
Officer-in-Charge (OIC) sheets	These sheets record daily storage levels/volumes, rainfall and releases at a major on-river storage. They are called OIC sheets because they are usually filled in every morning by the officer-in-charge at the storage.
on-farm storage (OFS)	On-farm storage, usually referring to a large private storage constructed on an irrigator's property to store water.
OFS airspace	This is the portion of an on-farm storage that is left unfilled after access to a supplementary water event, ready to capture any future storm runoff

	from the cropped areas. The exact amount of the airspace is calculated on a farm-by-farm basis, but it is generally a function of antecedent conditions, ie wetter soils could generate more runoff that needs to be captured.
OFS reserve	Irrigators that are further from Copeton Dam tend to hold an amount of water in their on-farm storages to get through periods where they have underestimated their crop water requirements and travel times are too long to wait for additional regulated water to arrive. The exact amount of the reserve is calculated on a farm-by-farm basis, but it is generally a function of travel time to the storage and time of year.
on-allocation (ONA) extraction	Water that is ordered by the irrigator from the dam to satisfy their crop water requirements or future management needs. This water is debited from the irrigators' water share for the year. The water supplied to the irrigator may be directly released from the dam or come from d/s tributaries, or from a combination of both.
pump capacity	The maximum pump extraction rate for an irrigation node (ML/d).
r^2	This is the symbol used in a statistical sense to express the degree of correlation between two sets of data (eg historical data versus model simulations). Its value is always expressed as a decimal less than 1.0, such that the closer its value is to 1.0, then the better the correlation.
rain rejection	This occurs when orders that are in transit are not extracted from the river because of rainfall that has occurred since it was released from the head-water storage. The water is not extracted from the river because either: • the rainfall has met the crop water requirements and regulated water in the river is no longer required. In a water use debit scheme the ordered water would not be extracted and would effectively become part of the system surplus; • the rainfall is ponding on the cropped area and needs to evacuated before the crops drown. In this situation, the irrigator may not have enough pumps to evacuate this water and access their orders in the river simultaneously. Therefore, even in a water order debit scheme, the ordered water would not be extracted and would effectively become part of the system surplus.
rainfall harvesting (RFH)	Water obtained from local rainfall events that are sufficiently intense to generate runoff on the land-holder's property or nearby land. Existing water recycling systems are usually enhanced to catch runoff from the planted and/or developed area of a property. This includes water: • Pumped from the on-farm cropped area or nearby areas into spare OFS capacity (ie during localised storm events), using secondary lift pumps; and • Gravity fed from the on-farm cropped area or nearby areas into spare

	OFS capacity (ie during large localised storm events). This water is not metered and hence there is no good quality historical RFH data available.
rainfall-runoff model	see "Sacramento model".
reach	A defined length of river. Usually represented by a number of model links connected together.
regulated river	The section of river that is downstream of a major storage from which supply of water to irrigators or users can be regulated or controlled.
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-stream between the gauges. The outflow from this catchment is estimated using a combination of: • the difference between the flow of upstream and downstream gauges, taking into consideration river losses and irrigation extractions; and • a correlation with nearby gauged tributaries, taking into consideration differences in catchment characteristics and rainfall distribution.
resource assessment	The process of calculating an AWD based on the current and predicted water resource availability and water requirements of all water users.
Sacramento model	The Sacramento rainfall-runoff model is 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; it uses local rainfall and evaporation data as well as catchment details. The model is calibrated to reproduce the short term observed flow at the gauging station [DLWC, 1998[i]]. A long-term streamflow sequence can then be generated by inputting the long-term rainfall and evaporation. The model was developed by Burnash et al. [1973] in Sacramento California.
supplementary water (SW)/surplus flow extraction	Previously known as off-allocation water. This is water that is extracted from the river during an supplementary water/surplus flow period. This water is not debited from the irrigators' water share for the year and is usually "billed" at a lesser cost.
supplementary water/surplus flow 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 these periods may be subject to a number of other conditions such as equity, ease of access or environmental requirements.
on-river 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 AWD.
tributary	An unregulated river that flows into a larger stream or water body.
tributary utilisation	The proportion of today's flow from a tributary that can be used to meet water orders.
unregulated river	A river with no major storages by which flows are regulated.
u/s	Upstream.
water order debit scheme	In this accounting scheme the irrigators' orders are debited against their water share volume, regardless of whether or not the water was extracted.
water share	Also referred to as "entitlement" or "license volume". This is the total amount of licensed water an irrigator has and remains static over time. In an annual accounting system, the water share is mulitiplied by the AWD to determine the water available in their account for the current water year.
water use debit scheme	In this accounting scheme the irrigators' extractions are debited against their water share volume.
water year	A continuous period (usually 12 months) starting from a specified month for water accounting purposes. In the Gwydir Valley, the water years were as follows: • pre-01/07/1988: 1st July to 30th June • transition 1988/89: 1st July 1988 to 30th September 1989 • 01/10/1989 – 30/09/2002: 1st October to 30th September • transition 2002/03: 1st October 2002 to 30th June 2003 • post-30/06/2003: 1st July to 30th June.

1. Introduction

1.1. BACKGROUND TO IQQM

Prior to the early 1990's, monthly time step computer models had been configured, calibrated and implemented in most of the major river basins in NSW. These monthly models were only capable of long term water budget analysis and were suitable for investigating and developing the various water management and sharing policy initiatives at that time, e.g., establishing the security of water supply for consumers.

During the 1990's a large number of developments occurred in water management policies, including diversion limitations under the MDBMC Cap [MDBMC, 1996], development of management rules and river flow objectives to achieve these limitations and water quality modelling requirements. These changes required a much greater level of model complexity, where representation of the short term variability in flows became increasingly more important.

In the late 1980's, prototypes of daily time step modelling software were being developed, with the WARAS model being one of the fore-runners [Lyall, 1986]. Building on many of the concepts within the WARAS model, the DLWC proceeded to develop a more generalised and complete river basin simulation model that can be used as a tool to investigate water resources management issues. This modelling tool is called the Integrated Quantity/Quality Model (IQQM).

IQQM operates at a maximum time step of one day, which allows a more realistic representation of hydrologic processes in both regulated and unregulated rivers. IQQM is also able to simulate in-stream water quality constituents, such as salinity and nutrients. 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 GWYDIR RIVER VALLEY

IQQM is being implemented for the regulated part of the Gwydir Valley from Copeton Dam to its junction with the Barwon River and including major effluents such as the Mehi River, Moomin Creek and Carole Creek.

The aim of implementing IQQM in the Gwydir is to establish and define a tool that is capable of simulating daily hydrologic processes over a 100+ year period. The model is required for the following purposes:

- Reproduction of river system behaviour over the calibration and validation periods;
- Reproduction of daily flows at key locations for assessment of environmental flow rules;
- Analysis of the impacts of alternative irrigation development scenarios over a long simulation period (100+ years);
- Development and analysis of impacts of environmental flow and river operation rules to meet specific river flow objectives;
- Estimation of the long term average annual diversions for the Gwydir Valley under a 1993/94 development conditions and management rules scenario, ie the Cap scenario; and

- Assessment of current irrigation diversions relative to those that would have occurred under 1993/94 development conditions and management rules with the current climatic inputs, ie the Cap Audit scenario. This scenario is required for the MDBMC Cap auditing process.

1.3. IQQM IMPLEMENTATION

1.3.1. Procedure

The main steps in the implementation of the Gwydir IQQM were as follows:

1) Configure and calibrate the model to reproduce historical data;
2) Model configuration for 1993/94 development conditions and management rules (Cap scenario);
3) Validate the Cap scenario for a period considered representative of 1993/94 development conditions and management rules;
4) Simulate the long term Cap scenario for 100+ years to establish the long-term MDBMC Cap;
5) Simulate the short term Cap Audit scenario since 1997/98 to compare the Gwydir Valley's performance relative to the MDBMC Cap;

1.3.2. Status

The model was originally configured in an old version of IQQM and over the past 12 months we have been upgrading it to the latest version by repeating the process listed in Section 1.3.1.

The model configuration, calibration and validation have now been completed. The long term simulation model has been prepared for both the 1993/94 Cap scenario. This scenario is documented in this report.

A number of different management scenarios were also configured in the old version of IQQM and will need to be upgraded. These include the Natural Conditions scenario and the 1999/00 Water Sharing Plan - Plan Limit scenario. This work will commence at the end of this project.

The Cap Audit scenario was also configured in the old version of IQQM and has only been run up to the 2002/03 water year. The old configuration and analysis will be superseded and extended to include the 2004/05 irrigation season during Steps (4) and (5) above.

1.4. AIM AND OBJECTIVE OF THIS REPORT

This Gwydir IQQM Cap Implementation Summary Report is of a highly technical nature and is intended to be used as a technical reference document. The aim of this summary report is to summarise the full calibration and configuration process into a single document to be presented to the Murray-Darling Basin Commission (MDBC) as part of the Cap scenario approval process.

1.5. SCOPE OF THIS REPORT

The scope of work covered in this report includes:

- Description of the Gwydir River Valley (Chapter 2);
- Configuration and calibration of the Gwydir IQQM (Chapter 3);
- Configure, validate and simulate the long term 1993/94 Cap scenario (Chapter 4);
- Configure and simulate the short term 1993/94 Cap Audit scenario (Chapter 4);

- Outline of model improvement plans (Chapter 5);
- Details of the climatic and streamflow stations used in the model (Appendix A);
- A summary of the model configuration (Appendix B);
- Node link diagram (Appendix C);
- Some background to modelling the planting decision (Appendix D);
- A description of the quality assessment guidelines (Appendix E);
- Details of the 1993/94 Cap development conditions and management rules (Appendix F);
- A copy of the user-survey filled in by representative Gwydir irrigators (Appendix G).

1.6. QUALITY ASSESSMENT SYSTEM

A consistent set of quality assessment guidelines (Appendix E) has been used in this report to evaluate and report on main features of the model's calibration and validation. The general meanings attributed to the quality ratings are expressed in relation to the confidence that the model can replicate historical flows, diversions, storage behaviour and planted areas as follows:

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

The quality of the observed data is also considered. The climatic representativeness of the data is assessed based on the period of calibration.

2. The Gwydir River Valley

2.1. CATCHMENT DESCRIPTION

The Gwydir River Valley lies to the west of the Great Dividing Range in northern NSW and is part of the Murray-Darling drainage system (Figure 2.1). The catchment covers an area of 25,900 km^2, from the Great Dividing Range to the Barwon River near Collarenebri. It is separated from the Border Rivers Valley to the north by the Mastermans Range and from the Namoi Valley to the south by the Nandewar Range.

From its headwaters in the New England Tablelands near Guyra and Uralla, up to 1,050 metres above sea level, the Gwydir River flows north-west through steep-sided valleys. It is joined by the Horton River, the largest tributary flowing north from the Nandewar Range, before it enters the plains near Gravesend. West of Pallamallawa, the valley widens into an almost completely flat flood plain, through which the Gwydir River flows slowly westward between natural levee banks. Downstream of Moree is an alluvial fan covering 20,000 hectares, an area known as the Gwydir Wetlands. The lower half of the basin is characterised by numerous anabranches and effluents, the most significant being the Mehi River and Moomin Creek to the south of the main Gwydir channel and the Carole-Gil Gil Creek system to the north. The latter actually joins up with the southern effluents of the Border Rivers system before entering the Barwon River.

Over half of the catchment area is used for livestock grazing and almost a quarter for dryland agriculture. The flood plains of the lower valley consist of self-mulching grey-black soils that are well-suited to irrigated agriculture. Irrigation development has occurred quite rapidly since the early 1960s and up to 100,000 hectares is now used to grow crops such as cotton, cereals and oilseeds. Most of the summer crops such as cotton are irrigated, whilst much of the water demand for winter is satisfied by rainfall.

Irrigation water, town water supplies for Bingara and Gravesend and environmental releases for the wetlands are supplied from Copeton Dam, which has a capacity of 1,362 GL and a catchment area of 5,240 km^2. The major irrigation diversions occur below Pallamallawa and are facilitated by a network of weirs and regulators on the Gwydir River and its effluents.

Table 2.1: Storage capacity

Storage	Dead Storage Volume (ML)	Full Storage Volume (ML)
Copeton Dam	18,490	1,361,720

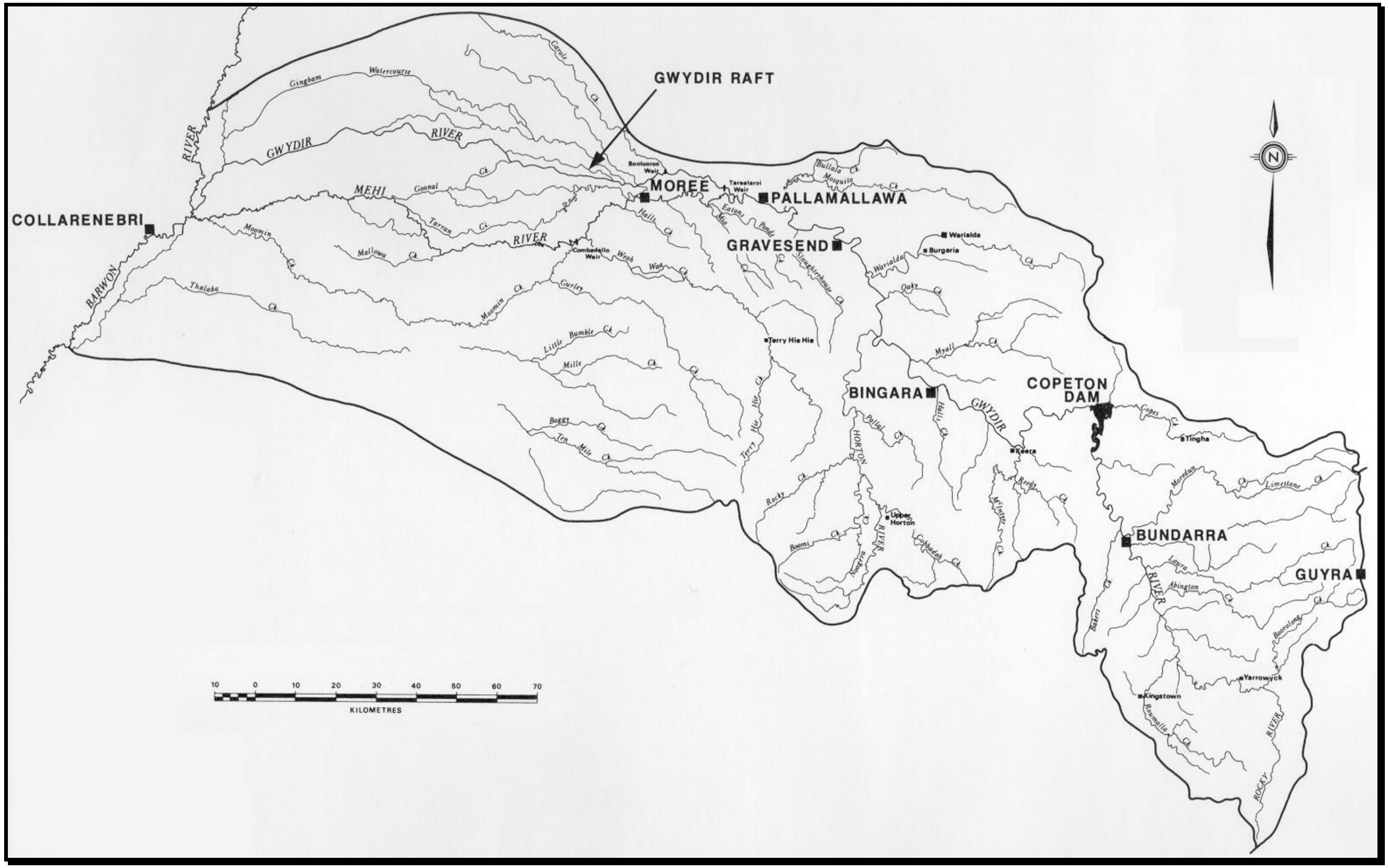

Figure 2.1: The Gwydir River Valley

2.2. STREAMFLOW DATA

Downstream of Copeton Dam the Gwydir River and its tributaries flow north-west through undulating and often rugged country to Gravesend. Approximately 30 km upstream of this township the Gwydir River is joined by its major tributary the Horton River, which rises high in the Nandewar Ranges east of Narrabri. Downstream of Gravesend the river enters the plains and flows generally westward to eventually join the Barwon River near Collarenebri. The lower reaches of the Gwydir Basin, downstream of Moree, can be described as an inland river delta where the channels diverge, and display characteristics of a delta watercourse.

A remarkable feature of the Gwydir River Valley is the “raft”, an immense obstruction of timber, sediment and debris, which has formed in the lower Gwydir River anabranch. The formation of the “raft” coincided with first settlement in the valley shortly before the turn of the century. Appreciable clearing of timber by ringbarking took place as settlers began to cultivate the upper slopes and led to an increased silt load being carried by the river. A sharply diminishing river channel capacity at the point of transmission into swampland together with the rapidly flattening bed gradient and accompanying drop in velocity, made this section of the river the perfect trap for water-borne debris including logs, rubbish and silt.

Figure 2.2 presents a schematic layout of the Gwydir River network. The overall flow distribution figures (in annual average inflows and outflow distribution) are indicated on the diagram. These figures are based on the long term Cap scenario.

Streamflow data is required in the Gwydir IQQM for:

- representing gauged and ungauged tributary inflows;
- calibrating in-stream losses and routing parameters.

This data needs to be collected such that it covers both the calibration period (Section 3.1.1) and the long term simulation period (Section 4.3).

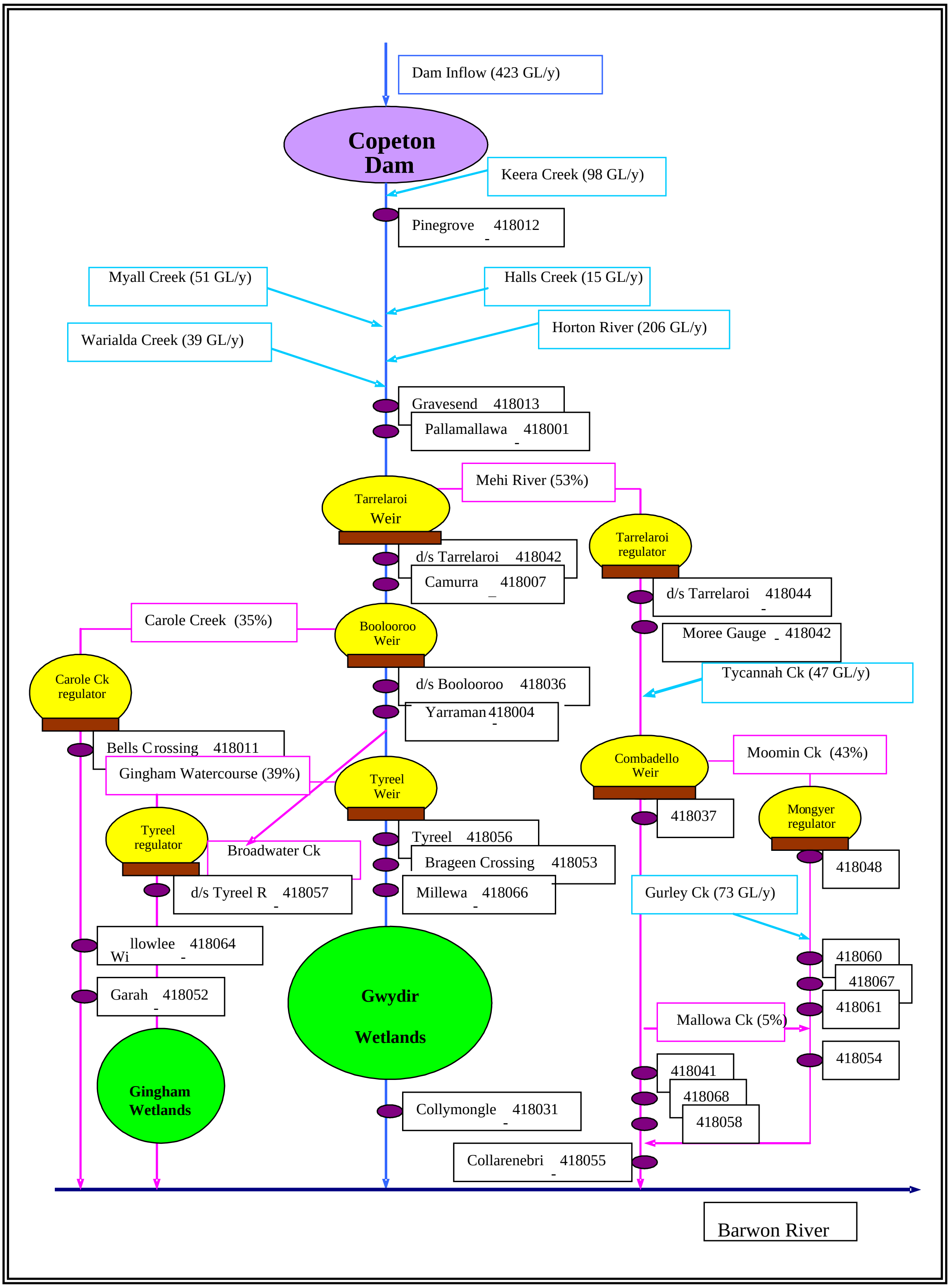

Figure 2.2: Gwydir Valley schematic representation

2.2.1. Inflow into dams

Copeton Dam has a good set of "Officer-in-Charge" (OIC) sheets [DWR, 1979-2001] that record daily storage levels/volumes, rainfall and releases since the storage first became operational. The historical dam inflows can be derived from this information and is used during model calibration (Section 3.6.1).

However, the long term Copeton Dam inflow sequence for simulation modelling cannot be derived from the OIC sheet data (these records only begin once the storage has been built, in 1979). Therefore an examination of the available data for the sub-catchments upstream of Copeton Dam is required. There are a number of upstream sub-catchment gauging stations, as indicated in Table A.6. These were used to generate long term Copeton Dam inflows (Section 4.3.2).

2.2.2. Main-stream gauging stations

There are a number of main-stream gauging stations on the Gwydir River. These all had varying periods of record and quality of data, as indicated in Table A.5.

Sections 3.1.1 and 3.4 explain how these stations are selected, analysed and used in Gwydir IQQM.

2.2.3. Gauged tributary inflows

The principal flow-contributing tributaries of the Gwydir River (the Horton River and Keera, Halls, Myall and Warialda Creeks) enter the river upstream of Pallamallawa. The only significant gauged tributary below that is Tycannah Creek, which flows into the Mehi River below Moree.

The relevant gauged tributary inflow sites in the Gwydir Valley are listed in Table A.6.

2.2.4. Ungauged tributary inflows

In the upper half of the Gwydir Valley, both above and below Copeton Dam, the gauging stations on 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.

In the lower half of the Gwydir Valley, there are a number of ungauged tributary contributions. The most significant being Gurley Creek which flows in Moomin Creek below the offtake from Mehi River. There are a number of smaller stream around this area that contribute flow during localised flood events. Marshall Ponds Creek and the upper Gil Gil Creek, both of which flow into Carole Creek are also ungauged.

Representation of these inflows is described in Section 3.4.

2.3. CLIMATIC DATA

Climatic data is required in the Gwydir IQQM for:

- rainfall-runoff modelling;
- generating crop water requirements;
- modelling the net rainfall/evaporation at on-river storages, on-farm storages and river reaches.

This data needs to be collected such that it covers both the calibration period and the long term simulation period.

2.3.1. Rainfall

Rainfall in the Gwydir Valley decreases from a median of 900 mm per year along the eastern catchment boundary and around Mt. Lindsay in the Nandewar Range to 450 mm per year in the west (Figure 2.3). On average, the catchment receives about 60% of its annual rainfall in the warmer months (November to March), often as storms that cause flooding and erosion. Winter flooding may also occur if soils remain saturated after late summer rains. Rainfall also varies greatly from year to year.

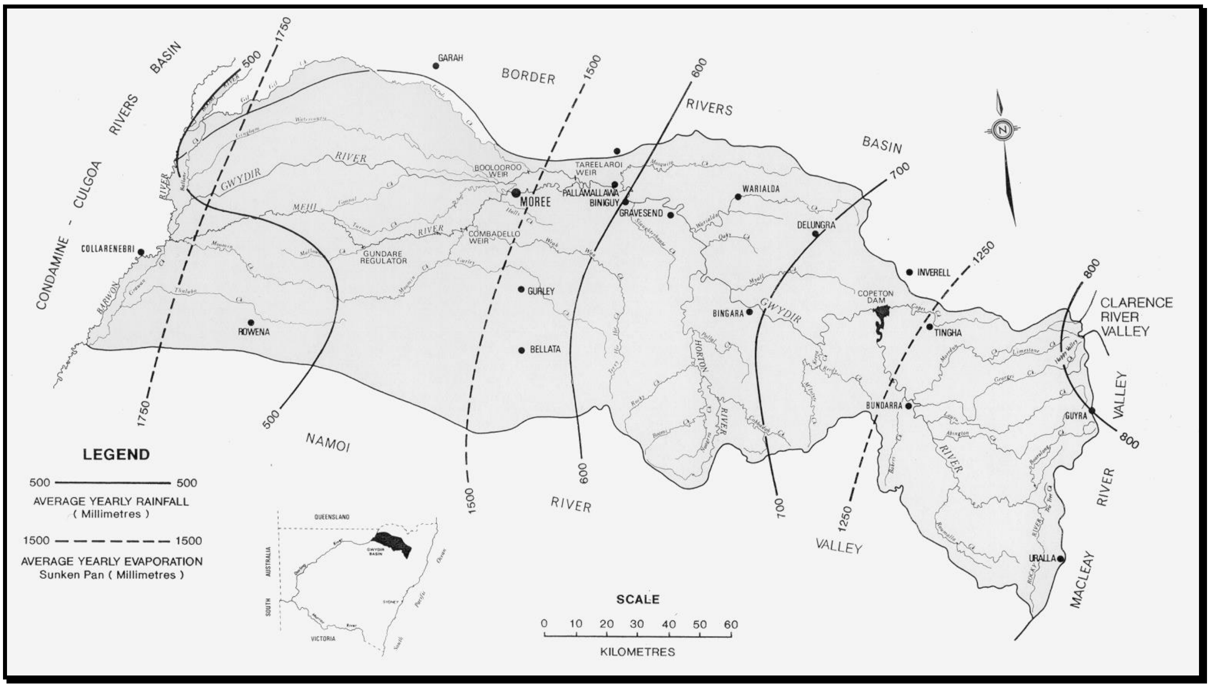

Figure 2.3: Rainfall and evaporation information

2.3.2. Evaporation

Evaporation potential, as measured in pans, exceeds average rainfall throughout the whole Valley. It ranges from 1200 mm/year in the east to 1750 mm/year in the west, as shown on Figure 2.3.

There are four evaporation stations located within the Gwydir River Valley including two in Moree (053048 and 053115), one in Inverell (054158) and one at Copeton Dam (054128).

2.4. IRRIGATION INFORMATION

2.4.1. Irrigation licences

The irrigators supplied with water from Copeton Dam were converted from area-based licenses to volumetric licenses at the commencement of the 1981/82 season. There has been an administrative embargo on the issuing of new licenses (with the exception of stock, domestic, industrial and town water supplies) since 1980. This became a statutory embargo in 1981. Therefore, the license volume has remained essentially static since then. For these reasons, we considered the data on licensed irrigation volumes and license types downloaded and analysed in 1999/00 as representative of the license volumes in the valley over the last 20 years. This data is separated into high security and general security licence portions and summarised for each river section in Table 2.2.

Table 2.2: Licensed Volumes (active at the end of 1999/00)

River Section	No. of Licences	GS License Vol # (ML)	HS License Vol (ML)	Total License Vol (ML)
Gwydir River	94	112,366	13,405	125,771
Mehi River	42	121,132		121,132
Moomin Creek	42	162,340		162,340
Carole-Gil Gil Creek	44	118,152		118,152
Total Valley	222	513,990	13,405	527,395

Notes: # There are small S&D license volumes (total of 2,788 ML) and other minor licenses such as horticulture, recreation and experimental research for irrigation purposes (total of 388 ML) included in the GS Licensed Volume in each river reach.

2.4.2. Pump capacity

There was very little historical yearly pump capacity data, so the information taken from DNR's licensing information (authorised pump capacities) and regional surveys (installed pump capacities) was summarised (as shown in Table 2.3) for configuration into IQQM during calibration (Section 3.5) and simulation (Sections 4.4.2.1).

Table 2.3: Gwydir Valley installed pump capacity

River Section	Installed Pump capacity (ML/d)		
	Pre 1990	1990 to 1998	1999 to 2004
Gwydir River (1)	-	2,858	4,340
Carole-Gil Gil Creek	-	3,940	6,279
Mehi River	-	4,532	4,532
Moomin Creek	-	6,714	6,714
Total Valley	14,150	18,044	21,865

Notes: (1) Includes HS pump capacity of 137 ML/d.

2.4.3. Irrigation extraction data

DNR has historical records of metered irrigation diversions for the Gwydir River Valley, as summarised in Table 2.4. The data has not always been collected at regular monthly intervals and the Region has estimated the monthly usage in some circumstances.

The Irrigators Survey and Pers. comm [2004-2005] indicated that rain rejection can occur when rainfall ponds on the cropped area and needs to evacuated before the crops drown. In this situation, the irrigator may not have enough pumps to simultaneously evacuate this water and access their orders in the river. Therefore, the ordered water is not extracted and is added to system surpluses.

Table 2.4: Total GS irrigation diversions by water year (ML)

Water Year	Total Diversions (1)	On Allocation Diversions (1)	SWater / Off-allocation Diversions (1)
1980/81	281,793	-	-
1981/82	273,678	-	-
1982/83	137,429	-	-
1983/84	193,144	-	-
1984/85	246,942	-	-
1985/86	421,144	-	-
1986/87	442,124	-	-
1987/88	244,125	-	-
1988/89 (2)	300,324	203,871	96,453
1989/90	292,089	135,556	156,523
1990/91	393,242	286,702	106,540
1991/92	260,958	247,505	13,453
1992/93	142,745	98,818	43,927
1993/94	48,280	9,259	39,021
1994/95	63,998	0	63,998
1995/96	222,859	44,846	178,013
1996/97	405,343	326,038	79,305
1997/98	520,823	364,649	156,174
1998/99	294,553	232,114	62,439
1999/00	433,431	346,763	86,668
2000/01	413,630	267,549	146,081
2001/02	449,569	400,906	48,663
2002/03 (3)	227,503	221,521	5,982
2003/04	159,250	47,339	111,911

Notes: (1) All data is based on DNR's records;
(2) The figure for 1988/89 is a 15-month total (01/07/1988 – 30/09/1989) because of the water year change;
(3) The figure for 2002/03 is a 9-month total (01/10/2002 – 30/06/2003) because of the water year change.

2.4.4. Crop areas and crop mix

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

DNR's historical records on crop areas have been challenged by irrigators' representatives on a number of occasions. Significant differences in the data provided by the irrigators have initiated a number of studies by different organisations including Agrecon [Lourens et al., 2001] and Water Studies Pty Ltd [Water Studies, 2002] to compare the figures and determine which ones were more accurate/representative of the true figures. In general these studies concluded that it was difficult to differentiate between the data sets, making adoption of an appropriate set an issue that affected the calibration process (Section 3.7).

Irrespective of the total area planted, cotton is the dominant crop in terms of summer irrigation water use. Irrigated winter crop areas are significantly lower than irrigated summer crop areas.

Figure 2.4 and Table 2.5 show details of historical irrigated cotton areas for the Gwydir Valley based on figures provided by Cotton Australia [Cotton Yearbook, 1989-2004]. Table 2.6 outlines the historical crop mix, which may include some unregulated/groundwater cotton irrigation.

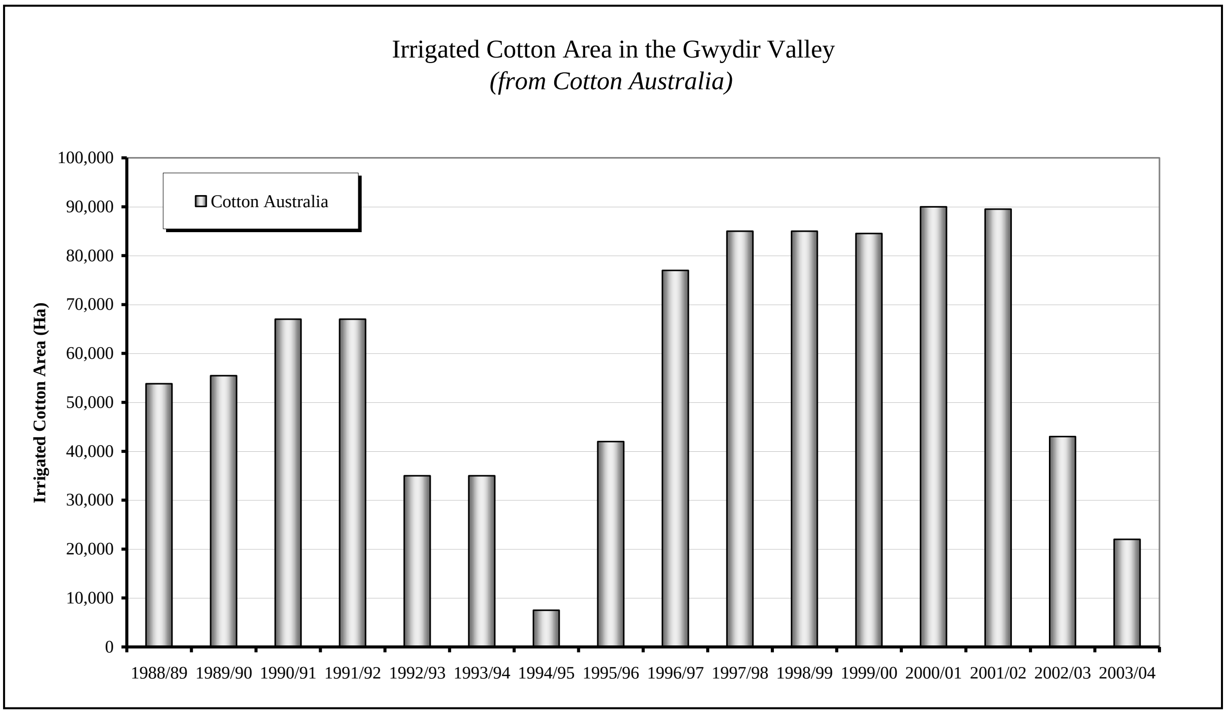

Figure 2.4: Historical planted cotton areas

Table 2.5: Historical GS total planted crop areas

Water Year	DNR Cotton	DNR Other	DNR Total	ACF [(1)]	Agrecon [(2)]
1979/80	7,625	12,633	20,258		
1980/81	23,759	15,554	39,313		
1981/82	34,495	10,509	45,004		
1982/83	19,713	7,008	26,721		19,727
1983/84	36,050	4,985	41,035		
1984/85	44,559	7,859	52,418		44,916
1985/86	48,068	17,824	65,892		
1986/87	48,597	18,756	67,353		62,098
1987/88	42,127	5,819	47,946		
1988/89	48,195	7,549	55,744	53,824	
1989/90	50,593	3,293	53,886	55,443	
1990/91	73,519	3,763	77,282	67,000	69,652
1991/92	62,033	3,179	65,212	67,000	
1992/93	30,716	1,682	32,398	35,000	
1993/94	19,183	2,097	21,280	35,000	19,168
1994/95	6,265	2,696	8,961	7,500	
1995/96	36,761	8,926	45,687	42,000	
1996/97	72,585	6,080	78,665	77,000	
1997/98	79,337	4,118	83,455	85,000	79,912
1998/99	62,394	2,407	64,801	85,000	
1999/00	59,215	6,524	65,739	84,514	81,978
2000/01	65,539	4,553	70,092	90,000	84,526
2001/02	77,668	21,366	99,034	89,500	
2002/03			38,249	43,000	
2003/04				22,000	

Notes: (1) Reported in Cotton Yearbook [1989-2004].
(2) Reported in Lourens et al. [2001].

Table 2.6: Historical crop mix

Year	Cotton (%)	Lucerne (%)	Summer Cereal* (%)	Summer Pasture (%)	Wheat* (%)	Winter Cereal* (%)	Summer Oilseeds (%)	Others (%)
1979/80	37	2	n/a	23	33	n/a	2	3
1980/81	60	1	n/a	15	21	n/a	0	3
1981/82	70	1	n/a	2	13	n/a	13	1
1982/83	60	1	n/a	15	21	n/a	0	3
1983/84	70	1	n/a	2	13	n/a	13	1
1984/85	74	2	n/a	2	15	n/a	3	4
1985/86	88	0	n/a	1	4	n/a	4	3
1986/87	85	0	n/a	1	12	n/a	0	2
1987/88	73	0	n/a	3	14	n/a	4	6
1988/89	86	0	n/a	1	0	n/a	11	2
1989/90	94	0	n/a	1	2	n/a	1	2
1990/91	95	0	n/a	0	1	n/a	2	2
1991/92	95	0	n/a	1	2	n/a	1	1
1992/93	95	0	n/a	0	2	n/a	0	3
1993/94	94	0	2	0	3	1	0	0
1994/95	61	0	31	0	5	0	0	3
1995/96	82	0	13	0	5	0	0	0
1996/97	94	0	1	0	5	0	0	0
1997/98	96	0	3	0	1	0	0	0
1998/99	93	0	1	0	4	0	0	2
1999/00	91	1	3	0	3	1	0	1
2000/01	90	0	2	0	7	0	0	1
2001/02	79	1	10	0	9	0	0	1

Notes: * The pre-1992/93 wheat percentages include cereals.

2.4.5. On-farm storage infrastructure and usage

2.4.5.1 Capacity

Significant volumes of OFS have been built in the Gwydir Valley. Early records of volumes are sparse with the first detailed survey undertaken in 1987/88. Surveys of OFS volumes were initially collected intermittently, however, they are now collected generally twice a season via irrigators' returns.

DNR's historical records on OFS capacity were challenged by irrigators' representatives a few years ago. This challenge initiated a DNR review and an irrigators' review of the figures. The DNR review was based on detailed data from three sample years (1994, 2001 and 2004) provided by extensive ground-truthing projects in the past [Falkenmire, 2004]. The irrigators' review was based on a combination of their own records and satellite imagery analysis conducted by Agrecon [Lourens et al., 2001]. The data from these two independent studies generally concurred and therefore DNR's historical record of OFS capacity was adjusted from 1993/94 onwards to reflect this information. The latest figures are presented in Table 2.7.

Table 2.7: OFS volumes

Year	Historical on-farm storage capacity (ML)
1981/82	*21,000* *
1982/83	*28,000* *
1983/84	*37,000* *
1984/85	*93,000* *
1985/86	*95,000* *
1986/87	*97,000* *
1987/88	*100,000* *
1988/89	*102,000* *
1989/90	*244,000* *
1990/91	*269,000* *
1991/92	*276,500* *
1992/93	*314,500* *
1993/94	363,358
1994/95	368,790
1995/96	388,608
1996/97	404,468
1997/98	421,620
1998/99	443,890
1999/00	467,125
2000/01	467,125
2001/02	484,520
2002/03	499,630
2003/04	520,800

Notes: * Estimated figure.

Information regarding the management of on-farm storages was provided by irrigators through a series of workshops and a written survey. The results of these were analysed and representative parameters were derived for the model, which were subsequently fine-tuned during the valibration process (see chapter 3). These parameters include reserves, airspace, and aspects relating to rainfall and floodplain harvesting.

2.4.5.2 Reserves

Irrigators that are further from Copeton Dam tend to hold an amount of water in their on-farm storages to get through periods where they have underestimated their crop water requirements and travel times are too long to wait for additional regulated water to arrive, or channel capacity problems restrict the rate at which water can be ordered. This amount of water is called the OFS reserve.

The exact amount of the OFS reserve varies on a farm-by-farm basis, but the irrigator-surveys [Gwydir Irrigators Survey and Pers. comm, 2004-2005] indicated the following:

- for irrigators at the bottom of the system, the travel time for regulated releases to arrive can be up to 2 weeks, meaning they have to forecast their crop water requirements for this period;
- the crop water requirements increase significantly during high temperatures. If the temperature exceeds their forecast, then crops will need to be watered more often during this period;
- in the hottest months, some of the lower irrigators keep around 2-3 waterings in their reserve, which equates to 2-3 ML/ha, to protect their crop from this problem;
- towards the end of the season, this water is drawn down to meet crop water requirements, and less water is ordered from the major headworks storages.

2.4.5.3 Airspace

Runoff from cropped areas is not allowed to directly enter nearby waterways since it contains insecticides and fertilisers that could harm the in-stream ecosystems. For this reason, irrigators leave a portion of their on-farm storage unfilled after access to a supplementary water event, ready to capture the storm runoff from their cropped areas. This portion is called the OFS air-space.

The exact amount of the OFS airspace varies on a farm-by-farm basis, but the irrigator-surveys [Gwydir Irrigators Survey and Pers. comm, 2004-2005] indicated the following:

- the amount of airspace is dependent on antecedent conditions. If the soil is already saturated, then more airspace is required;
- typical allowance for runoff of between 0mm (dry soil) up to 75-100mm (wet soil);
- the calculation is based on their planted crop area, since this is the critical area to capture runoff from.

2.4.5.4 Rainfall harvesting

Rainfall harvesting (RFH) is collecting water generated by runoff from local on-farm areas or nearby land during localised storm events, as defined in the "*Glossary of Terms*".

There was no comprehensive information on RFH, with most of the information gained through consultation with regional representatives and irrigator-surveys [Gwydir Irrigators Survey and Pers. comm, 2004-2005]. These surveys indicated that the amount of RFH is a function of:

- the characteristics of the storm event. Higher intensity rainfalls generate more RFH volume since the rainfall rate exceeds the infiltration rate;
- the antecedent conditions. If the soil is already saturated, then more RFH will occur, with figures of up to 75-100mm reported;
- the pump capacity if using pumps to collect the water;
- the OFS capacity to store the RFH water;
- the volume of water in the OFS. As it fills, the effective pump capacity reduces because the head-lift required increases;
- the timing and volume of OFA access. If the SW event occurs prior to the RFH event, then the available OFS capacity will be reduced. Depending on the volume of the OFA event, the available capacity may only be the airspace. If the OFA event occurs simultaneously to a potential RFH event, then generally the RFH takes priority to avoid crop damage;
- in more recent years, irrigators have begun to leave some crop stubble on harvested land to prevent the soil from "sealing" and thus increase the rainfall infiltration rate. This also reduces the volume of water required for pre-watering before a crop is sown or watering up just after it is sown.

2.4.5.5 Floodplain harvesting

Floodplain harvesting (FPH) is collecting water generated by runoff from upstream events, as defined in the "*Glossary of Terms*".

There was no comprehensive information on FPH, with most of the information gained through consultation with regional representatives and irrigator-surveys [Gwydir Irrigators Survey and Pers. comm, 2004-2005]. These surveys indicated that the amount of FPH is a function of:

- the characteristics of the flood event. Short/sharp events will yield less FPH water than a long/smooth event of the same volume;
- the pump capacity if using pumps to collect the water;
- the OFS capacity to store the FPH water;
- the volume of water in the OFS. As it fills, the effective pump capacity reduces because the head-lift required increases;
- the amount of prior OFA access. The OFA cap on diversions will govern the amount of water that is already in the OFS prior to the FPH water arriving;
- priority of water use. They have to use their pumps to remove water that is ponding on their crops otherwise it will drown after 2-3 days. This often prevents them from using their pumps to access FPH.

2.4.6. Transfer market

A scheme permitting the temporary transfer of water shares is allowed in the Gwydir Valley.

Some irrigation groups, particularly in the Upper Gwydir and some big licence holders on the Mehi under-utilise their resources in a number of years, making them potentially available to trade to other more dynamic users. Trade by trade information is held in the Department's corporated database.

2.5. TOWN WATER SUPPLY

Town water demands are a small component of the total water use in the valley (generally < 0.1%) and their demands are less variable and influenced to a lesser extent by climate.

In the Gwydir River Valley, there are 2 regulated town water supplies. These are Bingara and Gravesend, with annual high security water shares of 660 ML and 120 ML respectively.

There is also a high security water share of 3 GL allocated to Inverell TWS as a “Premier’s grant”.

2.6. STOCK AND DOMESTIC REQUIREMENTS

In the Gwydir Valley, apart from stock and domestic entitlements included with general security users, the releases for stock & domestic requirements are considered replenishments. These are detailed in Section 2.12.

2.7. INDUSTRIAL AND MINING EXTRACTIONS

DNR licensing records indicate water shares for industrial and mining licenses of approximately 525 ML. This includes 236 ML industrial sand and gravel water share, 115 ML of horticulture water share, 213 ML of recreation water share and 60 ML for experimental research for irrigation purposes. Water diversion records indicate that only a very small amount of this water share is ever diverted.

2.8. GROUNDWATER ACCESS

There is generally very little data available on the area grown using groundwater, so it has been assumed that these diversions do not contribute to the crop areas reported for regulated surface water users (see Section 2.4).

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2.9. RESOURCE ASSESSMENT

Under an annual accounting allocation system all licenses are issued with a license volume. In any irrigation season, the amount of water available for general security irrigation is the available water determination (AWD – previously known as the announced allocation) mulitiplied by the license volume. This is called share component of an access licence, previously known as an annual entitlementvolume. The AWD is the outcome 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.

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 reviewed or reserves for essential supplies or environmental purposes may be reassessed.

Under the annual accounting allocation system, the resource assessments are usually made prior to the beginning of the water year and may be updated (increased only) through the end of January if there is significant inflow to Copeton Dam. This system was in place prior to November 1998 in the Gwydir Valley.

The historical AWD's for the Gwydir Valley under the annual accounting system are presented in Figure 2.5.

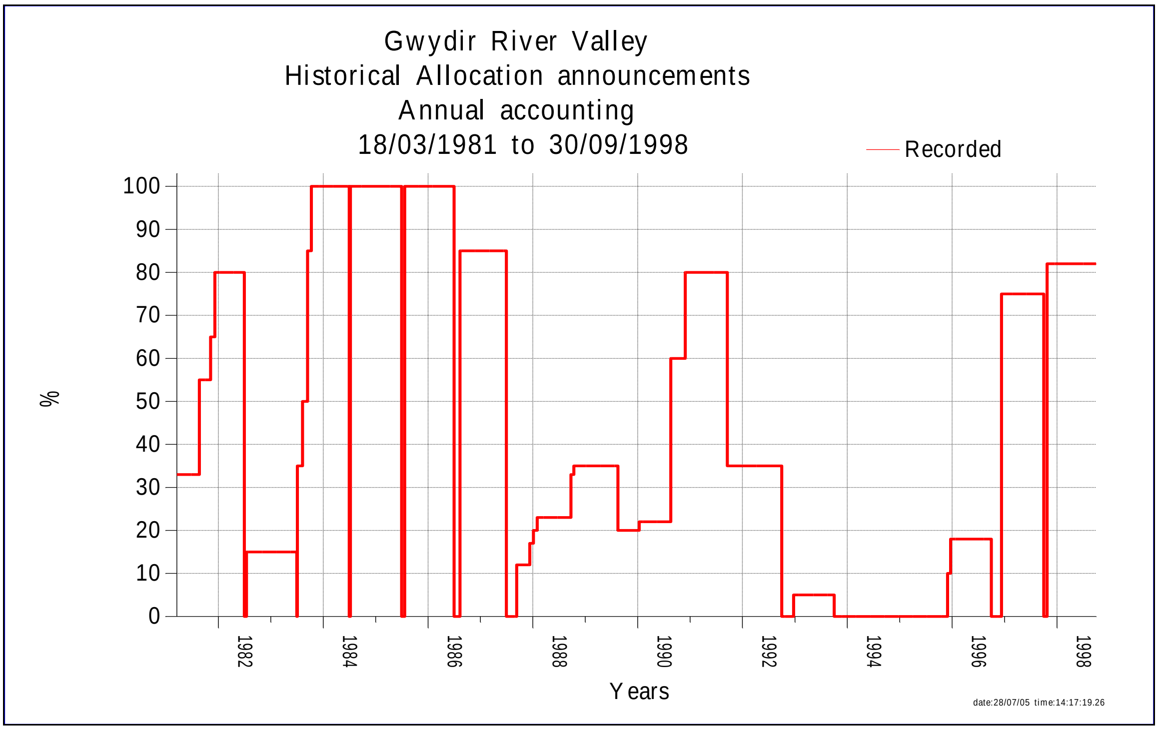

Figure 2.5: Historical AWD's under the annual accounting system

Under the continuous accounting allocation system, the resource assessments are made on a monthly basis throughout the year. This system has been in place since November 1998 in the Gwydir Valley.

In continuous accounting, valley-wide AWD's are not announced but rather each individual irrigator has their own balance. We computed effective valley-wide AWD based on these individual irrigators' balances. The effective historical valley AWD for the Gwydir Valley under the continuous accounting system are presented in Figure 2.6.

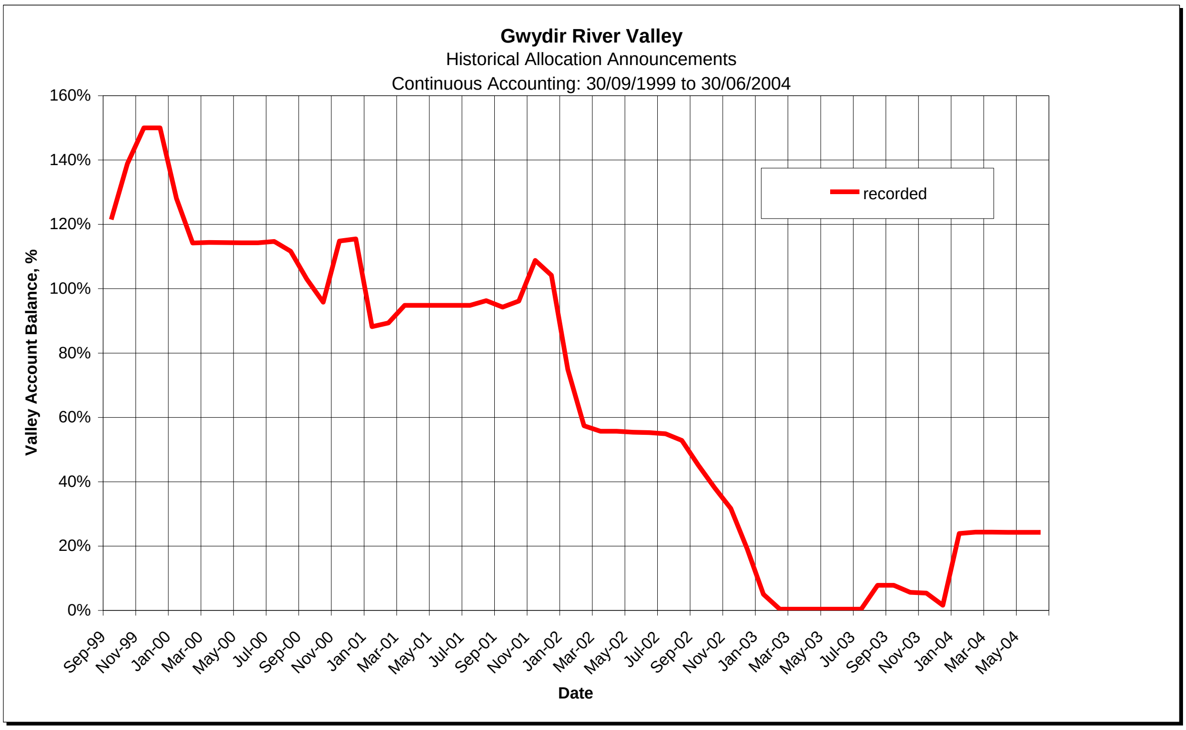

Figure 2.6: Historical effective AWD's under the continuous accounting system

2.10. RIVER AND STORAGE OPERATION

The Gwydir 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 Copeton Dam to satisfy consumptive requirements, the river operators forecast inflow contributions they expect from downstream tributaries and adjust the releases accordingly. In practice a range of factors influence the river operators' decision, including recent weather and the most recently observed inflows from the various downstream tributaries. When releases are made from Copeton Dam, flows entering the Gwydir River between Pinegrove and Gravesend are considered. These include flow from Horton River and Myall, Warialda and Halls Creeks.

Representation and calibration of tributary utilisation in Gwydir IQQM is discussed in Section 3.6.2.

2.10.2. Operational surpluses

Operational surpluses result from mismatches between forecast and actual irrigation demands and transmission losses, both of which can be quite variable. They can also be a result of over-releasing by dam operators to allow for inaccuracies, flow routing and over-ordering by irrigators. The Gwydir River regulated system is operated under a water order debiting scheme where any water ordered by an irrigator is debited against their account, regardless of whether or not the water was actually extracted.

Representation and calibration of over-ordering in Gwydir IQQM is discussed in Section 3.6.3.

2.10.3. Flood mitigation releases

The maximum permitted level in Copeton Dam corresponds to a volume of 1,418 GL. From a volume of 1,116 GL up to this level, the dam operators make flood mitigation releases by opening and closing nine radial gates, each 14.6 m wide and 13 m high. These gates are operated to make releases as per the Flood Operation Manual for Copeton Dam [DWR, 1984]. There is no fixed airspace, and a variable airspace policy has been adopted. Under this policy pre-releases can be made to create temporary airspace for potential flood mitigation where inflows will be sufficient to refill the storage prior to the onset of irrigation demand.

2.11. SURPLUS FLOW ACCESS

Supplementary water (SW)/surplus flow periods may be announced in the Gwydir system downstream of Copeton Dam when flows are in excess of demands. Surplus flows may comprise operational excess flows, tributary inflows and spill releases from Copeton Dam. During these OFA periods water may be extracted without debit to the irrigators' water account. The volume of water available is usually announced as a percentage of licensed water share. 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.

In the WSP scenario there are specific rules for OFA access, as described in Section 2.12.2.

Records of monthly OFA extraction volumes were available. Also available were the OFA announcement periods with specified shares and access areas. Announcements for access to OFA 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.

Calibration of OFA in Gwydir IQQM is discussed in Section 3.5.3.

2.12. RIVER FLOW REQUIREMENTS

At present, Copeton Dam provides river flows for :

- a number of minimum flow targets;
- a number of stock and domestic replenishments;
- Gwydir Wetlands; and
- Gingham Watercourse.

Over the past 20 years the management rules governing these releases have been modified a number of times. For the purposes of the Gwydir IQQM, we need to define these rules as they were for the scenarios to be simulated.

2.12.1. 1993/94 Rules

2.12.1.1 Flow constraints

There is a maximum regulated outlet capacity into Moomin Creek of about 2,000ML/d. Irrigation orders sometimes need to be rostered at peak times to deal with this limitation.

2.12.1.2 Minimum flows

There were fixed minimum release requirements from Copeton Dam under 1993/94 management rules to meet end-of-system targets as follows:

- Gwydir River @ Wondoona 10ML/d;
- Carole Creek @ Galloway 10ML/d;
- Mehi River @ Collarenebri 10ML/d;

2.12.1.3 Stock & domestic replenishments

There were a number of stock & domestic replenishment releases from Copeton Dam under 1993/94 management rules, with a total volume of 20,500 ML/yr as follows:

- Lower Gwydir 40 ML/d up to a volume of 4,000 ML;
- Thalaba Creek 50 ML/d up to a volume of 4,000 ML;
- Gingham Creek 50 ML/d up to a volume of 6,000 ML;
- Mallowa Creek 50 ML/d up to a volume of 6,000 ML;
- Ballin Boora Creek 20 ML/d up to a volume of 500 ML;

These replenishments are released based on antecedent conditions. Typically releases are made February and March and in August and September if required.

2.12.1.4 Environmental releases

There were no specific environmental releases (other than those listed above) under 1993/94 management rules.

2.12.2. Water Sharing Plan Rules

Some preliminary discussions of the Water Sharing Plan rules have been included in the report for completeness. However no modelling of these rules is detailed in this report.

2.12.2.1 Flow constraints

The flow constraints in the system are unchanged from the 1993/94 constraints.

2.12.2.2 Minimum flows

The minimum flow requirements in the system are unchanged from the 1993/94 targets.

2.12.2.3 Stock & domestic replenishments

The replenishments in the system are unchanged from the 1993/94 targets.

2.12.2.4 Environmental flows

Three main environmental flow rules were introduced in the Water Sharing Plan, these were:

The first environmental flow rule in the Gwydir under WSP rules is the **low flow protection** rule. When the total tributary inflow downstream of Copeton Dam is less than 500ML/d, this flow is not used to meet irrigation orders and is passed through to the Gwydir Wetlands/Gingham Watercourse. The total tributary inflow is defined as the sum of the gauged inflows entering GwydirRiver between the Pinegrove and Garvesend including Halls Creek, Horton River, Myall and Warialda Creeks.

The second environmental flow rule in the Gwydir under WSP rules is the **50:50 supplementary water sharing** rule. Supplementary water extractions are limited to a maximum of 50% of the surplus flow events. These surplus flow events are not declared until flows exceed the downstream water use requirements by at least 1,000 ML/d. Therefore, both this surplus margin and the remaining 50% of the SW event are passed through to the Gwydir Wetlands/Gingham Watercourse.

The third environmental flow rule in the Gwydir under WSP rules is the **45 GL ECA** rule. Each year a general security water share of 45 GL (measured at Copeton Dam) is set aside for use in supporting bird breeding events in the Gwydir wetlands. The actual volume released is a function of the AWD and antecedent conditions in the wetlands at specified times of the year. Although there is some variation from year to year, typically the replenishment water is released in the period from October to May, with these periods typically coinciding with historical bird breeding events [NPWS, 1995-2004]. The NPWS also indicated that the expected long term ECA triggering frequency would be in 2 out of 3 years [NPWS, 1995-2004]. The target flow rate is 300 ML/d at Yarraman.

The 2nd and 3rd environmental flow rules were first implemented in the Gwydir Valley in February 1996, while the 1st rule was first implemented in the following water year.

3. Model Calibration

3.1. MODEL CONFIGURATION

The Gwydir 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 Gwydir IQQM model contains over 270 nodes and over 100 links with hydrologic routing. Presentation of the node-link diagram is contained in Appendix C.

3.1.1. Streamflow

In the model calibration phase, streamflow data is required for all main-stream and tributary inflow gauging stations represented in the model. The main-stream gauging stations are used to derive losses and flow routing parameters for each river reach. The tributary inflows are used to achieve mass balance within each river reach, to model extended sequences of tributary inflows, and as an input to the completed models.

An extensive network of main-stream gauging stations measures the flows in the Gwydir Valley. The following criteria were used to select an appropriate sub-set for calibration of main-stream flows:

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

There were also a number of tributary gauging stations measuring flows contributing from tributaries upstream and downstream of Copeton Dam. The following criteria were used to select an appropriate sub-set to represent the tributary flow contributions:

- significance of the flow contribution from that catchment;
- maximise coverage of the gauged catchment area within the valley;
- sites with good quality records to cover the intended calibration period and long term simulation period, with a minimum number of missing periods;
- availability of nearby gauging stations for gap-filling and extending the data;
- availability of nearby rainfall and evaporation stations that could be used to set-up rainfall-runoff models for gap-filling and extending the data.

Ungauged catchemnts' contribution was estimated during flow calibration using in-house methodology [DLWC, 1998[h]].

3.1.2. Rainfall

Rainfall data is used in IQQM to drive the soil moisture accounting in the irrigation module (Section 3.5), for computing the contribution of rain falling onto the surface of reservoirs (Section 3.6) and river reaches (Section 3.4). Rainfall data is also used for generating and extending historical tributary inflows using Sacramento rainfall-runoff modelling (Section 4.3).

Of the available rainfall stations in the valley, the following criteria were used to select an appropriate sub-set for use in the Gwydir 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 simulation period;
- continuity and quality of data; and

Based on these criteria, 13 rainfall stations were used to represent the spatial rainfall distribution to drive the crop water requirements in different geographic zones in the Gwydir IQQM, as listed in Table A.1. The data for these stations was downloaded from the Bureau of Meteorology's (BOM) SILO database. This data has been gap-filled by the BOM and is therefore long term and continuous.

Of these rainfall stations, 4 were selected for use in rainfall-runoff modelling downstream of Copeton Dam. An additional 4 sites were used for rainfall-runoff modelling for the catchments upstream of Copeton Dam. These rainfall sites are listed in Table A.2.

3.1.3. Evaporation

Evaporation data is used in IQQM to estimate the evapotranspiration from crops (Section 3.5), for computing evaporation losses from reservoirs (Section 3.6) and for computing evaporation losses from river reaches (Section 3.4). Evaporation data is also used for generating and extending historical tributary inflows using Sacramento rainfall-runoff modelling (Section 4.3).

Of the available evaporation stations in the valley, the following criteria were used to select an appropriate sub-set for use in the Gwydir IQQM:

- adequate representation of spatial variability of the evaporation;
- availability of long term records to cover not just the intended calibration period, but also as much of the intended long term modelling period as possible. It should be noted that daily evaporation data has only been regularly recorded in the last 30 years or so. Therefore, there are very few sites that have a longer period of record than that;
- continuity and quality of data; and
- availability of a nearby rainfall site that could be used to generate long term evaporation data for use in model simulation.

Based on these criteria, 3 weather stations were used to represent the spatial evaporation distribution to drive the crop water requirements in the different geographic zones in the Gwydir IQQM. An additional evaporation site was used to represent the evaporation from Copeton Dam. All of these sites are listed in Table A.1.

An analysis of these sites revealed that only the Moree Comparison (053048) site is within the Gwydir catchment boundaries and has evaporation data for a relatively long-term period, in excess of 26 years. Evaporation data at the other sites do not exceed a total of three years, and therefore could not been used for generation of the long-term time series of daily evaporation for use within the Gwydir IQQM.

Additional analysis of the data at Moree Comparison revealed a number of problems regarding its quality, which are discussed in DLWC [2001]. As a result, additional evaporation stations located just outside the Gwydir catchment boundaries with the best record available, namely Wallangra (Wallangra Station, 054036) and Walgett (CBM, 052026), were used to build long-term evaporation sequences at a number of sites within the valley (Table A.3).

There were an additional 6 sites selected for use in rainfall-runoff modelling (Table A.3).

3.1.4. Irrigation

DNR records of total on-allocation diversions, supplementary water diversions, crop areas and crop mixes were generally available for individual irrigators throughout the calibration period. The information was amalgamated such that it represented a broad cross-section of geographic location and usage behaviour, thus producing 28 different irrigator groups that were used to represent the irrigators in the valley. These groups are listed in Table 3.1.

Table 3.1: Irrigator groupings used in Gwydir IQQM

Model Reach	Upstream Location	to	Downstream Location	Name of irrigator groups	Number of Licenses	% of Valley License Volume	% of Valley Max. Area [(1)]
1	Copeton Dam	to	Pinegrove (418012)	no irrigation	0	n/a	n/a
2	Pinegrove (418012)	to	Gravesend (418013)	no irrigation	0	n/a	n/a
3	Gravesend (418013)	to	Pallamallawa (418001)	Gwydir 1 (HS), Gwydir 1a	43	3.6%	1.0%
4	Pallamallawa (418001)	to	Yarraman (418004)	Gwydir 1b, 2a & Pool	27	8.6%	10.4%
5	Yarraman (418004)	to	Millewa (418066)	Gwydir 2b, 3a & 3b	21	10.6%	11.5%
6	Millewa (418066)	to	Collymongle (418031)	Gwydir 3c	3	0.9%	0.8%
7	Bells Crossing	to	Galloway (416052)	Carole 1, 2a, 2b & 2c	44	22.4%	22.0%
8	Gingham offtake on Gwydir R.	to	Gingham Wetlands	no irrigation	0	n/a	n/a
9	Meehi Offtake on Gwydir R.	to	D/S Combadello Weir (418037)	Mehi 1a & 1b	16	2.1%	2.5%
10	D/S Combadello Weir (418037)	to	D/S Gundare Regulator (418041)	Mehi 2	8	11.8%	9.4%
11	D/S Gundare Regulator (418041)	to	U/S Ballin Boora Ck (418068)	Mehi 3	8	3.0%	2.6%
12	U/S Ballin Boora Ck (418068)	to	Bronte (418058)	Mehi 4, CollyGaralem & CollyCentral [(2)]	8	5.7% [(3)]	10.7%
13	Bronte (418058)	to	near Collarenebri (418055)	Mehi 5 & CollyMyamba [(2)]	2	0.4% [(3)]	0.3%
14	Mallowa Ck offtake on Mehi R.	to	Mallowa Ck return (Moomin Ck)	no irrigation	0	n/a	n/a
15	Moomin Ck offtake on Mehi R.	to	Glendello (418060)	Moomin 1a	12	5.9%	5.0%
16	Glendello (418060)	to	Clarendon Bridge (418067)	Moomin 1b	9	8.2%	7.2%
17	Clarendon Bridge (418067)	to	Alma Bridge (418061)	Moomin 2	13	3.0%	2.3%
18	Alma Bridge (418061)	to	Iffley (418054)	Moomin 3 & CollyIffley [(4)]	5	13.4%	14.1%
19	Iffley (418054)	to	Mehi Junction	Moomin 4 & CollySurge [(4)]	3	0.4%	0.2%

Notes:
(1) based on 2001/02 data;
(2) a single licence is issued for Colly Central and Colly Myambla;
(3) for consistency with license volumes, this figure includes/doesn't include Colly Myambla area, for which individual area data is available;
(4) a single licence is issued for Colly Iffley and Colly Surge.

3.2. LIMITATIONS AND EXCLUSIONS

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

Licensed water users extracting water from unregulated streams generally have not been included in the Gwydir Valley IQQM. The exception of this is the Colly Farms' access to unregulated Barwon River flows. This is represented in the model.

To date most of the unregulated licenses 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 licenses has not been closely monitored and there has generally been very little data collected on water extractions and cropping by these licenses. It is intended that, if sufficient information should become available, the model would be expanded to represent unregulated licenses.

The effects of this 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 historical inflows to represent any changes in unregulated license activity has been made.

In IQQM the transfer market cannot be modelled explicitly. However, IQQM does assume full activation of water shares within an irrigation node but no transfer of water shares from node to node. If there was a regular transfer of water from one reach to another historically, then we included this as a permanent transfer of license volume in the model.

3.3. CALIBRATION OVERVIEW

Calibration of IQQM involves adjusting the parameters 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 Gwydir Valley involves six (6) major steps. Each step estimates specific parameters for that step, whilst forcing all other parameters to observed data. At the end of the six (6) stage process, all the estimated parameters are brought together to see how well the overall model calibration reproduces historical information. The six (6) 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 set to those observed historically. Routing parameters, transmission losses and ungauged inflows are calibrated during this step.
- On-allocation diversion calibration – to reproduce observed ONA irrigation extractions, given observed crop areas, crop mix, pump capacities and on-farm storage development. Irrigation efficiency, rainfall losses, soil moisture stores, OFS operation (including OFS reserves and airspace and rainfall and floodplain harvesting) are calibrated during this step.
- Supplementary water diversion calibration – to reproduce observed OFA extractions and announcement periods. Monthly supplementary water thresholds are calibrated during this step.
- Storage behaviour calibration – to reproduce the observed volumes in Copeton Dam, throughout the calibration period. The tributary utilisation and over-order factors are calibrated during this step.
- Planted area calibration – calibrates an irrigator's decision making process to reproduce observed planted crop areas. Maximum and minimum area, crop mix and farmers planting decision process are calibrated during this step.
- Resource assessment configuration – configures the model's resource assessment module to reflect the regional practises in making AWD's. Transmission/operation loss functions, storage reserves, minimum inflow sequences and announcement constraints are configured during this step.

IQQM calibration is a complex process and although we try to maintain it as a sequential process, typically many iterations between each of these steps are required to maximise the quality of the final overall calibration.

Selection of the calibration and validation periods was constrained by the availability of data, especially 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 available reach by reach) was not used for calibration. The final calibration periods chosen are summarised below:

- Flow calibration – different for various reaches, ranging from 01/05/1965 up to 31/12/2000.

- Diversion calibration – from 01/10/1992 to 30/06/2004 (due to poor quality diversion data, the period prior to 1992/93 was excluded from the calibration period). Within this period, there were 3 separate sub-periods, for reasons explained in Section 3.5.1.
- Storage behaviour calibration – from 01/10/1988 to 30/06/2004. Within this period, there were 3 separate sub-periods, for reasons explained in Section 3.5.1.
- Planted area calibration – This step was done over 2 separate periods, because the irrigator behaviour has changed significantly in the past 15 years, as discussed in Section 3.7.1. The calibration period of 01/10/1989 to 30/09/1995 was used to determine an appropriate risk function for the 1993/94 Cap scenario. The period from 01/10/1999 to 30/06/04 was used to determine an appropriate risk function for the WSP scenario.

3.4. FLOW CALIBRATION

The objective of this step is to calibrate the river system flows over the calibration period [DLWC, 1998[c]]. All known components of the water balance within the river valley are set to the observed data. Irrigation demands are disaggregated from the historical data to a daily time-step [DLWC, 1998[j]] and included as extractions from their relevant river reaches. Town water is extracted from river reaches as per fixed patterns. Known system inflows (gauged tributaries and reservoir inflows [DLWC, 1998[g]]) are used as inputs to the model.

After a review of the available main-stream gauging stations and consideration of the criteria listed in Section 3.1.1, there were 2 gauging stations upstream of Copeton Dam and 31 gauging stations downstream of Copeton Dam selected for use in model flow calibration (Table A.5), creating 27 flow calibration reaches in the Gwydir IQQM (Table B.1).

After a review of the available tributary gauging stations and consideration of the criteria listed in Section 3.1.1, there were 5 gauging stations selected to represent inflows upstream of Copeton Dam and 6 gauging stations selected to represent inflows downstream of Copeton Dam, creating 11 gauged inflow contributions to the Gwydir IQQM (Table A.6).

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.

Flows contributing from ungauged catchments were estimated in the Gwydir IQQM using a combination of correlation with other gauged catchments and mass balance calculations within each reach along the river [DLWC, 1998[h]]. The river reaches that have ungauged or "residual" catchment inflows estimations are listed in Table B.2.

The remaining unknowns: river routing [DLWC, 1998[k]] and transmission losses [DLWC, 1998[e]] for each river reach are calibrated by trial and error to achieve the best overall match to each of the selected main-stream gauges (Appendix E.1).

Presented in Figure 3.1 to Figure 3.8 are the results obtained from the flow calibration model for river flow replication at four key gauging stations:

- Gwydir R. @ Pallamallawa (418001) — the point of maximum flow and a good quality continuous long term record
- Mehi R. @ Moree (418002) — a representative gauge on the Mehi River
- Gwydir @ Yarraman Bridge (418004) — indicative of flows going to the Gwydir Wetlands
- Carole Ck @ Garah (418052) — a representative gauge on Carole Creek

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.1.

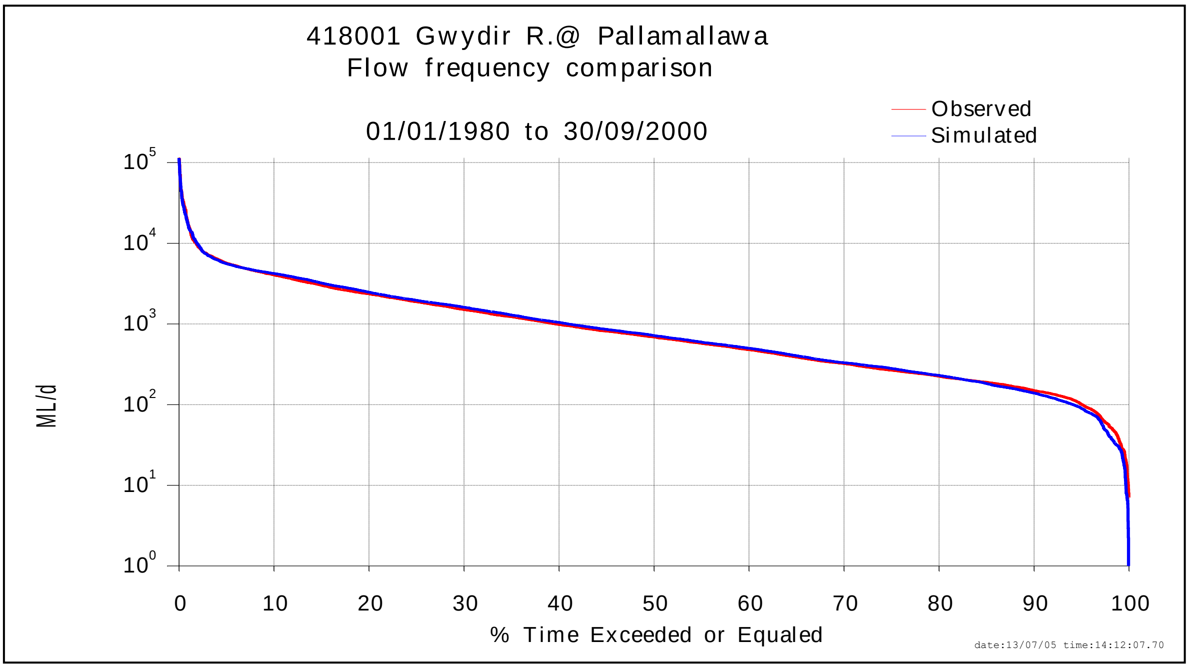

Figure 3.1: Gwydir River at Pallamallawa – daily flow calibration exceedance plot

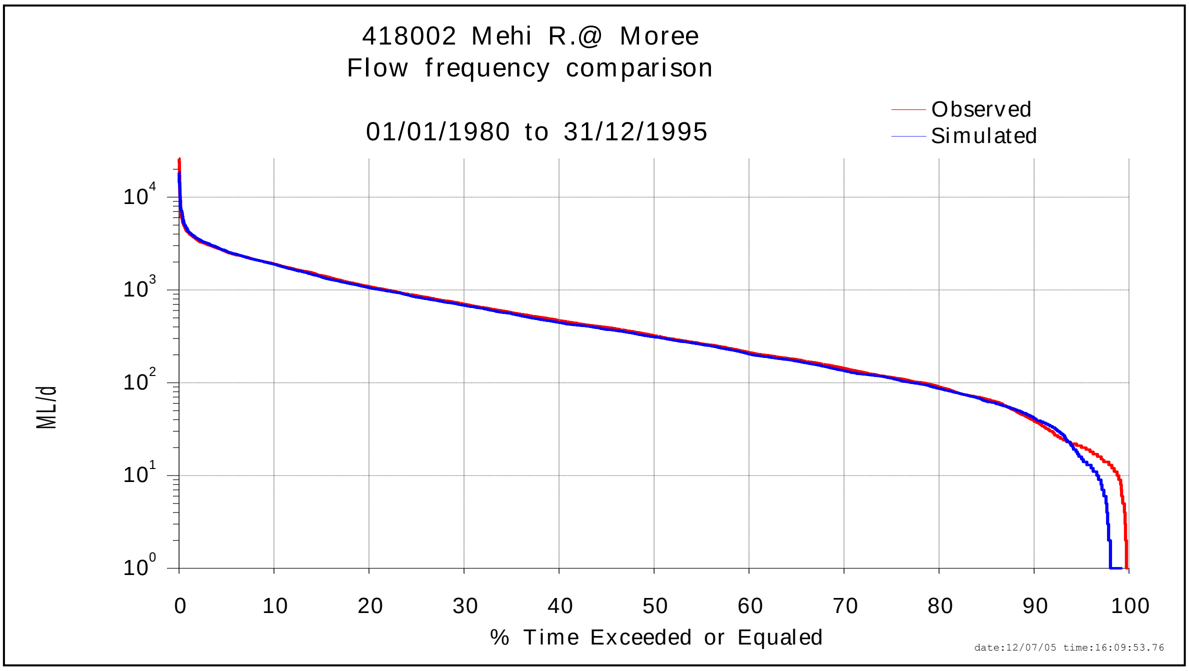

Figure 3.2: Mehi River at Moree – daily flow calibration exceedance plot

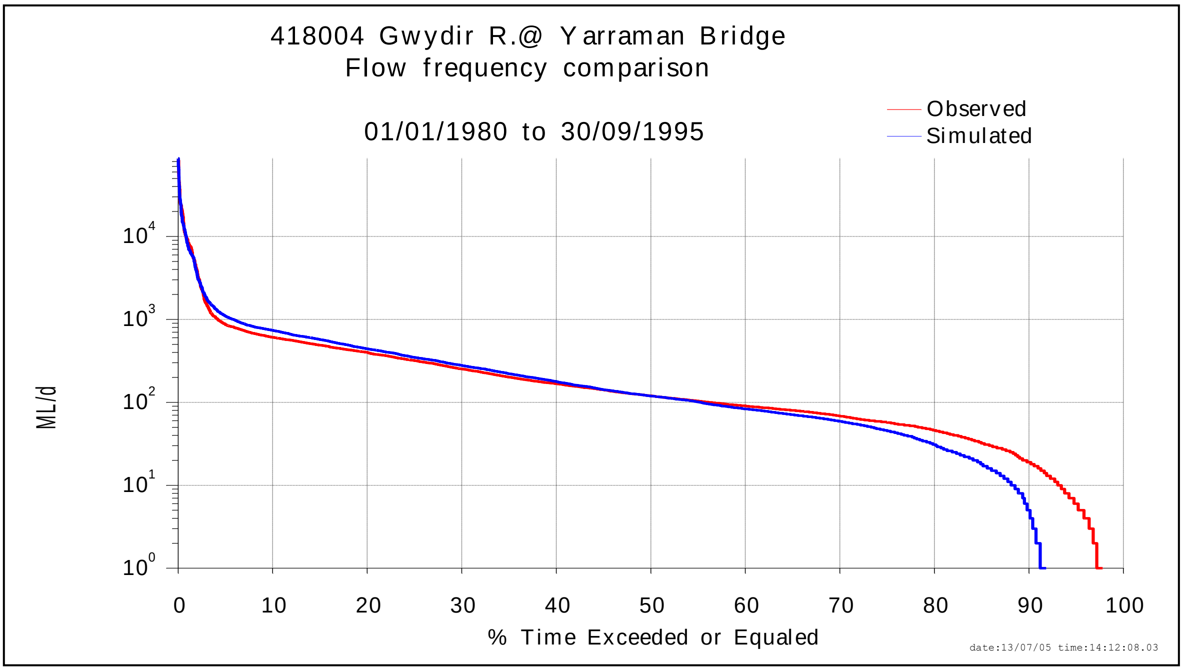

Figure 3.3: Gwydir River at Yarraman Bridge – daily flow calibration exceedance plot

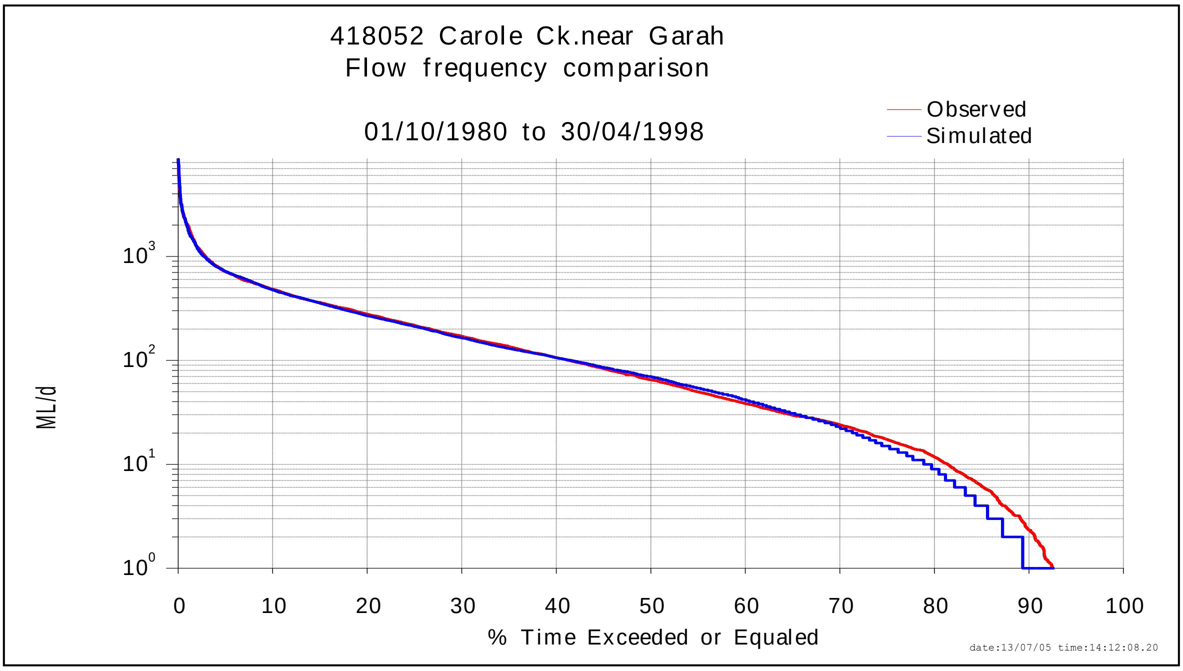

Figure 3.4: Carole Creek near Garah – daily flow calibration exceedance plot

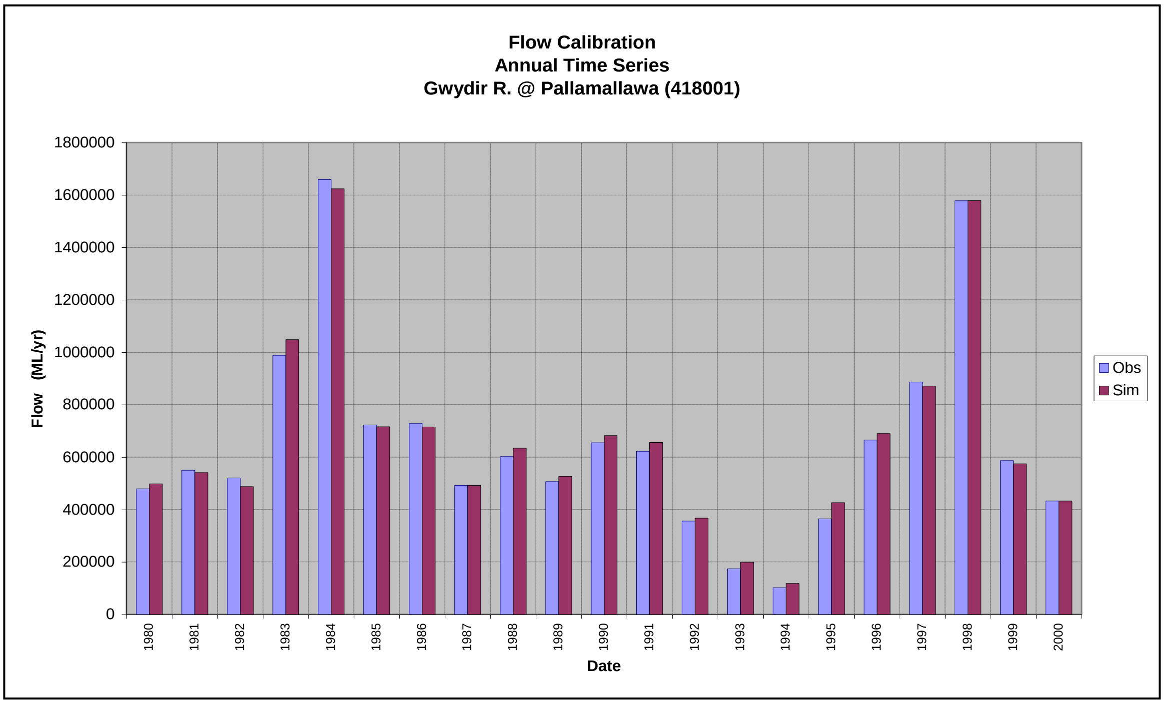

Figure 3.5: Gwydir River at Pallamallawa – annual flow calibration time series plot

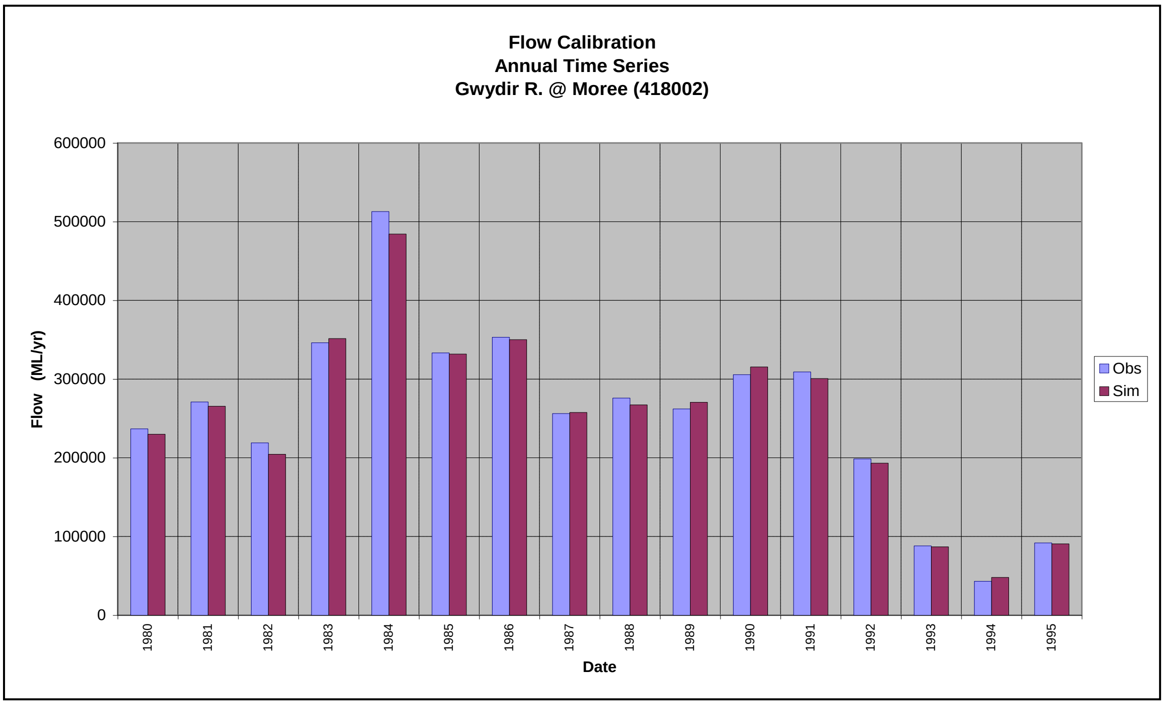

Figure 3.6: Mehi River at Moree – annual flow calibration time series plot

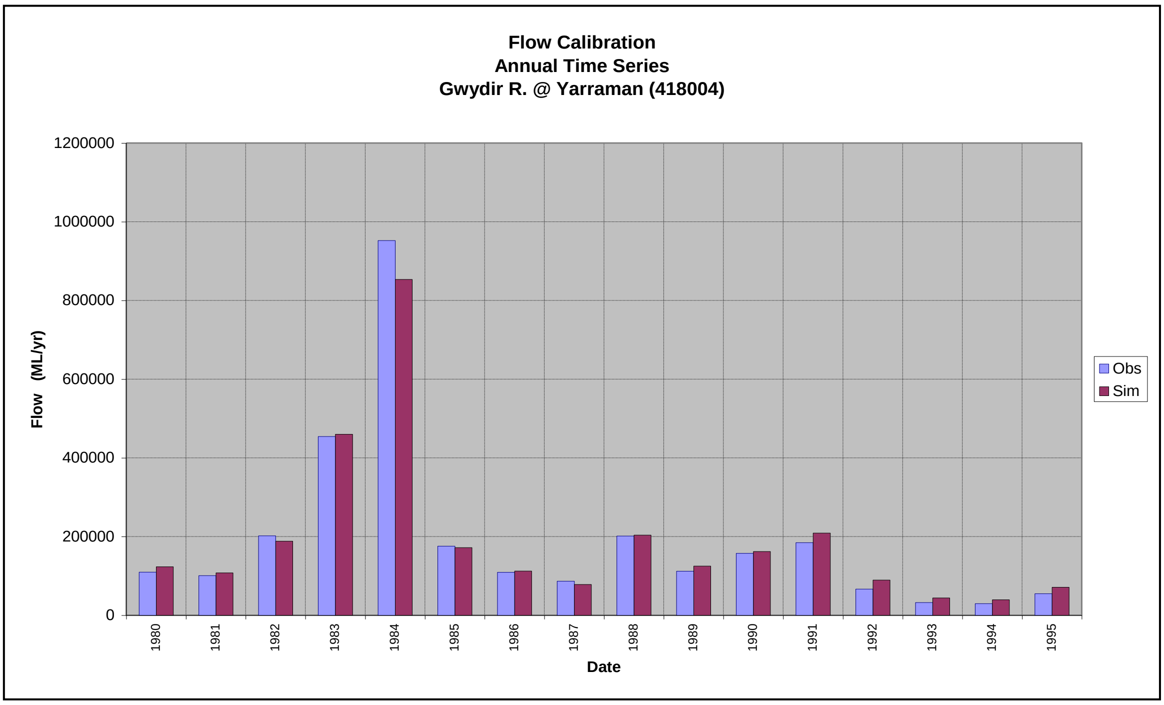

Figure 3.7: Gwydir River at Yarraman Bridge – annual flow calibration time series plot

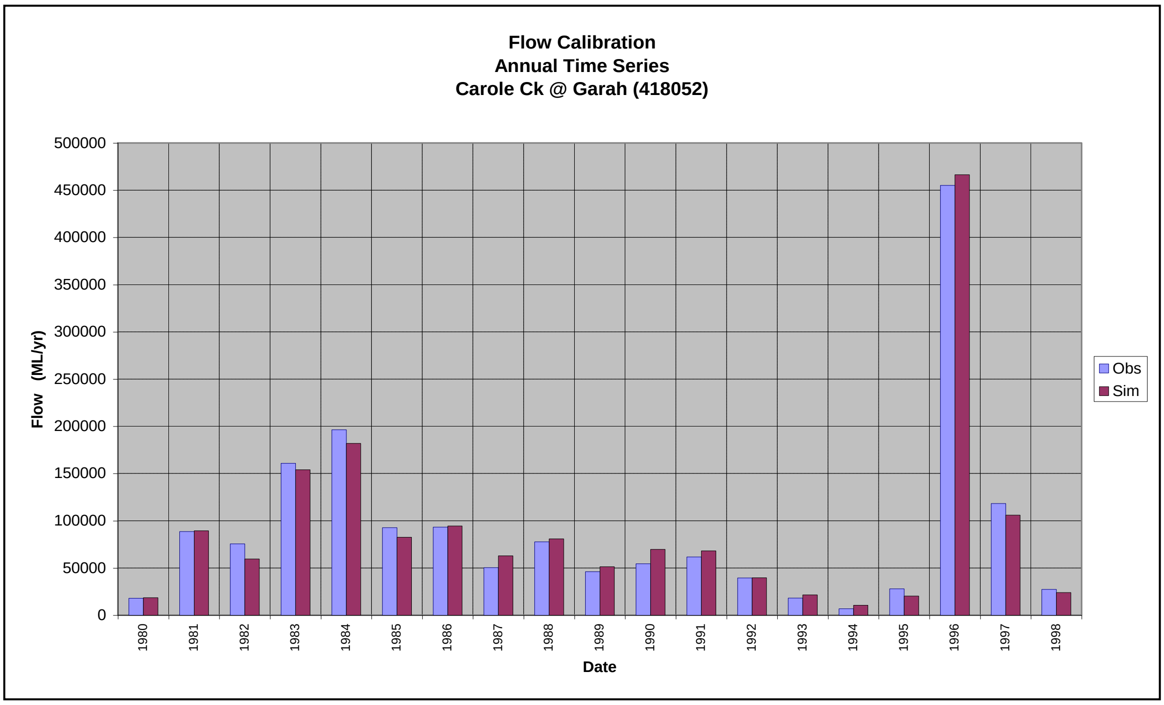

Figure 3.8: Carole Creek near Garah – annual flow calibration time series plot

Table 3.2: Flow calibration quality assessment

SUBJECT		Flow Frequency Match				Time Series Match	
Location	Parameter	Whole Range	Low Range	Mid Range	High Range	Daily 1-r²	Annual CMAAD
Gwydir R.	Exceedance (%ile)	-	< 20	20 to 95	> 95	-	-
@	Lower Limit(ML/d)	0	0	229	5,622	-	-
Pallamallawa	Upper Limit (ML/d)	114,179	228	5,621	114,179	-	-
(418001)	Total Obs (GL)	13,595	213	8,017	5,365	-	-
	Total Sim (GL)	13,802	199	8,381	5,222	-	-
	Apparent Error (%)	1.5%	-6.5%	4.6%	-2.7%	3%	3.3%
	Rating	V. High	High	High	V. High	V. High	V. High
Mehi R.	Exceedance (%ile)	-	< 20	20 to 95	> 95	-	-
@	Lower Limit(ML/d)	0	0	90	2,600	-	-
Moree	Upper Limit (ML/d)	26,128	89	2,599	26,128	-	-
(418002)	Total Obs (GL)	3,977	48	2,829	1,100	-	-
	Total Sim (GL)	3,922	47	2,757	1,118	-	-
	Apparent Error (%)	-1.4%	-2.6%	-2.5%	1.7%	5%	2.8%
	Rating	V. High	V. High	High	V. High	V. High	V. High
Gwydir R.	Exceedance (%ile)	-	< 50	50 to 95	> 95	-	-
@	Lower Limit(ML/d)	0	0	75	836	-	-
Yarraman	Upper Limit (ML/d)	87,471	74	835	87,471	-	-
(418004)	Total Obs (GL)	2,970	71	877	2,023	-	-
	Total Sim (GL)	2,981	51	977	1,953	-	-
	Apparent Error (%)	0.4%	-28.4%	11.4%	-3.4%	9%	8.6%
	Rating	V. High	Low	Moderate	V. High	High	High
Carole Ck	Exceedance (%ile)	-	< 30	30 to 95	> 95	-	-
@	Lower Limit(ML/d)	0	0	25	716	-	-
Garah	Upper Limit (ML/d)	8,765	24	715	8,765	-	-
(418052)	Total Obs (GL)	1,219	15	733	471	-	-
	Total Sim (GL)	1,212	12	730	470	-	-
	Apparent Error (%)	-0.6%	-20.0%	-0.3%	-0.3%	16%	7.8%
	Rating	V. High	Moderate	V. High	V. High	Moderate	High
Overall	Apparent Error (%)	0.7%	-11.0%	3.1%	-2.2%	8.3%	5.6%
	Rating	V. High	Moderate	High	V. High	High	High

The flow calibration has not been reviewed since we updated it in early 2001, therefore the results presented in this report are based on that update. For most locations the availability of good quality diversion information limited the period of calibration. This information is required on a daily time-step. Therefore the historical data needs to be disaggregated from the monthly or 3-monthly time-step that it is recorded. We need to represent the extractions in the reach otherwise they will effectively be double-counted in the derived losses. In the Pallamallawa reach we were able to calibrate up to 2000 by representing the small diversions in this reach using a fixed extraction pattern and a target annual volume.

The results presented here generally cover the period from 1980 up to (at most) 2000. For most sites we also performed a flow calibration on periods prior to significant irrigation development to sanity check the derived losses. For brevity, the results of this analysis are not presented in this report.

The flow calibration at the indicative sites presented above indicates that at most locations we were able to achieve a High to V. High quality calibration for both the flow frequency and the time series comparisons.

We had some problems at Pallamallawa with high flow rating issues and we had to cross check the historical flow data with upstream and downstream gauges to address these problems.

We also had some problems with getting the daily low-range flow match at Yarraman and Garah because of the significant number of zero flow days at these two locations. The method we used to disaggregate the diversion data down to a daily time step has some problems that we were unable to resolve at the very low end of the flow duration curve. This problem effectively pushes some of the low-range flows into the mid-range (Table 3.2). We feel that this is not a significant problem considering the actual quantity of water involved.

3.5. DIVERSION CALIBRATION

3.5.1. 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 license 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 residual inflows) are used, crop areas and types and supplementary water 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 based on factors contained in the literature [Allen, et. al., 1998] and [Doorenbos and Pruitt, 1984]. The calibration parameters are the size of the soil moisture store and rainfall interception loss for each irrigator group and the crop watering efficiency for each crop type. The on-farm storage operation is also modelled at this step. This includes estimation of on-farm storage reserves and airspace and rainfall and floodplain harvesting configuration. Values for all of these parameters are adjusted until the simulated crop water demands best match the observed data (Appendix E.2). This is a complex process with all of the parameters interacting with each other and a number of iterations are required.

An appropriate calibration period must be selected for the demand calibration. IQQM can allow for development changes over the calibration period with the use of time series input parameters, but the management rules in the Valley must be stationary. There must also be good quality, reach-by-reach diversion data available. Consideration of these issues resulted in 3 separate calibration periods for the Gwydir Valley:

- 1988/89 to 1995/96: Annual accounting with carryover;
Water year October to September.

- 1995/96 to 1998/99: Annual accounting with carryover;
  Water year October to September;
  Provision of ECA;
  50:50 surplus flow/SW sharing.
- 1999/00 to 2003/04: Continuous accounting;
  Water year July to June;
  Provision of ECA;
  Low flow protection;
  50:50 surplus flow/off sharing;

Each of these periods was configured separately in the model, with the development changes and management rules that were applicable for those periods. The implications of the three separate periods are described in more detail in the following sections.

The historical irrigation diversion data was disaggregated into daily data [DLWC, 1998[j]] during the flow calibration stage (Section 3.4). This data was used as the basis for demand calibration.

3.5.2. On-allocation diversion calibration

Calibration of the crop water requirements and on-farm water management results in the irrigators placing orders for water. These orders are debited against the irrigators' account and released from Copeton Dam, routed down the river and diverted by the irrigator to meet the crop water requirements. These diversions are known as on-allocation diversions and the model is calibrated to reproduce the observed data.

The climatic data used to drive the crop water requirements is selected as indicated in Sections 3.1.2 and 3.1.3. Crop factors for all crops were estimated from guidelines published by the United Nations Food and Agriculture Organisation [Allen, et. al., 1998]. The crop factors used for different crops are presented in Table B.3.

Parameters such as soil moisture store, initial rainfall losses and irrigation efficiency are calibrated during this step. The irrigation efficiency parameters derived during the calibration process are shown in Table B.4. Other relevant demand calibration parameters are presented in Table B.5.

The ONA diversions are also affected by on-farm water management. For example, increased rainfall and floodplain harvesting reduces the need for crop water requirements to be satisfied from ONA extractions. Therefore, the ONA extractions are actually calibrated iteratively with the SW calibration and on-farm management configuration.

3.5.3. Supplementary water diversion calibration

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

A set of thresholds were developed by calibrating to match as best as possible the recorded days of supplementary water and the supplementary water volumes diverted. Table F.5 shows the supplementary water thresholds derived during the calibration and these were adopted for 1993/94 development conditions.

The SW diversions are affected by on-farm water management. For example, increased rainfall and floodplain harvesting affects the amount of available capacity in the OFS. Therefore, the SW extractions are actually calibrated iteratively with the ONA calibration and on-farm management configuration.

3.5.4. On-farm management calibration

The calibration process was complicated by irrigators having access to significant quantities of other water including on-farm rainfall-runoff harvesting and floodplain harvesting (Section 2.4.5). There is no data available for these quantities of water, so information was gathered through user-surveys [Gwydir Irrigators Survey and Pers. comm, 2004-2005] and a water balance within each reach.

<u>On-farm storage reserves</u> – These were required in the model because it effectively reduces the amount of available capacity in the on-farm storage, thus impacting on supplementary water extractions and rainfall and floodplain harvesting volumes. Wherever possible we tried to represent the OFS reserves to match the information gained from the user-surveys (Section 2.4.5). Some fine-tuning was required in combination with the other on-farm management parameters to achieve an optimum match with the historical ONA and SW extractions. The OFS reserves used in the model calibration changed over time to match historical behavioural changes, with relevant values adopted and validated for the 1993/94 scenario (Section 4.4.2).

<u>On-farm storage airspace</u> – This was required in the model because it effectively reduces the amount of available capacity in the on-farm storage during supplementary water and floodplain harvesting events, thus impacting on supplementary water extractions and floodplain harvesting volumes. Wherever possible we tried to represent the OFS airspace to match the information gained from the user-surveys (Section 2.4.5). Some fine tuning was required in combination with the other on-farm management parameters to achieve an optimum match with the historical ONA and SW extractions. The OFS airspace used in the model calibration changed over time to match historical behavioural changes, with relevant values adopted and validated for the 1993/94 scenario (Section 4.4.2).

<u>Rainfall harvesting (RFH)</u> – This process is significant in the Gwydir Valley and therefore we needed to represent it to achieve a good on- and supplementary water calibration. In IQQM, this process is affected by the daily rainfall volume, rainfall interception loss, rainfall harvesting area, rainfall infiltration rate and preceding soil moisture. Some of these parameters are constant over relatively long periods of time, such as those reflecting particular soil/landscaping characteristics (ie, allowable soil moisture depletion, fallow upper soil moisture depth and the infiltration rate from the upper to lower fallow store). Other parameters change dynamically as a function of development and behaviour (ie, pump capacity, channel/storage capacity and rainfall harvesting areas). No good

quality data on rainfall harvesting volumes exists, but wherever possible we configured the rainfall harvesting parameters such that the simulated volumes matched the information gained from the user-surveys (Section 2.4.5) and from a mass balance of river flows. Some fine-tuning was required in combination with the other on-farm management parameters to achieve an optimum match with the historical ONA and SW extractions. The rainfall harvesting configuration used in the model calibration changed over time to match historical behavioural changes, with a relevant configuration adopted and validated for the 1993/94 scenario (Section 4.4.2)

Floodplain harvesting (FPH) – This process is significant in the Gwydir Valley and therefore we needed to represent it to achieve a good on-allocation and supplementary water calibration. In IQQM, this process is driven by a flow trigger threshold and then a configuration of second lift pumps to pump the water into the OFS. No good quality data on floodplain harvesting volumes exists, but wherever possible we configured the floodplain harvesting parameters such that the simulated volumes matched the information gained from the user-surveys (Section 2.4.5) and from a mass balance of river flows. Some fine-tuning was required in combination with the other on-farm management parameters to achieve an optimum match with the historical on-allocation and supplementary water extractions. The floodplain harvesting configuration used in the model calibration changed over time to match historical behavioural changes, with a relevant configuration adopted and validated for the 1993/94 scenario (Section 4.4.2).

3.5.5. Results and discussion

Figure 3.9 to Figure 3.11 show the modelled and observed diversion volumes over the whole valley for the diversion calibration model. Table 3.3 summarises the calibration using the quality guidelines outlined in Appendix E.2.

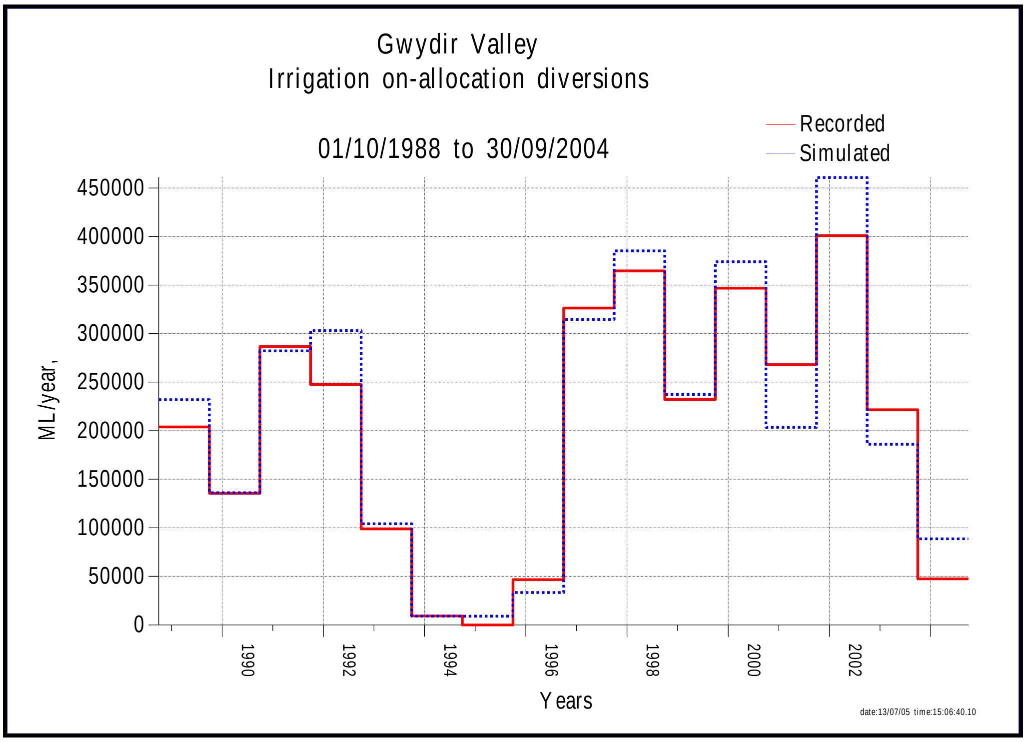

Figure 3.9: Annual comparison of observed and simulated on-allocation diversions

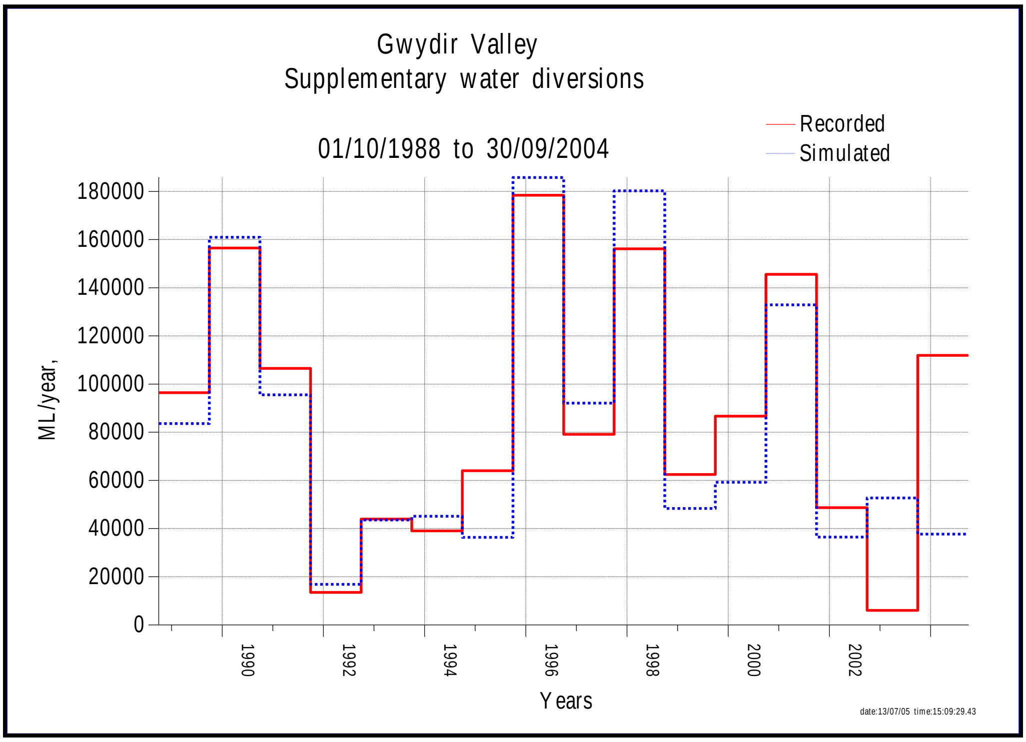

Figure 3.10: Annual comparison of observed and simulated supplementary water diversions

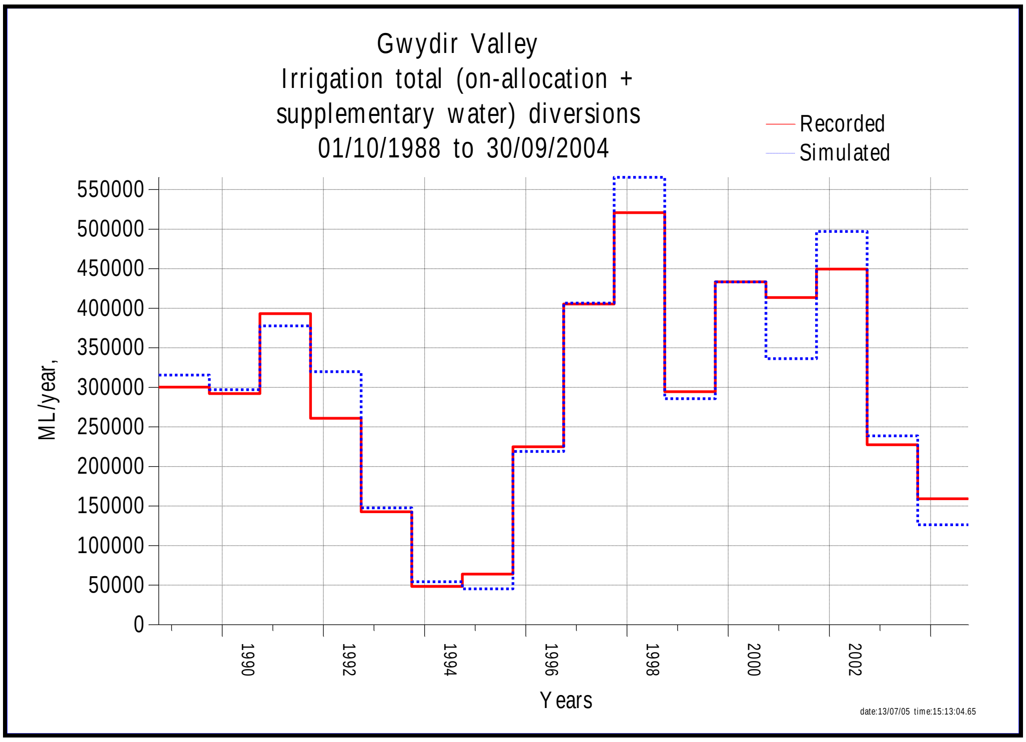

Figure 3.11: Annual comparison of observed and simulated total diversions

For simplicity, we have presented the calibrated annual diversions in a single, continuous graph. In reality, we had to simulate the three calibration periods (Section 3.5.1) separately because of the changes in management rules. Most of the parameters between each of these periods are consistent, with the exception of the irrigation efficiency. Extensive consultation with irrigation representatives indicated that the industry has become about 10% more efficient since 1993/94. This has been achieved through a number of processes including better watering practises, less ploughing of the land to increase rainfall infiltration and watering smaller amounts but more often to increase yield [Gwydir Irrigators Survey and Pers. comm, 2004-2005].

We found that to achieve a good demand calibration we had to increase the cotton irrigation efficiency parameter for each irrigation node in the Gwydir IQQM by approximately the reported 10% from the 1989/90 – 1994/95 period to the 1999/00 – 2003/04 periods.

The demand calibration is very difficult for a number of reasons. Firstly, the area data is assumed to be perfect and used as input to the model during this stage of the calibration. Secondly, the interaction between the ONA, SW and on-farm management parameters requires many iterations to achieve a good result. Invaluable is the incorporation of additional data from user-surveys and sanity checking with storage releases and end-of-system flows. Thirdly, reach-by-reach diversion data was not always available for all of the years of the calibration and so only an annual comparison of diversion totals was possible. Fourthly, in reality the SW access is a variable process based on a number of different factors. In IQQM, we simplify this process using the static monthly SW access thresholds. Therefore, in any one year, it is difficult to get an exact match between the historical and the simulated extractions.

The overall volume match for the ONA diversions shows a small over-estimate. This is due to the slight underestimate in SW diversions. This underestimate is caused mainly by differences in two separate seasons. In the 2003/04 season the model under-calibrates by about 70 GL using the fixed monthly thresholds. In the 1993/94 season, the model also under-calibrates by about 30 GL. These under-estimates have a direct flow-on effect to the ONA which compensates for the SW to meet the planted crop requirement. Historically in these drier years, the irrigators got greater access to any supplementary water flows than in other years, thus the fixed monthly thresholds in IQQM tend to underestimate the access.

Considering these results are for the model using the fixed monthly thresholds, the quality of the calibration is rated as High to V.High for each component of the diversions (Table 3.3).

Table 3.3: Diversion calibration quality assessment

SUBJECT		Diversion Volume Comparison			Time Series Match (CMAAD)		
Parameter		ONA	SW	Total	ONA	SW	Total
Total Obs	(GL)	3,236	1,395	4,631	-	-	-
Total Sim	(GL)	3,358	1,307	4,666	-	-	-
Volume Ratio	(%)	103.8%	93.7%	100.8%	-	-	-
Assessment	(%)	3.8%	-6.3%	0.8%	11.8%	21.3%	7.6%
Rating		High	V. High	V. High	High	High	V. High

3.6. STORAGE BEHAVIOUR CALIBRATION

Storage behaviour calibration provides the best numerical check of the model's overall performance because all components of the system contribute to Copeton Dam storage behaviour. In addition, any differences will be cumulative in terms of their impact on the storage volume. These differences will therefore be quite apparent when comparing modelled and historical storage behaviour.

In this stage of model calibration, the adopted parameters from flow and demand calibration are used and the crop areas and supplementary water extractions are still forced to observed data.

The following sections detail the different processes required for storage calibration.

3.6.1. Inflow to dams

To minimise potential sources of errors, the historical dam inflows are used as input to Copeton Dam during the storage calibration. These can be derived using a back-calculation procedure [DLWC, 1998[g]] based on information obtained from the dam's OIC sheets [DWR, 1980-2001]. The back-calculation technique is based on a water balance of dam inputs and outputs (Equation 3.1).

$$\text{Inflow} = \Delta\text{Storage} + \text{Outflows} + \text{Net}(\text{Evap} - \text{Rainfall}) \qquad \{Eq.3.1\}$$

After a review of the available rainfall and evaporation stations and consideration of the criteria outlined in Section 3.1, the rainfall and evaporation stations listed in Table A.1 and Table A.3 respectively were selected to provide the climatic data that is not contained in the OIC sheets.

The inflows were then derived, using the back-calculation formula, to cover the calibration period.

3.6.2. 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 a number of gauged tributaries 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.6. These are generally consistent with advice received from river operators regarding typical tributary utilisation factors.

3.6.3. Operational surplus

Operational surpluses are modelled by applying a fixed over-order factor to the orders placed by each of the irrigation groups. These operational surpluses allows for attenuation and variable losses.

The fixed over-order factors that produce the best calibration of storage behaviour over the calibration period are presented in Table B.7. These factors are generally consistent with advice received from the river operator regarding typical operational surpluses.

3.6.4. Results

Figure 3.12 shows the storage calibration for Copeton Dam. Table 3.4 summarises the calibration results in terms of the quality guidelines outlined in Appendix E.3.

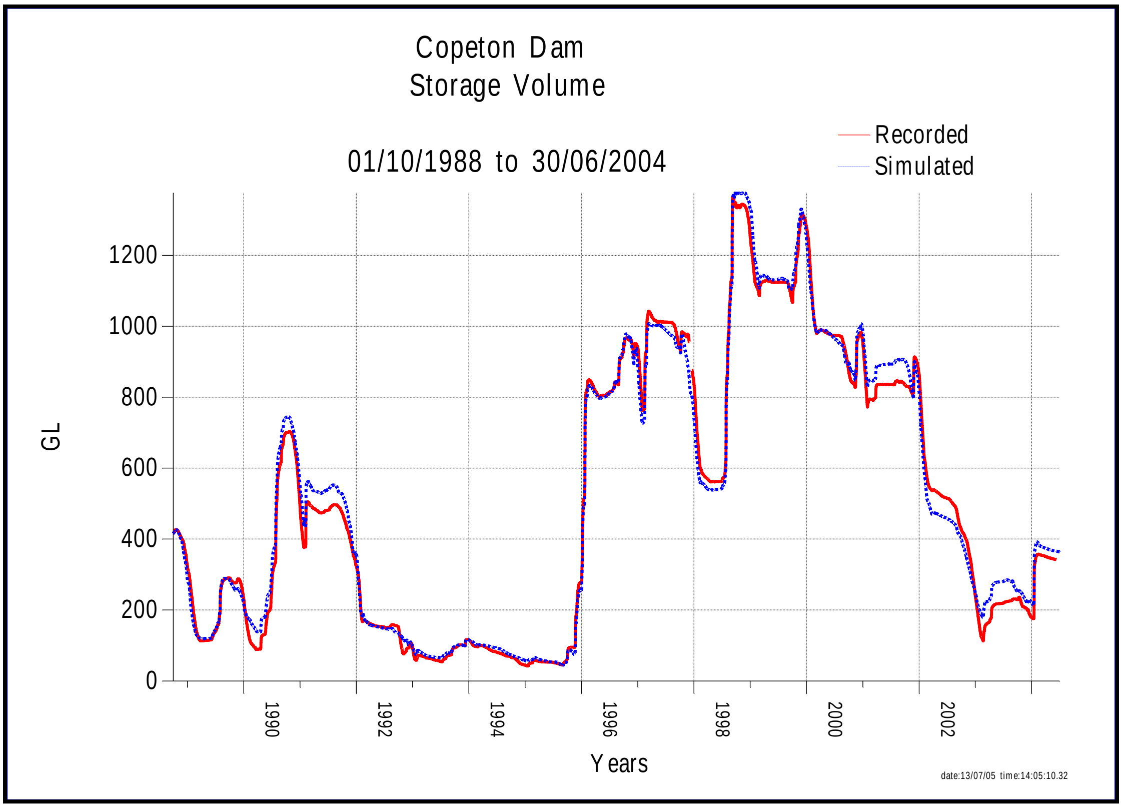

Figure 3.12: Observed vs simulated Copeton storage behaviour

We achieved a V.High rating on the Copeton Dam storage behaviour calibration (Table 3.4). Figure 3.12 is actually a combined plot of the three separate calibration periods (Section 3.5.1).

Table 3.4: Storage calibration quality achieved

Subject	Time Series End-of-Month Match (CMASDD)
Assessment (%)	2.3%
Rating	V. High

3.7. PLANTED AREA CALIBRATION

The planted area during the calibration period usually changes as a result of a number of factors including climate, development in the valley and market conditions. Therefore matching the historical planted area is the most difficult process in the model calibration. Consequently it has been forced to historical values for most stages of the calibration. In fact for these reasons it is difficult to calibrate the farmer's risk function for each individual node. The process is a combination of:

- calibration to match the historical data;
- consultation with irrigation representatives to understand their decision making processes;
- an allowance for different planting decisions due to antecedent conditions, which affect both the amount of planted area and the timing;
- an allowance for changed behaviour due to different water management rules;
- an allowance for changed attitudes to boom-bust vs reliable water supply behaviour;
- an allowance for growth in the maximum area over the calibration period;
- an allowance for access to other water sources including rainfall and floodplain harvesting;
- variations in historical data obtained from different sources.

The effects of external factors such as commodity prices and financial status are not modelled explicitly in IQQM. These may be linked to climatic conditions so indirectly they would be taken into account to a certain degree.

3.7.1. Background information

The following background information is relevant for the Gwydir IQQM area calibration:

1) To derive appropriate parameters for the risk functions, we used data from 1988/89 to 2003/04;
2) Climatic variability is reasonably well represented over this period, with a number of wet and dry years, with varying resource availability. We would expect the historical planted areas to be reasonably indicative of the farmers' behaviour over a range of climatic situations;
3) There is a general trend of increasing planted areas up to the 1990's (Table 2.5), even when variations in climatic conditions are taken into consideration;
4) Up to the mid-1990's there appears to be a typical boom-bust style of behaviour in irrigator decisions, characterised by high risk in planting decisions in wet years and low planted areas in dry years. This could have been for a number of reasons including that there was no SW cap or specific environmental flow considerations at the time;
5) There was a severe drought from 1992 to 1995, which tended to mask the maximum area that could be planted, and resulted in planted areas with very high levels of risk. Irrigation was abandoned mid-season for some significant areas of cotton crops during this period due to lack of water, and it is probable that the level of risk taken by some during this period was unsustainable in the longer term.
6) Post mid-1990's and certainly since 2000, the boom-bust behaviour has tended to be replaced with more consistent planting behaviour, characterised by generally higher target application rates (i.e. lower risk) when deciding on areas to be planted in wetter years and lower target application rates (i.e. higher risk) in drier years. This results in a smaller difference between the

planted areas from year to year. This style of behaviour is more cost-effective for the irrigators as staff turnover is smaller and income is more stable [Gwydir Irrigators Survey and Pers. comm, 2004-2005];

7) For these reasons, the risk function varies over time and therefore we need to examine years that are representative of the scenario being configured. For the 1993/94 Cap scenario, we chose to focus on the period 1988/89 to 1994/95. We also used these risk functions over the 1995/96 to 1999/00 period to test the reported changes in behaviour over this period;

8) Crops are planted based on the water that is available at the planting date only, which includes the ONA balance and water already in OFS. The irrigator then calculates how much area to plant by dividing this by an amount of ML/ha. Inherent in the adopted ML/ha is some allowance for both increases in AWD after the planting date and access to water from other sources, such as SW, RFH and FPH. Different application rates are applied to the resources available in Copeton Dam (AWD plus carry over) vs the resources available in the OFS. Reported target application rates on water stored in Copeton Dam were approximately 6 ML/ha, whereas for water stored in OFS, it is approximately 8-9 ML/ha [Gwydir Irrigators Survey and Pers. comm, 2004-2005];

9) 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 water sharerequired to plant the summer area. The balance remaining at the winter decision date was used to determine the area to plant in winter;

10) There was little information available to estimate a winter planting decision. Reviewing the cropping data indicated a very high application rate for winter cropping, suggesting that their planting decision is governed by more factors than available resource alone.

Consideration of these specific issues during the area calibration process resulted in appropriate risk functions for each irrigation node for the 1993/94 scenario in the Gwydir IQQM, as discussed further in Sections 4.4.3.

3.7.2. Results

The farmers' risk function is calibrated by comparing the modelled and historical planted areas. We used 2 separate periods to calibrate the risk functions, with the intention of being able to adopt one set for the 1993/94 Cap scenario and the other for the WSP scenario.

For the 1988/89 to 1994/95 period, the farmers' risk adopted for individual irrigation nodes varies from a maximum risk of about 3.5 ML/ha in wetter conditions to just over 4.5 ML/ha in drier conditions. There is some variation from irrigator group to irrigator group with higher risk observed on Moomin Creek in dry and average conditions, and Carole Creek irrigators being slightly more conservative under the same conditions than irrigators in the rest of the Valley.

The average farmers' risk over this period is approximately 4 ML/ha. This means that if the irrigation node has a total AWD plus carry over plus OFS water of 1,000 ML on the decision date (1st October) then it would plant 250 ha of summer crops. The individual irrigation node risk functions are presented in Table F.3.

For the 1999/00 to 2003/04 period, the average farmers' risk is approximately 6 ML/ha, with significant variation from node to node and due to antecedent conditions. Of note is the much lower risk that was required to match the historical information, supporting the irrigators' reported behavioural changes (Section 3.7.1).

We have presented the area calibration results for the two separate calibration periods in Figure 3.13 and Figure 3.14. Table 3.5 and Table 3.6 summarise the quality of the area calibration for each of the calibration periods using the guidelines in Appendix E.4.

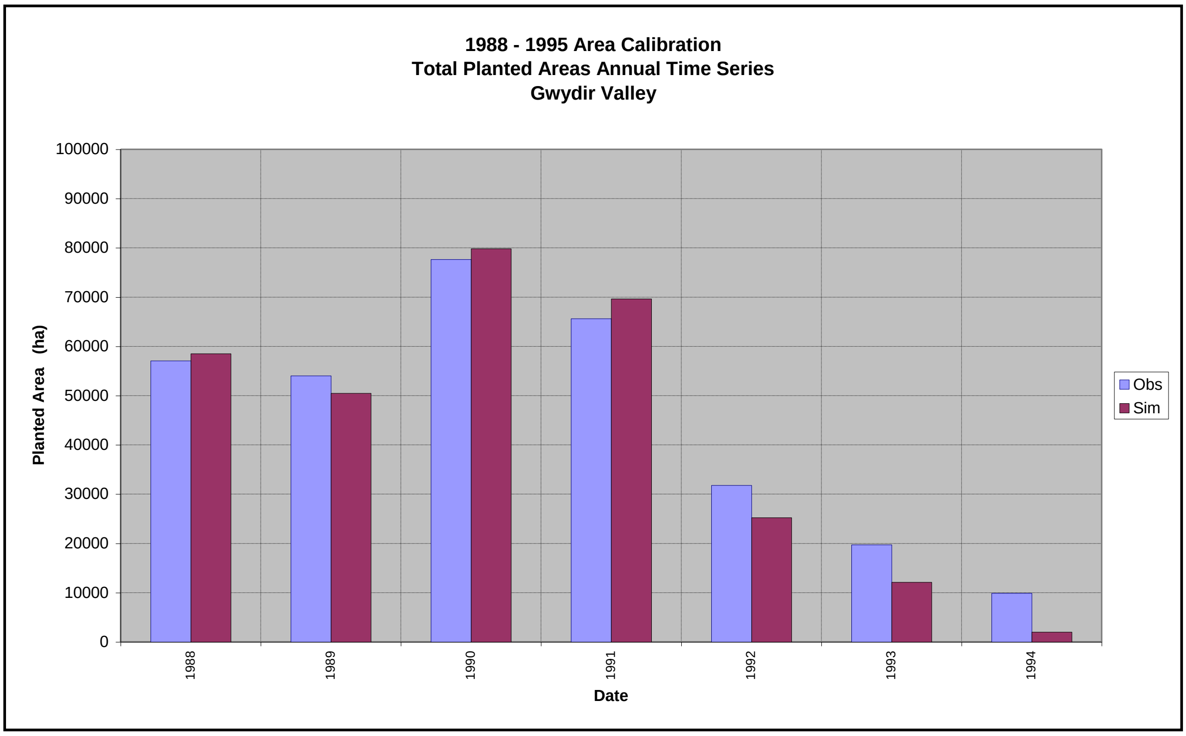

Figure 3.13: Comparison of observed and simulated planted areas for 1988 to 1995

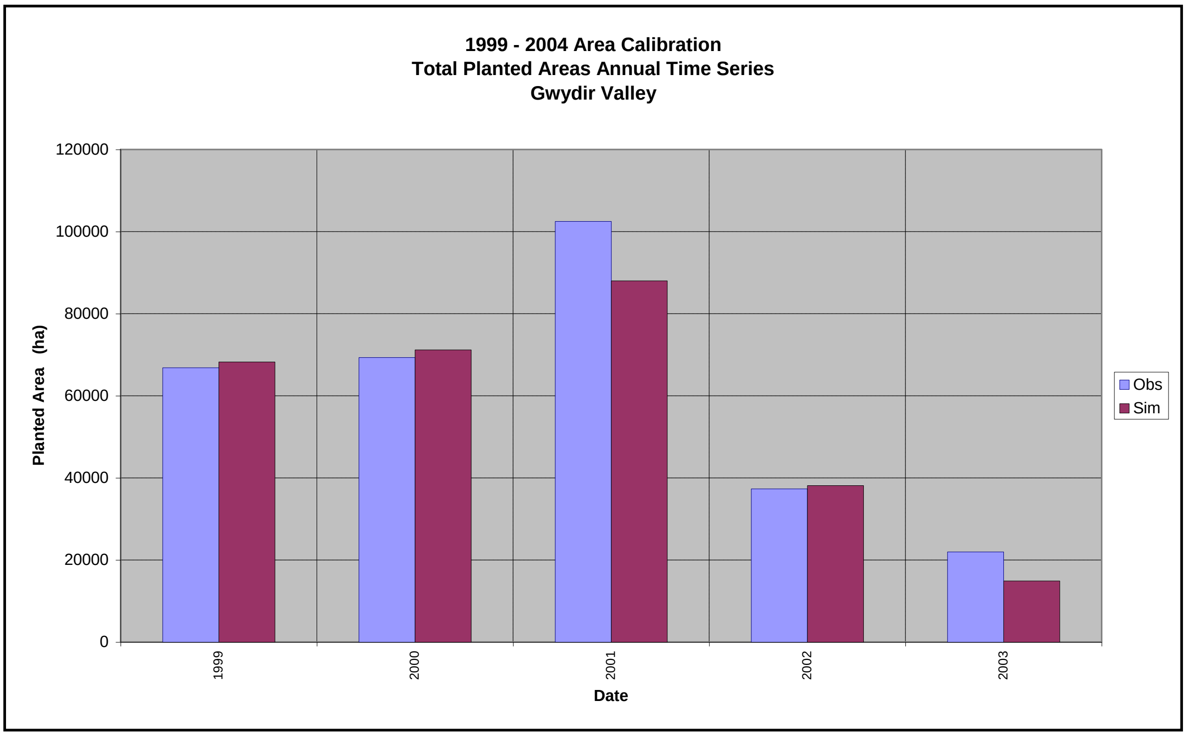

Figure 3.14: Comparison of observed and simulated planted areas for 1999 to 2004

Table 3.5: Planted area calibration quality achieved 1988 – 1995

SUBJECT		Planted Area Comparison			Time Series Match (CMAAD)		
Parameter		Summer	Winter	Total	Summer	Winter	Total
Total Obs	(ha)	307	9	316	-	-	-
Total Sim	(ha)	294	4	298	-	-	-
Area Ratio	(%)	95.5%	51.5%	94.3%	-	-	-
Assessment	(%)	-4.5%	-48.5%	-5.7%	10.8%	69.4%	10.5%
Rating		High	Low	High	High	Low	High

Table 3.6: Planted area calibration quality achieved 1999 – 2004

SUBJECT		Planted Area Comparison			Time Series Match (CMAAD)		
Parameter		Summer	Winter	Total	Summer	Winter	Total
Total Obs	(ha)	275	23	298	-	-	-
Total Sim	(ha)	265	15	281	-	-	-
Area Ratio	(%)	96.5%	66.5%	94.1%	-	-	-
Assessment	(%)	-3.5%	-33.5%	-5.9%	6.9%	66.1%	8.6%
Rating		V. High	Moderate	High	V. High	Low	V. High

To derive irrigators' risk functions for the 1988/89 to 1994/95 period, we had to not only force the AWD's to the historical announcements, but also to transfer them to the start of the season. This was because there were a number of historical occasions when the AWD rose late in the planting season and in reality the planted areas were either increased or delayed as a result. In IQQM, there is a single decision data for how much area of crop to plant. This date is configured in the Gwydir IQQM as 1st October. Therefore any water not available on this date is not considered in the planted area decision. This resulted in the model underestimating the planted areas in a couple of the seasons in this period.

For the 1999/00 to 2003/04 period, the AWD's were not forced to match the historical announcements, as the introduction of continuous accounting removed much of the variation in dates of AWDs. We were able to achieve a very good calibration in this period except for the 2001/02 season. In this season, the summer area matches quite well at around 90,000 ha, but the amount of reported winter area of approximately 9,500 ha was a lot higher than the simulated value.

When we compared the adopted risk functions for the two periods with the planted areas over the 1995/96 to 1999/00 period, we also found that this tended to support the reported changes in behaviour between the two periods.

We had quite a bit of difficulty in matching the planted winter areas. This is thought to be largely due to reported irrigated winter area that was not actually irrigated but solely rain-fed.

3.8. RESOURCE ASSESSMENT CONFIGURATION

Resource assessment involves assessing how to distribute the available water resources to all water users. Current and future needs of high security users are provided for initially and then remaining resources are allocated to general security users. The operation of the system and any environmental needs are taken into consideration during this process. Up until the 1998/99 water year the Gwydir Valley was operated on an annual accounting system. From 1999/00 onwards the resource assessment of the Gwydir has been undertaken on a continuous accounting basis. The water years also changed from Oct – Sep to Jul-Jun in 2002/03.

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;
- recession on current inflows 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 of 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 were configured in IQQM that were relevant to the proposed scenario runs as described in Sections 4.9. The resource assessment modules for these scenarios were then validated as described in Sections 4.13.1.

3.9. OVERALL QUALITY OF THE MODEL CALIBRATION

The overall quality of the model calibration has been assessed using a combination of selected key indicators (Appendix E.6). The results of this evaluation are summarised in Table 3.7.

Table 3.7: Evaluation of overall quality of model calibration

Subject					Individual Ratings			
Calibration	Period			Location	Overall Ratio		Pattern Match	
Stage	Start	End	Length		Achieved	Standard	Achieved	Standard
Flow	1980	2000	21	Pallamallawa	1.5%	3.8%	3.3%	3.3%
Demand	1988	2004	17	Whole valley	0.8%	0.5%	7.6%	2.5%
Storage	1988	2004	17	Copeton	0.4%	0.9%	2.3%	2.9%
Area	1988	1995	8	Whole valley	-5.7%	-8.4%	10.5%	7.2%
Area	1999	2004	6	Whole valley	-5.9%	-5.9%	8.6%	3.6%
Sub-total					3.9%		3.9%	
Average					3.9%			
OQI	14				2.1%		V. High	

There were two separate periods used to calibrate some of the components of the Gwydir IQQM. Therefore these periods were included separately in Table 3.7. The adopted calibration period length for climatic representativeness purposes (Appendix E.5) is 14 years. We decided that this the effective climatic period that the model was fully tested over, since we did not include the 1996 to 1998 period in the area calibration.

According to the guidelines in Appendix E.6, the Gwydir IQQM calibration achieved a V. High Overall Quality Indicator. Based on this rating, the model is appropriate for the following uses as listed in Table E.6:

- Short term Cap Auditing;
- Long term Cap modelling;
- Long term analysis of management rule variations;
- Long term analysis of development variations;
- Long term analysis of infrastructure changes;
- Long term analysis of storage behaviour, yield and spilling frequency;
- Long term analysis of flow regimes and environmental flows at key locations.

4. 1993/94 Development Conditions (Cap) Scenario

The Gwydir River Valley is a designated river valley under Schedule F [MDBC, 1998] 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 – [MDBMC, 1996]). DNR will use the Gwydir 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 IQQM has been configured and calibrated for the Gwydir Valley. This chapter outlines how IQQM has been further developed to perform a long term simulation of the valley at 1993/94 levels of development and management rules and using historical climatic data as input. This scenario will be referred as "*the Cap scenario*". This chapter also outlines how the Cap scenario has been used for short term Cap auditing, ie the Cap scenario simulated from 1997/98 onwards. This scenario will be referred to as "*the Cap Audit scenario*".

For the reasons given in Section 3.2, both the Cap scenario and the Cap Audit scenario only relate to the regulated system and any recent catchment changes on unregulated tributaries are effectively incorporated into the historical streamflow information used as model input.

4.1. CAP IN BRIEF

The Gwydir IQQM was used to simulate the Cap scenario over the 115 year period from 1890 to 2004 to determine long term average annual diversions. The Gwydir IQQM was also used to simulate the Cap Audit scenario, as required under Schedule F, for the period from 1997/98 to 2003/04 water years. The following assumptions were used to configure the Cap scenario:

- Copeton Dam infrastructure and operation policy as per 1993/94 conditions;
- Pump capacity as indicated in Table 2.3 for the 1990 to 1998 period;
- On-farm storage capacity as installed in the 1993/94 irrigation season;
- The crop mix based on observed data in the 1993/94 irrigation season;
- Farmers' risk derived based on relevant historical data;
- Maximum and minimum planted areas derived based on relevant historical data and information obtained from the irrigators' survey and Pers. comm [2004-2005];
- Management rules applicable in the 1993/94 irrigation season.

All of these components in the Gwydir IQQM must be configured with values relevant to the 1993/94 irrigation season. Appendix F contains details of specific model configuration parameters for the 1993/94 scenario.

4.2. CLIMATIC DATA

4.2.1. Rainfall

For the long term Cap scenario and the Cap Audit scenarios, the rainfall stations selected during calibration (Section 3.1.2) were extended using SILO gapless data to cover the intended simulation period.

4.2.2. Evaporation

For the long term Cap scenario and the Cap Audit scenarios, the evaporation data for all stations (Table A.3) except Copeton Dam was extracted from the SILO data base, which provides long-term, gap-filled data.

For Copeton Dam, we used the 30-year record of daily evaporations and the long-term rainfall records to generate long-term evaporation. This method is based on a relationship between historical monthly evaporation totals and number of rain days in the month using the rainfall station listed in Table A.3.

4.3. FLOW DATA

4.3.1. Streamflows

For model scenario runs, the main-stream flows are no longer required because the flows within the system are simulated based on the dam inflows/releases, the tributary inflows and the calibrated routing, losses and ungauged inflows in the system.

The rainfall and evaporation stations selected for rainfall-runoff modelling (Sections 3.1.2 and 3.1.3) were extended to cover the intended simulation period.

The tributary gauges selected for use in the model (Table A.6) do 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 such that it covered the intended simulation period.

The long term ungauged catchment inflows were then derived based on applying the methodology outlined in Section 3.4 and Table B.2 using the long term tributary inflow sites.

4.3.2. Inflows into Copeton Dam

To derive the required long-term inflow sequence to Copeton Dam, the OIC sheet mass balance approach was no longer sufficient (these records only begin once the storage has been built, in 1979).

The long term inflows to Copeton Dam were therefore produced by assembling a model of the sub-catchments upstream of Copeton dam. This model consists of two calibration reaches (Table B.1), five gauged inflow locations (Table A.6) and two ungauged inflow locations (Table B.2).

The first upstream Copeton Dam flow calibration reach is between 418029 (Gwydir River @ Stonybatter) and 418008 (Gwydir River @ Bundarra). All of the available observed data at 418008 (Gywdir River @ Bundarra), i.e. 1936-2004, was used for calibration.

The second upstream Copeton Dam flow calibration reach is between 418008 (Gwydir River @ Bundarra) and Copeton Dam, using back-calculated inflows derived as described in Section 3.6.1. The period 1980-2004 was used for calibration.

A comparison of the simulated versus historical back-calculated inflows is presented in Figure 4.1.

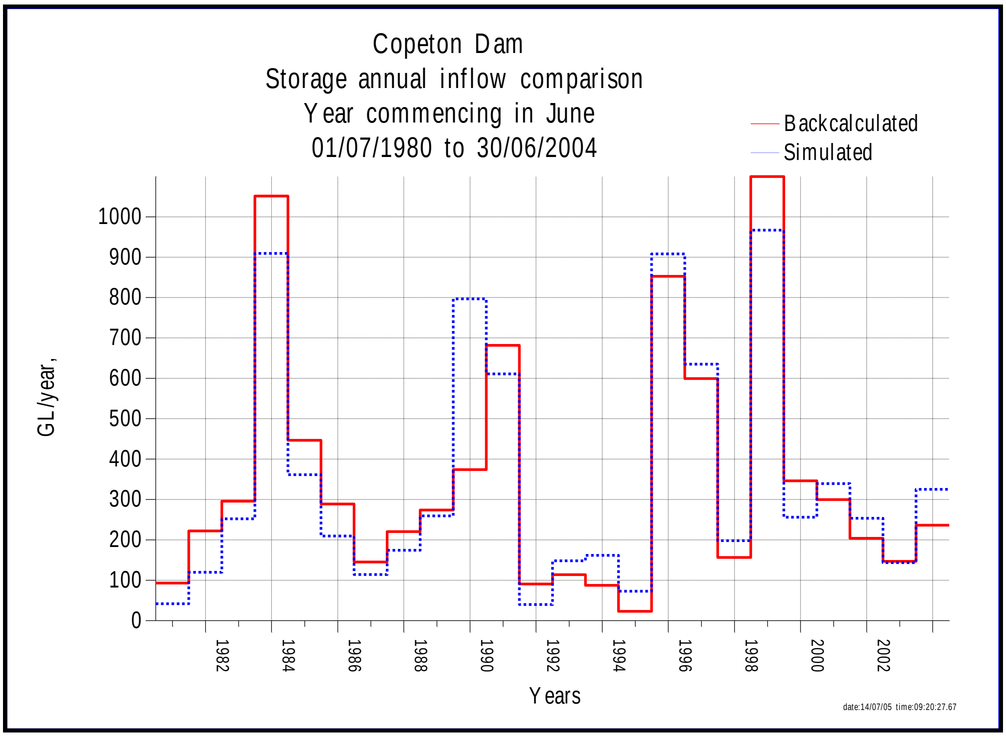

Figure 4.1: Comparison of OIC and simulated Copeton Dam inflows for 1980 to 2004

Once the upstream model was calibrated, Sacramento models for each of the gauged sub-catchments upstream of the dam were calibrated to the available observed data [DLWC, 1998[i]]. Long term SILO rainfall and evaporation data was used for each of the weather stations used in the Sacramento models. Long term runoff at each site was then generated and used to gap-fill and extend the observed data at each of their respective gauging stations to cover the simulation period.

The long term flows at each of the sub-catchments were then used as input to the upstream Copeton Dam model to generate a long term inflow sequence to Copeton 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).

Irrigation parameters such as crop irrigation efficiency were determined during model calibration (Section 3.5). A full listing of the parameters describing the Gwydir IQQM Cap scenario is in Appendix F.

4.4.1. Irrigation licenses

The irrigation water share volume in 1999/00 (Section 2.4.1) was used for the Cap scenario (Appendix F).

4.4.2. On-farm storage infrastructure and usage

The OFS parameters are derived based on a combination of available data, calibration and consultation with irrigation representatives.

4.4.2.1 Capacity

The historical on-farm storage volumes and pump capacities for the 1993/94 irrigation season were used for 1993/94 Cap scenario (Section 2.4 and Appendix F).

4.4.2.2 Reserves

During extreme drought periods there are severe resource constraints, so it is common practice not to put any water into the OFS reserves. It appears that this practice was adopted in the very dry climatic period around 1993/94, since the best calibration (Section 3.5.4) and validation (Section 4.13.3) for this period was achieved with the OFS reserves set to zero.

Since we do not have the facility to vary the OFS reserve from year to year in the scenario runs, we considered it more important to adopt values that are representative of long-term on-farm operation at that time as ascertained by the user-surveys [Gwydir Irrigators Survey and Pers. comm., 2004-2005]. ie they were *not* set to zero.

The adopted OFS reserve for each irrigation node in the 1993/94 scenario is presented in Table F.9.

4.4.2.3 Airspace

The on-farm storages' airspace required for the Cap scenario are static for the entire simulation, whereas those required to achieve calibration over the 1988/89 to 1994/95 period were dynamic (Section 3.5.4). Therefore a single set of airspace volumes were selected that produced a satisfactory validation of the 1993/94 scenario over the 1988/89 to 1994/95 period (Section 4.13).

Adopting these values effectively includes all relevant data and considers the irrigators' behaviour representative of that time as ascertained by the user-surveys [Gwydir Irrigators Survey and Pers. comm., 2004-2005].

The adopted OFS airspace for each irrigation node in the 1993/94 scenario is presented in Table F.8.

4.4.2.4 Rainfall Harvesting

The rainfall harvesting configuration adopted for the Cap scenario was based on a combination of the configuration required to achieve both calibration and validation over the 1988/89 to 1994/95 period (Sections 3.5.4 and 4.13).

Therefore, adopting such a configuration effectively includes all relevant data and considers the irrigators' behaviour representative of that time as ascertained by the user-surveys [Gwydir Irrigators Survey and Pers. comm., 2004-2005].

Particular aspects of the rainfall harvesting configuration for the 1993/94 scenario included a decreased usage of rainfall harvested water relative to more recent years. This was due to pumping and infrastructure limitations and higher access to SW extractions and floodplain harvesting.

The adopted rainfall harvesting parameters for each irrigation node in the 1993/94 scenario is presented in Table F.7.

4.4.2.5 Floodplain Harvesting

The floodplain harvesting configuration adopted for the Cap scenario was based on the configuration required to achieve calibration over the 1988/89 to 1994/95 period (Section 3.5.4). Adopting this configuration effectively includes all relevant data and considers the irrigators' behaviour at that time as ascertained by the user-surveys [Gwydir Irrigators Survey and Pers. comm, 2004-2005].

Particular characteristics included a higher access to floodplain harvested water relative to more recent years. This was due to lower access to rainfall harvested water.

The adopted floodplain harvesting parameters for each irrigation node in the 1993/94 scenario is presented in Table F.6.

4.4.3. Cropping information

There are a number of important cropping information parameters that require configuration in an IQQM simulation. Some of these parameters are derived during calibration, including an indication of the relevant farmers' risk and planting decisions at the time (Section 3.7). Other parameters are based on historical data, such as crop mix.

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 adopt for the 1993/94 scenario.

Table 2.6 shows that the crop mix from 1990/91 to 1993/94 was very consistent. Despite an AWD of zero being announced in 1993/94, the crop mix did not show any significant change. The drought's effect on crop mix appears to affect the following two seasons where there is a significant drop in the percentage of cotton planted. To reflect the variations to the crop mix over the 7-year period around 1993/94, a weighted average of the crops from 1990/91 to 1996/97 was adopted as representative of the behaviour under 1993/94 conditions and therefore adopted for the 1993/94 Cap scenario.

This results in an overall valley crop mix of approximately 90% cotton, 3% wheat, 5% summer and <2% of Pecan nuts, winter cereals and others, as presented in Table F.4. The Pecan nuts plantation is represented by a permanent crop of 700 ha at the HS irrigation node in the model. The crop mix at each irrigation node remains constant for the entire simulation period.

4.4.3.2 Maximum area

The maximum planted area is specified in IQQM to represent the most that irrigators would plant given sufficient resources available. In reality, this is not always the case and 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.

Determination of an appropriate maximum area to adopt for the 1993/94 Cap scenario in IQQM is not a simple process considering there are a number of factors that need to be considered including:

- climatic variability;
- historical increases in development;
- variation in irrigators' behaviour both for each individual from year to year and from individual reach to individual reach, due to any number of reasons including economic factors;
- variations in figures obtained from different data sources.

Specifically in the Gwydir IQQM, we considered the following issues:

1) Up to the early 1990's there are a number of years of 100% AWD and reasonable supplementary water supplies, such that we would expect the historical maximum planted area to be reasonably indicative of the potential maximum area up to that date;

2) There is a general trend of increasing planted areas up to the early 1990's (Table 2.5), even when variations in climatic conditions are taken into consideration. After that, it is difficult to identify a specific trend in the planted areas;

3) The maximum total valley planted areas in the years from the mid-1980's up to 1993/94 yields a figure of 77,282 ha in 1990/91 based on DNR's data (Table 2.5);

4) The maximum individual irrigator planted areas in the years from the mid-1980's up to 1993/94 indicated that in the 1990/91 season, there were some irrigators that had no historical planted area data, but had planted in other years. These irrigators were located on Gil Gil Creek between its junction with Carole Creek and Galloway (represented as Carole 2b and 2c in IQQM) and between the junction with Carole Creek and Weemelah #2 (represented as Carole 2b and 2c in IQQM). An examination of maximum planted areas for these irrigators in surrounding years indicates that their maximum planted areas should be 374 ha (recorded in 1997/98) and 524 ha (recorded in 1999/00) respectively. This effectively results in an increase of approximately 900ha above the 1990/91 figure;

5) Irrigator surveys and consultation with regional representatives indicated that there was some further development between 1990/91 and 1993/94 that did not get fully utilised until a number of years later due to resource and economic constraints. The estimated figure was that the true development increase was about 5% from 1990/01 to 1993/94.

6) There was little information available on planted winter areas. Discussion with irrigation representatives indicated that an appropriate maximum winter area is about 3,000 ha;

Consideration of these specific issues resulted in an appropriate maximum total valley planted area for the Cap scenario in the Gwydir IQQM of 83,800 ha. This figure is for both summer (80,903 ha) and winter (2,897 ha) crops irrigated from regulated water supplies and includes 700 ha of HS irrigation for permanent crops. Note that both the HS and GS permanent crop areas are included in the summer crop area figures only. This maximum total valley planted area is disaggregated to each irrigation node (Table F.2) and remains constant for the entire simulation period.

This analysis provides a similar result to a previous recommendation by the Independent Audit Group to adopt a maximum area of 80,000 ha for Cap conditions modelling.

4.4.3.3 Minimum area

The concept of a minimum planted area is based on the notion that, during severely resource constrained seasons, irrigators will still 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. We also recognise that if there is no resource available at all, then there would be no planted area. This behaviour is consistent with that reported during the irrigators' surveys and Pers. comm. [2004-2005].

Determination of an appropriate minimum area to adopt for the 1993/94 Cap scenario in IQQM is not a simple process considering there are a number of factors that need to be considered including:

- climatic variability;
- historical increases in development;
- variation in irrigators' behaviour both for each individual from year to year and from individual to individual, due to any number of reasons including economic factors;
- variations in figures obtained from different data sources.

Specifically in the Gwydir IQQM, we considered the following issues:

1) Up to the early 1990's there are a number of years of 0% AWD with little or no opportunity to store or harvest water from other sources. Therefore we would expect the historical minimum planted area to be reasonably indicative of the true minimum area up to that date;
2) The minimum total valley planted areas in the years from the mid-1980's up to 1994/95 (which was the worst year of an extended drought sequence) yields a figure of 10,260 ha in 1994/95 based on DNR's data (Table 2.5);
3) The minimum individual irrigator planted areas in the years from the mid-1980's up to 1994/95 indicates that the 1994/95 season was also a reasonably good indication of the minimum individual planted areas;
4) There was little information available on planted winter areas. Discussion with irrigation representatives indicated that an appropriate minimum winter area is 0 ha;

Consideration of these specific issues resulted in an appropriate minimum total valley planted area for the Cap scenario in the Gwydir IQQM of 9,058 ha. This figure is for crops irrigated from regulated water supplies and includes 700 ha of HS irrigation for permanent crops. This minimum total valley planted area is disaggregated to each irrigation node (Table F.2) and remains constant for the entire simulation period.

4.4.3.4 Farmers' risk function

The concept of a farmers' risk function is 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 reality, the farmer determines an appropriate ML/ha at the start of each irrigation season to decide how much area to plant based on the amount of resources available.

Determination of an appropriate farmers' risk function to adopt for the 1993/94 Cap scenario in the Gwydir IQQM is not a simple process considering there are a number of factors that need to be considered including:

- the full range of climatic variability and resource availability;
- historical increases in development;
- variation in irrigators' behaviour both from individual to individual and from year to year, due to any number of reasons including economic factors;
- variations in figures obtained from different data sources.

This process is a combination of calibration (Section 3.7) and consideration of the fact that the risk function can vary over time and therefore we need to examine years that are representative of the scenario being configured. For the 1993/94 Cap scenario, we chose to focus on the period 1988/89 to 1994/95 to derive an appropriate risk function, as there was consistent behaviour and development throughout this period. Therefore we used the parameters derived during area calibration over this period for each individual irrigation node.

There was little information available on planted winter areas. Discussion with irrigation representatives and a review of the cropping data indicated that the winter planting decision is goverened by other factors than just available resource, such as likely water availability for the next summer crop, and the commodity prices. An appropriate application rate in deciding how much winter crop to plant was determined such that the average winter planted area of about 2,350 ha (ie 80% of the maximum winter area) was achieved in the long term simulation. This is achieved with a winter risk application rate of 25 ML/ha in the model.

The weighted average total valley risk function for the 1993/94 Cap scenario is presented in Figure 4.2. The small triangular points marked on this figure are the output from the latest 1993/94 Cap scenario for each individual year of the simulation, overlaid with relevant historical data. The parameters for each irrigation node's risk function are presented in Table F.3.

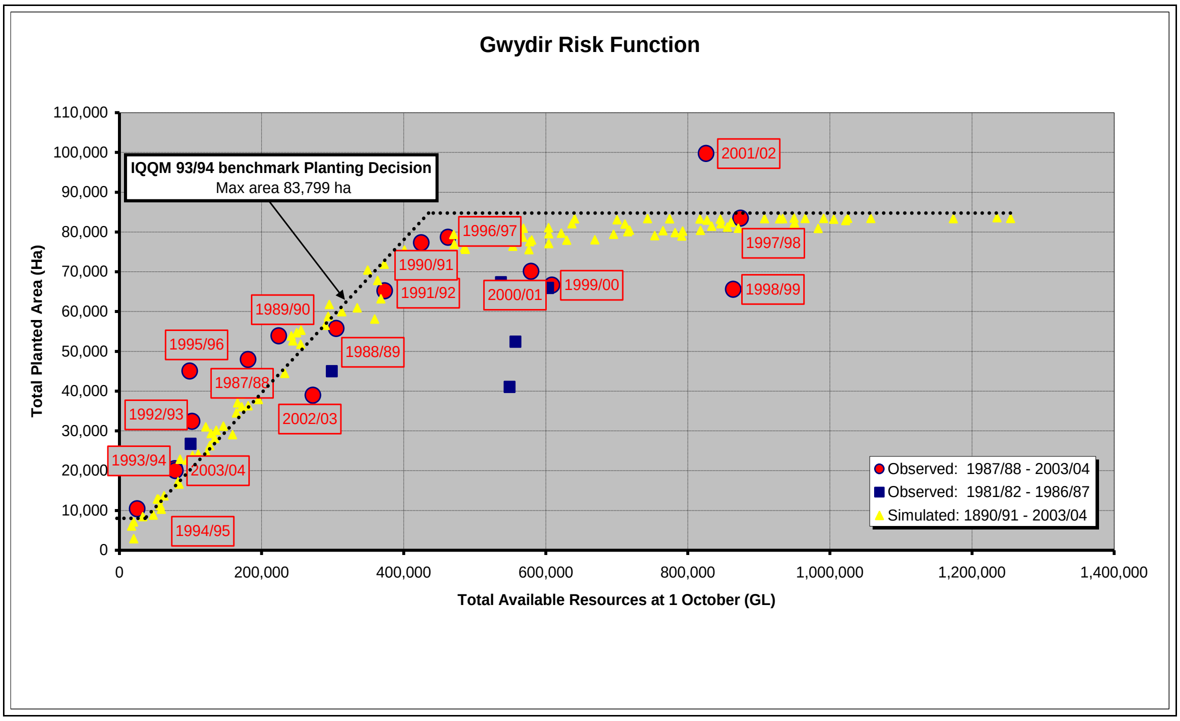

Figure 4.2: Historical and simulated total valley planting risk for the 1993/94 scenario

4.4.4. End-of-year diversions

The Gwydir Valley has significant on-farm storages, and the observed diversion data shows evidence of ordering on-allocation water in September. This water is either directly applied to fallow ground prior to crop planting (pre-watering) or stored in the on-farm storage for use after the crop has been planted (watering up). This behaviour is generally for the benefit of the crops, but may also be in part due to a use-it-or-lose it mentality typically developed under annual accounting systems.

Following advice from the irrigators [Gwydir Irrigators Survey and Pers. comm, 2004-2005] we configured the Gwydir IQQM 1993/94 scenario to use end-of-year diversions (in September) for pre-watering of the following season's crops. All irrigation nodes order water for pre-watering provided there is water remaining in their accounts. The target application rate used to calibrate the model varies between 1-2 ML/ha, with the calibrated figures implemented in the 1993/94 scenario.

4.4.5. Transfer market

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.

Although there appears to be some anecdotal evidence of water trading within the Gwydir Valley (Section 2.4.6), the model calibration process did not indicate significant permanent market transfers. In addition, there was no data on where this licence volume may be transferred to. For these reasons, no market transfers were assumed in the Gwydir IQQM.

4.4.6. High security irrigation

There is a single HS irrigation node in the Gwydir IQQM with a maximum water share of 13,405 ML/yr to represent the 700 ha permanent pecan nut plantation in the Upper Gwydir.

4.4.7. Unregulated use

The unregulated licenses on tributaries and in the upper catchment have not been included explicitly in the Gwydir IQQM. Colly Farms' access to unregulated Barwon water is represented in the model. Other than this licence, the 1993/94 Cap scenario therefore only relates to the regulated system.

It is important to note, however, that the tributary inflows used in the Gwydir 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 licenses 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 Gwydir 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 licenses explicitly, as discussed in Chapter 5.

4.5. TOWN WATER SUPPLY

Bingara and Gravesend are the only TWS modelled in the Gwydir IQQM 1993/94 scenario. They are modelled as fixed annual demands with a monthly pattern of use. The annual demand for each of these is set to represent 1993/94 diversion levels, as specified in Section 2.5. These annual requirements are also included in the resource assessment.

4.6. STOCK AND DOMESTIC SUPPLY

In the Gwydir Valley, the releases for stock & domestic requirements are considered replenishments. They are configured as per 1993/94 conditions as detailed in Section 4.12.3.

4.7. INDUSTRIAL AND MINING EXTRACTIONS

The industrial and mining extractions (Section 2.7) did not have sufficient annual or monthly extraction data to allow separate configuration in the Gwydir IQQM. However, the 525 ML licence volume is incorporated into the model in the general security irrigation nodes.

If more information on usage patterns becomes available, then these can be modelled explicitly in the Gwydir IQQM. Consideration of this issue will be part of future model improvements (Chapter 5).

4.8. GROUNDWATER ACCESS

No groundwater access has been represented explicitly in the Gwydir IQQM Cap scenario. Consideration of this issue will be part of future model improvements (Chapter 5).

4.9. RESOURCE ASSESSMENT

The typical information required to make resource assessments for the Gwydir Valley was obtained from regional representatives and configured into the Gwydir IQQM. The main features of the resource assessment system that were in place for the 1993/94 season are listed below:

- Copeton Dam is the headwater storage;
- Annual accounting with carry over that is reset to zero at the start of March;
- Maximum AWD of 100%;
- No borrow from the following year's balance;
- The transmission/operational losses are a function of the AWD and time of the year, with the maximum allowance being 120 GL/year;
- The Copeton storage reserve is 40 GL irrespective of Copeton volume and time of the year.

More details and other parameters relevant to the resource assessment are listed in Table F.1.

4.10. RIVER AND STORAGE OPERATION RULES

4.10.1. Tributary utilisation

During extreme drought periods the tributaries do not flow much and the system losses are highly variable, so it is common practice not to utilise the tributary flow to meet irrigation demands. It appears that this practice was adopted in the period around 1993/94 since the best calibration (Section 3.6.2) and validation (Section 4.13.6) for this period was achieved with the tributary utilisation set to zero.

Since we do not have the facility to vary the tributary utilisation in the scenario runs, we considered it more important to adopt values that are representative of long-term river operation. In non-drought periods (most of the time), higher tributary utilisation factors appear to be appropriate, and were adopterd for the long-term scenario ahead of those observed in the 1992 – 1995 drought.

The adopted tributary utilisation values are presented in Table B.6.

4.10.2. Operational surplus

The over-order factors developed in calibration (Section 3.6.3) and described in Table B.7 were adopted for the Cap scenario.

4.10.3. Flood mitigation releases

Copeton Dam is operated as a gated storage node with spillway release rules adopted as per the flood mitigation zone release rules explained in Section 2.10.3. There has been no major changes to flood operation practices between the start of the calibration period and those used in 1993/94 or currently.

4.11. SURPLUS FLOW ACCESS (SUPPLEMENTARY WATER)

The supplementary water thresholds developed in calibration (Section 3.5.3) and described in Table F.5 were adopted for the Cap scenario.

4.12. RIVER FLOW REQUIREMENTS

4.12.1. Flow constraints

The flow constraints described in Section 2.12.1.1 were configured in the Gwydir IQQM 1993/94 Cap scenario.

4.12.2. Minimum flows

The minimum flow requirements described in Section 2.12.1.2 were configured in the Gwydir IQQM 1993/94 Cap scenario.

These minimum end-of-system flow requirements are supplied from Copeton Dam if the surplus flows at the target location are not met from downstream tributaries. In addition, analysis of the historical Copeton releases [DWR, 1979-2001] demonstrated that the minimum storage releases over the relevant period are between 25 ML/day and 35 ML/day. Therefore, a minimum flow requirement of 30 ML/day just downstream of Copeton Dam is also configured in the 1993/94 Cap scenario.

4.12.3. Stock & domestic replenishments

The stock and domestic replenishment requirements described in Section 2.12.1.3 were configured in the Gwydir IQQM 1993/94 Cap scenario as antecedent conditions based release volumes made over a number of days in February to March and August to September if required.

These releases are triggered if the specified replenishment volume has not arrived at this location in the 4 months preceding the replenishment dates. The replenishment release is made until either the total flow volume at that location, including those in the preceding window equate to the target replenishment volume or there is no water left in the account for the replenishment.

4.12.4. Environmental flows

There were no specific environmental flow rules (other than those listed above) in the Gwydir Valley under 1993/94 management rules.

4.13. 1993/94 CAP SIMULATION MODEL VALIDATION

To assess the robustness of the 1993/94 Cap scenario, a simulation was performed over the period where irrigation development and management rules were closest to 1993/94 conditions.

Using the irrigation seasons immediately before and after the 1993/94 water year was not feasible because these were years of severe resource constraint in the Gwydir Valley and the validation would have been inconclusive. Closer examination of this drought shows that it commences in the 1992/93 irrigation season and finishes in late 1994/95, with a recovery by the start of the 1995/96 irrigation season. The years prior to this had more resources available and we thought it would be useful to include them in the validation despite the lack of accurate data over those years. Therefore we chose the period from 1988/89 to 1994/95 to validate the 1993/94 Cap scenario.

The proposed parameters for the 1993/94 Cap scenario are then configured into the model and the model is run for this period.

The observed and simulated results were compared for a number of processes including AWD's (Figure 4.3), planted areas (Figure 4.4), ONA diversions (Figure 4.5), SW diversions (Figure 4.6) and Copeton storage behaviour (Figure 4.8).

Table 4.1: Key observed vs simulated parameters for 1988/89 – 1994/95

Parameter		1988/89	1989/90	1990/91	1991/92	1992/93	1993/94	1994/95
AWD (%)								
October	Modelled	31	11	91	16	0	0	0
	Observed	33	20	60	35	0	0	0
Areas (Ha)								
Total	Modelled	58,019	39,747	81,515	57,881	15,641	19,688	4,800
	Observed	55,744	53,886	77,282	65,212	32,398	21,280	8,961
	Difference	+4%	-26%	+5%	-11%	-52%	-7%	-46%
Diversions (GL)								
Total	Modelled	328	262	378	317	95	74	52
	Observed	300	292	393	261	143	48	64
	Difference	+9%	-10%	-4%	+21%	-33%	+54%	-19%
On-allocation	Modelled	242	105	282	299	50	30	15
	Observed	204	135	286	248	99	9	0
Supplementary water	Modelled	86	158	96	18	46	45	37
	Observed	96	157	107	13	44	39	64
Diversions/Area Ratio (ML/Ha)								
	Modelled	5.7	6.6	4.6	5.5	6.1	3.8	10.8
	Observed	5.4	5.4	5.1	4.0	4.4	2.3	7.1
Flows (GL)								
Copeton releases	Modelled	369	176	446	439	114	88	66
	Observed	342	258	451	392	195	65	44
	Difference	+8%	-32%	-1%	+12%	-42%	+35%	+50%
Pallamallawa	Modelled	567	558	675	479	216	175	197
	Observed	511	564	n/a	389	265	122	153
	Difference	+11%	-1%	n/a	+23%	-18%	+43%	+29%

4.13.1. Discussion of observed and simulated AWD's

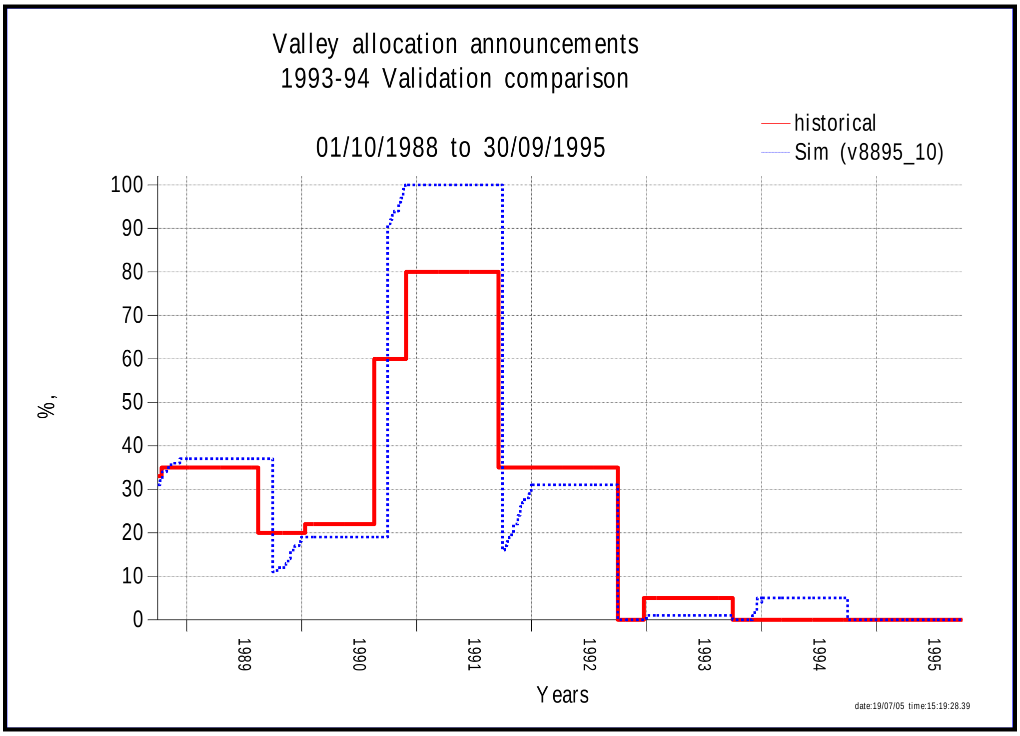

Figure 4.3: Validation of the 1993/94 Cap scenario for AWD's

Other than in the 1990/91 season, the model achieved a good replication of the historical AWD's, as demonstrated in Figure 4.3.

In 1990/91, the simulated AWD reached 100% whereas it only reached 80% in reality. Further analysis of the historical AWD announcements revealed that in this season, a much higher than usual carry over reserve was adopted in Copeton Dam. This effectively reduces the amount of water available for the AWD. DNR's resource assessment calculation records show that 220 GL and 100 GL of storage reserve was applied in August/September and November, 1990 respectively. In the other years of this validation period, the carry over reserves varied from 20 GL to 70 GL, with an average of approximately 40 GL. In the 1993/94 scenario (and therefore in this validation) we adopted a static carry over reserve of 40 GL (Section 4.9), thus resulting in the higher simulated AWD in the 1990/91 irrigation season.

In some years, the simulated AWD started at lower levels at the beginning of the water year and caught up with the historical AWD later in the season. This was due to differences in the timing of the inflows to the dam between those produced by the model and inflows observed in those years.

4.13.2. Discussion of observed and simulated areas

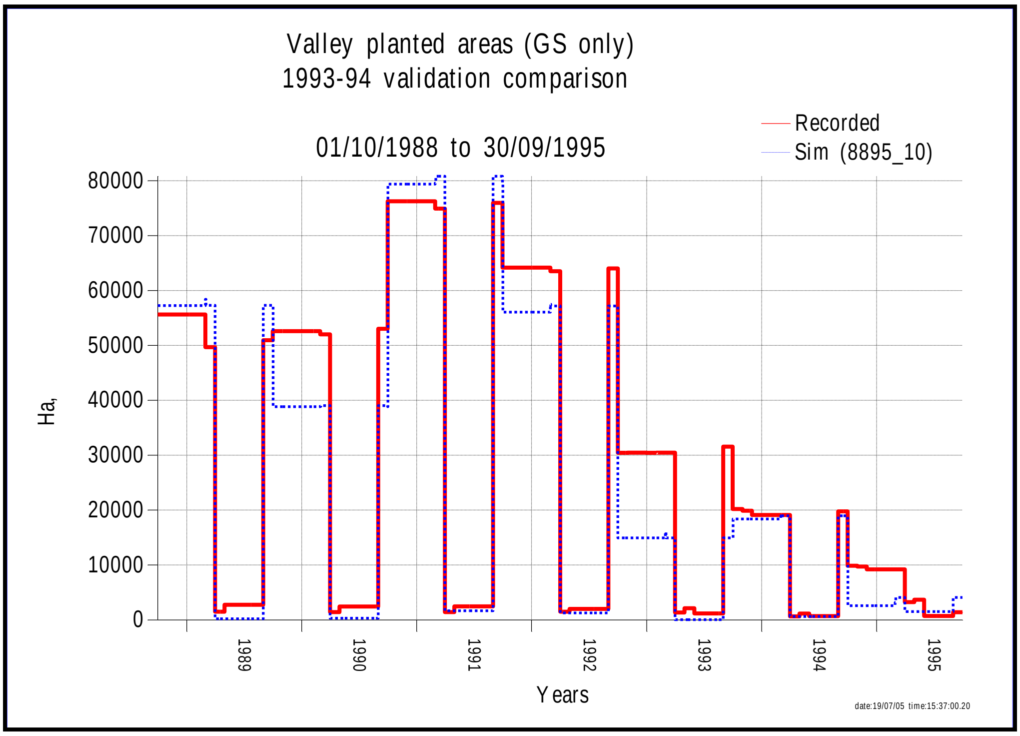

Figure 4.4: Validation of the 1993/94 Cap scenario for planted areas

When comparing the observed and simulated planted areas, over the 1988/89 to 1994/95 validation period, there are a number of major factors that affect the results:

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

A comparison of the observed and simulated areas shows that in general there is a good overall match (Figure 4.4) considering:

- the model uses a fixed average risk taking behaviour over this period. In reality, this behaviour varies on both an individual-to-individual basis and a year-to-year basis, depending on economic factors and farmer-specific decisions;
- the model's planting decision is made on the specified date only (1st October) based on the available resources on that date. In reality, the planting decision can be made within a certain time window based on a number of factors;
- the model uses a fixed crop mix representative of the 1993/94 season over the entire validation period. Even when the overall valley's mix in a particular year may be very similar, on a reach by reach basis it may vary significantly which would impact on water ordering and

distribution within the system and affect resource availability at the next winter or summer crop decision date;

- wherever possible we set the model's initial conditions at the beginning of the validation period to match the historical data, for example Copeton storage volume and irrigation account balances. Where this information is unknown, we had to estimate the starting values based on other information, for example the OFS stored volumes. Other parameters in the model have fixed starting values and these could also differ from reality, for example the soil moisture store.

4.13.3. Discussion of observed and simulated ONA diversions

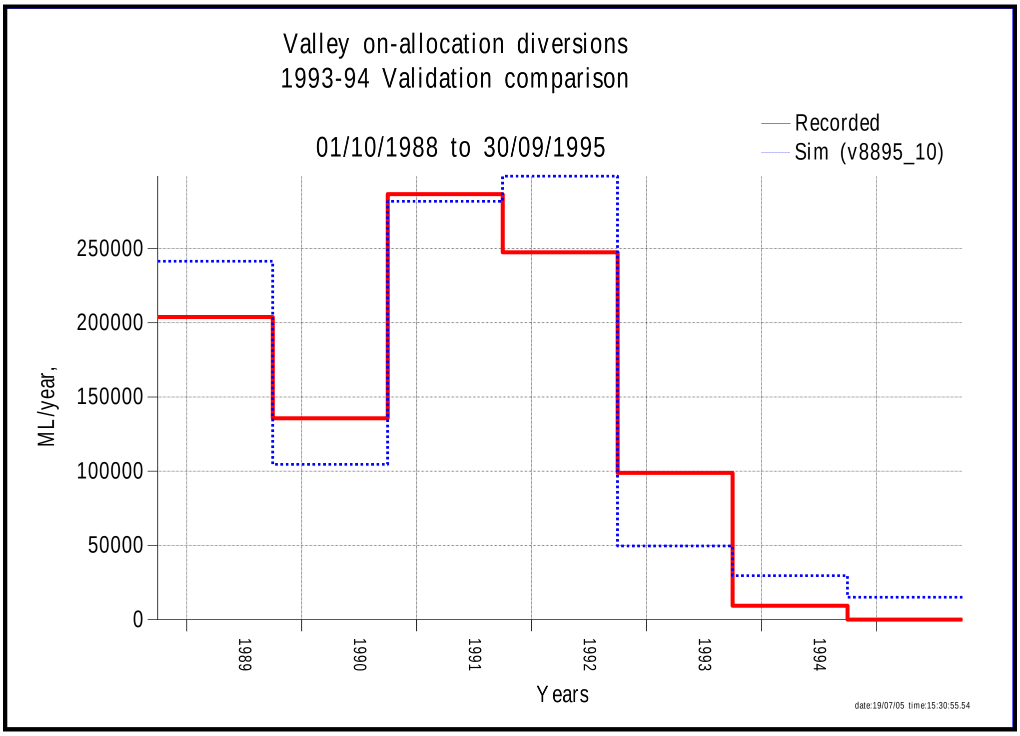

Figure 4.5: Validation of the 1993/94 Cap scenario for ONA diversions

When comparing the observed and modelled ONA diversions over the 1988/89 to 1994/95 validation period, there are a number of major factors that affect the results:

- the differences between observed and modelled planted areas will flow onto differences in the ONA diversions;
- the ONA diversions are directly impacted by the volume of SW, FPH and RFH extractions;
- the ONA diversions are directly impacted by the initial OFS volume.

A comparison of the simulated and historical ONA diversions shows that the overall match achieved is 104%. This is considered a very good match considering the factors listed above.

4.13.4. Discussion of observed and simulated SW diversions

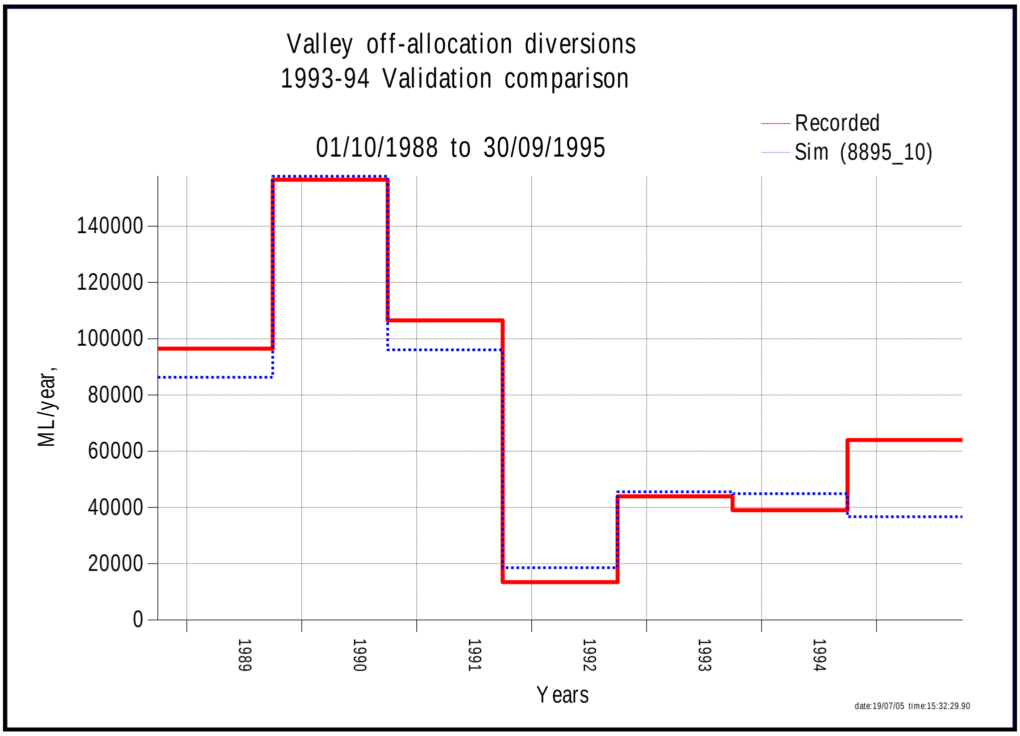

Figure 4.6: Validation of the 1993/94 Cap scenario for SW diversions

When comparing the observed and modelled SW diversions over the 1988/89 to 1994/95 validation period, there are a number of major factors that affect the results:

- the SW diversions are directly impacted by the volume of OFS available during a supplementary water event. Therefore, a number of factors including FPH and RFH extractions, OFS airspace and reserves together with the supplementary water event size all affect the results;
- the SW access thresholds are dynamic in reality whereas in the model a single, static set of monthly supplementary water thresholds are used;
- the OFS operation (i.e. airspace and reserves) is modelled using a static set of monthly values (% and ML/ha respectively). In reality those values may change significantly from year to year based on a number of reasons including climatic conditions. For example, bigger OFS airspaces and lower reserves are typically used by the irrigators in wetter years.
- the SW diversions are directly impacted by the initial OFS volume;
- there was a general growth in the volume of OFS capacity over the validation period from about 100 GL to 300 GL (Table 2.7). In the validation model, the capacity remains static at 1993/94 levels;

A comparison of the simulated and historical SW diversions shows that the overall match achieved is 94%.

4.13.5. Discussion of observed and simulated Total diversions

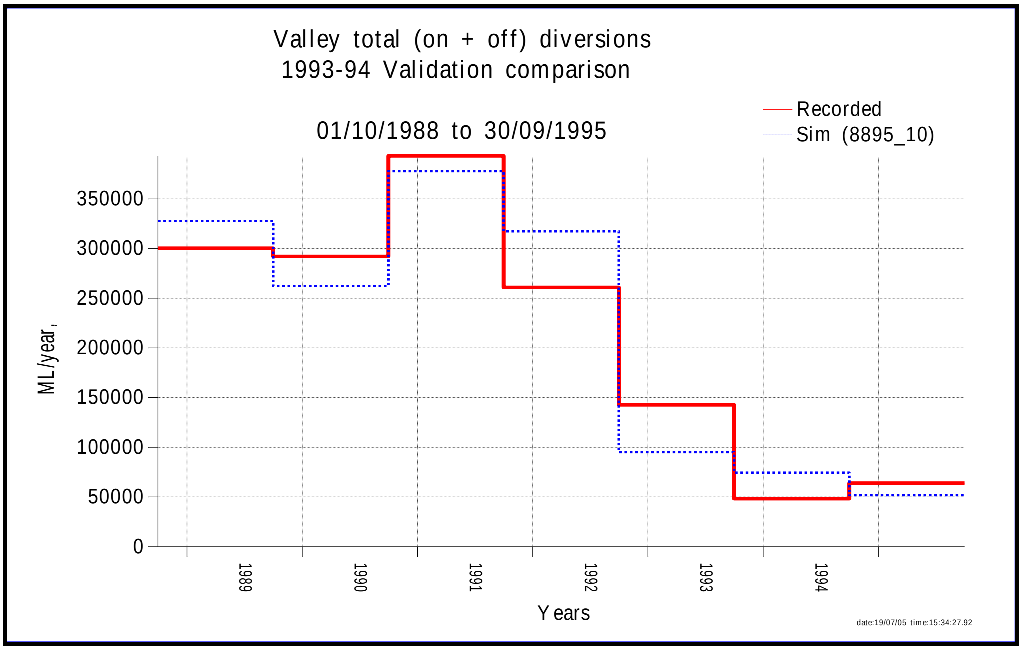

Figure 4.7: Validation of the 1993/94 Cap scenario for Total (ONA + SW) diversions

Given all of the difficulties in achieving a 100% match for both ONA and SW diversions separately during the validation, our primary target was to achieve a good match for the total auditable valley extractions, as demonstrated in Figure 4.7.

The total diversion (combined ONA and SW diversions) match is approximately 100%. This is considered a very good match considering the factors listed in Sections 4.13.3 and 4.13.4.

4.13.6. Discussion of observed and simulated storage behaviour

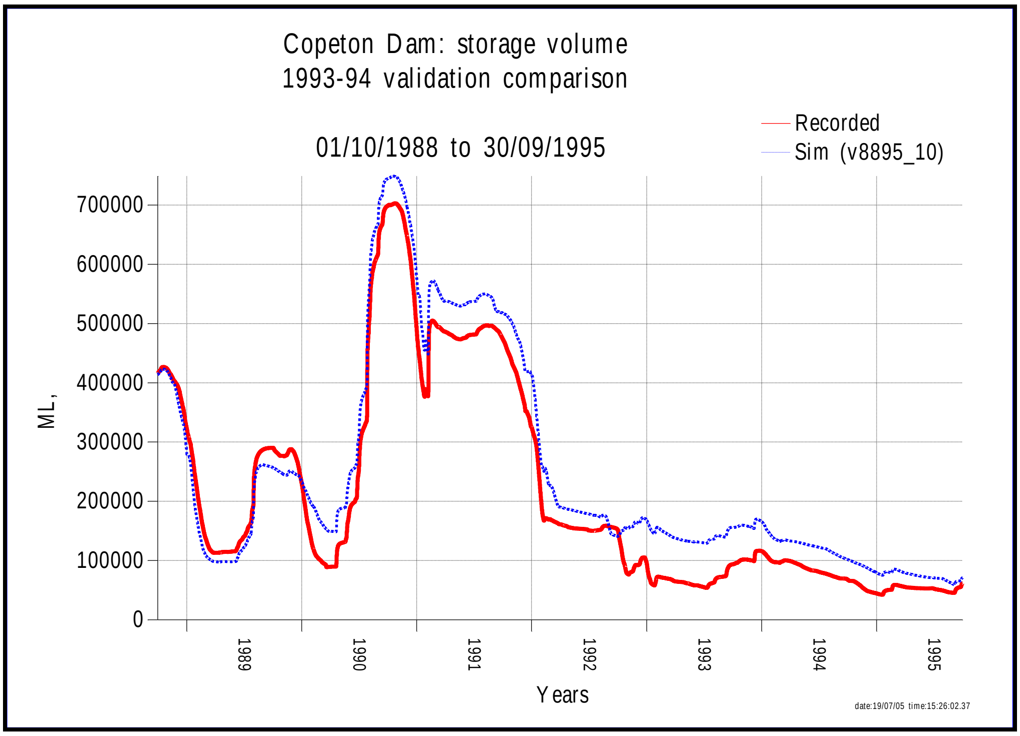

Figure 4.8: Validation of the 1993/94 Cap scenario for Copeton Dam storage behaviour

When comparing the observed and modelled Copeton storage behaviour over the 1988/89 to 1994/95 validation period, there are a number of major factors that affect the results:

- the storage behaviour is directly affected by the outflows, which are in turn governed by the ONA diversions. Therefore any differences in these diversions will have a flow-on affect to the storage behaviour;
- the tributary utilisation and operational surpluses are dynamic in reality whereas in the model static values are used for each of these parameters;
- the model uses static, average losses in the river reaches as a function of river flow. In reality, these losses also vary as a result of antecedent conditions;

The yearly change in storage (between the start and end of a water year) in years with approximately the same amount of on-allocation water diverted such as 1992/93 and 1993/94 is very similar to that recorded. However, detailed analysis of the storage volume as a function of irrigation demand for both simulated and recorded data showed that the difference in irrigation demand/diversions is not the only reason for differences encountered in storage behaviour.

For example, about 8 GL of on-allocation water was diverted and about 18.5 GL released to satisfy stock and domestic requirements (S&D) in the model in 1993/94. In reality, no ONA diversions and 20.5 GL of S&D requirements were released. The difference in Copeton's volume in that year in the model, though, was in excess of 18 GL. In contrast, there were lower irrigation demand/diversions in

December to February in the model (considering that significantly more was released in reality in August – September, whereas the yearly totals are the about the same – 271 GL) results in a larger drawdown in Copeton's volume in January - February. This is caused by the use of average losses in the model, which underestimate demand in very dry years while overestimating it in very wet years.

In addition, some timing differences in storage releases can be observed in the 1992/93 irrigation season. This can be explained by the operation decision in that year to release 71,640 ML of irrigators' carry over from the previous year in the first two weeks of the 1992/93 irrigation season. In the model irrigation demand in 1992/93 is not triggered before late November because of the much smaller areas planted.

During extreme drought periods the tributaries do not flow much and the system losses are usually higher, so it is common practice allow for higher losses. However, due to constant losses used in the model it appears as if tribs are underutilised on such ocasions. It appears that this practise was adopted in the period around 1993/94 since the best validation for this period was achieved with the tributary utilisation set to zero. The presented validation graphs use the tributary utilisation as per that adopted for the long-term scenario.

4.13.7. Overall conclusions

The validation of the 1993/94 scenario over the 1988/89 to 1994/95 period is considered to be very good considering the model uses:

- a static level of development over this period;
- a static set of management rules over this period, with simplified stock & domestic releases and environmental flow rules;
- a static set of monthly SW access thresholds;
- a static set of river losses based on the current river flow only;
- a static farmers' risk function for each irrigation node;
- a static crop mix for each irrigation node;
- a simulated upstream model to generate inflows to Copeton Dam;
- a static set of tributary utilisation factors;
- a static set of operational surplus factors;
- a single planting decision date with no capability to review planted areas during the season.

4.14. 1993/94 CAP SIMULATION MODEL RESULTS

4.14.1. Long term Cap annual diversions

Table 4.2 summarises the model results for the 1993/94 Cap scenario being run over the long-term period from 01/01/1890 to 30/06/2004.

Table 4.2: Summary outputs from the 1993/94 Cap scenario

Category	Component	Average Annual Figures [1]
System file		dev93412.sqq
Water usage	General security on-allocation	225 GL
	General Security supplementary water	112 GL
	High security/stock & domestic/town water supply	9 GL
	Sub-Total [2]	**346 GL**
	Floodplain harvesting	24 GL
	Rainfall runoff harvesting	88 GL
	Total	**458 GL**
Planted areas	Average general security planted area (summer and winter)	60,376 Ha
	Maximum general security planted area (summer and winter)	82,889 Ha
	Average general security planted area (summer)	58,592 Ha
	Maximum general security planted area (summer)	79,993 Ha
	Average general security planted area (winter)	1,784 Ha
	Maximum general security planted area (winter)	2,897 Ha
River flows	Gwydir River at Pallamallawa	779 GL/year
	Gwydir River at Yarraman	211 GL/year
	Mehi River at Moree	428 GL/year
	Carole Creek near Garah	52 GL/year

Gwydir Reliability on 01/10 [3]	100%	75%	50%	5%
(% of years that achieved ≥ stated % effective AWD, where effective AWD = AWD + carry over)	41%	48%	60%	93%

Notes: [1] Long term average annual figures are based on the (01/10/1890 – 30/09/2003) period (October – September water year).
[2] This figure is used for long-term Cap assessment in Table 4.3.
[3] For clarification, these figures indicate that there is a 41% chance of achieving an effective AWD of 100% under Cap conditions in the Gwydir Valley.

4.14.2. 2004/05 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 Gwydir 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. OFS and Copeton Dam stored volumes 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.

Determination of the appropriate historical starting volumes for the OFS is not a simple process because there is no good quality historical data available. To derive a valid estimate, we used a combination of the following:

- an examination of the historical pre-watering and supplementary water extractions in the 1996/97 water year. We used an indicative pre-watering rate of 1.5 ML/ha and determined the required volume of water based on the historical planted areas in 1997/98. The difference between the required volume and the extracted volume gives us an indication of how much water must have already been available in the OFS for pre-watering. Using this method, we determined that the minimum amount of water in the OFS was approximately 60 GL;
- an examination of the historical ONA diversions at the start of the 1997/98 water year in combination with known OFS reserve targets. We used an indicative OFS reserve target of 1.5 ML/ha and determined the required volume of water based on the historical planted areas in 1997/98. The difference between the required volume and the extracted volume gives us an indication of how much water must have already been available in the OFS for the reserve. Using this method, we determined that an additional 80 GL was in the OFS;
- the calibration model for the period using all known historical information as input. This model simulates the storage volumes prior to pre-watering for the 1997/98 water year of 125 GL. We would expect it to be a reasonable estimate because all known components of the historical data are used as input;
- the long-term 1993/94 Cap scenario starting in 1890. This model simulates the storage volumes at the start of the 1997/98 water year (prior to pre-watering in September 1997) of about 140 GL. but can be different to the historical levels because of the interdependency with previous years.

Based on this analysis, we adopted a starting OFS volume of 125 GL at the start of the 1997/98 water year for the Cap Audit simulation. This is the figure simulated by the calibration model. It is both consistent with the numbers derived using the other methods and is thought to be the best representation of the historical value.

The annual Cap simulation results for the 1997/98 to 2003/2004 irrigation seasons are presented in Table 4.3, with a comparison to the observed data. These results show for the Gwydir Valley, at the end of the 2004/05 water year, that the cumulative observed diversions are 224 GL below the diversions predicted by the model. Thus we can conclude that the Gwydir Valley is not in breach of Schedule F of the MDBMC Cap.

Table 4.3: Gwydir Valley Schedule F account to 2004/05

Water year	Historical Total Diversions (GL)	Simulated Total Diversions (GL)	Difference (GL)	Cumulative Difference (GL)
1997/98	521	613	-93	-93
1998/99	295	263	+32	-61
1999/00	433	486	-53	-113
2000/01	414	306	+108	-6
2001/02	450	434	+16	+10
2002/03	228	398	-170	-160
2003/04	159	116	+43	-117
2004/05	159	259	-107	-224
Cumulative total	**2,500**	**2,620**	**-224**	
Cumulative Performance			Below Cap	
Long-term average	)	346 (1)		
20% Tolerance		69		
Trigger Performance		n/a (2)		

Notes: (1) Average based on 1890/91 to 2002/03 period, as per Table 4.2.
(2) Not applicable because the Cumulative Performance is Below Cap.

5. Improvement Plans

Maintenance of the Gwydir IQQM is an ongoing process and includes updating the model for:

- New generic IQQM capabilities;
- Improvements to existing model capabilities, including bug-fixes;
- 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 MDBC will be informed of the changes to the results and the reason why the changes have occurred.

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

5.1. UPGRADES TO THE FLOW CALIBRATION

5.1.1. Extended streamflow records

Since the outset of implementing the Gwydir IQQM, it has been intended that the flow calibration of the individual reaches would be reviewed based on the availability of more recent and better quality streamflow data. It is envisaged that this upgrading process would occur on approximately a five (5) year cycle. The flow calibration has not been updated since 2000, therefore it does not include the recent drought period. This period could provide some useful information on losses at low flows and during dry periods. Reviewing the flow calibration is a large task because it involves the collection, analysis and disaggregation of flow data and diversion data for all reaches.

The calibrated Sacramento models used to extend the inflow data to cover the simulation period could also be reviewed based on new streamflow information at the gauged tributaries.

5.1.2. Moomin Ck offtake flow constraint

The Moomin Creek offtake has an outlet capacity that prevents on-allocation ordered water being supplied when needed and supplementary water being equally shared between the Mehi/Moomin systems. In a practical operation sense these problems are overcome by pre-ordering on-allocation water and rostering of supplementary water. The Gwydir IQQM does not represent this behaviour at present because it assumes there are no outlet capacity problems at the Moomin Creek offtake. Enhancements to the IQQM code would have to be made to simulate actual conditions. Re-calibration of the model would also be required.

5.1.3. Antecedent conditions based losses

Incorporation of antecedent conditions in river losses. This would take into account that losses are probably higher if they are preceded by a drought period as opposed to a period of floods.

5.1.4. Variable river surface area based on streamflow

This will provide a better representation of varying evaporation from the water surface based on streamflow and therefore better representation of the source of losses and gains in a river reach.

5.2. UPGRADES TO THE DEMAND AND AREA CALIBRATION

5.2.1. Improved modelling of rainfall and floodplain harvesting

Both floodplain harvesting and rainfall runoff harvesting appear to be major water resources used by some Gwydir Valley irrigators. Calibration of the Gwydir IQQM could only be achieved when these processes are represented in the model (Section 3.5). At this stage however, there is no detailed information on quantities of water accessed from these sources. Better monitoring and access to data would improve our representation of these processes in the Gwydir IQQM.

5.2.2. Extended irrigation demand data

As for the flow calibration, it is also intended that the demand calibration would be reviewed based on the availability of more recent and better quality crop area and irrigation extraction data. DNR is currently reviewing collected area data with a view to centralising the databases and analysing the quality of the data. It is also possible that remote sensing capabilities may improve in the short to medium term, providing better estimates of cropped areas. This improved data may allow for recalibration of the Gwydir IQQM in the future. It is envisaged that this upgrading process would occur on approximately a five (5) year cycle.

5.2.3. Crop modelling using crop model 3

This improved crop module will incorporate varying ‘windows of opportunity’ for planting, crop growth based on degree-days and determine the effect on crop yield due to water shortage. The new module will also simulate farmer behavioural practices, such as changing crop areas and mix in response to past and present resource availability.

5.2.4. Representation of transfer market

At present, the transfers are either assumed to be insignificant or a simplified approach is used to represent this mechanism (Section 4.4.5).

Better information on the water trading market in terms of volumes traded, reasons for trading and locations the water is traded from and to will allow the incorporation of a dynamic water trading module in the Gwydir IQQM.

5.2.5. Better spatial representation of rainfall used to generate crop demands

Gwydir IQQM performs a dual role for long term simulation and short term MDBC Cap Auditing. Therefore, only 9 long term rainfall sites were calibrated into the model to represent rainfall at the irrigation nodes (Table A.1). These results in a certain amount of smoothing of orders placed by the irrigation groups, since their demands are being generated based on similar rainfall data. In reality, there is a much larger degree of spatial variability in the rainfall.

Investigations could be undertaken to see if shorter term rainfall sites can provide more information on spatial variability of rainfall on the irrigation areas. These rainfall sites could then be extended to cover the long term simulation period and incorporated into the simulation model.

5.2.6. Improved representation of on-farm storage usage

On-farm storage operation in the model is currently based on reported irrigator behaviour and to achieve the best possible diversion calibration. However, as more information becomes available, it may be possible to represent explicitly on-farm activities such as reuse of irrigation tailwater and division of on-farm storages into cells to reduce evaporation.

5.2.7. Explicit representation of unregulated users

Explicit representation of unregulated irrigation extractions on tributary inflows and upstream of Copeton Dam. This may also require a review of inflow contributions from these tributaries.

5.2.8. Explicit representation of industrial, mining and other high security users

The industrial, mining and other high security extractions did not have sufficient annual or monthly extraction data to allow separate configuration in the Gwydir IQQM. However, the 525 ML license volume is incorporated into the model in the general security irrigation nodes.

If more information on usage patterns becomes available, then these can be modelled explicitly in the Gwydir IQQM.

5.2.9. Town water supply modelling

Replace the fixed monthly pattern modelling approach with a demand calibrated to climate (rainfall and evaporation) and population.

5.3. UPGRADES TO THE STORAGE BEHAVIOUR MODELLING

5.3.1. Variable tributary utilisation

IQQM currently uses a fixed factor to represent recessions on current flows when estimating the flow that will contribute to meeting order requirements. In reality, this prediction is a function of many factors including the preceding flows (ie rising or falling) and the time of year.

5.3.2. Variable operational surplus

IQQM currently uses a fixed over-order factor to represent long-term operational surplus. In reality, this factor is a function of many factors including the magnitude of the orders, antecedent conditions and time of year.

5.3.3. On-river weir modelling

Only one of the existing six on-river weirs (Tareelaroi Weir) is currently incorporated into the Gwydir IQQM. This is because the small on-river weirs cause an irrigation order pulsing problem in the past. Recent code developments in IQQM have improved on-river weir modelling and we may need to investigate incorporating these weirs into the model, with appropriate testing and re-calibration.

5.4. GENERAL UPGRADES

5.4.1. Water Year Change for WSP scenario

The water year change from October – September to July – June in the 2003/04 water year has not been incorporated into the WSP scenario. At present, we still model the water year as being October – September because we are getting an unresolved problem with the simulation shut-down when we change to the July – June water year. When we resolve this problem and change to a July – June water year in the model, the differences are expected to be insignificant since the Valley uses a continuous accounting system.

5.4.2. Separation of consumptive users from environmental requirements

Currently in the model, there are a number of replenishment flows that are non-consumptive. In reality, these are provided for a combination of consumptive users, such as stock and domestic supply, and non-consumptive users, such as minimum flows for instream habitat. This improvement will require an assessment of current replenishment flow volumes and their intended purposes.

5.4.3. Incorporate any access to groundwater resources

Modelling of groundwater access to supplement surface water to meet irrigated crop water requirements, especially in dry/low AWD years. This would require an investigation of the extent of groundwater use and a relationship with surface water access and crop water requirements.

5.4.4. Improved modelling of Gwydir Wetlands

At present the Gwydir Wetlands are represented as a river reach with no specific routing or storage characteristics. This simple representation could be replaced by either a hydrologic model based on flows at an upstream location or hydraulic model based on water levels. Some work on the hydrologic model has begun at the University of New England, but will not be completed until next year. The hydraulic model will require extensive data collection, but may provide better modelling of inundation areas than the hydrologic model. Modelling of these wetlands could then be linked with ecological models to quantify the effect of valley management and development changes on key ecological processes.

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Appendix A. Climatic and Streamflow Stations

Table A.1: Rainfall stations used in IQQM

Geographic Zone	IQQM Reaches	Rain Gauges		
		Station	Name	Notes
Lake Copeton gap-filled / extended with gap-filled / extended with	Copeton Dam	54128 418035 56006	Copeton Dam Copeton storage gauge Bundarra Post Office	
Gwydir R: Gravesend to Tareelaroi Weir	Gwyd HS, 01a, 01b	54017	Gravesend Post Office	
Gwydir R: Tareelaroi Weir to Brageen Crossing	Gwyd 02a, 03a	53048	Moree Comparison	was M.O.
Gwydir R: Brageen Crossing to Millewa	Gwyd 03b	52017	Garah (Iolanthe)	
Gwydir R: d/s Millewa	Gwyd 03c	52010	Weemelah (Crinolyn)	
Mehi R: to Combadello Weir	Mehi 01a, 01b	53048	Moree Comparison	was M.O.
Mehi R: Combadello Weir to Ballin Boora Ck	Mehi 02, 03	53014	Gurley (Glenroy)	× 0.957
Mehi R: Ballin Boora Ck return to Bronte	Mehi 04, CollyC	52002	Rowena (Iffley)	
Mehi R: d/s Bronte	Mehi 05, CollyM	48031	Collarenebri (Viewpoint)	was Post Office
Moomin Ck: to Clarendon Bridge	Moomin 01a, 01b	53014	Gurley (Glenroy)	× 0.957
Moomin Ck: Clarendon Bridge to Alma Bridge	Moomin 02	52008	Rowena (Bunna Bunna)	
Moomin Ck: d/s Alma Bridge	Moomin 03, 04, CollyI	52002	Rowena (Iffley)	
Carole Ck: Boolooroo Weir to Garah	Car 01	52017	Garah (Iolanthe)	
Carole Ck: Garah to Gil Gil Ck Junction	Car 02a	52020	Mungindi Post Office	× 0.915
Gil Gil Ck: Carole Ck junction to Weemelah	Car 02b	53011	Garah Post Office	
Gil Gil Ck: d/s Weemelah	Car 02c	52020	Mungindi Post Office	× 0.915

Table A.2: Rainfall stations used for Sacramento rainfall-runoff modelling

Catchment	Rain Gauges		
	Station No	Name	Thiessen Weight
Horton R. @ Rider (Killara) (418015)	54014	Bingara (Derra Derra)	0.50
	54021	Barraba (Mount Lindsay)	0.50
Warialda Ck. @ Warialda No3 (418016)	54029	Warialda Post Office	1.00
Myall Ck. @ Molroy (418017)	54029	Warialda Post Office	0.25
	56018	Inverell Research Centre	0.75
Keera Ck. @ Keera (418018)	54039	Bingara (Keera)	0.60
	56006	Bundarra P.O	0.40
Halls Ck. @ Bingara (418025)	54004	Bingara Post Office	1.00
Tycannah Ck. @ Horseshoe Lagoon (418032)	54017	Gravesend Post Office	1.00

Table A.3: Evaporation stations used in IQQM

Geographic Zone	IQQM Reaches	Evaporation Gauges		
		Station	Name	Weight
Lake Copeton gap-filled / extended with	Copeton Dam	54128 54039	Copeton Dam Bingara (Keera)	100% -
Gwydir R: Gravesend to Tareelaroi Weir	Gwyd HS, 01a, 01b	53048 54036	Moree Comparison Wallangra Station	74% 26%
Gwydir R: d/s Tareelaroi Weir	Gwyd 02a, 02b, pool, 03a, 03b, 03c	53048 52026	Moree Comparison Walgett Council Depot	80% 20%
Mehi R: to Gundare Regulator	Mehi 01a, 01b, 02	53048 52026	Moree Comparison Walgett Council Depot	91% 9%
Mehi R: Gundare Regulator to Bronte	Mehi 03, 04, CollyC	53048 52026	Moree Comparison Walgett Council Depot	61% 39%
Mehi R: d/s Bronte	Mehi 05, CollyM	53048 52026	Moree Comparison Walgett Council Depot	36% 64%
Moomin Ck: Combadello Weir to Alma Bridge	Moomin 01a, 01b, 02	53048 52026	Moree Comparison Walgett Council Depot	80% 20%
Moomin Ck: d/s Alma Bridge	Moomin 03, 04, CollyI	53048 52026	Moree Comparison Walgett Council Depot	51% 49%
Carole Ck: Boolooroo Weir to Garah	Car 01	53048 52026	Moree Comparison Walgett Council Depot	95% 5%
Carole Ck: Garah to Gil Gil Ck junction	Car 02a	53048 52026	Moree Comparison Walgett Council Depot	65% 35%
Gil Gil Ck: d/s Carole Ck junction	Car 02b, 02c	53048 52026	Moree Comparison Walgett Council Depot	65% 35%

Table A.4: Evaporation stations used for Sacramento rainfall-runoff modelling

Catchment	Rain Gauges		
	Station No	Name	Thiessen Weight
Horton R. @ Rider (Killara) (418015)	54014 54021	Bingara (Derra Derra) Barraba (Mount Lindsay)	0.50 0.50
Warialda Ck. @ Warialda No3 (418016)	54029	Warialda Post Office	1.00
Myall Ck. @ Molroy (418017)	54029	Warialda Post Office	1.00
Keera Ck. @ Keera (418018)	54039	Bingara (Keera)	1.00
Halls Ck. @ Bingara (418025)	54004 54039	Bingara Post Office Bingara (Keera)	0.51 0.49
Tycannah Ck. @ Horseshoe Lagoon (418032)	54004 54017 54021	Bingara Post Office Gravesend Post Office Barraba (Mount Lindsay)	0.31 0.50 0.19

Table A.5: Main-stream gauging stations used in Gwydir IQQM

Gauge Number	Gauge Name	Period of Record *
UPSTREAM OF COPETON DAM *for calibrating long term Copeton inflow model*		
418029	Gwydir R.@ Stonybatter	13/06/1967 to 31/12/1988
418008	Gwydir River @ Bundarra	03/12/1936 to 02/11/2003
DOWNSTREAM OF COPETON DAM *for calibrating in-stream losses, routing and residual catchments*		
418026	Gwydir River d/s Copeton Dam	22/07/1966 to 23/10/2002
418012	Gwydir River @ Pinegrove	02/09/1949 to 06/05/2001
418013	Gwydir River @ Gravesend Rd Bridge	01/09/1950 to 31/12/2000
418001	Gwydir River @ Pallamallawa	01/01/1892 to 30/09/2000
418042	Gwydir River @ d/s Tareelaroi	20/10/1976 to 06/04/2000
418004	Gwydir River @ Yarraman	01/08/1929 to 30/09/1995
418063	Gwydir River @ d/s Tyreel	24/09/1985 to 28/02/2001
418053	Gwydir River @ Brageen Crossing	23/10/1982 to 30/05/2000
418066	Gwydir River @ Millewa	01/06/1988 to 27/07/2000
418031	Gwydir River @ Collymongle	10/12/1970 to 24/09/1999
418064	Gingham Ck @ Willowlee	09/03/1990 to 24/09/1996
418011	Carole Ck @ Bells Crossing	04/08/1939 to 15/02/2001
418052	Carole Ck near Garah	02/10/1980 to 29/11/1994
416027	Gil Gil Ck @ Weemelah	01/04/1968 to 11/04/2001
416052	Gil Gil Ck @ Galloway	03/06/1987 to 10/04/2001
418044	Mehi R. d/s Tareelaroi Regulator	02/02/1977 to 06/04/2000
418002	Mehi R. @ Moree	01/01/1915 to 02/02/2001
418037	Mehi R. d/s Combadello Weir	10/06/1977 to 05/04/2000
418041	Mehi R. d/s Gundare Regulator	02/10/1980 to 27/02/2001
418068	Mehi R. u/s Ballin Boora Ck	07/02/1989 to 01/12/1999
418058	Mehi R. @ Bronte	07/02/1982 to 13/12/2000
418055	Mehi R. near Collarenebri	12/06/1980 to 13/12/2000
418062	Moomin Ck @ Offtake	01/01/1994 to 30/09/2000
418048	Moomin Ck @ Combadello Cutting	06/05/1982 to 01/03/2001
418060	Moomin Ck @ Glendello	01/12/1990 to 06/03/2001
418067	Moomin Ck @ Clarendon Bridge	23/01/1993 to 06/03/2001
418061	Moomin Ck @ Alma Bridge	01/10/1990 to 14/06/2000
418054	Moomin Ck @ Iffley	16/10/1990 to 19/03/1992
418049	Mallowa Ck d/s Regulator	02/12/1986 to 12/12/2000

Notes: * Period of record used for calibration of Gwydir IQQM.

Table A.6: Tributary gauging stations used in Gwydir IQQM

Gauge Number	Gauge Name	Period of Record *
UPSTREAM OF COPETON DAM *for simulating long term Copeton inflows*		
418021	Laura Ck.@ Laura	01/06/1965 to 18/12/2003
418022	Georges Ck.@ Clerkness	03/04/1966 to 16/01/1989
418023	Moredun Ck.@ Bundarra	03/01/1966 to 12/05/1988
418033	Bakers Ck.@ Bundarra	31/05/1972 to 04/02/1993
418005	Copes Ck.@ Kimberley	17/04/1929 to 06/11/2003
DOWNSTREAM OF COPETON DAM *to meet irrigation orders and environmental requirements*		
418018	Keera Ck @ Keera	01/05/1964 to 16/01/1989
418025	Halls Ck @ Bingara	25/03/1966 to 30/06/2004
418017	Myall Ck @ Molroy	19/05/1964 to 30/06/2004
418015	Horton River @ Rider	30/06/2004 to 30/06/2004
418016	Warialda Ck @ Warialda N°. 3	09/02/1972 to 30/06/2004
418032	Tycannah Ck @ Horseshoe Lagoon	01/06/1971 to 30/06/2004

Notes: * Period of record used for input to Gwydir IQQM.

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Appendix B. Model Calibration Parameters

Table B.1: Streamflow calibration reaches in Gwydir IQQM

Rch	Upstream Location			to	Downstream Location		
	Stream	Station	No.		Stream	Station	No.
UPSTREAM OF COPETON DAM							
00a	Gwydir	Stonybatter	418029	to	Gwydir	Bundarra	418008
00b	Gwydir	Bundarra	418008	to	Gwydir	Copeton Dam	n/a
DOWNSTREAM OF COPETON DAM							
01	Gwydir	Copeton Dam	418026	to	Gwydir	Pinegrove	418012
02	Gwydir	Pinegrove	418012	to	Gwydir	Gravesend Rd Bridge	418013
03	Gwydir	Gravesend Rd Bridge	418013	to	Gwydir	Pallamallawa	418001
04	Gwydir	Pallamallawa	418001	to	Gwydir	d/s Tareelaroi	418042
05	Gwydir	d/s Tareelaroi	418042	to	Gwydir	Yarraman	418004
06	Gwydir	Yarraman	418004	to	Gwydir	d/s Tyreel	418063
07	Gwydir	d/s Tyreel	418063	to	Gwydir	Brageen Crossing	418053
08	Gwydir	Brageen Crossing	418053	to	Gwydir	Millewa	418066
09	Gwydir	Millewa	418066	to	Gwydir	Collymongle	418031
10	Gingham	d/s Regulator	418057	to	Gingham	Willowlee	418064
11	Carole	Bells Crossing	418011	to	Carole	Garah	418052
12	Carole	Garah	418052	to	GilGil	Weemelah	416027
13	GilGil	Weemelah	416027	to	GilGil	Galloway	416052
14	Mehi	d/s Tareelaroi Regultr	418044	to	Mehi	Moree	418002
15	Mehi	Moree	418002	to	Mehi	d/s Combadello Weir	418037
16	Mehi	d/s Combadello Weir	418037	to	Mehi	d/s Gundare Regulator	418041
17	Mehi	d/s Gundare Regulator	418041	to	Mehi	U/S Ballin Boora Ck	418068
18	Mehi	U/S Ballin Boora Ck	418068	to	Mehi	Bronte	418058
19	Mehi	Bronte	418058	to	Mehi	(near) Collarenebri	418055
20	Moomin	Offtake Combadello Cutting	418062 418048	to	Moomin	Glendello	418060
21	Moomin	Glendello	418060	to	Moomin	Clarendon Bridge	418067
22	Moomin	Clarendon Bridge	418067	to	Moomin	Alma Bridge	418061
23	Moomin	Alma Bridge	418061	to	Moomin	Iffley	418054
24	Moomin	Iffley	418054	to	Mehi	(near) Collarenebri	418055
25	Mallowa	d/s Regulator	418049	to	Mallowa	Kamilaroi West	418046

Table B.2: Ungauged inflow sites modelled in Gwydir IQQM

Ungauged Inflows in Reach			How Derived		
Residual Name	**from**	**to**	**Gauged Inflow Station**		**Factor**
UPSTREAM OF COPETON DAM *for simulating long term Copeton inflows*					
Ungauged #00a	418029	418008	418029	Gwydir R. @ Stonybatter	1.30
Ungauged #00b	418008	Copeton Dam	418023	Moredun Ck @ Bundarra	1.00
DOWNSTREAM OF COPETON DAM *to match historical main-stream flows*					
Ungauged #01	418026	418012	418015	Horton R. @ Rider	0.16
Ungauged #02	418026	418012	418015	Horton R. @ Rider	0.16
Ungauged #03	418012	418013	418025	Halls Ck. @ Bingara	1.03
Horton Residual	418012	418013	418015	Horton R. @ Rider	0.08
Ungauged #04	418012	418013	418017	Myall Ck. @ Molroy	0.62
Ungauged #05	418012	418013	418016	Warialda Ck. @ Warialda No.3	0.67
Ungauged #06	418013	418001	418016	Warialda Ck. @ Warialda No.3	2.79
Ungauged #07	418042	418004	418016	Warialda Ck. @ Warialda No.3	1.00
Marshall Ponds Ck	418011	418052	418016	Warialda Ck. @ Warialda No.3	0.30
Gil Gil Ck	418052	416027	418016	Warialda Ck. @ Warialda No.3	3.70
Ungauged #08	418044	418002	418032	Tycannah Ck. @ Horseshoe Lagoon	0.58
Ungauged #09	418002	418037	418032	Tycannah Ck. @ Horseshoe Lagoon	0.12
Ungauged #10	418002	418037	418032	Tycannah Ck. @ Horseshoe Lagoon	0.35
Gurley Ck	418048	418060	418032	Tycannah Ck. @ Horseshoe Lagoon	2.30
Colly Farms 'C'	Colly Farms diversion from Barwon-Darling R.		Output from Barwon-Darling IQQM: 'Colly 1B'		1.00
Colly Farms 'G'	Colly Farms diversion from Barwon-Darling R.		Output from Barwon-Darling IQQM: 'Colly Gravity'		1.00
Colly Farms 'B'	Colly Farms diversion from Barwon-Darling R.		Output from Barwon-Darling IQQM: 'Colly 2B'		1.00

Table B.3: Crop factors

Crop	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Cotton	0.72	0.64	0.30	0.00	0.00	0.00	0.00	0.00	-0.35	0.35	0.34	0.46
Wheat	0.00	0.00	0.30	0.70	0.70	0.71	0.71	0.64	0.40	0.00	0.00	0.00
Lucerne	0.95	0.90	0.80	0.80	0.70	0.55	0.55	0.65	0.75	0.85	0.95	1.00
Pecans	0.95	0.95	0.95	0.00	0.00	0.00	0.00	0.00	0.00	0.70	0.75	0.95
SCereal	0.70	0.70	0.60	0.00	0.00	0.00	0.00	0.00	-0.30	0.40	0.52	0.65
WCereal	0.00	0.00	0.10	0.20	0.70	0.70	0.71	0.71	0.64	0.00	0.00	0.00
Pasture 1	0.70	0.70	0.60	0.60	0.50	0.45	0.40	0.45	0.55	0.65	0.70	0.70
Pasture 2	0.42	0.41	0.41	0.41	0.41	0.36	0.32	0.35	0.38	0.41	0.41	0.42
Others	0.66	0.70	0.70	0.60	0.60	0.52	0.45	0.50	0.41	0.53	0.56	0.76

Notes: Negative crop factors indicate pre-watering in that month.

Table B.4: Irrigation efficiencies

Reach	Irrigation Efficiency #
	1993/94 Scenario
IrrGwyd1-high irri	0.70
IRRGwyd01a, 01b	0.82
IRRMehi01a	0.82
IRRMehi01b	0.82
IRRMehi02, 03, 04	0.82
IRRCollyCentral	0.82
IRRMehi05	0.63
IRRCollyMyambla	0.82
IRRMoom01a, 01b	0.82
IRRMoom02	0.82
IRRMoom03, CollyIffley	0.82
IRRMoom04	0.82
IRRGwyd02a, 02b, Pool	0.82
IRRGwy03a, 03b, 03c	0.82
IRRCar01, 02a, 02b, 02c	0.82

Notes: # The listed efficiencies are for the main crop for each irrigation node.

Table B.5: Rainfall interception loss and soil moisture store parameters

Reach	Rainfall Interception Loss (mm)	Soil Moisture Store (mm)	Upper Fallow Depth (mm)	Infiltration Rate # (mm)
Gwydir R. & Carole Ck Irrigators	5	300	50	2
Mehi R. & Moomin Ck Irrigators	5	300	10	2

Notes: # The infiltration rate from the upper to the lower fallow store.

Table B.6: Tributary utilisation factors

Gauge Number	Gauge Name	Utilisation
418018	Keera Ck	0%
418025	Halls Ck	100%
418017	Myall Ck	100%
418015	Horton River	100%
418016	Warialda Ck	100%
All ungauged tributary inflows		0%

Table B.7: Over-order factors

Reach	Over-Order Factor
All irrigation nodes	1.00

Appendix C. Gwydir Node-Link Diagram

In the following node-link diagrams, the nodes are labelled with a shape, a node number and a node description. The node key indicates what the shapes refer to in terms of their node type. These node types are then further described in Table C.1.

Table C.1: Nodes types used in IQQM

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	Unmodelled tributaries joining the main river.
1.2	Pumped inflow	Allows water pumped from Nt 3.2, 3.3, 3.4 or 3.5 nodes to inflow into a river section.
2.0	On-river storage (ungated)	Ungated on-river storage (uses storage routing procedure during flood operation); unmet orders are passed to next storage upstream.
2.1	Head-water storage (ungated)	As above, except no upstream storage to pass unmet 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 Nt 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 Nt 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 Nt 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 Nt 9.0, except also sets the boundaries for supplementary water reaches.
10.0	Wetland	Wetland requirement calculations based on irrigation AWD’s for the year.
10.2	Wetland	Wetland demands are input as a pattern.
11.0	Confluence	Confluence of two river sections.

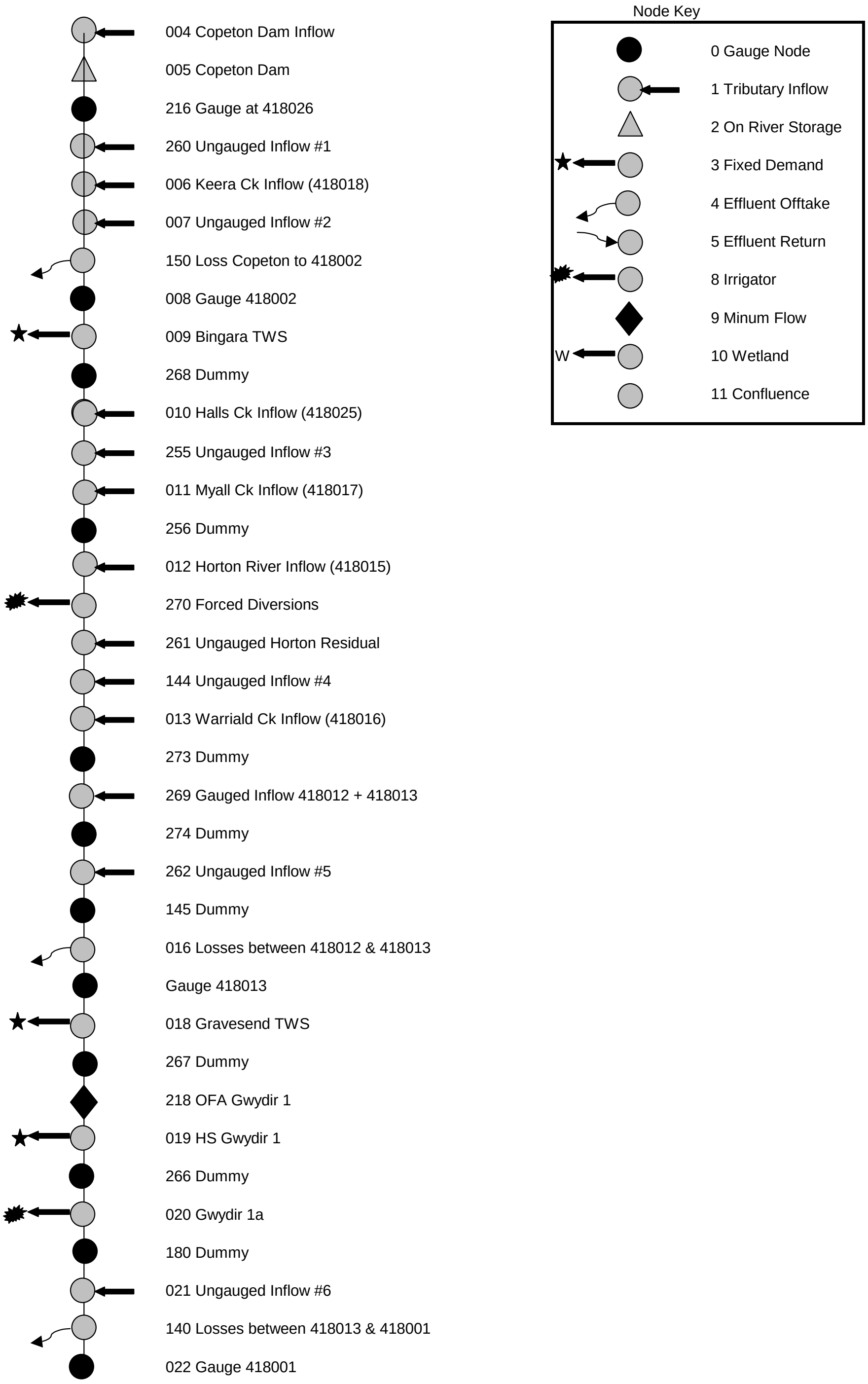

Figure C.1: Gwydir IQQM node-link diagram (Part 1 of 3)

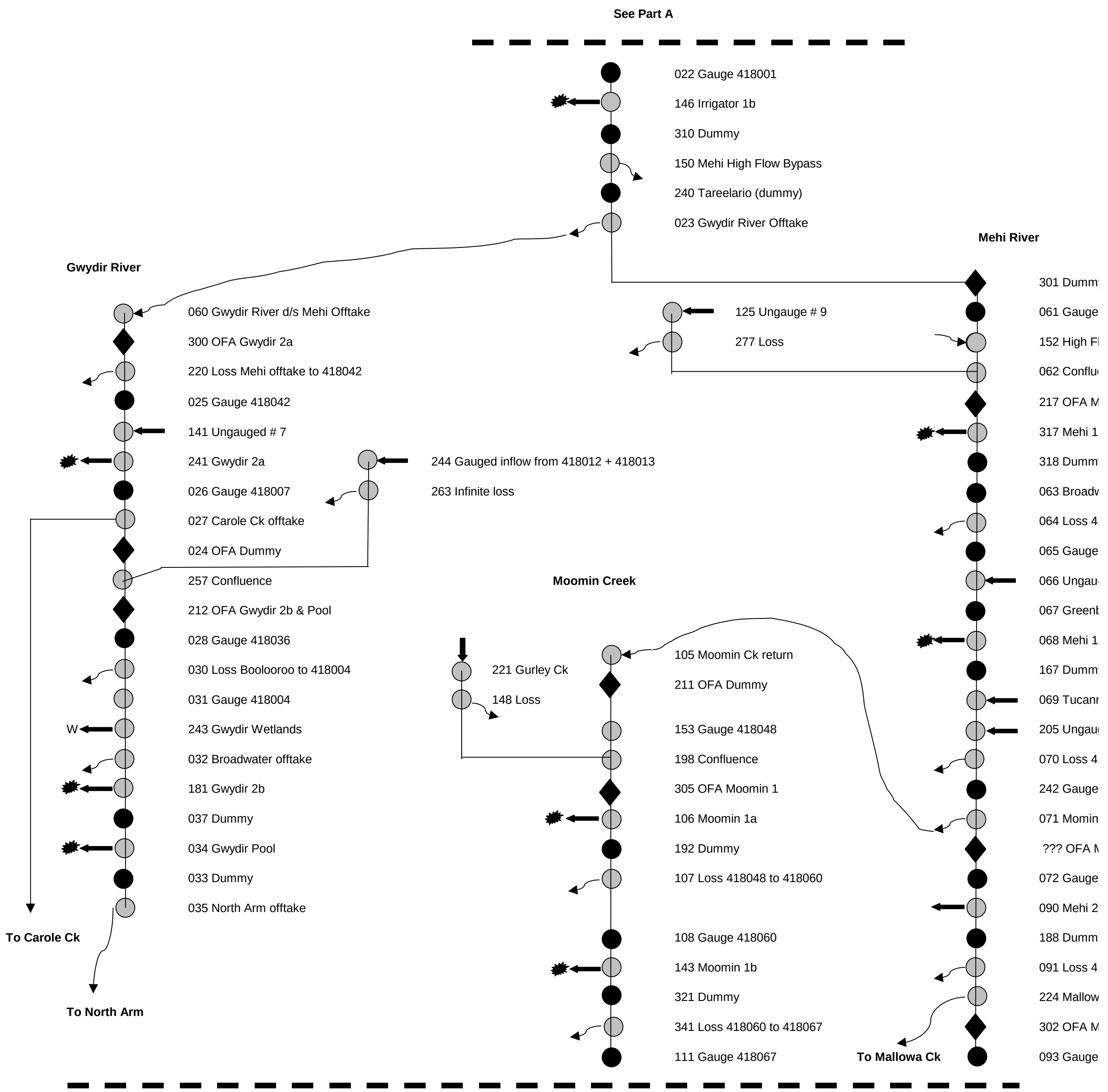

Figure C.2: Gwydir IQQM node-link diagram (Part 2 of 3)

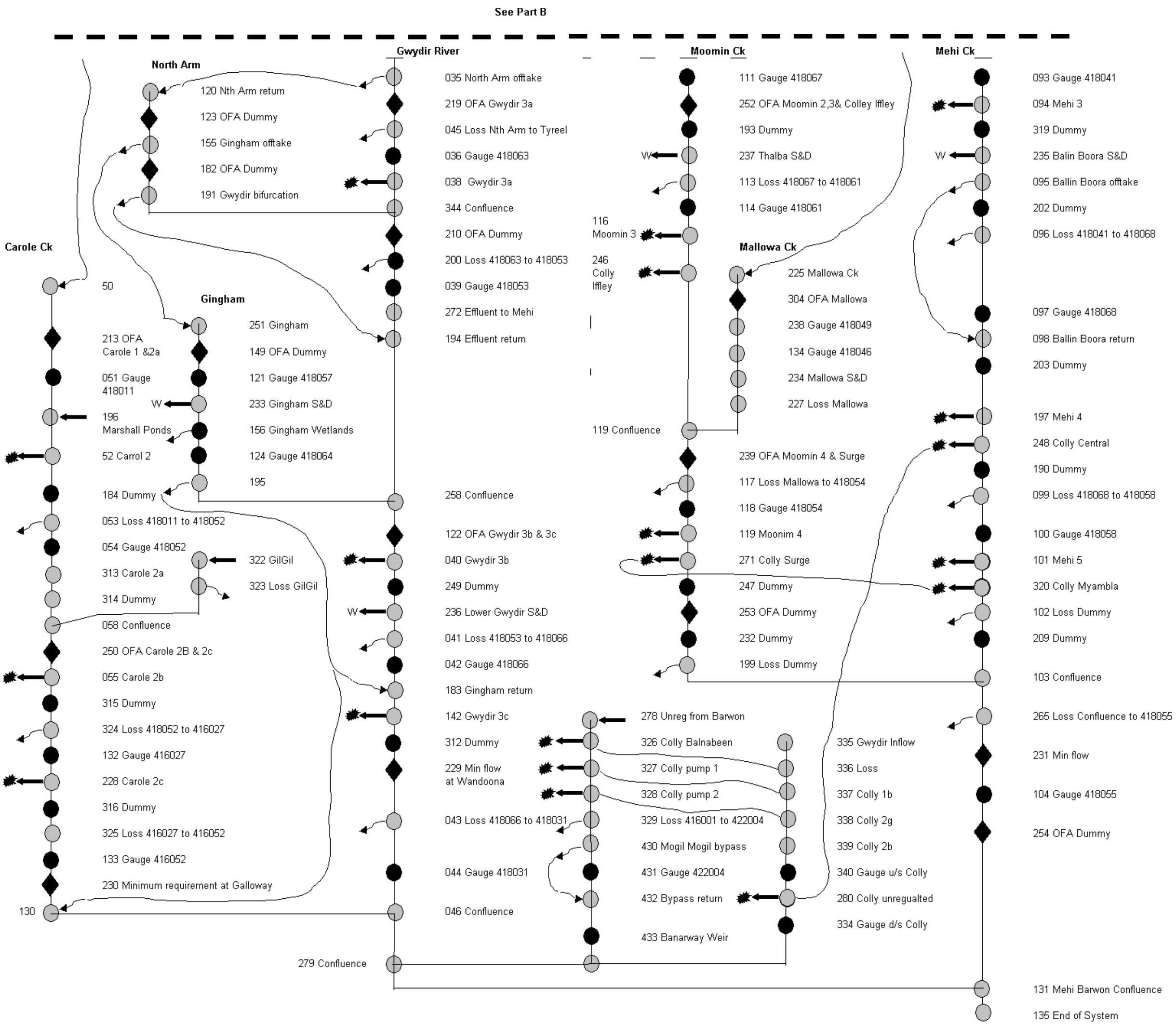

Figure C.3: Gwydir IQQM node-link diagram (Part 3 of 3)

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Appendix D. Modelling the Planting Decision

D.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 application rate (or "irrigator behaviour function") 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. This process is also 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 Eq. D.1:

$$\text{Total Area} = f^n(CWA, IPR) \qquad \{Eq.\ D.1\}$$

Where: *CWA* = current water available (ML)
= AWD * licensed volume (annual accounting)
+ water in on-farm storage

IPR = the irrigators' planting risk (ML/ha)
= a target application rate based on the CWA at the planting decision date.

The IPR will reflect a number of influences including the actual crop water requirements, expectations that the irrigators may have in regard to further increases in AWD, future access to supplementary water, rainfall on the crop during the growing season and a range of economic considerations.

The total area is also bounded by a maximum and minimum planted area.

An irrigator's planting decision is generally regarded as being specific to a particular model scenario (eg 1993/94 or 2002/03 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 static for that period.

The mix of crop types that make up the total area and their relative proportion of the total area are also selected based on the historical information during the calibration period. These are input for a given scenario and remain static for the entire simulation period.

D.2. DERIVATION OF AN APPROPRIATE IRRIGATORS' PLANTING RISK

As mentioned above, the irrigators' planting risk in IQQM can vary over time and can be configured separately for both the summer and winter crops. When selecting an appropriate IPR, parameters derived in earlier calibration stages are used to give an indication of appropriate parameter values for the scenario being configured. The main objective of selecting an appropriate IPR decision is to generate the planted areas that are representative of the relevant farmer behaviour at the time relevant to the scenario being configured.

In this process, there are several important factors that need to be considered, including:

- The effects of growth in utilisation of water shares;
- 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.

Appendix E. Quality Assessment Guidelines

This Appendix describes the methodology for assessing the quality of the IQQM model calibration. Further information can be found in [DLWC, 1998[d]]

The assessment system is based on rating the confidence that the model can be used to closely replicate both the time series and statistical distribution of the real system, under a specified set of development conditions. These quality rating guidelines have been developed by DNR's senior modelling staff, based on their experience and knowledge. The quality ratings are used to assess each of the major calibration steps and the overall assembled model.

The five categories used for expressing the quality rating of a particular indicator 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 these five quality ranges, to define the quality of the calibration for that indicator. The bandwidth of these categories varies to reflect the measurement uncertainty in that indicator. For example, we would expect the uncertainty in the historical flow data to be smaller than the uncertainty in the historical planted area data. The assessment indicators also vary depending on the stage being assessed.

The overall model calibration assessment also takes into account the quality achieved for each of the stages of the model calibration and the length of the calibration period.

E.1. FLOW CALIBRATION QUALITY INDICATORS AND RATINGS

The primary quality indicator used for assessment of flow calibration is the percentage (ratio) of the model simulated flow volume versus the historical flow volume, over the calibration period. This is intended to assess whether the mass balance in the reach is preserved.

Secondly, the percentage (ratio) of the model simulated flow volume versus the historical flow volume in the low, mid and high flow ranges, over the calibration period is assessed. This is intended to assess whether the historical flow regime in the reach is reproduced.

Thirdly, the correlation between the simulated and historical daily flows over the calibration period is assessed. This is intended to assess whether the timing and shape of historical flows is reproduced.

Finally, the match between the simulated and historical annual flows over the calibration period is assessed. DNR developed a new statistic to quantify this comparison called the coefficient of mean absolute annual differences (CMAAD) as described in Eq. E.1.

$$CMAAD\ (\%) = \sum_{j=1}^{y} abs(SAV_j - OAV_j) \ / \ \sum_{j=1}^{y} OAV_j \qquad \{Eq.\ E.1\}$$

Where: *abs* = the absolute value

SAV_j = the simulated annual flows in year(j)

OMV_j = the historical annual flows in year(j)

y = number of years in the calibration period

The flow calibration can be assessed on an individual reach-by-reach basis, where the main-stream flows at the upstream site are used as inputs and the flows at the downstream site are being assessed. In this instance the accuracy of the match is expected to be much higher than for an assembled model. In the assembled model, only the historical inflows at the top end of the system are used (for example dam outflows) and the flows at all the downstream gauges are simulated and assessed relative to the historical data. The quality assessment criteria are adjusted to reflect these two situations.

The generic flow calibration quality assessment criteria are presented in Table E.1.

Table E.1: Flow calibration quality assessment criteria

QUALITY INDICATOR	***PARAMETER***	***QUALITY RATING GUIDELINES***				
		Very High	High	Moderate	Low	Very Low
VOLUME RATIO = (∑Sim / ∑Obs) %	Whole flow range individual reaches assembled model	 ± 2% ± 4%	 ± 5% ± 10%	 ± 10% ± 15%	 ± 20% ± 25%	 ± 30% ± 35%
	Low-flow range: 0 to X%ile [1] individual reaches assembled model	 ± 3% ± 5%	 ± 7% ± 10%	 ± 15% ± 20%	 ± 25% ± 30%	 ± 35% ± 40%
	Mid-flow range: X to Y%ile [1] individual reaches assembled model	 ± 2% ± 4%	 ± 5% ± 10%	 ± 10% ± 15%	 ± 20% ± 25%	 ± 30% ± 35%
	High-flow range: Y to 100%ile [1] individual reaches assembled model	 ± 4% ± 7%	 ± 10% ± 15%	 ± 20% ± 25%	 ± 35% ± 40%	 ± 50% ± 50%
TIME SERIES MATCH = (1 - r2) %	Daily Correlation individual reaches assembled model	 ± 5% ± 7%	 ± 10% ± 15%	 ± 25% ± 30%	 ± 40% ± 45%	 ± 50% ± 50%
TIME SERIES MATCH = CMAAD %	Annual Match individual reaches assembled model	 ± 5% ± 10%	 ± 10% ± 15%	 ± 15% ± 20%	 ± 20% ± 25%	 ± 25% ± 30%

Notes: [1] The “X%ile” and “Y%ile” points are defined from examination of the ranked flow-duration plot of daily flows over the calibration period. The “X%ile” point is 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 30 to 10%ile). The “Y%ile” point is 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 90 to 95%ile).

E.2. DIVERSION CALIBRATION QUALITY INDICATORS AND RATINGS

The primary quality indicator used for assessment of diversion calibration is the percentage (ratio) of the model simulated diversion volume versus the historical diversion volume, over the calibration period. This is done for ONA, OFA and Total diversions. This is intended to assess whether the overall total diversion and the split between ONA and OFA diversions in the system are preserved.

Secondly, the match between the simulated and historical monthly ONA diversions over the calibration period is assessed. This is intended to assess whether the crop module is reproducing the historical pattern of use. DNR developed a new statistic to quantify this comparison called the coefficient of mean absolute monthly differences (CMAMD) as described in Eq. E.2.

$$CMAMD\ (\%) = \sum_{i=1}^{m} abs(SMV_i - OMV_i) \ / \ \sum_{i=1}^{m} OMV_i \qquad \{Eq.\ E.2\}$$

Where:	*abs*	=	the absolute value
	SMV_i	=	the simulated monthly ONA diversions in month(i)
	OMV_i	=	the historical monthly ONA diversions in month(i)
	m	=	number of months in the calibration period

Finally, the match between the simulated and historical annual ONA, OFA and Total diversions over the calibration period is assessed. To quantify this comparison we used the CMAAD as described in Eq. E.1.

The diversion calibration can be assessed using AWD's and planted areas forced to the historical values. This stage is aimed at isolating the diversion calibration parameters (Section 3.5). In this instance the accuracy of the match is expected to be much higher than for an assembled model. In the assembled model, the AWD's and planted areas are not forced to historical values and the simulated diversions are not expected to match as closely as previously. The quality assessment criteria are adjusted to reflect these two situations.

The generic diversion calibration quality assessment criteria are presented in Table E.2.

Table E.2: Diversion calibration quality assessment criteria

QUALITY INDICATOR	*PARAMETER*	*QUALITY RATING GUIDELINES*				
		Very High	High	Moderate	Low	Very Low
VOLUME RATIO = (∑Sim / ∑Obs) %	ONA Diversions					
	with areas forced to obs	± 2%	± 5%	± 15%	± 25%	± 35%
	with areas simulated	± 5%	± 10%	± 20%	± 30%	± 40%
	OFA Diversions					
	with varying monthly thresholds	± 3%	± 7%	± 20%	± 35%	± 50%
	with fixed monthly thresholds	± 10%	± 20%	± 30%	± 40%	± 50%
	Total Diversions					
	with forced configuration	± 2%	± 5%	± 15%	± 25%	± 35%
	with simulated configuration	± 7%	± 15%	± 20%	± 30%	± 40%
TIME SERIES MATCH = CMAMD %	Monthly ONA Diversions					
	with areas forced to obs	± 10%	± 15%	± 20%	± 30%	± 40%
	with areas simulated	± 20%	± 25%	± 30%	± 40%	± 50%
TIME SERIES MATCH = CMAAD %	Annual ONA Diversions					
	with areas forced to obs	± 10%	± 15%	± 20%	± 25%	± 35%
	with areas simulated	± 15%	± 20%	± 25%	± 30%	± 40%
	Annual OFA Diversions					
	with varying monthly thresholds	± 10%	± 15%	± 20%	± 30%	± 40%
	with fixed monthly thresholds	± 20%	± 25%	± 30%	± 40%	± 50%
	Annual Total Diversions					
	with forced configuration	± 10%	± 15%	± 20%	± 25%	± 35%
	with simulated configuration	± 15%	± 20%	± 25%	± 30%	± 40%

E.3. STORAGE CALIBRATION QUALITY INDICATORS AND RATINGS

The match between the simulated and historical storage behaviour over the calibration period is assessed using a DNR developed statistic called the coefficient of mean absolute storage drawdown deviation (CMASDD) as described in Eq. E.3.

$$CMASDD\ (\%) = \sum_{i=1}^{m} abs(SMDS_i - OMDS_i) \ / \ (MaxOD * m) \qquad \{Eq.\ E.3\}$$

Where:
- *abs* = the absolute value
- $SMDS_i$ = simulated monthly change in storage volume in month(i)
- $OMDS_i$ = observed monthly change in storage volume in month(i)
- *MaxOD* = maximum observed drawdown in a single water year over the calibration period.
- *m* = number of months in the calibration period

The storage calibration can be assessed using diversions forced to the historical values. This stage is aimed at isolating the storage calibration parameters (Section 3.6). In this instance the accuracy of the match is expected to be much higher than for an assembled model. In the assembled model, the AWD's, planted areas and diversions are not forced to historical values and the simulated storage behaviour is not expected to match as closely as previously. The quality assessment criteria are adjusted to reflect these two situations.

The generic storage calibration quality assessment criteria are presented in Table E.3.

Table E.3: Storage calibration quality assessment criteria

QUALITY INDICATOR	*PARAMETER*	*QUALITY RATING GUIDELINES*				
		Very High	High	Moderate	Low	Very Low
TIME SERIES MATCH = CMASDD %	Daily storage behaviour with diversions forced to obs with diversions simulated	 ± 2% ± 4%	 ± 5% ± 10%	 ± 8% ± 15%	 ± 15% ± 20%	 ± 20% ± 25%

E.4. PLANTED AREA CALIBRATION QUALITY INDICATORS AND RATINGS

The primary quality indicator used for assessment of planted area calibration is the percentage (ratio) of the model simulated areas versus the historical areas, over the calibration period. This is intended to assess whether the irrigator behaviour functions are reproducing the historical planted areas.

Additionally, the match between the simulated and historical annual planted areas over the calibration period is assessed. To quantify this comparison we used the CMAAD as described in Eq. E.1.

The generic planted area calibration quality assessment criteria are presented in Table E.4.

Table E.4: Planted area calibration quality assessment criteria

QUALITY INDICATOR	*PARAMETER*	*QUALITY RATING GUIDELINES*				
		Very High	High	Moderate	Low	Very Low
Area RATIO = (∑Sim / ∑Obs) %	Ratio of summer planted areas AWD's forced AWD's simulated	 ± 3% ± 5%	 ± 7% ± 10%	 ± 15% ± 20%	 ± 25% ± 30%	 ± 35% ± 40%
	Ratio of winter planted areas AWD's forced AWD's simulated	 ± 15% ± 15%	 ± 30% ± 30%	 ± 40% ± 40%	 ± 50% ± 50%	 ± 60% ± 60%
	Ratio of total planted areas AWD's forced AWD's simulated	 ± 3% ± 5%	 ± 7% ± 10%	 ± 15% ± 20%	 ± 25% ± 30%	 ± 35% ± 40%
TIME SERIES MATCH = CMAAD %	Match of summer planted areas AWD's forced AWD's simulated	 ± 7% ± 12%	 ± 15% ± 20%	 ± 20% ± 25%	 ± 25% ± 30%	 ± 35% ± 40%
	Match of winter planted areas AWD's forced AWD's simulated	 ± 20% ± 20%	 ± 40% ± 40%	 ± 60% ± 60%	 ± 80% ± 80%	 ±100% ±100%
	Match of total planted areas AWD's forced AWD's simulated	 ± 7% ± 12%	 ± 15% ± 20%	 ± 20% ± 25%	 ± 25% ± 30%	 ± 35% ± 40%

E.5. REPRESENTATIVENESS OF CALIBRATION PERIOD

The calibration period should be representative of the ranges of climatic conditions expected in the long term simulation run. For example, if there were no wet years or no dry years then we would have lower confidence in the model's ability to simulate the system's behaviour under these conditions. By default, a longer calibration period will be more representative of the range of climatic conditions and behaviour experienced in the valley. Therefore we use the length of the calibration period as an indication of its representativeness, as presented in Table E.5.

Table E.5: Climatic representativeness classification guidelines

QUALITY INDICATOR	*PARAMETER*	*QUALITY RATING GUIDELINES*				
		Very High	High	Moderate	Low	Very Low
RECORD LENGTH	Length of calibration period	> 10 years	5 – 10 years	2 – 4 years	1 year	< 1year

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 we have not developed a quantitative measure to test for this, but it is mentioned here for completeness.

E.6. 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 for Cap Auditing and long term scenario comparisons the following indicators have been chosen:

1) Flow match at a key gauging station (Mid range volume ratio and CMAAD);
2) Total diversion match for the valley (Volume ratio and CMAAD);
3) Storage behaviour match (CMASDD);
4) Total planted area match for the valley (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 reproducing farmer's risk. As each of these criteria is of equal importance they have been given an equal weighting in the overall assessment of the model.

The quality guidelines for each of these indicators have five categories of confidence with various limits. To enable the calculation of a combined quality rating these confidence intervals need to be transformed into a standard rating scale as follows:

1) Very High $0\% \leq x \leq 5\%$
2) High $5\% < x \leq 10\%$
3) Moderate $10\% < x \leq 15\%$
4) Low $15\% < x \leq 20\%$
5) Very low $x \geq 20\%$

The transformation for each indicator is carried out as follows:

$$SI_i = (I_i - LL_i) * (SU_i - SL_i) / (UL_i - LL_i) + SL_i \qquad \{Eq.\ E.4\}$$

Where:			
	SI_i	=	standardised indicator of quality
	I_i	=	quality achieved for the selected indicator
	UL_i	=	upper limit of the confidence band that *I* lies between
	LL_i	=	lower limit of the confidence band that *I* lies between
	SU_i	=	standardised upper confidence limit of equivalent indicator confidence limit
	SL_i	=	standardised lower confidence limit of equivalent indicator confidence limit
	i	=	the indicator number

To obtain an overall quality indicator (OQI) each of the selected individual indicators are standardised and averaged using Eq. E.5.

$$AQI = \sum_{i=1}^{k} SI_i \; / \; k \qquad \{Eq.\ E.5\}$$

Where:			
	AQI	=	average of the quality indicators
	k	=	number of contributing indicators to the overall indicator

This average quality indicator is then adjusted for climatic representativeness of the calibration period using Eq. E.6:

$$OQI = AQI * 3.0 * NY^{-0.65} \qquad \{Eq.\ E.6\}$$

Where:			
	OQI	=	overall quality indicator
	NY	=	number of years of calibration period

The adjustment for climatic representativeness (Eq. E.6) 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. In doing this we assume that calibration period length is a reasonable surrogate for climatic representativeness. If the calibration period does not contain dry and wet periods then this adjustment may not be appropriate.

The overall quality indicator can be used to determine appropriate uses for the model (Table E.6).

Table E.6: Appropriate uses for the model

POSSIBLE USE	***APPROPRIATE USES BASED ON OQI (** *Eq. E.6)*				
	0 – 5 %	5 – 10 %	10 – 15 %	15 – 20 %	≥ 20 %
Short term Cap Auditing	√				
Long term Cap modelling	√	√			
Long term analysis of management rule variations	√	√			
Long term analysis of development variations	√	√			
Long term analysis of infrastructure changes	√	√			
Long term analysis of storage behaviour, yield and spilling frequency	√	√			
Long term analysis of flow regimes and environmental flows at key locations	√	√	√		
Simplified unregulated system modelling			√		
Understanding flow regimes			√		
Requires more data			√	√	
Requires further calibration					√

Appendix F. 1993/94 Cap Scenario Parameters

Table F.1: Infrastructure & development parameters for the 1993/94 Cap scenario

ITEMS	DESCRIPTION		COMMENTS
GENERAL			
Simulation Period		01/01/1890 to 30/06/2004	
Water Year		01/10 to 30/09	
CATCHMENT INFORMATION			
Storages modelled		Copeton	
Storage Volumes *(ML)*	Dead Storage 18,490	Maximum Capacity 1,418,000	
FLOW INFORMATION	*(Annual averages over simulation period)*		
Storage Inflows *(GL/yr)*		423	
Tributary inflows *(GL/yr)*	Gauged Ungauged	321 408	
IRRIGATION INFORMATION			
General Security (GS) license volume *(ML)*	Gwydir River Mehi River Moomin Ck Carole/Gil Gil Cks TOTAL	112,366 121,132 162,340 118,152 **513,990**	
High Security (HS) license volume *(ML)*		13,405	
Accounting system	Annual accounting Water order debiting		
Maximum irrigable area *(Ha)*	Gwydir River Mehi River Moomin Ck Carole/Gil Gil Cks TOTAL	(1) 16,912 27,048 26,305 13,535 **83,800**	(1) includes 700 ha of permanent plantings.
On-farm storage capacity *(ML)*	Gwydir River Mehi River Moomin Ck Carole/Gil Gil Cks TOTAL	63,400 110,000 111,990 77,968 **363,358**	
Pump capacity *(ML/d)*	Gwydir River Mehi River Moomin Ck	(2) 2,858 4,532 6,714	(2) includes 137 ML/d of pump capacity for the HS irrigator.

	Carole/Gil Gil Cks 3,940 TOTAL **18,044**	
Maximum Usage	Allowed up to 100% in any 1-year period	
Irrigator Carry-Over	Allowed up to 100%; Total reduction up to: ➢ 31st December = -10%; ➢ 31st January = -20%; ➢ 28th February = -30%; ➢ 01st March = -100%.	
On-farm storage operation	Flood plain harvesting yes End-of-year diversions no Pre-watering yes Rainfall runoff harvesting yes Airspace yes Reserve yes	See Table F.6 for details See Table F.7 for details See Table F.8 for details See Table F.9 for details
Active license factors *(%)*	100%	Weighted average
Average crop mix *(%)*	Cotton 90% Summer Cereals 5% Wheat 3% Other 2%	See Table F.4 for details
OTHER EXTRACTIONS		
Town water supply *(ML/yr)*	Bingara (3) 660 Gravesend (3) 120 TOTAL (3) **780**	(3) Modelled as a fixed monthly pattern for each year of the simulation.
Stock & domestic *(ML/yr)*	Max Rate (ML/d) / Max Vol (4) (ML) Lower Gwydir 40 4,000 Thalaba Creek 50 4,000 Gingham Creek 50 6,000 Mallowa Creek 50 6,000 Ballin Boora Creek 20 500 **TOTAL** **20,500**	(4) Amount released every six months (Feb-Mar and Aug-Sep) if demand is not met from surplus flows
Industrial/mining/other *(ML/yr)*	Not modelled explicitly	
Groundwater access *(ML/yr)*	Not modelled explicitly	
RESOURCE ASSESSMENT		
Storage Reserve *(GL)*	at Empty Storage 0 at Full Storage (5) 40,000	(5) Does not vary.
Transmission / operation loss *(GL)*	at 100% AWD (6) 120,000 in October	(6) Varies with time of year and AWD.

Minimum storage inflows *(ML)*	(7) 3,300	(7) Varies with time of year
Minimum tributary inflows *(ML)*	(8) 3,250	(8) Varies with time of year
System development factor *(%)*	100%	Used in resource assessment
Maximum AWD *(%)*	100%	
RIVER AND STORAGE OPERATING RULES		
Tributary recession factors *(%)*	Halls Ck @ Bingara (418025) 100% Myall Ck @ Molroy (418017) 100% Horton R@ Rider (418015) 100% Warialda Ck @ War #3 (418016) 100%	
Over order allowances *(%)*	All irrigation nodes 0%	
SURPLUS FLOW ACCESS		
Supplementary water cap *(GL/yr)*	No Cap	
Supplementary water thresholds	Fixed monthly thresholds	See Table F.5 for details
RIVER FLOW REQUIREMENTS		
Minimum flow requirements *(ML/d)*	Gwydir R. @ d/s Copeton Dam 30 Mehi R.@ Collarenebri (418055) 10 Gwydir R.@ Wandoona 10 Gil Gil Ck.@ Galloway (416052) 10	
Low Flow Protection	Protect d/s tributaries No	
OFA sharing	Env. share above threshold 0%	
Gwydir Wetland and Gingham Watercourse replenishments	ECA 0 GL	

Table F.2: Adopted maximum and minimum area for the 1993/94 Cap scenario

Reach	Maximum Area (ha)		Minimum Area (ha)	
	Summer	**Winter**	**Summer**	**Winter**
IrrGwyd1-high irri (permanent crop) #	700	0	700	0
IRRGwyd01a	250	0	0	0
IRRGwyd01b	968	70	223	0
IRRMehi01a	500	12	233	0
IRRMehi01b	1,393	250	249	0
IRRMehi02	9,922	800	685	0
IRRMehi03	2,671	0	302	0
IRRMehi04	2,784	0	61	0
IRRCollyCentral	7,008	0	1240	0
IRRMehi05	232	60	0	0
IRRCollyMyambla	1,416	0	0	0
IRRMoom1a	4,165	200	179	0
IRRMoom1b	5,643	80	262	0
IRRMoom2	2,600	0	149	0
IRRMoom3	7,662	800	1,117	0
IRRCollyIffley	5,070	0	0	0
IRRMoom4	85	0	55	0
IRRGwyd02a	3,100	400	865	0
IRRGwyd02b	1,700	0	207	0
IrrGwydirPool	700	0	0	0
IRRGwy03a	3,149	0	503	0
IRRGwyd3b	5,725	0	532	0
IRRGwyd3c	150	0	0	0
IRRCar01	8,987	0	340	0
IRRCar02a	3,486	0	916	0
IRRCar02b	337	25	240	0
IRRCar02c	500	200	0	0
Total	**80,903**	**2,897**	**9,058**	**0**

Notes: # Permanent crops are included in the summer planted areas only.

Table F.3: Adopted irrigators' planting risk for the 1993/94 Cap scenario

Reach	Adopted Irrigators' Planting Risk [1] (ML/ha)
IRRGwyd01a	4.0
IRRGwyd01b	4.0
IRRMehi01a	4.0
IRRMehi01b	4.0
IRRMehi02	4.4
IRRMehi03	4.3
IRRMehi04	4.3
IRRCollyCentral	4.3
IRRMehi05	4.6
IRRCollyMyambla	4.6
IRRMoom1a	4.0
IRRMoom1b	4.0
IRRMoom2	4.4
IRRMoom3	4.4
IRRCollyIffley	3.6
IRRMoom4	4.0
IRRGwyd02a	4.0
IRRGwyd02b	4.0
IrrGwydirPool	4.3
IRRGwy03a	4.3
IRRGwyd3b	4.1
IRRGwyd3c	4.3
IRRCar01	3.9
IRRCar02a	4.2
IRRCar02b	4.3
IRRCar02c	4.3
Average [2]	**4.2**

Notes: (1) Figures are for the summer area planting decision date. The winter area planting decision uses all remaining water to plant a winter area for relevant nodes that grow winter crops.

(2) Non-weighted average, ie not weighted by area planted.

Table F.4: Adopted crop mix for the 1993/94 Cap scenario

Reach	Percentage of crop (%)							
	Cotton	**Lucerne**	**Summer Cereal**	**Summer Pasture**	**Wheat**	**Winter Cereal**	**Pecans**	**Others**
IrrGwyd1-high irri	0.0	0.0	0.0	0.0	0.0	0.0	100.0	0.0
IRRGwyd01a	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
IRRGwyd01b	92.1	1.2	0.0	0.0	0.0	6.7	0.0	0.0
IRRMehi01a	89.5	0.2	8.0	0.0	2.4	0.0	0.0	0.0
IRRMehi01b	66.2	0.0	18.6	0.0	15.2	0.0	0.0	0.0
IRRMehi02	83.8	0.0	8.8	0.0	7.5	0.0	0.0	0.0
IRRMehi03	97.1	0.0	2.9	0.0	0.0	0.0	0.0	0.0
IRRMehi04	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
IRRCollyCentral	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
IRRMehi05	0.0	0.0	79.5	0.0	14.6	6.0	0.0	0.0
IRRCollyMyambla	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
IRRMoom1a	94.9	0.0	0.5	0.0	4.6	0.0	0.0	0.0
IRRMoom1b	95.2	0.0	3.4	0.0	1.4	0.0	0.0	0.0
IRRMoom2	99.9	0.0	0.0	0.0	0.0	0.0	0.0	0.1
IRRMoom3	76.5	0.0	12.4	0.0	9.5	0.0	0.0	1.7
IRRCollyIffley	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
IRRMoom4	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
IRRGwyd02a	84.6	0.0	3.6	0.0	9.6	1.8	0.0	0.4
IRRGwyd02b	97.1	0.0	0.0	0.0	0.0	0.0	0.0	2.9
IrrGwydirPool	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
IRRGwy03a	81.3	0.0	18.7	0.0	0.0	0.0	0.0	0.0
IRRGwyd3b	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
IRRGwyd3c	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
IRRCar01	96.5	0.0	3.5	0.0	0.0	0.0	0.0	0.0
IRRCar02a	89.9	0.0	10.1	0.0	0.0	0.0	0.0	0.0
IRRCar02b	93.1	0.0	0.0	0.0	6.9	0.0	0.0	0.0
IRRCar02c	71.4	0.0	0.0	0.0	28.6	0.0	0.0	0.0
Overall #	**90.4**	**0.0**	**5.1**	**0.0**	**3.3**	**0.2**	**0.8**	**0.3**

Notes: # Weighted average based on planted area.

Table F.5: Adopted surplus OFA flow thresholds for the 1993/94 Cap scenario

Reach	OFA Threshold (ML/d)											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Gwyd 01	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000
Mehi 01	650	600	650	550	450	300	300	300	300	400	650	650
Mehi 02	550	550	350	250	250	250	250	280	300	400	500	500
Mehi 03, 04, 05	400	400	400	400	400	400	400	400	400	400	400	400
Colly Central	400	400	400	400	400	400	400	400	400	400	400	400
Colly Myambla	400	400	400	400	400	400	400	400	400	400	400	400
Moom 01	550	550	550	550	550	550	550	550	550	550	550	550
Moom 02, 03	400	400	400	400	400	400	400	400	400	400	400	400
Colly Iffley	400	400	400	400	400	400	400	400	400	400	400	400
Moom 04	50	50	50	50	50	50	50	50	50	50	50	50
Colly Surge	50	50	50	50	50	50	50	50	50	50	50	50
Gwyd 02a	550	550	550	550	550	550	550	550	550	550	550	550
Gwyd 02b, Pool	400	400	400	400	400	400	400	400	400	400	400	400
Gwyd 03a	400	400	400	400	400	400	400	400	400	400	400	400
Gwyd 03b, 03c	300	300	200	150	100	100	100	100	200	250	300	300
Car 01, 02a	300	370	250	200	100	100	100	100	200	300	300	350
Car 02b, 02c	300	300	300	300	300	300	300	300	300	300	300	300

Table F.6: Adopted parameters for floodplain harvesting in the 1993/94 Cap Scenario

Reach	Harvesting via Pumping			Harvesting via Gravity
	Flow Threshold (ML/d)	Flow Threshold Location	Pump Capacity (ML/d)	Local Flow Threshold (ML/d)
IrrGwyd1-high irri	n/a	n/a	n/a	n/a
IRRGwyd01a	n/a	n/a	n/a	n/a
IRRGwyd01b	n/a	n/a	n/a	n/a
IRRMehi01a	7,000	418044 Mehi R. d/s Tareelaroi Regulator	159	n/a
IRRMehi01b	7,000	418002 Mehi R.@ Moree	226	n/a
IRRMehi02	6,000	418037 Mehi R. d/s Combadello Weir	1,833	n/a
IRRMehi03	5,000	418041 Mehi R. d/s Gundare Regulator	799	n/a
IRRMehi04	4,000	local (u/s IRRMehi04)	749	n/a
IRRCollyCentral	3,000	local (u/s IRRMehi04)	440	n/a
IRRMehi05	2,000	418058 Mehi R.@ Bronte	45	n/a
IRRCollyMyambla	2,000	418058 Mehi R.@ Bronte	280	n/a
IRRMoom1a	3,000	u/s 418048 Moomin Ck.@ Combadello Cutting	1,793	10,000
IRRMoom1b	3,000	418060 Moomin Ck.@ Glendello	1,854	10,000
IRRMoom2	3,000	418067 Moomin Ck.@ Clarendon Bridge	622	10,000
IRRMoom3	3,000	418061 Moomin Ck.@ Alma Bridge	1,595	10,000
IRRCollyIffley	3,000	418061 Moomin Ck.@ Alma Bridge	760	10,000
IRRMoom4	2,000	418054 Moomin Ck.@ Iffley	20	9,500
IRRGwyd02a	40,000	418006 Gwydir R. u/s Mehi offtake	770	n/a
IRRGwyd02b	40,000	418006 Gwydir R. u/s Mehi offtake	330	n/a
IrrGwydirPool	n/a	n/a	n/a	n/a
IRRGwy03a	22,000	418004 Gwydir R.@ Yarraman Bridge	534	n/a
IRRGwyd3b	22,000	418004 Gwydir R.@ Yarraman Bridge	567	n/a
IRRGwyd3c	22,000	418004 Gwydir R.@ Yarraman Bridge	50	n/a
IRRCar01	15,000	Carole Ck. d/s Marshall Ponds Ck.	1,225	n/a
IRRCar02a	15,000	418052 Carole Ck.nr Garah	1,021	n/a
IRRCar02b	11,000	418052 Carole Ck.nr Garah	285	n/a
IRRCar02c	10,000	416027 GilGil Ck.@ Weemelah	184	n/a

Table F.7: Adopted parameters for rainfall runoff harvesting in the 1993/94 Cap Scenario

Reach	Rainfall Runoff Harvesting Areas (ha)		
	Harvesting Area	**Max. Crop Area**	**as % of Max. Area**
IrrGwyd1-high irri	n/a	700	n/a
IRRGwyd01a	450	250	n/a
IRRGwyd01b	1,200	1,038	116
IRRMehi01a	900	512	176
IRRMehi01b	2,000	1,643	122
IRRMehi02	11,000	10,722	103
IRRMehi03	3,000	2,671	112
IRRMehi04	3,500	2,784	126
IRRCollyCentral	7,500	7,008	107
IRRMehi05	400	292	137
IRRCollyMyambla	2,500	1,416	177
IRRMoom1a	7,000	4,365	160
IRRMoom1b	9,500	5,723	166
IRRMoom2	5,000	2,600	192
IRRMoom3	14,000	8,462	165
IRRCollyIffley	7,000	5,070	138
IRRMoom4	150	85	176
IRRGwyd02a	6,000	3,500	171
IRRGwyd02b	3,500	1,700	206
IrrGwydirPool	900	700	129
IRRGwy03a	5,000	3,149	159
IRRGwyd3b	7,000	5,725	122
IRRGwyd3c	350	150	233
IRRCar01	12,500	8,987	139
IRRCar02a	3,485	3,486	100
IRRCar02b	1,500	362	414
IRRCar02c	1,500	700	214

Table F.8: Adopted parameters for OFS airspace for the 1993/94 Cap scenario

Reach	Airspace Pattern (% of OFS volume)											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
IrrGwyd1-high irri	n/a - no OFS											
IRRGwyd01a	n/a - no OFS											
IRRGwyd01b	0.25	0.25	0.15	0.10	0.05	0.05	0.05	0.10	0.15	0.25	0.25	0.25
IRRMehi01a	0.25	0.25	0.20	0.10	0.05	0.05	0.05	0.05	0.15	0.20	0.20	0.25
IRRMehi01b	0.25	0.20	0.15	0.10	0.05	0.05	0.05	0.05	0.20	0.25	0.25	0.25
IRRMehi02	0.25	0.25	0.10	0.05	0.05	0.05	0.05	0.05	0.10	0.15	0.25	0.25
IRRMehi03	0.20	0.20	0.15	0.10	0.05	0.05	0.05	0.05	0.10	0.15	0.20	0.20
IRRMehi04	0.25	0.20	0.10	0.05	0.05	0.05	0.05	0.05	0.10	0.15	0.25	0.25
IRRCollyCentral	0.15	0.15	0.10	0.05	0.05	0.05	0.05	0.05	0.20	0.15	0.15	0.15
IRRMehi05	0.20	0.20	0.10	0.05	0.05	0.05	0.05	0.05	0.10	0.20	0.20	0.20
IRRCollyMyambla	0.25	0.25	0.10	0.05	0.05	0.05	0.05	0.05	0.10	0.15	0.25	0.25
IRRMoom1a	0.25	0.20	0.15	0.05	0.05	0.05	0.05	0.10	0.15	0.20	0.20	0.20
IRRMoom1b	0.25	0.25	0.15	0.05	0.05	0.05	0.05	0.10	0.15	0.20	0.25	0.25
IRRMoom2	0.25	0.25	0.15	0.05	0.05	0.05	0.05	0.10	0.15	0.20	0.25	0.25
IRRMoom3	0.25	0.25	0.15	0.05	0.05	0.05	0.05	0.10	0.15	0.20	0.25	0.25
IRRCollyIffley	0.30	0.25	0.20	0.05	0.05	0.05	0.05	0.10	0.15	0.25	0.30	0.30
IRRMoom4	0.25	0.25	0.15	0.10	0.05	0.05	0.05	0.10	0.15	0.25	0.25	0.25
IRRGwyd02a	0.20	0.20	0.15	0.10	0.05	0.05	0.05	0.10	0.15	0.15	0.20	0.20
IRRGwyd02b	0.25	0.25	0.15	0.10	0.05	0.05	0.05	0.10	0.15	0.20	0.25	0.25
IrrGwydirPool	n/a - no OFS											
IRRGwy03a	0.30	0.30	0.15	0.10	0.05	0.05	0.05	0.10	0.15	0.20	0.25	0.30
IRRGwyd3b	0.30	0.25	0.15	0.10	0.05	0.05	0.05	0.10	0.20	0.25	0.30	0.30
IRRGwyd3c	0.30	0.30	0.15	0.10	0.05	0.05	0.05	0.10	0.15	0.25	0.30	0.30
IRRCar01	0.25	0.25	0.15	0.05	0.05	0.05	0.05	0.10	0.15	0.20	0.25	0.25
IRRCar02a	0.25	0.25	0.15	0.05	0.05	0.05	0.05	0.10	0.15	0.20	0.25	0.25
IRRCar02b	0.30	0.25	0.10	0.05	0.05	0.05	0.05	0.10	0.15	0.20	0.25	0.30
IRRCar02c	0.25	0.20	0.10	0.05	0.05	0.05	0.05	0.10	0.15	0.25	0.25	0.25

Table F.9: Adopted parameters for OFS reserve for the 1993/94 Cap scenario

Reach	OFS Reserve Pattern (ML/ha stored in OFS)											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
IrrGwyd1-high irri	n/a - no OFS											
IRRGwyd01a	n/a - no OFS											
IRRGwyd01b	1.00	1.00	0.75	0.50	0.25	0.25	0.25	0.25	0.45	0.75	0.75	0.75
IRRMehi01a	0.75	0.75	0.20	0.10	0.00	0.00	0.00	0.00	0.25	0.50	0.50	0.75
IRRMehi01b	0.75	0.75	0.20	0.10	0.00	0.00	0.00	0.00	0.25	0.50	0.50	0.75
IRRMehi02	0.75	0.75	0.20	0.10	0.00	0.00	0.00	0.00	0.25	0.50	0.55	0.75
IRRMehi03	0.85	0.75	0.20	0.10	0.00	0.00	0.00	0.00	0.25	0.50	0.75	0.85
IRRMehi04	0.85	0.75	0.20	0.10	0.00	0.00	0.00	0.00	0.25	0.50	0.75	0.85
IRRCollyCentral	0.75	0.75	0.20	0.10	0.00	0.00	0.00	0.00	0.25	0.50	0.50	0.75
IRRMehi05	0.90	0.75	0.20	0.10	0.00	0.00	0.00	0.00	0.25	0.50	0.75	0.90
IRRCollyMyambla	1.00	1.00	0.20	0.10	0.00	0.00	0.00	0.00	0.25	0.75	0.85	1.00
IRRMoom1a	0.75	0.75	0.20	0.10	0.00	0.00	0.00	0.25	0.35	0.50	0.75	0.75
IRRMoom1b	0.75	0.75	0.20	0.10	0.00	0.00	0.00	0.25	0.50	0.50	0.75	0.75
IRRMoom2	0.75	0.75	0.20	0.10	0.00	0.00	0.00	0.25	0.50	0.50	0.75	0.75
IRRMoom3	0.75	0.75	0.20	0.10	0.00	0.00	0.00	0.25	0.30	0.50	0.75	0.75
IRRCollyIffley	1.00	1.00	0.75	0.65	0.10	0.10	0.10	0.50	0.85	0.75	1.00	1.00
IRRMoom4	1.00	1.00	0.20	0.10	0.00	0.00	0.00	0.25	0.30	0.50	0.75	1.00
IRRGwyd02a	1.00	1.00	0.75	0.50	0.50	0.50	0.50	0.50	0.50	0.75	0.80	1.00
IRRGwyd02b	1.00	1.00	0.75	0.50	0.50	0.50	0.50	0.50	0.50	0.75	0.75	1.00
IrrGwydirPool	n/a - no OFS											
IRRGwy03a	1.00	1.00	0.75	0.50	0.50	0.50	0.50	0.50	0.50	0.75	1.00	1.00
IRRGwyd3b	1.00	1.00	0.75	0.50	0.50	0.50	0.50	0.50	0.50	0.75	1.00	1.00
IRRGwyd3c	1.00	1.00	0.75	0.50	0.50	0.50	0.50	0.50	0.50	0.75	1.00	1.00
IRRCar01	1.00	1.00	0.75	0.20	0.10	0.10	0.10	0.10	0.50	0.60	0.75	1.00
IRRCar02a	1.00	1.00	0.75	0.20	0.10	0.10	0.10	0.10	0.50	0.75	1.00	1.00
IRRCar02b	1.00	1.00	0.75	0.20	0.10	0.10	0.10	0.10	0.50	0.75	1.00	1.00
IRRCar02c	1.20	1.00	0.75	0.20	0.10	0.10	0.10	0.10	0.50	0.75	1.00	1.20

Appendix G. Gwydir Irrigator Survey

Below is a copy of the questionnaire filled in by representatives of the Gwydir irrigators during the 2004 and 2005 meetings [Gwydir Irrigators Survey and Pers. comm, 2004-2005].

Could you please indicate which of the following river reaches your extraction point/s (ie., river pumps) are located in (if more than one, please indicate with # in descending order, eg., 1 for reach with the largest pump, 2 – for reach with second largest pump, etc.) *:

Location	Indicate
Carole Creek:	
Gwydir River To Garah	
Garah to Carole - Gil Gil Junction	
Carole - Gil Gil Junction to Weemelah #2	
Weemelah#2 to Galloway	
Gwydir River:	
Copeton dam to Pallamallawa	
Pallamallawa to Mehi Offtake	
Mehi Offtake to Yarraman	
Gwydir Pool	
Yarraman to Tyreel Regulator	
Tyreel Regulator to Brageen Crossing	
Brageen Crossing to Millewa Gauge	
Millewa Gauge to Collymongle Gauge	

Mehi River:	
Gwydir River To Moree	
Moree to Combadello Weir	
Combadello Weir to Mallowa Offtake	
Mallowa Offtake to Ballinboora Creek	
Ballinboora Creek to Bronte Gauge	
Bronte gauge to Barwon River Junction	
Moomin Creek:	
Combadello Weir to Glendelo Gauge	
Glendelo Gauge to Clarendon Bridge	
Clarendon Bridge to Alma Bridge	
Alma Bridge to Iffley Gauge	
Iffley Gauge to Mehi Junction	

(*): Please note, that there are no questions in this survey that formally identify your farm. However, due to the specific nature of the IQQM, accurate spatial representation of the irrigation development in the valley is essential for obtaining credible model results.

SECTION A

About your Farm

1.0 Please provide the following details about your enterprise as it was in the respective water year (where applicable):

1.1 Type of Irrigation Licence (surface water only) ________________________
(eg, General Security; High Security; Unregulated)

1.2 Licensed Volume ______________ ML

1.3 Total on-farm storage capacity __________ ML ________ML

3. Please provide the following details about your enterprise in the respective water year (where applicable):

	Water year:	**2000/2001**	**2003/2004**
2.1	Volume of available water on 1st October	________ ML	________ML
2.2	Volume of water in on-farm storage on 1st October	________ ML	________ML
2.3	Estimated volume in account at end of water year	________ ML	________ML
2.4	Estimated volume in OFS at end of water year	________ ML	________ML
2.5	Volume of on-allocation (ONA) used in the season	________ ML	________ML
2.6	Volume of supplementary water (OFA) used in the season	________ ML	________ML
2.7	Number of OFA pumping days in the season	________ ML	________ML

	Water year:	**2000/2001**	**2003/2004**
2.7	Area developed for irrigated production	_______ ha	_______ha
2.8	Did you have a rotation policy	_________	_________

If so, could you please give details below:

____

____

2.9	Area actually irrigated	_______ ha	_______ha
2.10	Maximum area you would have irrigated given unlimited water availability	_______ ha	_______ha
2.11	Planted Crops *(eg, Cotton 50% Lucerne 50%)*		
	_____________	________ %	________ %
	_____________	________ %	________ %
	_____________	________ %	________ %
	_____________	________ %	________ %
	_____________	________ %	________ %
2.12	Installed pump capacity		
	From river only (1st lift pumps)	______ ML/d	_____ML/d
	2nd lift pumps (if applicable)	______ ML/d	_____ML/d

SECTION B

Your Irrigation Practices

Irrigation Methods

1. Do you irrigate for plant establishment (either before or immediately after sowing) ?

☐ No: please go to "Area Planting Decisions".

☐ Yes: please specify below

Crop Type	Approximate Application Rate (ML/Ha)

2. What type of irrigation methods do you typically use? (eg, spray, drip, flood, etc.)

Crop Type	Irrigation Method

Area Planting Decisions

1. Could you please provide details on your decision window for how much area to plant:

Time of Year *(eg, 01/10 or 30/11)*	Crop *(eg, Cotton)*	Details *(eg, if late inflows)*

2. On the planting date what factors do you consider when determining the areas of crops that you will plant ? Please indicate the level of importance by ticking one box per option.

	Importance			
	High	Moderate	Low	N/A
1.1 Volume of water in on-farm storage(s)				
1.2 Volume of carry over water available				
1.3 Volume of allocated water available				
1.4 Recent climatic conditions				
1.5 Market Prices				
1.6 Others? : ____________________				

3. Application rates when making area-planting decisions:

3.1 What application rate do you count on from your regulated water supply? *(eg, 5 ML/Ha)*	
3.2 Do you vary this application rate for varying levels of available resource? *(eg, wet year 5 ML/Ha; dry year 4 ML/Ha)*	

4. Could you please estimate what planted crops you would have, depending on how much water is available in the season:

	Account Volume	Planted Crops		
	on 01/10 (% of Max)	On-Farm Storage	Type	Planted Area (Ha)
Least Water Available	0	Empty		
	0	Half Full		
	0	Full		
	50	Empty		
	50	Half Full		
	50	Full		
↓	100	Empty		
	100	Half Full		
Most Water Available	100	Full		

5. Decision window for how much area to cut-back if water shortage:

Time of Year *(eg, 01/01 or 01/02)*	Crop *(eg, Cotton)*	Details *(eg, reassess resources; cut-back progressively)*

On-Farm Storage Usage

1. If you have an on-farm storage (OFS), do you fill it with unused water in your account at any time of the year:

☐ Yes, please give details below:

____

____

____

☐ No

2. Do you leave any airspace in your OFS after pumping a supplementary water event ? If yes, please give details below, including what use it for:

____

____

____

____

3. Do you store any water in your OFS to cover short periods when your orders do not arrive when required (ie., an OFS reserve)? If yes, please give details below:

____

____

____

____

Ground-water Usage

1. Do you supplement your surface/river water supplies from ground water sources ? If yes, please give details below:

____

____

____

____

Water Harvesting

1. Do you supplement your surface/ground water supplies by harvesting water from the following alternative water sources ?

   1.1 Flood Plain Harvesting* ☐ Yes ☐ No: please, go to 1.2

   (* - harvesting/collecting water ponding on or flowing across your farm as a result of overbank flows)

   1.1.1 Could you please estimate minimum river flow at the nearest gauge or location of your farm at which a flood plain harvesting opportunity arises (ie., 15,000ML/day @ Moree)_______________________________________

   1.1.2 Could you please estimate the frequency of water years that a flood plain harvesting opportunity occurs (ie., every year, 1in 2, 9 in 10, etc):__________

   1.1.3 What method do you use to harvest water from the flood plain ?

   ☐ Gravity (water naturally flows into on-farm storage)

   Details: ____

   ____

   ☐ Pumping (water is pumped into on-farm storage)

   Details: ____

   ____

   ☐ Other: ____

   1.1.4 How much flood plain harvesting water would you extract during an average year with a flood plain harvesting opportunity:_________________________

   1.1.5 How much flood plain harvesting water did you extract during the 2000/2001 flood plain harvesting opportunity:_________________________________

1.2 Runoff Harvesting* ☐ Yes ☐ No: please, go to “Other Information”;

(*- harvesting/collecting water ponding on your farm as a result of excess rainfall)

1.2.1 What method do you use to harvest runoff water ?

☐ Gravity (water naturally flows into on farm storage)

Details: ____

____

☐ Pumping (water is pumped into on farm storage)

Details: ____

____

☐ Other: ____

1.2.2 What area do you harvest runoff water from?

☐ Cropped area only

☐ Fallow area only

☐ Total developed area (cropped and fallow areas)

☐ Other: ____

1.2.3 Could you please estimate after how much rainfall a runoff harvesting event occurs:____

1.2.4 Could you please estimate the maximum runoff water volume you would harvest in a wet year:____

1.2.5 Could you please estimate average annual runoff water volume you harvest from your farm:____

1.2.6 Do you store runoff harvested water before transferring it into your on-farm storage using field/tailwater channels/other temporary storages? If Yes, please provide details below:

2. If you use pumps to harvest both flood plain and runoff water, what water would you harvest first?

☐ Flood plain

☐ Runoff

☐ None of the above: please provide details below:

Other Information

1. Do you feel there is any other information we have not asked you that will help us to model your farm more adequately?

THANK-YOU FOR TAKING THE TIME TO COMPLETE THIS SURVEY.

PLEASE DON'T HESITATE TO CONTACT REPRESENTATIVES OF DNR's SURFACE AND GROUNDWATER PROCESSES UNIT IF YOU HAVE ANY QUERIES.