ECONOMIC ANALYSIS OF DIVERSION OPTIONS FOR THE MURRAY–DARLING BASIN PLAN:

Returns to irrigation under reduced water availability

A commissioned study for the Murray–Darling Basin Authority

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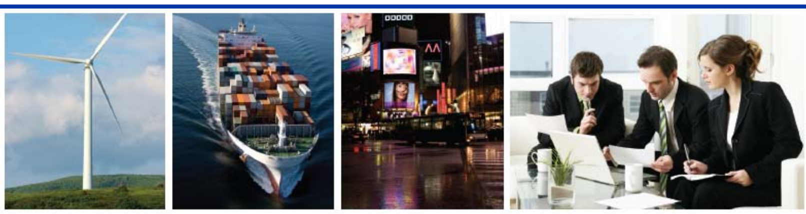

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The Murray-Darling Basin Authority commissioned this report, amongst a number of consultancy reports, to examine a range of different aspects of the socio-economic implications of reducing current diversion limits. These studies were conducted at specific points in time during the development of the proposed Basin Plan and aimed to analyse the likely implications of a range of potential scenarios for reducing long-term average diversion limits in order to inform the MDBA on options for setting Sustainable Diversion Limits and other aspects of the proposed Basin Plan.

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ABBREVIATIONS AND ACRONYMS

ABARE	:	Australian Bureau of Agricultural and Resource Economics
ABS	:	Australian Bureau of Statistics
CDL	:	Current Diversion Limit
CP	:	Common Property
CSIRO	:	Commonwealth Scientific and Industrial Research Organisation
GL	:	Gigalitre
Ha	:	Hectare
MDBA	:	Murray–Darling Basin Authority
M1	:	Murray 1
M2	:	Murray 2
M3	:	Murray 3
NSW	:	New South Wales
QLD	:	Queensland
RSMG	:	Risk and Sustainable Management Group
SA MDB	:	South Australian Murray–Darling Basin
SC	:	State-contingent
SDL	:	Sustainable Diversion Limit
SEQ	:	Sequential
TOR	:	Terms of Reference
$m	:	Million dollars

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SUMMARY

The Murray–Darling Basin Authority (MDBA), in its consideration of the proposed Basin Plan, asked the Risk and Sustainable Management Group (hereafter called: RSMG) of The University of Queensland to undertake an analysis of economic impacts of likely reductions in irrigation in the Murray–Darling Basin (hereafter called: Basin). This analysis is intended to assist MDBA in its assessment of the socio-economic impacts of the Basin Plan.

The analysis utilises hydrological data on surface water diversions supplied by MDBA that draws on the best available science. This data was used as input to RSMG's water allocation model to simulate producers' responses to changes in access to irrigation water. The model represents 19 catchments within the Basin, where annual irrigation allocation is regulated through a cap on surface water diversions. The hydrological data was used to define regional water availability caps for representative land use allocation models specified for each of these catchments. Using the best available data on agricultural production, optimal land allocations were simulated for a set of production systems that represent the major irrigated land use activities in the Basin. These production systems incorporate a range of water using technologies specified over a set of three states of nature relating to seasonal water availability. The model thus represents irrigators' options, input requirements and outputs achievable under normal, drought and wet conditions. Irrigators are assumed to choose activities that best utilise the available water under prevailing seasonal conditions. Returns to irrigation are calculated as a weighted sum over the three states of seasonal variability, to determine the best achievable outcome for the set of commodities considered.

The data supplied by MDBA was used to define the variability associated with water flow patterns under each state of nature for a 114 year historical period.

The analysis compares the economic returns from irrigation for the Baseline scenario that represents the current diversion limit (CDL) and the Basin Plan Cap scenario that incorporates sustainable diversion limits (SDL). The Basin Plan Cap, simulated across the 19 catchments, on average, represents a 37 per cent overall reduction in water availability compared to the Baseline.

To illustrate the impact of Basin Plan extraction limits under variable seasonal patterns, simulations were conducted using flow variability estimates for the full historical period as well as the recent decade, 1998 to 2008.

The RSMG model has two solution modes. In the sequential optimisation mode, the Basin water allocation is solved for the 19 catchments from Condamine to South Australian Murray in order as they appear in a connected network, but allowing for water trade within each catchment. In the global optimisation mode, the model allows for trade across regions in the southern connected system from Murrumbidgee to South Australian Murray. Within-region trade is allowed for other catchments, as is currently feasible. In this mode, a globally optimal water use pattern for the entire Basin is simulated, in a manner consistent with the current institutional rules for water trading.

The Baseline simulation of the RSMG model has been calibrated to be consistent with the 2000-01 irrigation water use data drawn from the Australian Bureau of Statistics (ABS) census of agriculture. The price data used represents 2007-08 values.

The simulations indicate that the Baseline water availability under the current diversion limit of 10,758 gigalitres is adequate to support an agricultural system consistent with the recent peak water use of 10,516 gigalitres in 2000-01. The model estimate of water use for this scenario of 10,560 gigalitres and the associated irrigated land area of 1,770 thousand hectares is comparable to ABS estimates. The small deviation in irrigated area between the modelled and ABS estimates is attributable to the advancements in technology since 2000-01 and the ABS area of 'other agriculture' (41,000 ha) that is not modelled in the production systems used in the model.

Under the Basin Plan scenario, the estimated water use fell by 3,746 gigalitres or 35.5 per cent compared to the Baseline scenario. The associated opportunity cost, in gross value of irrigated production was $1,445 million, or 16 per cent compared to the Baseline. The regional profit from agricultural production was estimated to fall from $2,325 million to $1,954 million, a drop of $371 million or 16 per cent from the Baseline.

The analysis indicates that if the current cap on diversions were to be reduced by 37 per cent to allow water for the environment, gross agricultural returns would fall by 16 per cent. The associated loss in regional economic surplus would also be 16 per cent.

These results are broadly consistent with the observed pattern of change in agricultural production in the Basin over the past ten years. In this period, levels of reduction in water availability ranged from 4 to 70 per cent, compared to 2000-01.

The model estimates noted above were drawn from the global optimisation runs of the RSMG model. In this mode, the model allows for water trade within a region only for all regions in Queensland and regions down to Lachlan in New South Wales. It allows for trade across regions in the southern connected system from Murrumbidgee to South Australian Murray. When the model was simulated in this mode, it solved for a globally optimal water use pattern for the Basin.

For comparison, the model was also run as a sequential optimisation where the Basin water allocation was solved for each catchment allowing water trade within each region. In these runs, under the Basin Plan, the estimated water use fell by 29 per cent compared to the Baseline. The area irrigated fell by 14 per cent with an associated drop in gross value of production and the regional surplus by 20 and 19 per cent respectively. The relative benefits of water trade under the Baseline scenario were around 4 and 9 per cent respectively for the gross value of production and regional surplus.

Therefore it is reasonable to conclude from this analysis that the proposed cut in current diversion limits to allow for environmental water would result in a reduction in irrigation net returns of around 16 to 20 per cent compared to the Baseline. In real 2007-08 dollars, this drop in economic surplus is equivalent to around $371 to $405 million per annum. Under the Basin Plan scenario, the trade related gain in estimated gross value of production was 7 per cent and the regional surplus was 12 per cent higher compared to the Baseline. This indicates that water trading is a significant factor that could mitigate the impact of reduced water availability on regional incomes under the Basin Plan.

A detailed discussion on the production impacts by key regions are presented in the report along with comparisons using ABS data.

The analysis presented here needs to be viewed as indicative only, taking account of the annual variability observed in recent years. It was noted in both the analysis of hydrological data, and in model simulations, that water flows were highly variable in northern catchments that represent tributaries of the Darling system. Flow variability is moderated in the Murray through storages that offer the ability to pool resources that can be reallocated through water trade.

Overall, the analysis indicates that the economic costs associated with changes in agricultural production due to reduced water availability resulting from the introduction of the Basin Plan will vary across regions. The magnitude of costs will be dependent on the extent of adjustment already undertaken by irrigators to respond to low water availability and the flexibility of the farming systems to adjust. In these adjustments availability of water trade provides greater flexibility thus providing opportunities to increase the productivity of water. The differences in the relative magnitude of production variables between the sequential and global model runs indicates the potential benefits of removing barriers to trade in water and allowing a more efficient allocation of water.

This analysis was undertaken within a short period of time to address the objectives stated earlier. By necessity, detailed analysis on adaptation options to examine how irrigators would handle the transition from high water availability to a low water availability regime was not possible. The analysis also does not take into account variations in the security attached to water entitlements such as low and high reliability. As the relative mix of these entitlements vary widely across catchments the impacts of water availability changes at the individual irrigator level will also vary widely. Further work is needed to better understand adaptation patterns in different regions and ways to minimise associated adjustment costs.

1. INTRODUCTION

This study was commissioned by the Murray–Darling Basin Authority to help inform social and economic analysis underpinning the development of the Murray–Darling Basin Plan. The analysis is to be based on the best available science and economic tools. This work is intended to supplement the main analysis of costs for the agricultural sector conducted by the Australian Bureau of Agricultural and Resource Economics (ABARE).

The analysis reported here is based on the Risk and Sustainable Management Group's Murray–Darling Basin model. This work has been commissioned with two objectives:

- To provide a basis to assess whether different leading models, in this case the University of Queensland's Murray–Darling Basin model, produces results that are similar to or divergent from results produced by ABARE. If results are divergent, the analysis will help gain insight into any divergence.
- To provide insight into the economic implications of the Basin Plan by understanding the relationship between the catchment level water availability and its variability as observed in historical data.

This report summarises model outputs and provides a discussion comparing likely patterns and expected returns from water use for irrigation. A series of model runs are discussed in comparison with observations from 1998-2008, using ABS data where available. The primary aim of this study is to estimate the regional impact of introducing sustainable diversion limits. The analysis assumes that the water users will respond by reallocating water between different production systems to maximise profits. The optimisation approach permits the assessment of changes in production benefits by comparing simulations for the Baseline and Basin Plan scenarios at the individual catchment and the Basin scale.

This analysis incorporates the best available hydrological data provided by MDBA which is used as input to an economic optimisation model. The research team worked closely with MDBA hydrologists and other researchers from CSIRO and ABARE working on the economic assessment. This interaction helped develop a shared understanding of the data set, its limitations and appropriate ways to summarise the data for economic analysis. The analysis remains independent.

The optimisation model used for the analysis is analytically robust as an economic assessment tool. It has received international peer review and has been used in similar work in the past (Adamson et al. 2007; Garnaut 2008: Mallawaarachchi et al. 2008).

The report is presented in four sections including this introduction. Section 2 provides an overview of the methods used. The model results are discussed in Section 3, including a discussion on variability and water trade. Section 4 provides a comparison of the RSMG model with the ABARE's Water Trade Model. Section 5 concludes the report with some general insights. The appendix includes detailed model documentation, some data tables and a short description of assumptions used.

2. METHODS

The key study objective was to determine, through model simulations, the potential impacts of reduced water availability on agricultural production in the Basin. This was to be achieved by undertaking model runs for scenarios that include:

- Baseline analysis of mean and variance; and
- A Basin Plan scenario that draws on data provided by MDBA that specified the specific spatial patterns of reduced water availability for consumptive water uses based on the ecologically determined sustainable diversion limits (SDLs) by catchment.

For both the Baseline and Basin Plan scenario, 114 years of annual water availability data are used to evaluate and report on the impacts of changes in allocation variability. To achieve this with limited data and time available a number of simplifying assumptions have been used both in data preparation and model simulation. This chapter outlines the study methods, including the assumptions and limitations of the modelling and analysis used.

DATA PREPARATION

Data supplied by MDBA was used to analyse variability associated with water flow patterns under each state of nature. The RSMG model data was modified using three simulated annual time series datasets (1895-2008) supplied by MDBA:

- 'Water availability' or the highest point of flow within a catchment;
- 'Current diversions limits' (CDLs) or the historical surface water diversions; and
- 'Sustainable diversions limits' (SDLs) or the expected future diversions as a result of cuts applied under the Basin Plan.

Data was drawn from the MDBA WRON hydrological database for each catchment as defined by CSIRO. As the spatial boundaries of individual data sets and those of the RSMG model were different, this data was adjusted to match the RSMG spatial boundaries which follow the Australian Government natural resource management regions.

This analysis was undertaken for the full 114 year historical series as well as for the recent ten years commencing in 1998. The flow variability is represented over the three states of nature for each catchment drawing on the catchment level data set provided. The flows that vary by state of nature for each catchment define the seasonal water availability constraint. The model then determines the water use by catchment within the diversion cap.

VARIABILITY

The RSMG model incorporates medium term water availability over individual states of nature, rather than just the mean. In this model three states of nature are used to represent normal, drought and wet years. These states of nature are defined as their probability of occurrence over the historical medium term. It is assumed that over the medium term the normal state occurs 50 per cent of the time, the drought state 20 per cent of the time, and the wet state 30 per cent of the time. These assumptions are based on historical records of Basin inflows confirmed through personal correspondence with the Murray Darling Basin Commission in July 2007.

This concept of representing variability was applied to annual time series data to find the volumes associated with each state of nature. This was achieved by fitting a statistical distribution to the diversion dataset, to produce a rank order for volumes available. The volume of the lowest 20th percentile of the distribution was used to represent water availability in a drought state. Similarly the volume of the 50th percentile and the 70th percentile were chosen to represent a normal and a wet year respectively.

Variability is represented as the difference between the volumes that define the three states of nature. Variability is treated as catchment specific, except the catchments of the river Murray (M1, M2, M3, Mallee, LMDB and SAMDB) which are pooled. The percentage change in the drought and the wet state volumes from the normal volumes reflects the skewness and variability in the dataset. These values of skewness are used as flow multipliers in the model to relate normal state flows over the dry and wet states.

RECENT EXPERIENCE

An analysis was conducted on water availability over the last 10 years, considering the change in the frequency of states of nature. The inflow variability and the availability of diversion volumes of the last 10 years have been different to the historical experience. Average water available was lower due to the higher frequency of drought years. Therefore, the probabilities of occurrence of the states of nature were adjusted accordingly. To update the probabilities, the number of occurrences of each state of nature, based on the historical flow volumes in the Basin over the last 10 years was determined. Over the last 10 years, the historical drought state occurred 60 per cent of the time, the normal state occurred 30 per cent of the time, and the wet state occurred only 10 per cent of the time. The comparable figures for the historical period were, 50, 20 and 30 per cent respectively.

SCENARIOS

Two different flow scenarios were chosen: a historical scenario based on the complete 114 years water availability dataset (1895-2008), and a reduced water availability scenario based on the last 10 years of the water availability dataset (1998-2008). After all adjustments have been made to the water availability for each state, the probabilities of occurrence were applied as weights to determine the expected average water availability over the medium term (Table 1).

CALIBRATION

Aggregated catchment level water availability and variability (volumes by state of nature) were adjusted to match the total Basin water availability and variability. This ensured that the variability was not overstated by assuming homogenous states of nature across the entire Basin. The approach adopted recognises that under the Basin Plan the flow variability may be lower in certain catchments.

For each catchment the volumes for a normal season were calibrated to the 50th percentile of the distribution, drawn from MDBA data. This was to ensure consistency with the ABARE model for the Baseline runs. The flow multipliers for the drought and the wet state of nature were calibrated to the 20th and 70th percentile of the distribution respectively.

FLOW REGULATION

Basin storages are a major mechanism to moderate the inter-annual variability of flows in the Basin. The affect of dams has been simulated in the model by adjusting the state contingent variability of inflows. Adjustments were made to catchments that have dams with capacity over 1,000 gigalitre, where a portion of wet state inflows are allowed to be transferred over to a dry state.

Table 1: MDBA Input Data for RSMG Model

Catchment	Dam Capacity (GL)	Historical diversions Normal (GL)	Dry*	Wet*	Baseline Cap Normal (GL)	Dry*	Wet*	Basin Plan Cap Normal (GL)	Dry*	Wet*
Condamine	139	858	0.34	1.66	482	0.42	1.50	285	0.60	1.27
Border Rivers QLD	69	536	0.35	1.64	256	0.50	1.37	178	0.52	1.40
Warrego Paroo		874	0.34	1.66	49	0.43	1.47	43	0.50	1.38
Namoi	883	879	0.37	1.83	266	0.72	1.11	226	0.93	1.03
Central West	1,556	1,536	0.47	1.30	380	0.57	1.29	292	0.33	1.68
Maranoa Balonne	92	478	0.34	1.66	241	0.42	1.50	143	0.60	1.27
Border Rivers Gwydir	1,927	1,441	0.74	1.24	507	0.67	1.18	366	0.79	1.11
Western		414	0.30	2.78	198	0.81	1.10	147	0.82	1.09
Lachlan	1,256	1,114	0.67	1.29	287	0.59	1.17	261	0.61	1.14
Murrumbidgee	2,657	4,304	0.73	1.10	2,106	0.87	1.06	1,267	0.85	1.07
North East	6,981	1,728	0.73	1.13	103	0.90	1.04	63	0.88	1.03
Murray 1		2,964	0.76	1.09	85	0.81	1.10	50	0.67	1.23
Goulburn Broken	4,171	3,369	0.71	1.11	1,790	0.88	1.05	1,095	0.82	1.05
Murray 2	524	988	0.76	1.09	847	0.83	1.08	500	0.72	1.20
North Central		501	0.48	1.37	1,454	0.89	1.05	890	0.82	1.05
Murray 3	2,355	222	0.76	1.09	762	0.87	1.06	450	0.75	1.13
Mallee		422	0.76	1.09	205	0.90	1.04	125	0.78	1.07
Lower Murray Darling		209	0.76	1.09	73	0.66	1.26	42	0.93	1.03
SA MDB		261	0.76	1.09	667	0.89	1.05	391	0.35	1.93
Adelaide		0	0	0	0	0	0	0	0	0
Coorong		0	0	0	0	0	0	0	0	0
TOTAL	22,609	23,098	0.71	1.14	10,758	0.81	1.11	6,814	0.75	1.15

Note: * The values for the Dry and Wet columns refer to the expected variability of the diversion volume compared to the Normal.

RSMG MODEL SETUP

Model overview

The RSMG water allocation model is a regional programming model developed by The University of Queensland to simulate water allocation for irrigated agriculture within the Basin. For 19 regions within the Basin, the model optimally allocates an amount of water among enterprises according to relative profitability. The impacts of water availability on production are quantified as changes in the gross value of irrigated agricultural production (GVIAP) for a set of commodities. The GVIAP reflect changes in areas and yields resulting from water reallocations, as prices are assumed fixed. Other outputs from the model are farm profit, land use and water use.

The RSMG model broadly reflects existing biophysical conditions in each of the regions. The RSMG model's 19 regions are broadly consistent with the CSIRO sustainable yield regions. The two additional entities not used in the current simulations account for urban water use in Adelaide and residual flows to the sea. These regions and entities are sequentially linked in the model to mimic the natural flow patterns of the Basin river system.

- Water availability in the model comprises both surface and groundwater. However, assumed reductions in water availability in the simulations reflect only the reductions in surface runoff. Groundwater availability over the medium term is incorporated in the specified diversion limits. For these simulations, flow variability has been accounted by region and state of nature.
- The regions are linked by endogenously determined flows of salt and water. For the current simulations the salt module has been switched off. Water flows into and out of a region are modelled as being equal to inflows (net of evaporation and seepage), less extractions, net of return flows. Maximum extraction rates for each region are specified via the Murray–Darling Basin Cap (the Cap).
- The irrigated agricultural enterprises modelled were horticulture (citrus, stone fruit, grapes, and vegetables), a number of broadacre systems including dairy, beef, sheep, wheat, rice–wheat (on a rotational system), cotton, grain legumes, and a generic dryland enterprise. The dryland option accounts for any shifts from irrigation to dryland production. That is, if returns to irrigated agriculture decline, or irrigation is constrained by reductions in water availability, land may be transferred from irrigated to dryland agriculture.
- While the model accounts for all irrigable land within each region it does not specifically identify individual irrigation schemes within regions. Within each region, water and land are allocated so as to maximise net returns subject to the Cap and other constraints such as available land in a catchment.
- The RSMG model assumes uniform water charges across the Basin. This is in contrast with the existing situation where a range of water charging arrangements exists, even within regions.
- In general, if agricultural commodity output falls, then any resultant price increases may offset the reductions in farm income. Such changes have not been considered in the current assessment. A key assumption made in this analysis is constant commodity prices. This assumption means that production impacts in response to reduced surface water availability are considered in isolation from any price changes.

- Under a medium-term analysis timeframe (approximately 10 years), key factors of production are assumed to be mobile. A wide set of technology choices provide greater flexibility in land use as water availability declines.

The modelling assumes annual allocations of water under the Cap and therefore water management policies within a season (such as storage releases) are not explicitly considered. Although the model parameters represent all available seasonal conditions for most regions, modelling estimates for some regions may not fully correspond to available estimates from other sources. However, disparities have been minimised through model calibrations. Further details on the RSMG model are at appendix A and can also be accessed from: http://www.uq.edu.au/rsmg/docs/RSMG_MDB_Model_Documentation_010610.docx.

Simulation of irrigation impacts

The RSMG model has two principal ways of modelling changes to water availability, or a diversion limit.

> Option 1: Determine the regional impact of SDL. Here the SDL is used within the catchment only with intraregional water trade (there is no water trade across catchments). The model is solved as water flows down the Basin flow network (sequential runs).
>
> Option 2: Optimise the Basin water allocations for the national benefit of the SDLs (global run).

In this case, the SDL must be used within the trading region incorporating a set of catchments (southern Basin including state borders) but the solution is globally optimised so that impacts of trade are incorporated.

Two sets of model simulations were conducted for the range of water availability across the three states of nature. The first set, the Baseline, developed a modelled irrigated land use that utilised water within the CDL. The second set, the Basin Plan scenario represents an alternative irrigated land use that utilised water within the Basin Plan Cap on diversions. The Basin Plan Cap, simulated across the 19 catchments, on average represents a 37 per cent Basin wide reduction of water availability compared to the Baseline scenario.

To illustrate the impact of Basin Plan extraction limits under variable seasonal patterns, simulations were conducted using flow variability estimates for the full historical period as well as the recent decade, 1998 to 2008.

All model runs were produced under both the sequential (SEQ) and global or common property (CP) modes of the RSMG model following the experimental plan summarised in Table 2. However, summary results are only provided for key model runs, R4, R8, R12 and R16. The discussion in the report draws on other model runs where appropriate.

Table 2: Experimental plan for model simulations

Run ID	Scenarios	Water Access Cap	State probabilities	Flow data coverage
R1	Baseline	CDL	Normal = 1	Historical data
R2	Baseline	CDL	Dry = 1	Historical data
R3	Baseline	CDL	Wet=1	Historical data
R4	Baseline	CDL	SC run (N:0.5;D:0.2;W:0.3)	Historical data
R5	Basin Plan	SDL	Normal = 1	Historical data
R6	Basin Plan	SDL	Dry = 1	Historical data
R7	Basin Plan	SDL	Wet=1	Historical data
R8	Basin Plan	SDL	SC run (N:0.5;D:0.2;W:0.3)	Historical data
R9	Baseline	CDL	Normal = 1	Last 10 years data
R10	Baseline	CDL	Dry = 1	Last 10 years data
R11	Baseline	CDL	Wet=1	Last 10 years data
R12	Baseline	CDL	SC run (N:0.3;D:0.6;W:0.1)	Last 10 years data
R13	Basin Plan	SDL	Normal = 1	Last 10 years data
R14	Basin Plan	SDL	Dry = 1	Last 10 years data
R15	Basin Plan	SDL	Wet=1	Last 10 years data
R16	Basin Plan	SDL	SC run (N:0.3;D:0.6;W:0.1)	Last 10 years data
R17	Supply Response	90% CDL	SC run (N:0.5;D:0.2;W:0.3)	SC model under historical
R18	Supply Response	80% CDL	SC run (N:0.5;D:0.2;W:0.3)	SC model under historical
R19	Supply Response	70% CDL	SC run (N:0.5;D:0.2;W:0.3)	SC model under historical
R20	Supply Response	60% CDL	SC run (N:0.5;D:0.2;W:0.3)	SC model under historical
R21	Supply Response	90% CDL	SC run (N:0.3;D:0.6;W:0.1)	SC model under Last 10 years data
R22	Supply Response	80% CDL	SC run (N:0.3;D:0.6;W:0.1)	SC model under Last 10 years data
R23	Supply Response	70% CDL	SC run (N:0.3;D:0.6;W:0.1)	SC model under Last 10 years data
R24	Supply Response	60% CDL	SC run (N:0.3;D:0.6;W:0.1)	SC model under Last 10 years data

The above run IDs were further coded as R1SEQ and R1CP etc, for the sequential and global (common property) solutions respectively.

3. RESULTS

3.1 BASELINE SCENARIO

In this section the results for the Baseline scenarios that represent the land allocation under current diversion limits are presented. The analysis focuses on the key variables, water use, land allocations, value of agricultural production, and profits from irrigated agricultural production for each scenario to meet the Terms of Reference (TOR).

> *TOR: A Baseline run results report including outputs on predicted water use, land allocation, value of agricultural production, and profits from irrigated agricultural production*

WATER USE AND LAND ALLOCATION

In this section, the results for the Baseline scenarios are presented. These are based on the historical data, assuming no trade between catchments. Three Baseline scenarios represent the Normal, Dry and Wet state of nature. These three simulations have been run independent by one another, to represent the mean and variance associated with flow diversions, which allow production systems to change depending on the availability of water. The expected value is the weighted average over the medium term. However, due to uncertainty, it is not possible for producers to change production systems so easily. In reality, constraints such as capital costs and fixed investments such as tree and vine crops, restrict the flexibility to adapt to year-to-year changes in water availability.

The state-contingent scenario provides results for production under the assumption that, over the medium term, producers adopt a set of production systems that give them the flexibility to respond to variable conditions based on the expected pattern of seasonal variability. The result is a higher irrigated area and water use than the expected value. Similarly the surplus and gross value of irrigated agriculture is lower. The summary results are shown in Table 3 below.

Table 3: Summary — Baseline scenario

Baseline	Normal	Dry	Wet	Expected Value	State-Contingent
Area irrigated (‘000 ha)	2,067	2,229	1,367	1,890	2,012
Water use (GL)	9,342	6,521	9,893	8,943	9,534
Surplus ($m)	2,555	1,508	3,570	2,650	2,118
Gross value ($m)	10,238	6,224	14,629	10,753	8,940

The irrigated area, water use and gross value of irrigated agriculture are presented by catchment in Tables 4, 5 and 6 below. In these results, in catchments where there is greater flexibility to respond to changes in seasonal conditions (state-allocable technological options), the return for irrigation are greater under the state-contingent specification.

Table 4: Baseline irrigated area, by catchment

Baseline ('000 ha)	Normal	Dry	Wet	Expected Value	State-Contingent
Condamine	84	84	84	84	84
Border Rivers QLD	88	88	88	88	58
Warrego Paroo	29	29	27	29	12
Namoi	141	47	47	94	59
Central West	130	55	59	93	130
Maranoa Balonne	45	45	45	45	45
Border Rivers Gwydir	158	135	72	128	164
Western	52	0	52	42	52
Lachlan	88	45	30	62	33
Murrumbidgee	341	458	238	333	458
North East	14	21	12	15	14
Murray 1	18	18	9	16	10
Goulburn Broken	197	334	189	222	204
Murray 2	228	216	82	182	228
North Central	165	362	151	200	172
Murray 3	168	168	71	139	168
Mallee	27	21	24	25	26
Lower Murray Darling	10	8	9	9	9
SA MDB	84	95	77	84	85
Total	2,067	2,229	1,367	1,890	2,012

Table 5: Baseline water use, by catchment

Baseline (GL)	Normal	Dry	Wet	Expected Value	State-Contingent
Condamine	427	65	431	356	347
Border Rivers QLD	256	59	256	217	256
Warrego Paroo	49	45	49	48	49
Namoi	266	105	266	234	266
Central West	380	61	380	316	380
Maranoa Balonne	223	26	223	183	178
Border Rivers Gwydir	507	290	507	464	507
Western	8	0	198	64	198
Lachlan	92	198	260	164	287
Murrumbidgee	2,106	1,425	2,106	1,970	2,106
North East	103	100	103	102	103
Murray 1	85	85	85	85	85
Goulburn Broken	1,790	1,531	1,790	1,738	1,790
Murray 2	847	847	847	847	847
North Central	496	614	850	626	602
Murray 3	762	614	762	732	762
Mallee	205	205	205	205	205
Lower Murray Darling	73	73	73	73	73
SA MDB	667	177	502	519	492
Total	9,342	6,521	9,893	8,943	9,534

Table 6: Baseline gross value of irrigated production, by catchment

Baseline ($million)	Normal	Dry	Wet	Expected Value	State-Contingent
Condamine	569	157	595	494	518
Border Rivers QLD	675	136	612	548	631
Warrego Paroo	92	38	31	63	58
Namoi	552	297	362	444	373
Central West	592	367	629	558	545
Maranoa Balonne	242	59	242	205	211
Border Rivers Gwydir	613	200	461	485	560
Western	132	0	96	95	83
Lachlan	406	260	859	513	307
Murrumbidgee	1,593	1,304	3,297	2,047	1,505
North East	128	104	360	193	133
Murray 1	63	46	70	62	56
Goulburn Broken	951	741	2,141	1,266	1,000
Murray 2	612	357	417	502	407
North Central	638	599	988	735	675
Murray 3	448	274	372	390	329
Mallee	485	363	1,648	810	466
Lower Murray Darling	180	141	413	242	173
SA MDB	1,269	781	1,035	1,101	908
Total	10,238	6,224	14,629	10,753	8,940

COMPARISON WITH ABS DATA

In order to evaluate the accuracy of the Baseline model solutions a comparison with various historical data provided by ABS was undertaken. This specifically meets the TOR:

> *TOR: A Baseline run results report including outputs on tables and discussion comparing predictions with recent observations from public reporting such as ABS data*

In considering the following analysis, two key points should be considered. Firstly, the results obtained in the modelling process are based on an optimised allocation of resources that provide the greatest net return. Secondly, the returns are based on gross margin budgets that represent average returns and production costs over a wide area. Consequently, farmers' actual yields, prices received and the costs associated with irrigated production will vary significantly from the gross margin budgets used here. Therefore, actual allocation of resources by individuals will be different to that described in the model as each producer rationally takes advantage of their own comparative advantage or resource constraints in determining production levels. However, the modelling results presented here provide an overview of the average comparative advantage for irrigated production across the Basin catchments.

In this comparison the simulation results are drawn from the sequential solution of RSMG runs because that run is more consistent with the water trade situation as of 2000-01.

LAND ALLOCATION

Historical ABS data for area distribution among irrigated activities within the Basin is shown in Table 7.

Table 7: Area irrigated in Murray–Darling Basin, by agricultural commodity

Area Irrigated ('000 ha)	2000-01	2001-02	2002-03	2003-04	2004-05	2005-06	2006-07	2007-08	2008-09
Pasture for dairy and other livestock farming	760	707	551	669	703	717	446	365	267
Rice	178	145	44	65	51	102	20	2	7
Cereals (excl. rice)	260	354	416	340	324	329	266	291	291
Cotton	405	394	218	174	258	247	126	53	128
Grapes	84	86	89	87	92	106	112	106	102
Horticulture (excl. grapes)	96	97	105	99	98	107	104	99	94
Other agricultural commodities	41	34	43	67	62	46	26	35	35
Total	1,824	1,817	1,466	1,501	1,588	1,654	1,101	958	929

Source: ABS 2010, ABS 2009a, ABS 2009b, ABS 2008

In Table 8, the model results for area irrigated by commodity in the Baseline scenario is compared to the 2000-01 ABS data.

Table 8: Area irrigated — ABS data and Baseline model comparison

Area Irrigated (‘000 ha)	ABS 2000–01	Baseline	Absolute Difference	Percentage Difference
Pasture for dairy and other livestock farming	760	398	-362	-48%
Rice	178	383	205	115%
Cereals (excl. rice)	260	501	241	93%
Cotton	405	533	128	31%
Grapes	84	72	-12	-15%
Horticulture (excl. grapes)	96	126	30	31%
Other agriculture	41	0	-41	
Total	1,824	2,012	188	10%

In Tables 9 to 12, ABS data for key parameters are shown for the 2000-01 to 2007-08 production periods, where available. This allows a comparison of irrigated agriculture within the Basin and those of the model results.

This data indicates that the Baseline of the RSMG model is broadly consistent with the 2000-01 agricultural production patterns estimated by ABS. It should be noted that the price data used represents 2007-08 values and hence 2000-01 ABS value data are not comparable to model estimates, except in a relative sense.

In this comparison the state-contingent Baseline results are compared to ABS data for key variables, area irrigated, water consumption, and gross value of irrigated agricultural production. The 2000-01 data has been used as the main year of comparison, as it is considered to be a normal year of rainfall and production in the Basin.

The simulations indicate that the Baseline water availability under the current diversion limit of 10,758 gigalitres is adequate to support an agricultural system largely consistent with the recent peak water use of 10,516 gigalitres in 2000-01. The model estimate of water use for this scenario of 10,560 gigalitres and the associated irrigated land area of 1,770 thousand hectares is comparable to ABS estimates. The small deviation in irrigated area between the modelled and ABS estimates, is attributable to the advancements in technology since 2000-01 and the ABS area of 'other agriculture' (41,000 ha) that is not modelled in the production systems used in the model.

WATER USE

Table 9 provides an overview of water consumption by different agricultural commodities produced within the Basin. This data and data in Table 10 indicates that the Baseline water use of the RSMG model is broadly consistent with the 2000-01 Agricultural production patterns estimated by ABS.

Table 9: Water consumption, by agricultural commodity

Water consumption (GL)	2000-01	2001-02	2002-03	2003-04	2004-05	2005-06	2006-07	2007-08	2008-09
Pasture for dairy and other livestock farming	3,227	2,971	2,343	2,549	2,371	2,571	1,143	997	760
Rice	2,418	1,978	615	814	619	1,252	239	27	101
Cereals (excl. rice)	751	1,015	1,230	876	844	782	572	805	789
Cotton	2,599	2,581	1,428	1,186	1,743	1,574	819	283	793
Grapes	469	479	492	489	510	515	534	434	439
Horticulture (excl. grapes)	538	541	567	576	551	565	542	480	494
Other agriculture	514	504	475	596	564	460	607	95	100
Total	10,516	10,069	7,150	7,087	7,204	7,720	4,458	3,142	3,492

Source: ABS 2009a, ABS 2009b, ABS 2009c, ABS 2009d; Note: Explanatory notes on the categorisation of agricultural commodities are provided in the Appendix.

In Table 10, the Baseline water consumption by commodity is compared to the 2000-01 data. In the model calibrations the focus was to seek consistency with the ABS data for the level of water consumption for key crops/cropping systems. It should be noted that when accounting for the nature of the rice farming system modelled, the area of rice rotation in the Baseline is not significantly higher than that observed in 2000-01.

Table 10: Water consumption — ABS data and Baseline model comparison

Water consumption (GL)	ABS 2000–01	Baseline	Absolute Difference	Percentage Difference
Pasture for dairy and other livestock farming	3,227	3,441	214	7%
Rice	2,418	3,452	1,034	43%
Cereals (excl. rice)	751	189	-562	-75%
Cotton	2,599	1,838	-761	-29%
Grapes	469	482	13	3%
Horticulture (excl. grapes)	538	1,159	621	115%
Other agriculture	514	0	-514	
Total	10,516	10,560	44	0%

SPATIAL DISTRIBUTION OF IRRIGATION AREA AND VOLUME

Due to a lack of earlier reporting, the ABS data for 2007-08 has been used to investigate the area and volume of irrigation, by state and by catchments in Table 11 and Table 12. These are only to be used as a general guide to the order of magnitudes as this was a very dry year.

Table 11: Comparison of spatial distribution of irrigation across states

Irrigation Area and Volume Proportion of total	ABS 2007-08		Baseline	
	Irrig. Area %	Vol. Applied %	Irrig. Area %	Vol. Applied %
Queensland	14	13	10	9
New South Wales	48	48	65	58
Victoria	30	29	21	28
South Australia	8	10	4	5
Total	100	100	100	100

Table 12: Comparison of spatial distribution of irrigation across catchments

Catchment Management Region	ABS 2007-08		Baseline	
	Irrig. Area % of total	Vol. Applied % of total	Irrig. Area % of total	Vol. Applied % of total
Condamine	6.6	4.6	4.2	3.6
Border Rivers QLD	7.7	8.4	2.9	2.7
Warrego-Paroo	0.0	0.0	0.6	0.5
Namoi	7.6	6.4	2.9	2.8
Central West	4.8	4.7	6.4	4.0
Maranoa-Balonne	0.0	0.0	2.2	1.9
Border Rivers-Gwydir	6.6	6.0	8.1	5.3
Western	1.0	1.2	2.6	2.1
Lachlan	7.7	7.8	1.7	3.0
Murrumbidgee	12.7	14.6	22.8	22.1
North East	1.4	1.4	0.7	1.1
Murray 1	6.1	4.9	20.2	17.8
Goulburn-Broken	13.7	12.2	10.2	18.8
Murray 2	-	-	-	-
North Central	11.0	9.1	8.6	6.3
Murray 3	-	-	-	-
Mallee	4.3	6.6	1.3	2.2
Lower Murray Darling	1.2	2.2	0.5	0.8
SA MDB	7.7	10.1	4.2	5.2
Total	100	100	100	100.

Source: ABS 2009b

VALUE OF AGRICULTURAL PRODUCTION

ABS data for the gross value of irrigated agricultural productions as presented in Table 13 refers to the gross value of agricultural commodities that are produced with the assistance of irrigation. The estimated values in the ABS data set (ABS 2009c) reflect the recorded value of production at the wholesale prices realised in the marketplace. The ABS explanatory notes highlight that the gross value of irrigated production should not be used as a proxy for determining the highest value of water uses. The data presented should rather be used as a tool for measuring changes over time or for comparing regional differences in irrigated agricultural production (ABS 2009c). Furthermore, in considering Table 14, it should be noted that estimates for GVIAP are presented in current (2007-08) prices; therefore changes between the years shown in these tables partly reflect the effects of price changes (ABS 2009c).

Table 13: Gross value of irrigated agricultural production — ABS estimates

Gross Value of Irrigated Agricultural Production ($m)	2000–01	2005–06	2006-07
Pasture for dairy and other livestock farming	1,395	1,798	1,662
Rice	349	274	55
Cereals (excl. rice)	149	180	191
Cotton	1,111	798	457
Grapes	785	721	651
Horticulture (excl. grapes)	1,169	1,566	1,777
Other agricultural commodities	90	150	129
Total Agriculture	5,085	5,522	4,936

Source: ABS data available on request, value of agricultural commodities produced, Australia, 2005–06

Table 14: Gross value of irrigated agricultural production — ABS data and Baseline model comparison

Gross Value of Irrigated Agriculture ($m)	ABS 2000–01	Baseline	Absolute Difference	Percentage Difference
Pasture for dairy and other livestock farming	1,395	1,311	-84	-6
Rice	349	1,022	673	193
Cereals (excl. rice)	149	426	277	186
Cotton	1,111	2,194	1,083	98
Grapes	785	1,133	347	44
Horticulture (excl. grapes)	1,169	2,856	1,687	144
Other agricultural commodities	90	0	-90	
Total Agriculture	5,085	8,940	3,855	76

3.2 BASIN PLAN SCENARIO

The purpose of this section is to address the next part of the TOR:
A MDBA plan run report including reporting on:

- *predicted water use, land allocation, value of agricultural production, and profits from irrigated agricultural production by region and crop,*
- *changes in (a) from Baseline, implied elasticities of supply with respect to water and/or water price by catchment and the extent possible commodity,*
- *tables and discussion comparing predictions to patterns of land and water use change reported publicly for the recent drought (e.g. ABS data for 2001 versus 2005 change trends in comparison to modelling results),*
- *for the MDBA plan run a with trade scenario - consider trade in the southern system subject to hydrologic constraints on the trade upstream into tributaries and upstream of the Barmah choke from downstream of the Barmah choke,*
- *model documentation (governing equations, relevant data and assumptions).*

In this section, the results for the Basin Plan scenarios are presented. Three scenarios represent the Normal, Dry and Wet state of nature. As with the Baseline scenario runs, the state-contingent scenario results in higher irrigated area and water use, and lower surplus and gross value of irrigated agriculture, when compared to the expected value, as shown in Table 15.

Table 15: Summary — Basin Plan scenario

Basin Plan	Normal	Dry	Wet	Expected Value	State-Contingent
Sequential solution					
Area irrigated (‘000 ha)	1,841	1,586	960	1,525	1,726
Water use (GL)	6,507	5,720	6,813	6,441	6,814
Surplus ($m)	2,184	1,217	2,787	2,172	1,713
Gross value ($m)	8,776	5,061	11,751	8,925	7,184

The irrigated area, water use and gross value of irrigated agriculture are presented by catchment in Tables 16, 17 and 18 below.

Table 16: Basin Plan scenario — irrigated area, by catchment

Basin Plan (‘000 ha)	Normal	Dry	Wet	Expected Value	State-Contingent
Condamine	84	84	84	84	69
Border Rivers QLD	88	88	75	84	39
Warrego-Paroo	29	26	24	27	11
Namoi	141	40	40	91	50
Central West	130	45	45	87	118
Maranoa-Balonne	45	45	45	45	36
Border Rivers-Gwydir	153	97	52	112	144
Western	52	38	40	46	52
Lachlan	88	40	28	60	31
Murrumbidgee	310	279	144	254	458
North East	9	13	7	9	9
Murray 1	18	12	6	13	6
Goulburn-Broken	120	232	117	141	123
Murray 2	228	126	48	154	228
North Central	102	227	93	124	106
Murray 3	168	114	42	119	168
Mallee	17	13	15	15	16
Lower Murray Darling	6	4	5	5	5
SA MDB	53	62	50	54	57
Total	1,841	1,586	960	1,525	1,726

Table 17: Basin Plan — water use, by catchment

Basin Plan (GL)	Normal	Dry	Wet	Expected Value	State-Contingent
Condamine	285	65	285	241	285
Border Rivers QLD	178	59	178	154	178
Warrego-Paroo	43	43	43	43	43
Namoi	226	105	226	202	226
Central West	292	61	292	246	292
Maranoa-Balonne	143	26	143	120	143
Border Rivers-Gwydir	366	290	366	351	366
Western	8	0	147	48	147
Lachlan	92	198	260	164	261
Murrumbidgee	1,267	1,267	1,267	1,267	1,267
North East	63	63	63	63	63
Murray 1	50	50	50	50	50
Goulburn Broken	1,095	1,095	1,095	1,095	1,095
Murray 2	500	500	500	500	500
North Central	890	890	890	890	890
Murray 3	450	450	450	450	450
Mallee	125	125	125	125	125
Lower Murray Darling	42	42	42	42	42
SA MDB	391	391	391	391	391
Total	6,507	5,720	6,813	6,441	6,814

Table 18: Basin Plan — gross value of irrigated production, by catchment

Basin Plan (million)	Normal	Dry	Wet	Expected Value	State-Contingent
Condamine	471	157	400	387	444
Border Rivers QLD	621	136	524	495	539
Warrego-Paroo	88	33	28	59	51
Namoi	516	253	311	402	318
Central West	542	313	548	498	464
Maranoa-Balonne	187	59	135	146	169
Border Rivers-Gwydir	530	147	345	398	440
Western	132	72	81	104	82
Lachlan	406	255	851	509	300
Murrumbidgee	1,450	1,029	2,965	1,820	1,268
North East	108	93	335	173	112
Murray 1	48	33	48	45	40
Goulburn-Broken	689	602	1,815	1,010	722
Murray 2	579	225	265	414	304
North Central	441	421	742	527	465
Murray 3	424	196	249	326	242
Mallee	296	222	1,005	494	284
Lower Murray Darling	104	81	238	139	100
SA MDB	1,148	736	867	981	842
Total	8,776	5,061	11,751	8,925	7,184

Under the Baseline scenario, the mean variance weighted solution (expected value) is an overestimation of the achievable production outcomes. But it provides a basis on which to compare the possible range of outcomes, given likely variability in seasonal flow patterns.

3.3 Comparison of Baseline and Basin Plan scenarios

In this comparison the state-contingent Basin Plan scenario results are compared with the Baseline scenario results for area irrigated, water consumption, and gross value of irrigated agricultural production. This comparison will show the impact of the cut in diversions limits as a result of implementing SDLs, other things being held constant.

As a result of the Basin Plan, in the absence of interregional water trade, the area irrigated will likely decline by 14 per cent, along with a decline in water use by 29 per cent, and a fall in gross value of irrigated agriculture of 20 per cent (Table 19). When full trade is allowed for the southern Basin, the regional economic impacts of the Basin Plan reduces somewhat, as water moves to more profitable uses.

Table 19: Summary comparison of Baseline and Basin Plan results

Comparison	Baseline	Basin Plan	Absolute Difference	Percentage Difference
Sequential solution				
Area irrigated (‘000 ha)	2,012	1,726	-286	-14
Water use (GL)	9,534	6,814	-2,720	-29
Surplus ($m)	2,118	1,713	-405	-19
Gross value ($m)	8,940	7,184	-1,756	-20
Global solution				
Area irrigated (‘000 ha)	1,821	1,614	-207	-11
Water use (GL)	10,560	6,814	-3,746	-35
Surplus ($m)	2,325	1,954	-371	-16
Gross value ($m)	9,170	7,725	-1,445	-16

Land allocation

In Table 20, the area irrigated by commodity, under the Basin Plan scenario is compared to the Baseline scenario. There is an overall reduction in irrigated land by 14 per cent. Land use shifts away from rice production and dairy, and cereal production is likely to increase. Grape production is likely to remain unchanged. This result is possibly due to changes in the reliability (reduced variance) in the availability of water for regions with permanent agriculture such as the Murray region. While there is large disparity, the biggest reductions in irrigated land is experienced in Victoria (39 per cent) followed by South Australia (34 per cent). Murrumbidgee, the catchment with the most irrigated land in the Basin, retains all of its area and as a result, the fall in NSW irrigated land is not as severe (Table 20).

Table 20: Area irrigated — comparison of Baseline and Basin Plan results, by commodity

Area irrigated ('000 ha)	Baseline	Basin Plan	Absolute Difference	Percentage Difference
Pasture for dairy and other livestock farming	398	213	-184	-46
Rice	383	151	-232	-60
Cereals (excl. rice)	501	730	229	46
Cotton	533	448	-85	-16
Grapes	72	72	0	0
Horticulture (excl. grapes)	126	112	-14	-11
Other agriculture	0	0	0	
Total	2,012	1,726	-286	-14

The comparison in Table 21 between the Baseline and the Basin Plan scenarios indicates the extent of the likely changes in irrigated land use.

Table 21: Area irrigated — comparison of Baseline and Basin Plan results, by catchment and state

Area irrigated ('000 ha)	Baseline	Basin Plan	Absolute Difference	Percentage Difference
Condamine	84	69	-16	-18
Border Rivers QLD	58	39	-20	-33
Warrego-Paroo	12	11	-2	-12
Namoi	59	50	-9	-15
Central West	130	118	-11	-9
Maranoa-Balonne	45	36	-9	-20
Border Rivers-Gwydir	164	144	-20	-12
Western	52	52	0	0
Lachlan	33	31	-3	-9
Murrumbidgee	458	458	0	0
North East	14	9	-5	-36
Murray 1	10	6	-4	-40
Goulburn-Broken	204	123	-81	-40
Murray 2	228	228	0	0
North Central	172	106	-66	-38
Murray 3	168	168	0	0
Mallee	26	16	-10	-39
Lower Murray Darling	9	5	-4	-42
SA MDB	85	57	-29	-34
QLD	199	154	-45	-23
NSW	1,302	1,255	-46	-4
Victoria	416	254	-162	-39
SA	85	57	-29	-34
Total	2,012	1,726	-286	-14

WATER USE

There is an overall reduction in water consumption by 14 per cent. As with land use, the biggest cuts are from the rice and dairy production systems, transferring to less water-intensive cereal crops. Water use for grape production falls by 10 per cent, although the land use remains unchanged (Table 22).

Table 22: Water consumption — comparison of Baseline and Basin Plan results, by commodity

Water consumption (GL)	Baseline	Basin Plan	Absolute Difference	Percentage Difference
Pasture for dairy and other livestock farming	3,441	1,644	-1,798	-52
Rice	3,452	1,740	-1,712	-50
Cereals (excl. rice)	189	813	624	330
Cotton	1,838	1,266	-572	-31
Grapes	482	432	-49	-10
Horticulture (excl. grapes)	1,159	920	-239	-21
Other agricultural	0	0	0	0
Total agricultural	10,560	6,814	-3,746	-35

Table 23: Water consumption — comparison of Baseline and Basin Plan results, by catchment and state

Water consumption (GL)	Baseline	Basin Plan	Absolute Difference	Percentage Difference
Condamine	347	285	-62	-18
Border Rivers QLD	256	178	-78	-30
Warrego-Paroo	49	43	-6	-12
Namoi	266	226	-40	-15
Central West	380	292	-88	-23
Maranoa-Balonne	178	143	-35	-20
Border Rivers-Gwydir	507	366	-141	-28
Western	198	147	-51	-26
Lachlan	287	261	-26	-9
Murrumbidgee	2,106	1,267	-839	-40
North East	103	63	-40	-39
Murray 1	85	50	-35	-41
Goulburn-Broken	1,790	1,095	-695	-39
Murray 2	847	500	-347	-41
North Central	602	890	288	48
Murray 3	762	450	-312	-41
Mallee	205	125	-80	-39
Lower Murray Darling	73	42	-31	-42
SA MDB	492	391	-101	-21
QLD	831	649	-182	-22
NSW	5,438	3,559	-1,879	-35
Victoria	2,700	2,173	-527	-20
SA	492	391	-101	-21
Total	9,534	6,814	-2,720	-29

The biggest reductions in water use are likely in NSW (35 per cent), and the Murrumbidgee water consumption is likely to fall by around 40 per cent. The fall in water use and retention of irrigated land indicates that there likely to be a partial shift in rice production to cereal production in the Murrumbidgee as a result of the Basin Plan (Table 23).

GROSS VALUE OF AGRICULTURAL PRODUCTION

There is an overall reduction in GVIAP by 20 per cent in the Basin, as the opportunity cost of contracting dairy (45 per cent fall) and rice (61 per cent fall) industries is not fully compensated for an increase in the value of cereal production (43 per cent increase). The reduction in water use for grapes does not result in a loss in value (Table 24).

Table 24: Gross value of irrigated agricultural production — comparison of Baseline and Basin Plan results, by commodity

Gross Value of Irrigated Agriculture ($m)	Baseline	Basin Plan	Absolute Difference	Percentage Difference
Pasture for dairy and other livestock farming	1,311	717	-594	-45
Rice	1,022	401	-621	-61
Cereals (excl. rice)	426	610	184	43
Cotton	2,194	1,741	-452	-21
Grapes	1,133	1,133	0	0
Horticulture (excl. grapes)	2,856	2,582	-274	-10
Other agricultural commodities	0	0	0	0
Total	8,940	7,184	-1,756	-20

The greatest fall in GVIAP was in Victoria, as a result of a shift away from dairy production (Table 25). It should be noted that the objective of the analysis was to determine the most profitable uses for water, and, in that search, activities with high gross values were only chosen if the associated net benefits were also high. As the opportunity costs of water increase, activities with lower profit margins would were phased out.

IMPACTS OF WATER TRADE

A number of studies indicate that, in adjusting to a low water availability environment, water trading has provided significant flexibility to irrigators (Mallawaarachchi and Foster 2009; National Water Commission 2010). Water trading facilitates an efficient allocation of water, allowing society to realise greater economic gains from limited available water.

While water trading is widespread in the Basin, much of the trade is limited to trading of water allocations, known commonly as temporary trade. Trading of water entitlements or permanent trade is limited but increasing. Ongoing water sector reform is expected to facilitate greater trade, but physical barriers such as a lack of storage may hinder trade in certain catchments which makes water transfers not possible.

In these simulations, water trading was incorporated in two ways. In the RSMG sequential model simulations, within-region trade was allowed for all catchments. In the global optimisation runs of the RSMG model, trade was allowed across regions in the southern connected system from Murrumbidgee to South Australian Murray. For all regions in Queensland, and regions down to Lachlan in New South Wales, trade is allowed only within a region, as is feasible at present. When the model was simulated in this mode, it solved for a globally optimal water use pattern for the Basin, within this extended trading regime.

Table 25: Gross value of irrigated agricultural production — comparison of Baseline and Basin Plan results, by catchment and state

GVIAP ($million)	Baseline	Basin Plan	Absolute Difference	Percentage Difference
Condamine	518	444	-74	-14
Border Rivers QLD	631	539	-92	-15
Warrego-Paroo	58	51	-7	-12
Namoi	373	318	-55	-15
Central West	545	464	-81	-15
Maranoa-Balonne	211	169	-42	-20
Border Rivers-Gwydir	560	440	-120	-21
Western	83	82	-1	-2
Lachlan	307	300	-8	-2
Murrumbidgee	1,505	1,268	-237	-16
North East	133	112	-21	-16
Murray 1	56	40	-17	-30
Goulburn-Broken	1,000	722	-278	-28
Murray 2	407	304	-104	-25
North Central	675	465	-210	-31
Murray 3	329	242	-87	-27
Mallee	466	284	-182	-39
Lower Murray Darling	173	100	-74	-42
SA MDB	908	842	-67	-7
QLD	1,418	1,203	-215	-15
NSW	4,166	3,457	-709	-17
Victoria	2,275	1,583	-692	-30
SA MDB	908	842	-67	-7
Total	8,940	7,184	-1,756	-20

Although there is some concern about the implications for water trading of some physical restrictions in the southern connected systems such as the Barmah choke, RSMG model does not incorporate a mechanism to introduce that restriction. The authors believe, on the basis of past experience, that the volume of trade that is likely to occur will not be effected by the restriction, because the upstream–downstream net flow is not large enough to cause difficulties for the water authorities to manage.

Model runs indicates that the availability of unrestricted trade in the southern Basin is important to contain the costs to irrigators of introducing the Basin Plan. For example, under the Basin Plan, the estimated benefits of water trading would be around $240 million or 12 per cent, in terms of regional surplus (Table 26). Under the more restricted flow conditions, as experienced over the past decade, the benefits would be limited to around $149 million. Water use fell by 29 per cent compared to the Base solution. With the availability of trade, production moves to higher value land uses, resulting in a lower irrigated area, but also higher returns.

Table 26: Effect on model parameters of allowing water trading

Model run	Area irrigated		Water use		GVIAP		Surplus	
	(Ha '000)	%	(GL)	%	($m)	%	($m)	%
Baseline (R4)	-190.6	-10	1026.4	10	394.1	4	206.7	9
Baseline recent flow (R12)	-76.4	-3	820.1	8	204.1	2	120.5	6
Basin Plan (R8)	-111.7	-7	0.0	0	540.4	7	240.5	12
Basin Plan recent flow (R16)	-252.9	-13	55.0	1	1192.9	12	148.6	8

Note: These values represent the difference between the global and sequential solutions for the respective model runs.

3.4 Variability analysis

Climatic variability is a key driver of adaptation in agricultural industries. At a broad level, past and ongoing water reforms have secured water rights, facilitated trade, and allowed carry-over storage, thus assisting water entitlement holders to manage the risks of increased climatic variability (Bates et al. 2010). However, at a regional or enterprise scale the differences in the operating environment (including water access and trading policies), permissible enterprise mix (bound by bio-physical constraints), as well as personal choices and financial circumstances will all affect the level of management of climatic and related risks.

The reliability of water allocations, in particular the timing of water allocation announcements has a significant bearing on irrigator returns. The model runs examined here assume perfect knowledge within a given season. Under that assumption the choice of cropping systems such as rice, dairy and cotton becomes more feasible as decisions are taken at a single point in time.

The data presented in Table 1indicates the extent of variability in the diversions for irrigation across different catchments. A close comparison indicates that, for a number of regions, the disparity between the Dry and Wet season availability of water is less under the Basin Plan scenario.

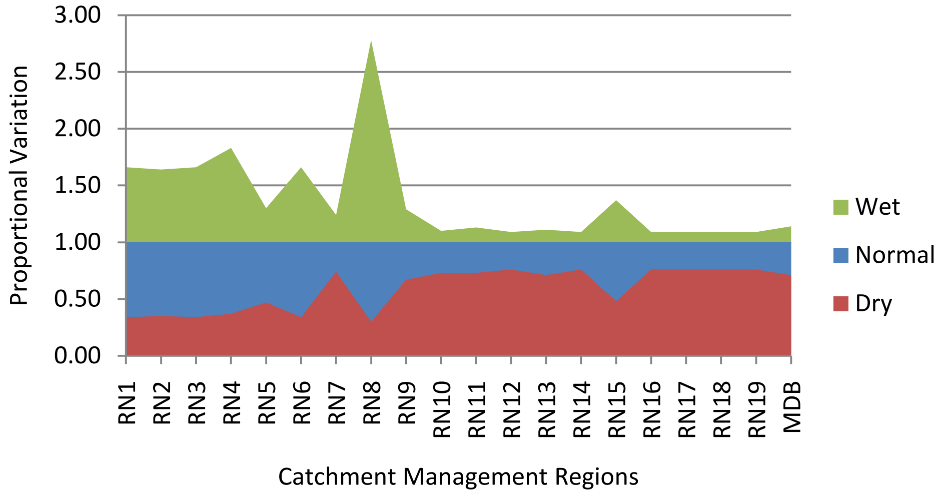
A detailed examination of model runs with respect to variability around the mean for the three states of nature shows the significance of reliability of water supply to irrigators in terms of likely economic impacts on farm and regional performance.

Regional variability in water use

This analysis recognises that the diversion limit proposed for a given catchment is an expected value, representing an average availability target for the purposes of planning. The actual amount of water available to irrigators in a particular catchment under a given diversion limit is thus influenced by the variability in the volume of water available across seasons. The dataset made available by the MDBA indicates that there is significant diversity in this variability across catchments within the Basin.

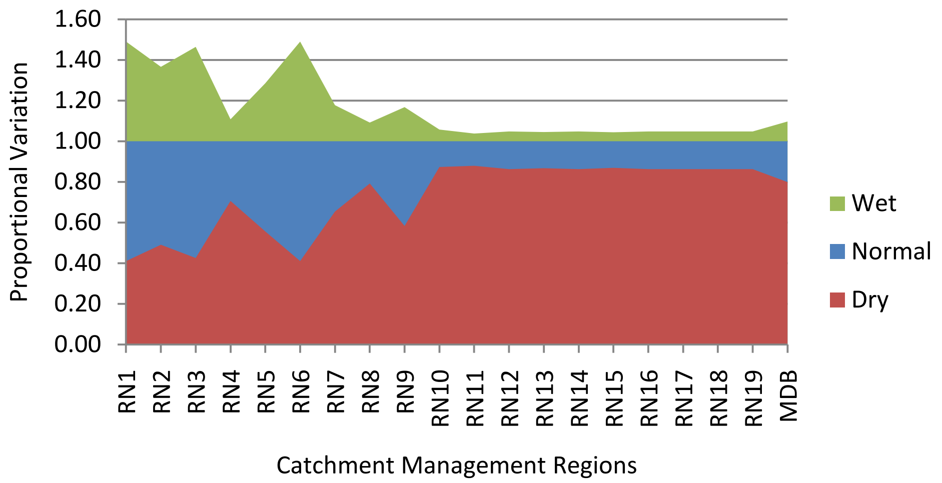
To analyse and compare variability across catchments, the proportional variation around the mean by states of nature was examined. As illustrated in Figure 1, historically the diversions are more variable in the northern catchments (Darling and its tributaries – RN1 to RN9), than in the southern catchments (Murray and its tributaries).

Figure 1: Historical variability in diversions for Basin catchments, by states of nature



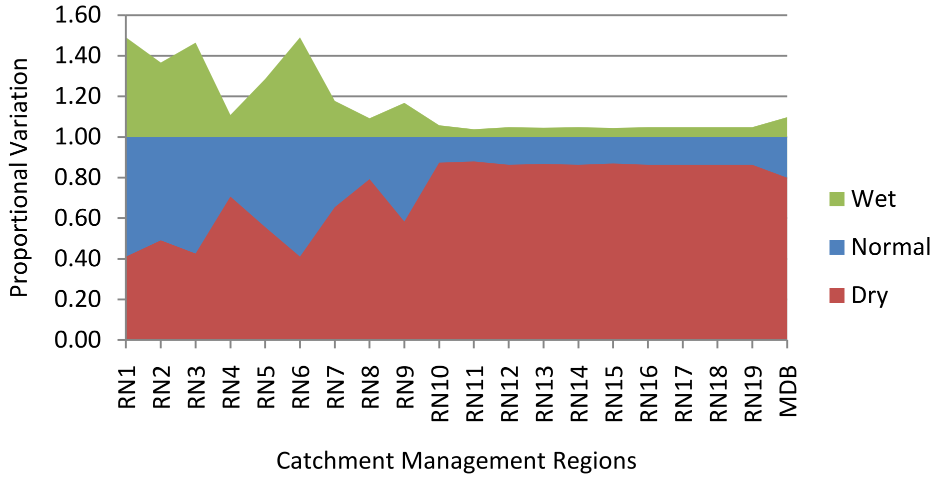
The variability by states of nature for the current diversion limits is illustrated in Figure 2.

Figure 2: Variability in diversions for Basin catchments, by states of nature (current diversion limits)



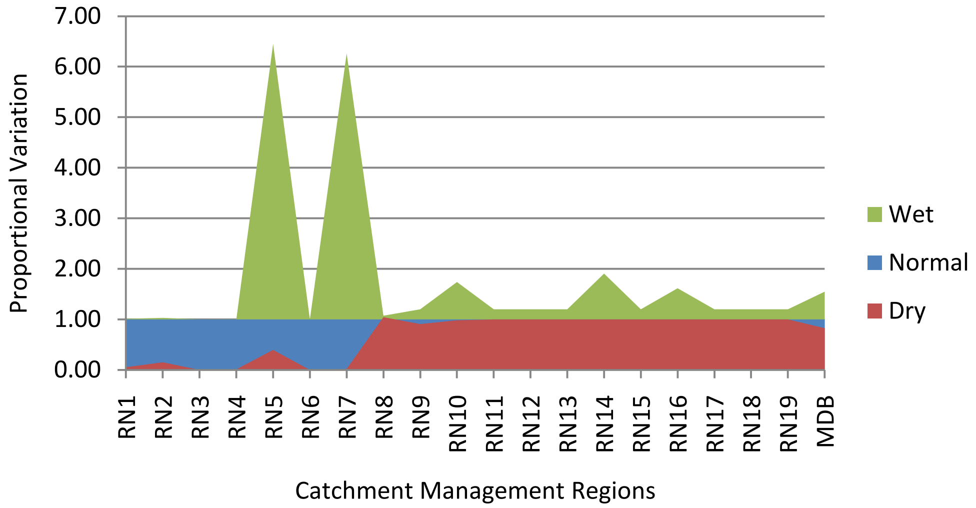
As illustrated in Figure 3, under the proposed sustainable diversion limits for the Basin Plan the variability decreases in some northern catchments, but increases in some southern catchments. What is clear, however, is that under the Basin Plan scenario the projected reliability of seasonal water availability increases under all states of nature for most catchments.

Figure 3: Variability in diversions for Basin catchments, by states of nature (Basin Plan scenario)



RSMG model simulations were used to examine the implications for irrigators of the projected changes in variability.

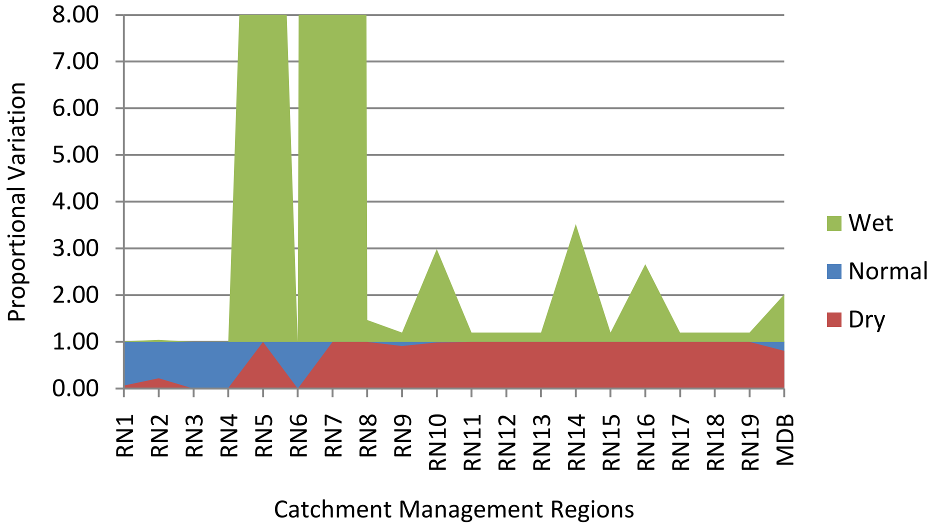
Figure 4: Water use pattern for Basin catchments, by states of nature (Baseline scenario)



The water use pattern under the Baseline scenario indicates that irrigators in the north choose production systems that allow maximum water use in the Normal and Wet years, while in Dry years, water use is reduced substantially (Figure 4). The spikes in Central West (RN5) and Border Rivers (RN7) is due to the heavy dependence in these regions on the cotton dry production system, which involves growing dryland cotton during the Normal and Dry seasons, and irrigated cotton during the Wet years. However other production systems are also employed in these catchments. The water use in southern catchments follows the opposite pattern. The water use peaks during Wet seasons, but maintains close to normal levels during Dry periods, which is made possible with storage releases.

The variability in water use under the Basin Plan (sustainable diversion limits) is illustrated in Figure 5. The spike in use for Central West (RN5) and Border Rivers (RN7) indicates that the dependence on Cotton Dry has been exacerbated by the cuts in diversions limits. Variability of water use also increases in the southern catchments, especially the Murrumbidgee (RN10), Murray 2 (RN14) and Murray 3 (RN16) catchments. This indicates that the reduction in available water will encourage NSW irrigators to employ production systems that conserve water in dry and normal years, and take advantage of higher water availability in the wet years.

Figure 5: Water use pattern for Basin catchments, by states of nature (Basin Plan scenario)



The following sequence of maps indicates how the key economic variables evaluated in this study have varied across catchments assuming there are no barriers to trade in the southern connected system. In considering the maps please refer to Table 1 and Table 2 for a description of different runs and data assumptions. R4CP, for example, refers to the Baseline global run and R8CP is the Basin Plan global run. R12 and R16 are respectively the Baseline and Basin Plan runs under the recent decade of climatic variability.

Figure 6: Change in irrigated area under different scenarios

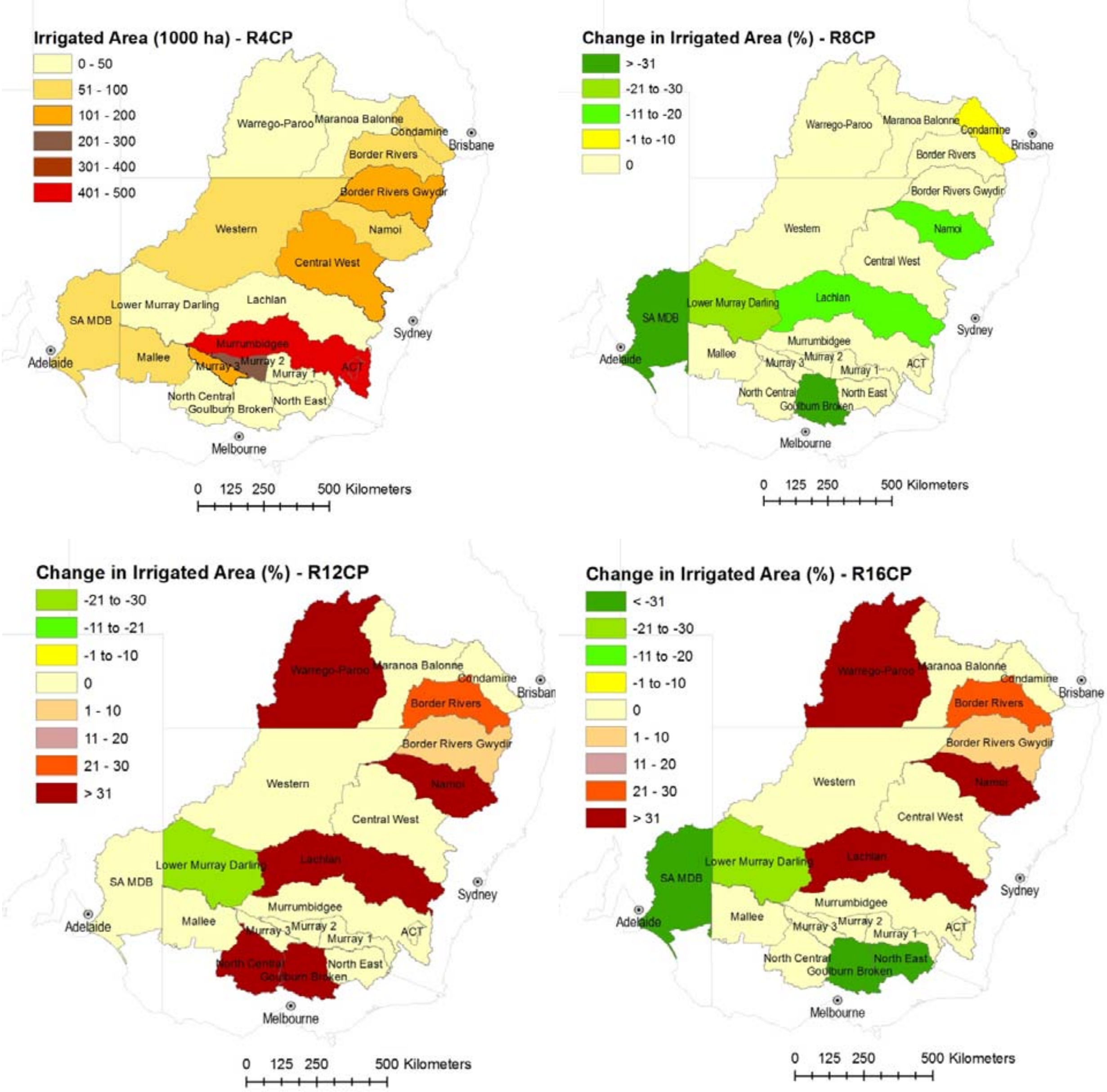


Figure 7: Change in water use

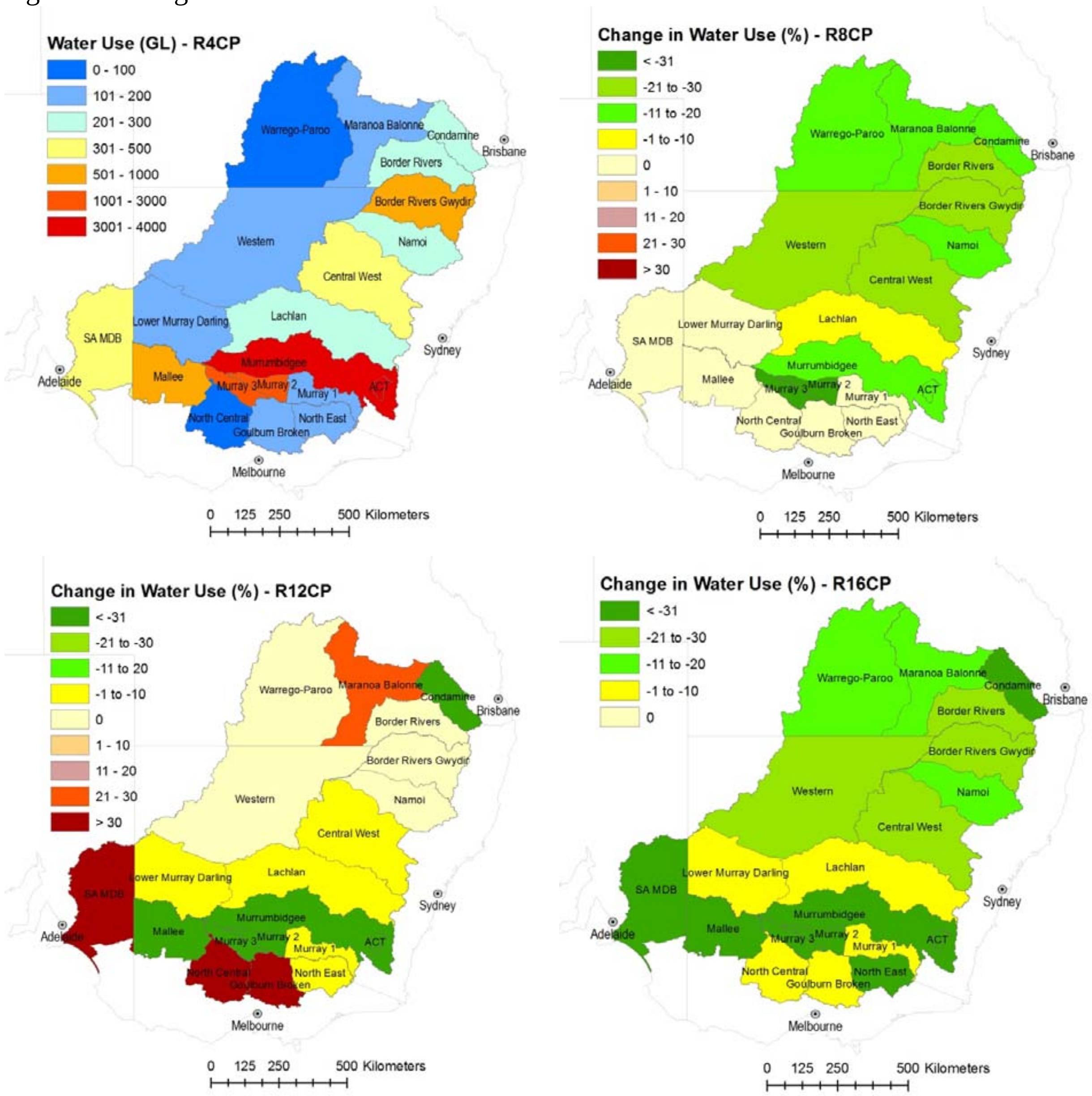


Figure 8: Change in the gross value of irrigated production

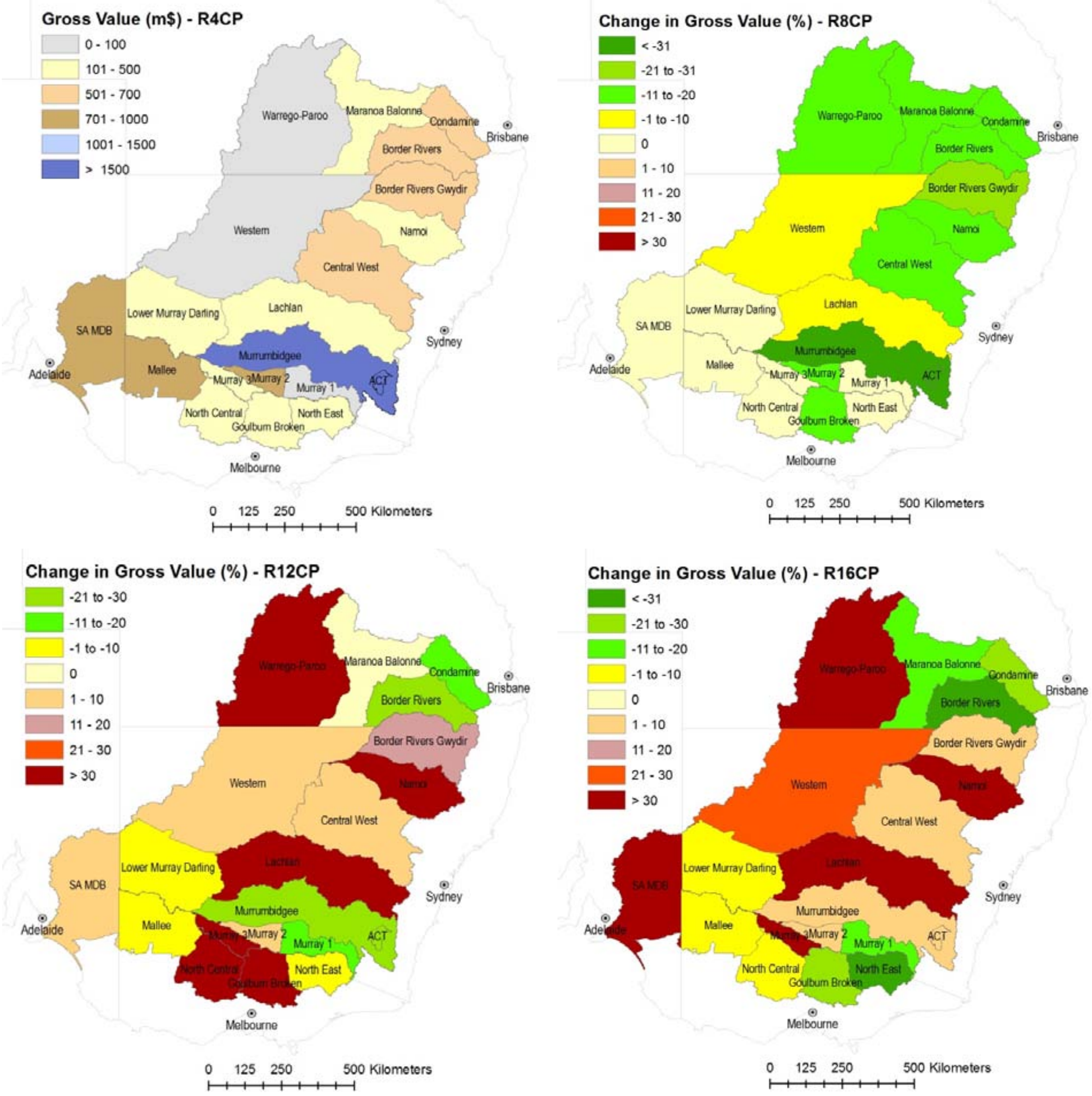
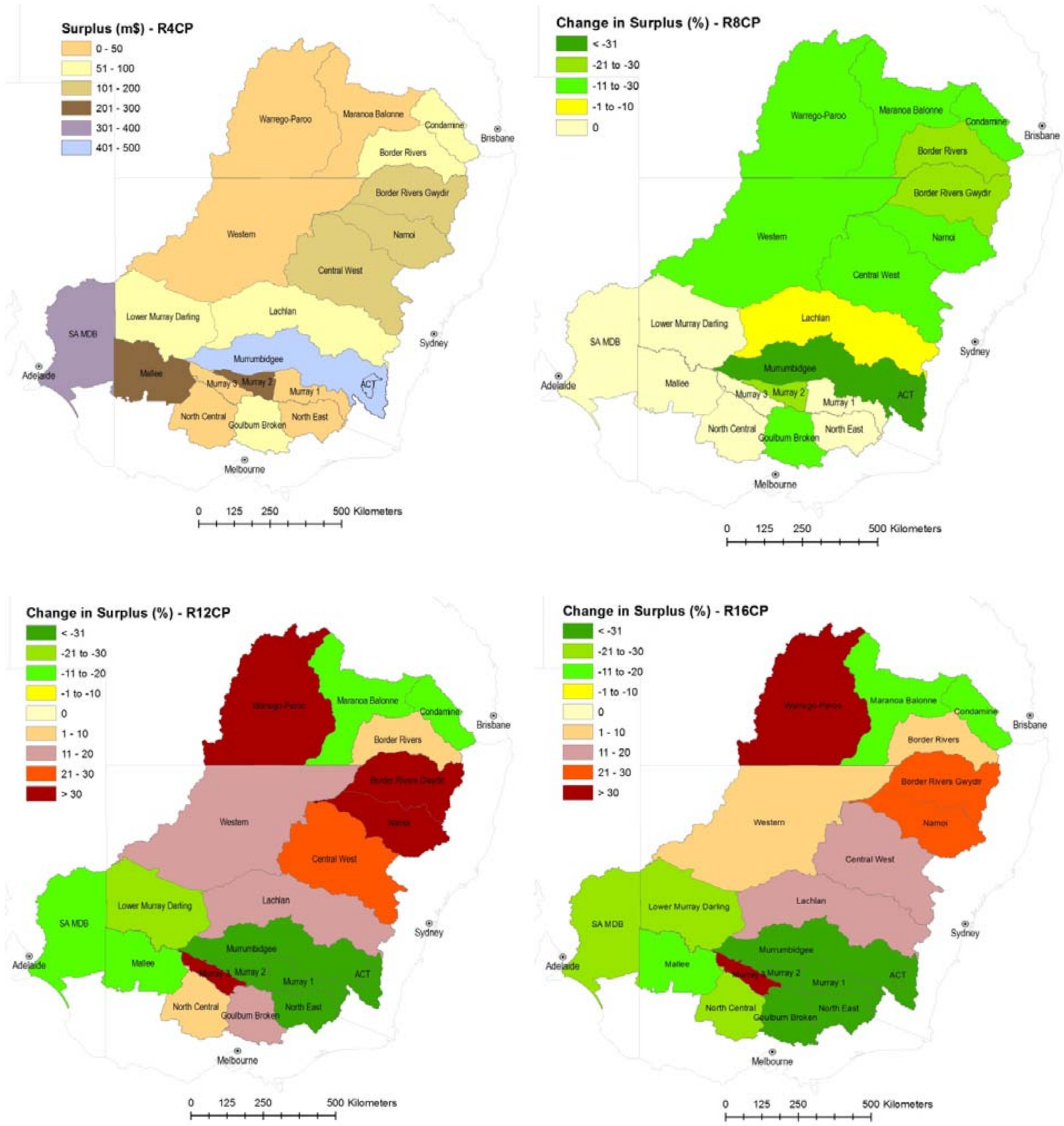


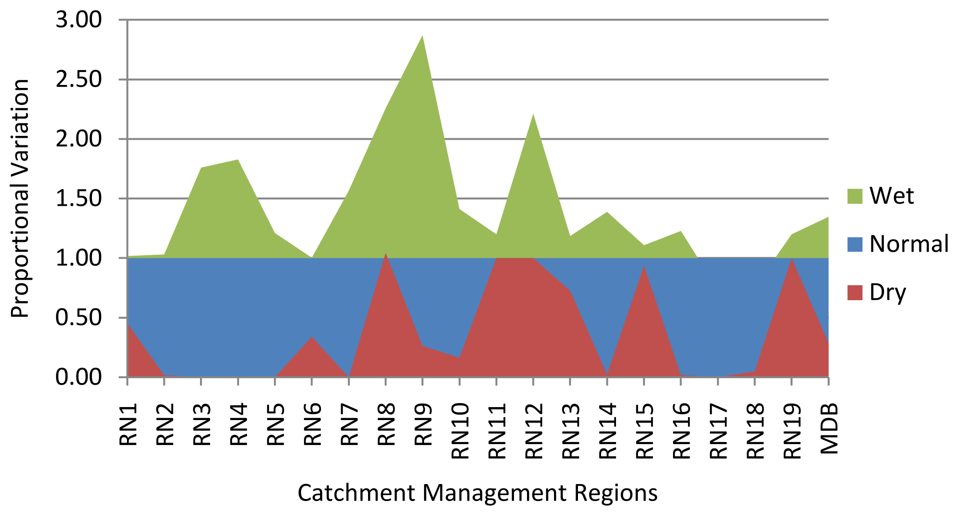
Figure 9: Change in surplus



The likelihood of realising these patterns of water use and economic consequences thereof would depend on a number of factors. First, the availability of water for irrigation use at the catchment level will be governed by rainfall in that catchment. Furthermore, the timing of rainfall will also be a factor in the case of the northern Basin, where storages are limited or absent. For the southern region inflows to storages will be the key influence in determining water availability and the potential for the above patterns of water use. While the analysis above is drawn from the CSIRO data set, and underpinned by historical patterns of rainfall, the pattern of rainfall and inflows to Basin storages over the past decade have been different to that of the historical pattern.

The optimal water use pattern under the inflow variability for the period 1999-2008 is illustrated in Figure 10. In this case, the water use pattern is different in that for a number of regions, the Dry season water use was zero. This result is consistent with the experience during this period, where the water allocations were close to zero in most cases.

Figure 10: Water use pattern for Basin catchments, by states of nature (Basin Plan scenario)



The implication of this result is that, if the future water availability in the Basin were to reflect what was observed over the past decade, the potential for the Basin Plan to meet its objectives of sustaining water use for the competing sectors may be difficult to achieve. Moreover, the analysis above assumes a uniform distribution of water entitlements across different catchments. This means that the actual differences that exist in the composition of high and low security entitlements are ignored. As these differences are quite substantial, in particular in large irrigation regions such as the Murrumbidgee and Murray Valley, further analysis that takes account of entitlement regimes would be necessary to better assess the regional implications of the Basin Plan.

The analysis also highlights the need to continue the reform process across the Basin so that the water entitlements in each catchment become comparable entities. The focus of an optimal allocation is to equate the opportunity costs of water across catchments; differences in entitlements will therefore hinder the achievement of an optimal allocation in practice.

3.5 Sensitivity analysis

Understanding irrigators' responsiveness to changes in water availability is important when evaluating the potential impacts of using quantitative restrictions as a policy instrument for demand management. The Basin Plan introduces a significant cut in the existing Cap for access to irrigation water, and the irrigators are expected to respond by prioritising the allocation of available water amongst land use activities with high water productivity.

Under a supply constraint, the underlying response by irrigators is akin to a demand response under increasing prices. This responsiveness, the elasticity of demand for water, is defined as the percentage change in demand in response to a unit change in its price. For most inputs to agriculture, there is an inverse relationship between price and quantity demanded, and the elasticity of demand is usually negative.

Elasticity estimates are sensitive to various factors; in particular the method used to estimate them, the flexibility to change other inputs (other than water), the range of change, and the mix of low, medium and high value activities covered. For these reasons, studies indicate a mean price elasticity of 0.48 and a median of 0.16, with larger elasticities in the longer run. The value of demand elasticity estimates ranges from 0.001 to 1.97 in some studies (Scheierling et al. 2006; Wheeler et al. 2008). Overall, irrigation water demand elasticities appear slightly more elastic at higher prices or under drought conditions which imply severe supply constraints.

To assess the responsiveness of irrigators to changes in supply restrictions, the RSMG model was run for a range of water availability scenarios by introducing a 10 per cent reduction in the CDL over four consecutive steps. That would simulate a reduction from the CDL to the SDL for most catchments. The results of this analysis for different simulations are summarised in the four panels of Figure 11 to Figure 14.

Figure 11: Model sensitivity under the historical flow pattern, sequential solution

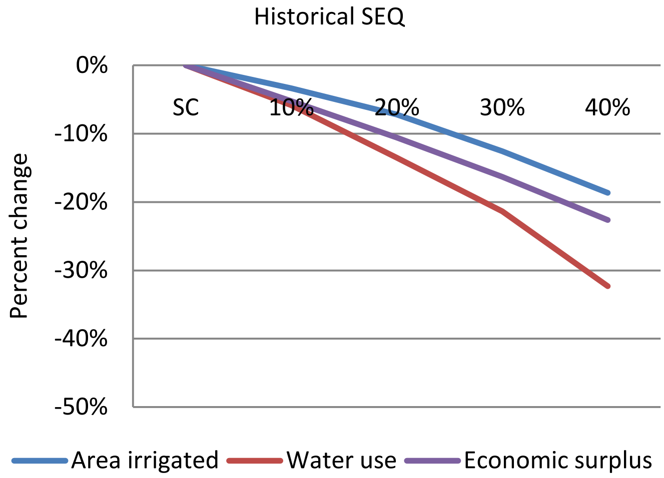


Figure 12: Model sensitivity under the recent flow pattern, sequential solution

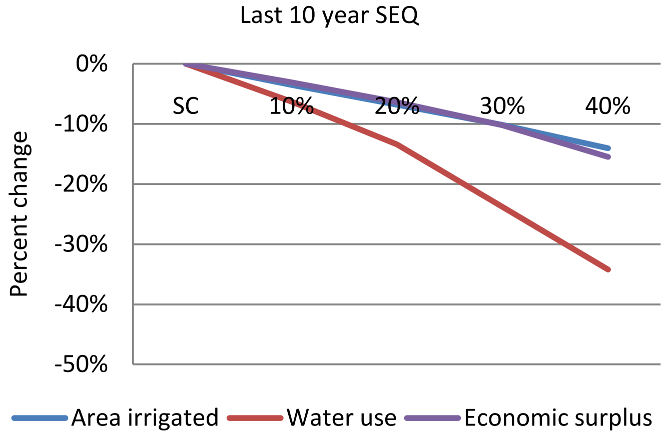


Figure 13: Model sensitivity under the historical flow pattern, global solution

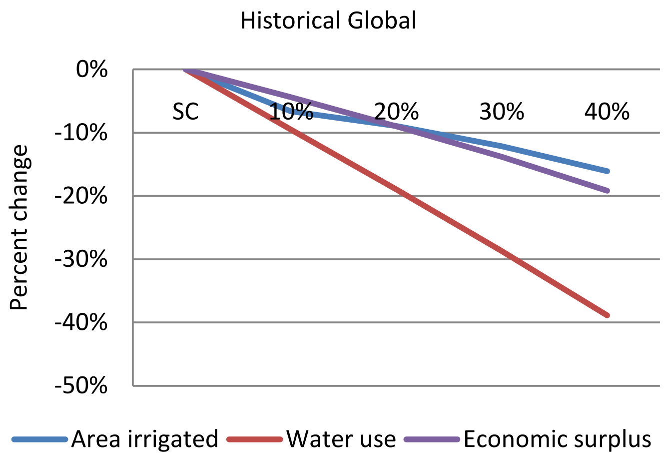
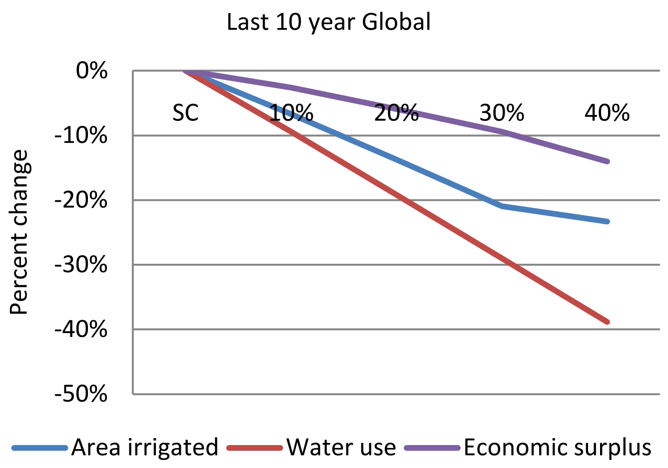


Figure 14: Model sensitivity under the recent flow pattern, global solution



The responsiveness of the model variables, calculated as implied elasticity estimates, are summarised in Table 27.

The analysis indicates that, as the water availability is reduced, the model responds by altering the area irrigated under different activities. This results in changes in the value of irrigated output and the regional surplus. The area irrigated and the water use is more sensitive than the financial estimates, the GVIAP and the regional surplus. This is because the increasing opportunity cost of water encourages the adoption of water conservation technology and the diversification of activities. These adjustments limit the impact of the gross value and the regional surplus.

Table 27: Implied elasticities under progressive reductions in water availability

Model run	Model variable	Level of reduction in SDL			
Historical SEQ		10%	20%	30%	40%
	Area irrigated	0.34	0.36	0.42	0.47
	Water use	0.58	0.67	0.71	0.81
	Economic surplus	0.52	0.53	0.54	0.57
	Gross value	0.52	0.53	0.55	0.58
Last 10 year SEQ		10%	20%	30%	40%
	Area irrigated	0.35	0.34	0.34	0.35
	Water use	0.63	0.67	0.79	0.85
	Economic surplus	0.31	0.32	0.34	0.39
	Gross value	0.25	0.25	0.27	0.30
Historical Global		10%	20%	30%	40%
	Area irrigated	0.66	0.45	0.41	0.40
	Water use	0.95	0.95	0.96	0.97
	Economic surplus	0.44	0.45	0.46	0.48
	Gross value	0.44	0.44	0.46	0.48
Last 10 year Global		10%	20%	30%	40%
	Area irrigated	0.67	0.69	0.70	0.58
	Water use	0.94	0.96	0.97	0.97
	Economic surplus	0.26	0.30	0.31	0.35
	Gross value	0.33	0.35	0.36	0.05

Based on the simulations, the implied price elasticity of demand for water allocations appears to be close to elastic, with elasticities strongly influenced by the drought conditions in the recent decade. These responses are more pronounced in the global solution because the availability of inter-regional trade allows greater flexibility to adjust. Although not directly comparable, these responses appear consistent with other estimates in the literature (Wheeler et al. 2008).

4. DISCUSSION

In this analysis, data supplied by MDBA on the modelled diversions for each Basin catchment were used in the RSMG water allocation model to examine the impacts on irrigators' returns of alternative water availability scenarios. To achieve this, RSMG undertook an analysis of the flow variability for the historic (114 year) period and for the last 10 year period (1998-2008). Current and proposed water diversion limits were applied in alternative scenarios to evaluate irrigators' responses at a catchment and the whole-of-Basin scale.

The simulations indicate that the Baseline water availability under the current diversion limit of 10,758 gigalitres is adequate to support an agricultural system largely consistent with the recent peak water use of 10,516 gigalitres in 2000-01. The model estimate of water use for this scenario of 10,560 gigalitres and the associated irrigated land area of 1,770 thousand hectares is comparable to ABS estimates. The small deviation in irrigated area between the modelled and ABS estimates, is attributable to the advancements in technology since 2000-01 and the ABS area of 'other agriculture' (41,000 ha) that is not modelled in the production systems used in the model.

Under the Basin Plan scenario, the estimated water use fell by 3,746 gigalitres or 35.5 per cent compared to the Baseline. The associated opportunity cost, in gross value of irrigated production, was $1,445 million, or 16 per cent compared to the Baseline. The regional surplus from agricultural production was estimated to fall from $2,325 million to $1,954 million, a drop of $371 million or 16 per cent from the Baseline.

The analysis indicates that if the current cap on diversions was reduced by 37 per cent to allow water for the environment, gross agricultural returns would fall by 16 per cent. The associated loss in regional economic surplus would also be 16 per cent.

Model comparisons between the sequential and global runs suggest that costs to irrigators in the short term would be higher if unrestricted water trading was not available. As there are differences in policies across states with regard to access entitlements and trading, the proposed cut in current diversion limits to allow for environmental water would result in a reduction in irrigation net returns of around 16 to 20 per cent compared to the Baseline. In real 2007-08 terms, this drop in economic surplus is equivalent to around $371 to $401 million per annum.

Under the Basin Plan scenario, the trade-related gain in estimated gross value of production was 8 per cent and the regional surplus was 14 per cent higher compared to the Baseline. This indicates that availability of water trading plays a significant role in minimising the impacts on regional incomes of reduced variability under the Basin Plan, in particular, for the pooled water resources in the Murray.

These results are consistent with the observed pattern of change in agricultural production in the Basin over the past ten years. In this period, levels of reduction in water availability ranged from 4 to 70 per cent, compared to 2000-01.

The model simulations indicate that reduced water availability will have an adverse impact on the profitability of irrigation enterprises. However, the estimated impacts on irrigators' profits are less than proportional to the reduction in water availability in most regions. This illustrates the capacity of irrigators, in the medium-term, to respond by rearranging enterprise mix to use available water where it is most profitable and feasible. It is important to note that availability of water trading provides more flexibility for irrigators to make this adjustment. For example, if unrestricted trade was available, economic losses to New South Wales under the Basin Plan would be significantly lower compared to a situation of limited trade.

There are likely to be substantial variations between regions, in terms of the impact of reduced water availability on farm profit and resource use. For example, the Queensland and New South Wales catchments are likely to be more affected (relative to the reference case) by the changes in water availability considered than the catchments in Victorian and South Australia. However, substantial changes in water use, similar to those of New South Wales, could be expected in the Victorian Murray region.

The proposed adjustments to the catchment level cap on irrigation diversions under the Basin Plan are not uniform. The net effect of these changes is that the net impact on Basin scale profits from irrigation are less severe than expected from a uniform reduction in water use across all catchments.

The water use impacts are more severe under the climatic pattern experienced in the recent decade. In this scenario, the southern regions could be expected to experience substantial reductions in water use. These differences are driven by biophysical conditions such as local variation in yield and existing patterns of development such as the proportion of high value horticulture in the production mix.

In these simulations, the focus was on estimating the extent of potential land use changes and the economic impacts thereof at a catchment and Basin wide level by simulating the reduction in access to water for irrigation. The impacts of the associated water use on river flows and other users have been ignored as the water taken away from irrigation would be expected to meet those needs.

In reality, however, the river system will provide water both for the environment and for consumptive uses, with the flow patterns having an indirect influence on crop productivity and environmental values as they influence river salinity. Although the RSMG model incorporates salinity and water flow relationships in the modelled river network, the salinity module was switched off in this analysis.

As these variables are interrelated, it would be instructive to undertake a more comprehensive analysis of production impacts in a full optimisation setting where the trade-offs between consumptive and non-consumptive uses of water can be examined. That would require data on environmental water allocations at a catchment level which was not available for this analysis. An integrated analysis that makes environmental considerations explicit, could estimate the benefits of alternative environmental allocations and determine the optimal trade-offs between consumptive and non-consumptive uses of water. It could thus highlight potential synergies and opportunities to maximise social returns from the government investment.

MODEL COMPARISON

One of the objectives of this study was to develop estimates that could be compared with the output of other economic assessment tools such as ABARE's Water Trade Model. As discussed, the RSMG model uses a non-linear optimisation framework that relies on regional gross margin data to estimate costs and returns to irrigation. Water is charged at a nominal $25 a megalitre such that the opportunity costs are determined internally, based on enterprise returns. Between runs these data sets are held constant and no attempt is made to calibrate a solution to meet a particular end point. The only calibration was to align Baseline scenario water use to 2000-01 ABS water use. This was achieved by providing a broad range of activity choices for the model with a range of technologies that, on average, represent what was observed.

Our experience suggests that the model results are sensitive to profit margins, and that enterprises such as cotton, dairy, and rice and wheat farming systems are more vulnerable to change as water access restrictions are imposed. Tree and vines are more stable under low levels of water availability or water availability reductions in particular where there is access to trade. Therefore, specification of trading rules, capital costs, and the way activities are organised within the model will lead to substantial differences in results.

Moreover, the state-contingent setting in the RSMG model allows for a more realistic representation of adaptation by farmers rather than the more traditional expected value result. The range of value estimates provided here allows for a comparison of the mean and variance for the key estimates.

5. CONCLUSION

The modelling of economic impacts, in terms of irrigators' returns under the proposed Basin Plan examined in this report, suggests that the reduced water availability could result in a 16 per cent decline in regional farm profits compared to the current diversion limits. However, the impacts could vary substantially across catchments, reflecting the mix of agricultural activities, the proposed adjustment to the current Cap compared to current water use, and the availability of water trading. All the above factors influence the opportunity costs faced by irrigators and the feasible options for adjustment.

As water access restrictions are imposed, the opportunity cost of water use increases, and the irrigators switch water use to more profitable activities. As has been observed during the past decade, irrigators will also adopt more water efficient technologies or to shift to dryland farming where appropriate (Mallawaarachchi and Foster 2009).

Because these adjustments partially offset the impact on farm profit, the proposed 37 per cent reduction in the Basin-wide Cap resulted in less-than-proportional decline in farm profits, relative to the Baseline.

The proposed cut in current diversion limits to allow for environmental water would be likely to result in a reduction in irrigation net returns of around 16 to 20 per cent compared to the Baseline. In real 2007-08 terms, this drop in economic surplus is equivalent to around $371 to $401 million per annum.

At the regional level, the impacts of reduced water availability are likely to differ markedly. Irrigated land use in New South Wales and Queensland could be more severely affected than in Victoria and South Australia. A generally improved river flow regime will have a more significant benefit to irrigators in South Australia. Geographically, the changes are likely to be more pronounced in the Murrumbidgee and Murray Valleys where most of the planned reductions would take place. However, these regions will benefit from an increase in opportunistic wet season activities due to increased reliability in seasonal water allocations.

As a result, assuming historical climate variability, the total area of irrigated rice and cotton production is likely to increase compared to the recent drought years (2005-06). This is likely to come at the expense of pasture for dairy and other livestock, which are likely to contract. It should be noted that the changes are sensitive to price assumptions. However, cotton production in the northern basin is likely to be more stable, highlighting regional differences in biophysical conditions and the profitable crop mix.

While the estimates presented and the conclusions drawn in this study are indicative of the relative magnitude of changes that can be expected, actual changes will be influenced by the ability of individual irrigators to bear the costs of change. While past and ongoing water reforms that have enabled water trade, allowed carry-over storage and assisted water entitlement holders to manage the risks of increased climatic variability, existing differences in the security of water entitlements will have a strong bearing on the net costs to irrigators. For example, these simulations have not taken into account the level of security of water entitlements in each catchment. Moreover, government programs such water buyback and infrastructure assistance may change relative opportunity costs in individual regions.

Furthermore, the analysis presented here needs to be viewed as indicative only, taking account of the annual variability observed in recent years. It was noted in both the analysis of hydrological data and in model simulations that water flows were highly variable in the northern catchments that represent the tributaries of the Darling River system. Flow variability is moderated in the Murray through storages that offer the ability to pool resources that can be reallocated through water trade.

These results therefore are of limited predictive value but provide broad guides to the potential economic impacts of reduced water availability for irrigation in the Basin within the limitations noted.

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APPENDIX

Clarification of terms and data assumptions

Diversions — Baseline water use is based on simulated 114 year current diversions limits (MDBA 2010), and is used to constrain the Baseline model. Diversions are assumed to take account of both surface and ground water use.

Reduced diversions — reductions in water availability are based on simulated 114 year sustainable diversions limits (MDBA 2010), and are used to constrain the Basin-Plan model.

Historical water availability — is determined by catchment, based on simulated 114 year water availability data (MDBA 2010). Water availability is assumed to be the highest flow point in the catchment and inclusive of water transfers.

Last 10 year water availability — is determined by catchments based on the last 10 years (1998-2008) of the simulated 114 year water availability data (MDBA 2010). This is used to simulate a reduced water availability scenario.

Uncertainty and variability — for all water availability and diversions constraints the effect of annual variability in climate is modelled by specifying the different states of seasonal conditions (Dry, Normal and Wet) and their probabilities, based on the historical record.

Reliability — the variability of water available in catchments that hold large dams is adjusted to take into account the inter-annual transfer of water between Wet and Dry years.

Water use optimisation — the RSMG model is solved globally (the Basin as a whole) mimicking existing institutional arrangements and flow patterns. Water use is constrained by diversions limits and water availability.

Trade — is allowed between connected catchments in the Southern Basin, however there is no trade between catchments in the north or catchments with naturally low end-of-system flows.

Water quality — is not taken into account for this analysis. Salinity constraints are switched off.

Timeframe — consistent with the scope of the study, a medium-term perspective (10 years) is assumed.

Reference case data — the structure of the economy and production data are based on the 2001 agricultural census data for modelling purposes, as this is considered to represent a normal year.

Government intervention — irrigator behaviour is assumed to be independent of drought assistance or other policy measures.

Simulation scenarios

Table 28: Simulation scenarios

Proportional Allocation				Global Allocation			
Run ID	**Diversion Limit**	**State Probabilities**	**Water Flow Pattern**	**Run ID**	**Diversion Limit**	**State Probabilities**	**Water Flow Pattern**
R1SEQ	Baseline	Normal = 1	Historical	R1CP	Baseline	Normal = 1	Historical
R2SEQ	Baseline	Dry = 1	Historical	R2CP	Baseline	Dry = 1	Historical
R3SEQ	Baseline	Wet=1	Historical	R3CP	Baseline	Wet=1	Historical
R4SEQ	Baseline	Normal = 0.5 Dry = 0.2 Wet = 0.3	Historical	R4CP	Baseline	Normal = 0.5 Dry = 0.2 Wet = 0.3	Historical
R5SEQ	Basin Plan	Normal = 1	Historical	R5CP	Basin Plan	Normal = 1	Historical
R6SEQ	Basin Plan	Dry = 1	Historical	R6CP	Basin Plan	Dry = 1	Historical
R7SEQ	Basin Plan	Wet=1	Historical	R7CP	Basin Plan	Wet=1	Historical
R8SEQ	Basin Plan	Normal = 0.5 Dry = 0.2 Wet = 0.3	Historical	R8CP	Basin Plan	Normal = 0.5 Dry = 0.2 Wet = 0.3	Historical
R9SEQ	Baseline	Normal = 1	Last 10 years	R9CP	Baseline	Normal = 1	Last 10 years
R10SEQ	Baseline	Dry = 1	Last 10 years	R10CP	Baseline	Dry = 1	Last 10 years
R11SEQ	Baseline	Wet=1	Last 10 years	R11CP	Baseline	Wet=1	Last 10 years
R12SEQ	Baseline	Normal = 0.5 Dry = 0.2 Wet = 0.3	Last 10 years	R12CP	Baseline	Normal = 0.5 Dry = 0.2 Wet = 0.3	Last 10 years
R13SEQ	Basin Plan	Normal = 1	Last 10 years	R13CP	Basin Plan	Normal = 1	Last 10 years
R14SEQ	Basin Plan	Dry = 1	Last 10 years	R14CP	Basin Plan	Dry = 1	Last 10 years
R15SEQ	Basin Plan	Wet=1	Last 10 years	R15CP	Basin Plan	Wet=1	Last 10 years
R16SEQ	Basin Plan	Normal = 0.5 Dry = 0.2 Wet = 0.3	Last 10 years	R16CP	Basin Plan	Normal = 0.5 Dry = 0.2 Wet = 0.3	Last 10 years

Interpretation of results

The simulation results are presented in the same format as available ABS data. The categorised agricultural commodities and production system are outlined in the Table 29 below.

Table 29: ABS and RSMG agricultural commodities and production systems

ABS agricultural commodity classes	RSMG production systems & commodity classes
Pasture for other livestock	Dairy
Rice	Rice
Cereals (excl. rice)	Wheat, Grain Legume, Sorghum
Cotton	Cotton Flex, Cotton, Dryland Cotton
Grapes	Grapes
Fruit (excl. grapes)	Citrus, Stone Fruit, Pome Fruit
Vegetables	Vegetables
Other agriculture	Oilseeds, Sheep, Beef

More details about the categorisation of commodities into commodity classes and production systems in the RSMG Model are outline in Table 30 below.

Table 30: RSMG Model production systems, commodity classifications and commodities

Production Systems	Commodity Classification	Commodities
	Citrus – High*	Grapefruit, Lemon, Lime, Mandarin, Orange
	Citrus – Low**	Grapefruit, Lemon, Lime, Mandarin, Orange
	Grapes	Table Grapes, Wine Grapes
	Stone Fruits – High*	Apricots, Cherry, Nectarine, Peach, Plum
	Stone Fruits – Low**	Apricots, Cherry, Nectarine, Peach, Plum
	Pome Fruit	Apple
	Vegetables	Asparagus, Beetroot, Broccoli, Burdock, Cabbage, Capsicum, Carrot, Cauliflower, Eggplant, Garlic, Lettuce, Onion, Potato, Pumpkin, Rockmelon, Sweet Corn, Tomato, Watermelon, Zucchini
Cotton Flex	Dryland Cotton	Non-irrigated Cotton
	Cotton	Irrigated Cotton
	Cotton Fix	Irrigated Cotton
Cotton / Chickpea	Cotton	Irrigated Cotton
	Chickpea	Irrigated Chickpea
Dryland Cotton	Dryland Cotton	Non-irrigated Cotton
	Cotton	Irrigated Cotton
Rice PSN	Rice PSD	Production System Drought Rice (less water use)
	Rice PSW	Production System Wet Rice (more water use)
Dryland Wheat	Dryland Wheat	Non-irrigated Wheat
	Rice PSW	Production System Wet Rice (more water use)
	Wheat	Irrigated Wheat
Wheat / Legume	Wheat	Irrigated Wheat
	Legume	Adzuki Beans, Chickpeas, Faba Bean, Mungbean, Navy / Bean, Peanut, Soybean,
	Sorghum	Sorghum
	Oil Seeds	Canola, Sunflower
Wheat / Sheep	Wheat	Irrigated Wheat
	Sheep	Sheep on improved pasture
	Dairy – High*	Dairy
	Dairy – Low**	Dairy
	Beef	Beef production using irrigated pasture
	Sheep	Sheep production using irrigated pasture
	Dryland	Dryland production

Note:*'High' implies a highly efficient irrigation technology, which means that a low volume of water is used in the production process; ** 'Low' implies that less efficient irrigation technology was used, which means that a high volume of water is used in the production system.

Generation of results

A detailed description of the RSMG model is available online under the following link: http://www.uq.edu.au/rsmg/docs/RSMG_MDB_Model_Documentation_010610.docx.

The economic return is determined by the following equation:

Profit = Income – Total costs

Where,

Income = Yield * Price (Basin-wide price, not gross margin budgets)

Total costs = Variable costs + Fixed costs

Variable costs = Gross margin budgets data (adjusted for basin wide water price and Basin-wide casual labour costs)

Fixed costs = Annualised capital payments + Operator labour (operator labour fixed Basin-wide)