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Review of the MDBA's Socio-Economic Impact Modelling

This report was prepared for the Murray-Darling Basin Authority.

28 November 2011

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1 Executive summary

1.1 Background and Scope of the Work

In accordance with the Commonwealth *Water Act (2007)*, the Murray-Darling Basin Authority (MDBA) is responsible for developing a plan for managing the water resources of the Murray-Darling Basin (the Basin). The Draft Basin Plan includes potential reductions in long-term sustainable diversion limits (SDLs) on extraction of surface and ground water from the Basin system. To assess the implications of these reductions, the MDBA has commissioned a number of analyses to assess the socio-economic impacts of reductions in SDLs.

In 2010, the MDBA commissioned economic modelling reports on the impacts of the proposed SDL reductions outlined in the Draft Basin Plan. These analyses were based on SDL reductions of 3,000 GL, 3,500 GL and 4,000 GL. In June 2011, KPMG provided an initial review of this modelling in our initial report *Review of MBDA's CGE Modelling Work*.

In 2011, the MDBA commissioned updated socio-economic impact modelling based on a revised SDL reduction target reductions of 2,400 GL, 2,800 GL and 3,200 GL. In October 2011, the MDBA commissioned KPMG to provide further review of both the 2010 and 2011 updated socio-economic impact modelling.

The papers considered in the review are outlined below.

- The 2010 modelling reports based on SDL reduction targets of 3,000 GL, 3,500 GL and 4,000 GL:
  - The Regional Economic Impacts of Sustainable Diversion Limits, Wittwer, November 2010
  - Economic Analysis of Diversion Limits in the MDB: Returns to Irrigation under Reduced Water Availability, UniQuest, June 2010
  - Environmentally Sustainable Diversion Limits in the MDB: Socio-economic Analysis, ABARES, October 2010
  - Assessing the Regional Impact of the Murray-Darling Basin Plan and the Australian Government's Water for the Future Program, ABARES, October 2010
- The 2011 updated modelling reports based on SDL reduction targets of 2,400 GL, 2,800 GL and 3,200 GL:
  - Economic Analysis of Alternative Sustainable Diversion Limit Options, ABARES for EBC, April 2011
  - Modelling the Economic Effects of the Murray-Darling Basin Plan, ABARES, October 2011
  - Basin Plan CGE Modelling using TERM-H2O, Wittwer, September 2011
  - Water Supply Variability & Sustainable Diversion Limits: Issues to consider in developing the Murray-Darling Basin Plan, UniQuest, August 2011.

The scope of KPMG Econtech's work for this updated review comprises the following:

- Meeting with authors of the reports to obtain information required to conduct a thorough and comparative assessment of the modelling approaches.
- Developing a comparative assessment of the modelling approaches, comparing and contrasting each modelling project to assess their relative strengths and weakness.
- Analysing the importance of variability in determining outcomes, particularly stochastic and state-contingent forecasts.
- Discussing the potential benefits of conducting micro-simulation analysis to assess regional impacts.
- Making recommendations in regards to potential improvements to the existing socio-economic impact modelling and the strategic direction of modelling work that could be adopted in the medium term.

In undertaking this review, KPMG Econtech has prepared a broad review of the commissioned economic modelling, however, the following aspects of the modelling are the focus of this report:

- model structure;
- definition of baseline, and the appropriateness of selecting a particular baseline;
- employment estimates;
- assumptions regarding dry-land production;
- time paths, short and long term outcomes;
- treatment of water trading; and
- regional outcomes, and the sensitivity/validity of the modelling results on regional results.

1.2 Key findings

1.2.1 Model Structure

The modelling tools used in the relevant projects are:

- ABARES-BRS (2010 and 2011) – ABARES-BRS's Water Trade Model (WTM) and AusRegion. The WTM is a partial equilibrium model for irrigated agricultural industries in the Basin that includes interregional and intraregional water trade specifications. AusRegon is a multi-region multi-sector comparative static CGE model.
- UniQuest (2010 and 2011) – a Risk and Sustainable Management Group – University of Queensland (RSMG-UQ) partial equilibrium model for detailed agriculture products by catchment region with state-contingent hydrological details.

- Wittwer (2010 and 2011) – TERM-H2O, bottom-up multi-region, multi-sector year-by-year dynamic computable general equilibrium (CGE) model with detailed agricultural production specifications.

The modelling structures used in 2010 and 2011 by all of the authors did not change significantly[1].

For each modelling approach, distinctive modelling structures, assumptions, and behavioural equations are employed. These differences are central to the analysis and interpretation of results and are outlined below.

ABARES-BRS (2010 and 2011)

- The focus of the ABARES-BRS approach is to estimate the direct and indirect economic impacts of the SDL reduction scenarios by sequentially and discretely linking a water trade model with an economy-wide model. This approach uses specific information about where water is purchased and how this will impact irrigator production in different regions within the Basin. The impacts on irrigator production are then incorporated in the economy-wide model to assess the implications for the wider economy.
- The strength of combining the water trade model with the economy-wide model is that it draws on hydrology data to calculate direct impacts and then places them within economic constraints of the economy-wide model to provide information on the relative magnitude of the flow-on impacts.
- The economy-wide model uses a 'comparative static' framework, which provides a before and after snapshot of the economy once it has fully adjusted to the reduction in SDL modelled.

UQ-RSMG (UniQuest 2010 and 2011)

- The focus of the UniQuest approach is to estimate the regional distribution of the impacts of reduced water availability. A key strength of the approach is incorporating detailed hydrological information into regional production systems to calculate the impacts of changes in water availability on agricultural production.
- A state contingent approach is used, which adds a layer of information on responsiveness to variability to the analysis.
- UniQuest do not use an economy-wide approach, rather the analysis is more focused on the economic implications of the reductions in water availability on agricultural production within the Basin.

[1] However, there are some notable changes made in the 2011 reports: UniQuest(2011) extended the UQ-RSMG model to capture the stochastic nature of the variability of water supply and to include both the social and environmental objectives into the model; ABARES-BRS (2011) refined the degree of water supply variability, the WTM baseline data sets, the relationship between water diversions and irrigation use, considerations of other government policies and a focus on both short and long run employment effects; and CoPS-Monash(2011) modified its theoretical framework to reflect more closely observed changes in dairy cattle production.

Monash-COPS (Wittwer 2010 and 2011)

- The Monash-COPS approach is to incorporate water as a factor of production within an economy-wide CGE model. This approach allows the analysis to be completed inside a single model, so that all direct and indirect outcomes can be solved simultaneously and remain consistent with overall economic constraints.
- The focus of the Monash-COPS approach is to provide a complete economic assessment of the SDLs reduction scenarios. A strength of the Monash-COPS approach is that it includes the impact of compensation and other effects such as changes in investment decisions.
- As the Monash-COPS model is dynamic, it captures how the economy is impacted as water rights are gradually purchased for environmental purposes. It also includes year-by-year rainfall scenarios, a key determinant of the level of water demanded by irrigators, allowing differing impacts on production between years.

The following table provides a summary of the key aspects of each modelling framework utilised.

Table 1-1: Key aspects of the modelling frameworks

	Monash-CoPS (Wittwer 2010 and 2011)	ABARES-BRS (2010 and 2011)	UQ-RSMG (UniQuest 2010 and 2011
General/partial equilibrium	General equilibrium	Interfacing between partial (WTM) and general equilibrium (AusRegion)	Partial equilibrium[2]
Regional dimension	Based on statistical local areas, 23 regions focusing on 18 MDB regions[3]	24 WTM regions and 7 MDB regions for AusRegion	21 regions including 19 catchment areas
Agriculture product/sectoral details	35 industries including 17 farm and 10 irrigation sectors, producing 28 commodities	WRM: 11 irrigated agriculture products/sectors AusRegion: 31 products including 16 agriculture products	23 sectors: 21 irrigated agriculture products/sectors, 1 dry land product, and Adelaide Water
Comparative static/dynamic analysis	Year-by-Year dynamics	WTM: comparative static analysis (short run nature)	Comparative static analysis (short run nature)

[2] Key objective function is to maximise the weighted average economic return from irrigation use across the three states of nature

[3] The bottom-up 18 MDB regions are mapped to 163 top-down regions.

	Monash-CoPS (Wittwer 2010 and 2011)	ABARES-BRS (2010 and 2011)	UQ-RSMG (UniQuest 2010 and 2011
		AusRegion: Comparative static analysis for both short and long run	
Water trade	Implicit treatments of water trade	Explicit treatments of water trade in WTM	Explicit treatments of water trade
Uncertainty of rainfall	Explicit scenario of rainfall over the simulation periods	Sensitivity tests in terms of the variability of rainfall (2011)	Contingent based analysis
Specification of dry land production	Explicit within a product, e.g. dry wheat and wet wheat	Irrigated sector only for WTM	Single dry land production State-contingent flexible[4] irrigated production technology
Role of water in irrigated agriculture production	Factor of production combined with irrigable land	WTM: volume of output depends on land and water use according to a Cobb-Douglas production function AusRegion: No specific role of water	Part of fixed costs along with operator labour cost and annualised capital payments
Key production substitutability	A wide range of substitutability between primary factors including water	WTM: little substitution among production factors including water AusRegion: a range of substitution between production factors – no water is explicitly specified in the agriculture production	Little substitution between water, labour and capital (however, the output mix is determined through a optimisation process)
Reported major model outcome variables	Agriculture product output and key macro variables for each region	WTM: GVIAP and Profit AusRegion: key regional macro variables	Irrigated areas and water used for each region, GVIAP and profits

[4] For example Wheat/Rice production includes dry land wheat in the normal and dry state, and irrigated rice in the wet state.

1.2.2 Simulation Design

Key simulation design features are summarised in the following table.

Table 1-2: Key simulation design features

	Monash-CoPS (Wittwer 2010 and 2011)	ABARES-BRS (2010 and 2011)	UQ-RSMG (UniQuest 2010 and 2011
Base year(s)	Wittwer (2011): 22 years from 2008 to 2029 Wittwer (2010): 17 years from 2010 to 2026	WTM: combined sources of 2005-06 crop and land use data set with 2000-01 water availability data (considered to be more representative of the long-run average levels of use) AusRegion: 2001-02 Australian economy	Water availability: estimated using the data from 2000-01 to 2009-10 Other underlying data is also continuously updated
Major SDL reduction scenario(s)	Wittwer (2011): 2,400 GL, 2,800GL and 3,200GL reduction with financial compensation over the simulation period Wittwer (2010): 3,500GL, 3,000GL and 4,000GL reductions with financial compensation over the simulation period Note that all the targets include the buy back from 2008 to the last observed period	ABARES (2011): 2,400GL, 2,800GL and 3,200GL SDL reduction scenario ABARES (2010): 3,000 GL, 3,500GL and 4,000GL SDL reduction scenarios	UQ (2011): 2,700GL reduction on average between the three states of rainfall UQ (2010): reduced water availability scenario based on 10 years from 1998 to 2008, while a base scenario (referred to as a historical scenario) based on the complete 114 years water availability data set (1895-2008)
Key scenario variations	Witter (2011): all proceeds of buyback exit the basin Infrastructure upgrades,with infrastructure upgrade on top of a buyback scheme Witter (2010): no buyback scheme	ABARES (2011): With/without interregional water trade With/without buybacks to date and with/without infrastructure investment Separate sensitivity analysis in terms of water supply variability such as "good", "dry" and "very dry"	UQ (2011): trade and stochastic contingency

	Monash-CoPS (Wittwer 2010 and 2011)	ABARES-BRS (2010 and 2011)	UQ-RSMG (UniQuest 2010 and 2011
		ABARES (2010): with/without interregional water trade	
Buyback schemes	Witter (2011): sales of water entitlement by 2019 Witter (2010): sales of SDLs target entitlement by 2022	ABARES (2011): no specific timing	Not applicable

1.2.3 Key Modelling Results

Key modelling results are summarised in the following tables.

Table 1-3: Key modelling results under 2,800 GL SDL reduction scenario – 2011 studies

	Monash-CoPS (Wittwer 2010 and 2011)[a]	ABARES-BRS (2010 and 2011)[b]	UQ-RSMG (UniQuest 2010 and 2011
National GDP	Year 2029: -0.013%	-	-
National employment	Fixed by long run assumption	Fixed by long run assumption	-
MDB GRP	Year 2020: -0.05% Year 2029: -0.16%	Short run: 0.21% Long run: -0.81%	
MDB employment	Year 2020: 0.23% Year 2029:-0.02%	Short run: 0.33% Long run: -0.03%	
MDB GVIAP	-	-5.8% (-12.7% for SDL reduction only)	

MDB profit levels	-	-5.7% (-8.2% for SDL reduction only)	-13% for SDL reduction only 5% for SDL reduction with trade

[a] With water buyback plus upgrade

[b] After interregional water trade and after water saving

Table 1-4: Key modelling results under 3,500 GL SDL reduction scenarios – 2010 Studies

	Monash-CoPS	ABARES-BRS
National GDP	Year 2026: -0.01%	Long run: -0.13%
National Employment	-	Long run: -0.03%
MDB GRP	Year 2026: -0.25%	Long run: -1.3%
MDB employment	Year 2026: -0.05%	Long run: -0.10%
MDB GVIAP	-	-19.0%
MDB profit levels	-	-9.9%

1.3 Appropriateness of Commissioned Modelling

Broadly, two types of models are used: partial equilibrium models focusing on water flows; and CGE models with the capacity for region-wide and national economy-wide flow-on impacts.

The Monash-CoPS CGE model is a hybrid of these two types of models, containing detailed agriculture sectoral specifications and water use modelling applied endogenously within an economy-wide modelling framework. TERM-H2O is also the most sophisticated CGE core of the two CGE modelling studies commissioned.

Two partial equilibrium models, the ABARES-BRS WTM and UQ's RSMG have significant levels of hydrological detail and a regional dimension to capture water flows in and through the Basin regions. ABARES-BRS informally interfaced their partial equilibrium WTM model and the AusRegion CGE model to capture the agriculture sectoral impacts by region along with the more broadly defined regional impacts.

The approaches employed to model the socio-economic impacts are considered to be appropriate. However, the ultimate efficacy of having modellers working independently using different modelling frameworks and different baseline assumptions, is more difficult to review. Each team has brought forward considerable and differing expertise to the analysis. The independent work conducted so far has provided many insights, but has been conducted in such a way that comparison between results from the studies provides limited information. A benefit of the independent approach is that it has highlighted the areas of strength and the limitations of each approach.

For future modelling work, it is our recommendation that the MDBA take the lessons of the work conducted so far and invest resources in pulling together a team of researchers to pursue a common, integrated research agenda. Part of this process would be the development of a modelling framework using the key strengths of these models, and others, built around a dynamic, regional CGE model. This would constitute best-practice for the next phase of the MDBA's research agenda.

With the focus on socio-economic impact modelling, a well-specified dynamic CGE model with either (a) the ability to interface with a detailed hydrological model of the basin or, (b) internal water-modelling capacity (at least in terms of specifying water costs in production functions) is essential to adequately capture the necessary interactions and responses.

Any restriction of water supply will directly affect agricultural producers. This may also impact downstream users and upstream suppliers leading to a range of flow on impacts at the micro and macroeconomic levels. To account for these complex and dynamic interactions, a CGE model is essential

A limitation of CGE models is the level of regional detail. CGE models require information that is detailed across productive activities, for example, trade and investment. However, quality data of this type is not usually available at the regional level. Furthermore, the specification of key CGE parameter values, such as elasticities of substitution, becomes problematic at this level of detail. An option that we recommend the MDBA consider is the use of micro-simulation techniques to generate information at this more granular level. Micro-simulation models generally deal with very detailed information about household income and expenditure patterns, but within a relatively unsophisticated behavioural framework which lacks the production, sales and trade data that is the strength of the CGE model framework. Detailed household income and expenditure can usually be acquired at the regional level. With knowledge of the types of households that exist at a detailed regional level, including how income is earned and the goods and services that are purchased, the CGE results for variables such as wages, industry output and prices could be used, along with a an understanding of the geographical distribution of productive activity (for example, the location of a rice mill), to infer the impacts on communities for a small set of, nonetheless, important metrics.

A key component of the modelling framework is the hydrological component. The strength of the ABARES-BRS and UQ-RSMG models is their detailed handling of river systems and the geographical and spatial elements of the basin plan's impacts. Whether formally or informally linked, this component of the framework ensures that the supply side of the water market is properly modelled, and that the regional linkages are also based on river systems and the downstream consequences of upstream producer decision making.

Overall, the MDBA has brought together an appropriately qualified and experienced set of subject matter experts, and has produced a set of informative studies that serve to (a) provide important insights into particular components of the problem and (b) highlight the need for a larger scale, more integrated approach to the socio-economic impact modelling. This phase of the analysis has benefited from the independence of the three groups of researchers, and it was appropriate for that independence to be allowed at this stage. The next phase of the research should pursue a more coordinated and cooperative approach. This approach should draw on the lessons of this first phase, and use the strengths of the various approaches in pursuing a common research agenda that includes agreement on scenario analysis and the appropriate formation of model baselines.

2 Introduction

In accordance with the Commonwealth *Water Act (2007)*, the Murray-Darling Basin Authority (MDBA) is responsible for developing a plan for managing the water resources of the Murray-Darling Basin (the Basin). The Draft Basin Plan includes potential reductions in long-term sustainable diversion limits (SDLs) on extraction of surface and ground water from the Basin system.

Central to this plan will be reducing the limits on the quantities of surface water and groundwater that can be extracted for consumptive use - known as sustainable diversion limit (SDL). These SDL[5] reductions will apply to the Basin's water resources as a whole, as well as at sub-regional levels.

In developing the Basin plan, the MDBA is required to consider the potential socio-economic impacts of possible changes in future water availability. Specifically, under Section 21 of *the Act* on the *'General basis on which Basin Plan to be developed'*, there is a requirement under subsection (4) (b) that the MDBA (and Minister) *'act on the basis of the best available scientific knowledge and socio-economic analysis'.* To adhere to the requirements of the Act, the MDBA have commissioned a number of studies to provide socio-economic advice, including modelling and analysis, of the potential impacts of the proposed SDL reductions.

KPMG was commissioned by the MDBA to undertake a rigorous review of selected socio-economic impact analyses. In completing this review, KPMG has:

- detailed and compared the modelling approaches and assumptions of the six reports (the three original and three subsequently updated reports) subject to review;
- presented and clarified the modelling results in terms of the insights that each provide to the socio-economic impacts from reductions in SDLs; and
- identified options for a workable path forward to improve the modelling completed to date and to enhance the future process in line with the requirements of the Act.

2.1 Report structure

The report is structured as follows

- Section 3 - Background - a discussion on the Basin, the MDBAs modelling objectives and an overview of economy-wide modelling;
- Section 4 - Modelling frameworks - a discussion of the different approaches used in the reports reviewed;
- Section 5 - Approach - details the general features of each model, the objectives of the analysis and the scenarios modelled;
- Section 6 - Results- summarises and compares the results of each analysis and the underlying assumptions that drive these results;

[5] Long-term average SDL represents the amount of water that can be used for consumption after the environmental requirements have been met.

- Section 7 - Conclusions - highlights the key outcomes for the MDBA in terms of the modelling to date; and
- Section 8 - Next steps - outlines possible options for managing the future modelling requirements of the MDBA.

3 Background

This section provides an overview of the MDBA modelling requirements, model options and value of economy-wide modelling.

Key points

- The Murray-Darling Basin is an area of national social, economic and environmental significance.
- The MDBA is charged with developing a Basin Plan that considers the potential implications of changes in future water availability.
- The MDBA has commissioned reports from three economic modelling groups to consider the socio-economic impacts.

This section is structured as follows:

- Section 3.1 provides an outline of the significance of the Murray-Darling Basin;
- Section 3.2 details the modelling requirements in relation to the development of the Basin Plan; and
- Section 3.3 provides an overview of economy-wide modelling.

3.1 The Murray-Darling Basin

The Murray–Darling Basin is Australia's largest river system, and one of the biggest systems in the world. It covers 1,059,000 square kilometres or 14 per cent of Australia's land area across south-eastern Australia, collecting the water draining west of the Great Dividing Range.

The Basin collects water that flows inland to the west across flat floodplains, forming rivers, creeks and wetlands as it goes. Passing through five states and territories — Queensland, New South Wales, Australian Capital Territory, Victoria and South Australia — its water eventually flows out to sea at Goolwa in South Australia.

Australia's three longest rivers, the Darling (2,740 km), Murray (2,530 km) and Murrumbidgee (1,690 km) are found in the Murray-Darling Basin (ABS, 2008), with the system including 23 major rivers in all.

Throughout the Basin there is great variation in climatic conditions and landscapes. From the warm, sub-tropical environment in the north, the Basin ranges through cooler, humid highlands to the east; cold alpine country further south; temperate regions in the south-east, and hot, arid plains in the west before reaching the sea.

3.1.1 Basin environments

Across the Basin's vast area, water flows in river channels; creates lakes and wetlands; spreads across floodplains; recharges groundwater and eventually creates an estuary environment where the fresh water of the river meets the salty sea water. These varieties of environments within the Basin support a huge range of Australia's plant and animal life. Many plant and animal species rely on the seasonal changes of water flow for their survival. Wetlands are an extremely important environment for many fish and bird species that need them for their feeding and breeding cycles.

The diversity of environments also allows the production of a great range of food types across the Basin, including tropical fruits in the north, dryland cropping and livestock grazing to the west, and cooler weather produce found in the southern regions.

3.1.2 Water availability

Water availability in the Basin is subject to large variations, throughout the year, between years and over longer periods. In the last 100 years, the Basin has been transformed by the construction of major water storages on the rivers. The total volume of publicly managed water storage capacity in the Basin is just under 35,000 GL. The area overseen by the MDBA includes storages that account for about one – third of that volume – with major storages at the Dartmouth Dam, Hume Dam, Lake Victoria, Torrumbarry Weir, the Menindee Lakes and other river regulatory structures. These storages have made it possible to store water during wet periods and release it as needed during summer or in droughts.

The volume of water extracted for consumptive use in the Basin increased from around 2,000 GL a year to more than 10,000 GL a year between the early and late 1900s (Productivity Commission 2010). Much of this increase was used to expand the irrigation sector. In 2004-05, industries (including Agriculture) and households in the Basin used more than half (52 per cent) of Australia's total water consumption. In 2004-05, 83 per cent of water consumed in the Basin was consumed by the Agriculture industry (ABS 2008).

3.1.3 Basin life

At the time of the ABS 2006 Census of Population and Housing there were just over 2 million people living in the Basin – around 10 per cent of Australia's population. Outside the Basin, a further 1.3 million people depend on its water resources, including Adelaide with the largest population base reliant on Basin water resources. Additionally, about 30 Aboriginal nations live in the Basin and are connected spiritually to the land, water and environment of the Murray-Darling river systems.

The Basin is Australia's most important agricultural area, producing over one–third of Australia's food supply. It produces 53 per cent of Australian cereals grown for grain (including 100 per cent of rice), 95 per cent of oranges, and 54 per cent of apples. The Basin supports 28 per cent of the nation's cattle herd, 45 per cent of sheep, and 62 per cent of pigs.

Agriculture is a significant employer in the Basin and in 2006, 10 per cent of all people employed in the Basin worked in dry land and irrigated agriculture, compared to 3 per cent Australia-wide. Almost 40 per cent of Australia's farmers reside in the Basin (ABS, 2008).

The Basin includes 65 per cent of Australia's irrigated agricultural land. In 2005–06, the Basin also accounted for around 40 per cent of Australia's gross value of agricultural production (GVAP) and 45 per cent of its gross value of irrigated agricultural production (GVIAP). The value of irrigated agricultural production in the Basin was equivalent to around 14 per cent of Australia's total GVAP in 2005–06 (ABS 2009).

The Basin's diverse landscapes — including over 77,000 km of rivers and more than 25,000 of wetlands — support a wide range of complex ecosystems. The Basin is home to at least 35 endangered species of birds and 16 endangered species of mammals. There are 46 known species of native fish in the waterways of the Basin of which 16 are listed as rare or threatened on state, territory or Commonwealth listings.

3.2 The Basin Plan

The MDBA was established in September 2008 to manage the water resources of the Basin in the national interest, assuming responsibility for all the functions of the former Murray-Darling Basin Commission. A key role for the MDBA is to prepare a Basin plan that will include reductions in long-term average SDLs on the use of both surface and groundwater in the Basin. The aim of these SDL reductions is to provide water for key environmental assets in the basin while still allowing water for irrigation, food production and other consumptive uses.

The Basin Plan will be a high-level plan to ensure the water resources of the Basin can be managed in a sustainable way. This will include developing a package of strategies that includes management practices, infrastructure and environmental flows that together provide security of access to water and an environment that is resilient to change.

The Basin Plan will identify, and seek to protect and restore, key environmental assets that are essential to the life of the rivers, their surrounding landscapes and the cultural values of the communities which depend on those water resources. The Basin Plan will also take into account the impact of this protection and restoration on individual communities, industries, regions and the wider economy. In developing the Plan, the MDBA has commissioned various modelling work to assess the environmental and socio-economic impacts of reductions in long term average SDLs.

4 Modelling Frameworks

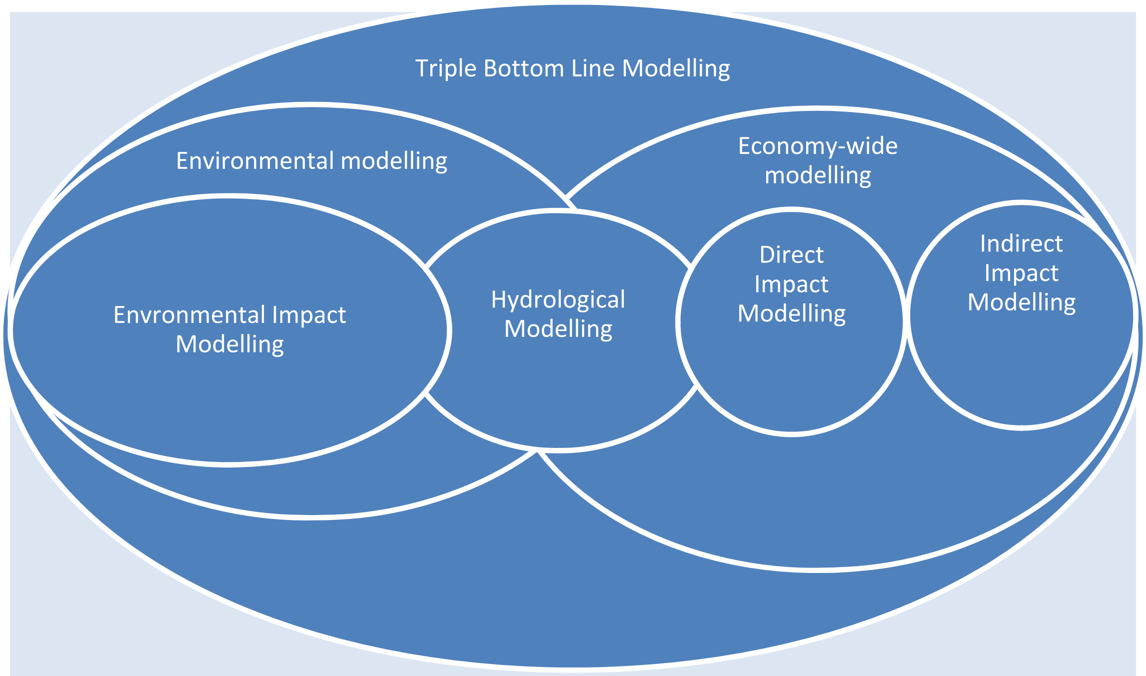
In this report, KPMG reviews three modelling approaches that analyse the socio-economic impacts of reductions in SDLs. The following diagram presents an overview of the some of the key modelling frameworks that are relevant to assessing these impacts.

All approaches seek to assess the socio-economic impacts of the SDL reductions either directly or on an economy-wide basis. These approaches analyse the impact of SDLs using a combination of partial-equilibrium and/or computable general equilibrium (CGE) models of the Australian economy:

- CoPS used a dynamic, bottom-up regional CGE model with internal water-modelling capacity;
- ABARES-BRS sequentially and informally linked a comparative static, bottom-up regional CGE model with a partial equilibrium hydrological model that includes some economic optimization behaviour; and
- UQ applied a partial-equilibrium hydrological model that some elements of economic optimization and an application of uncertainty in decision making.

Governments, at all levels, are interested in the economic impacts of major infrastructure projects and policy decisions. An ideal method for such analyses, and one that is now a necessary input into policy development around the world, is through the application of well-specified CGE models. The findings of detailed and focused partial equilibrium analysis of water trading are useful in informing economy wide impact analysis of relevant policies.

Figure 4-1: Modelling frameworks



4.1.1 CGE modelling approaches

CGE models account for economic behaviour and linkages between agents in the economy (consumers, workers, investors, governments, exporters, industries, etc) at varying levels of industry and regional detail. They are used to estimate the effect of a change in one part of the economy on the economy as a whole, at both a detailed industry and commodity level, and at the macroeconomic level. For example, a reduction in water availability will affect agricultural production and prices, the consumer price index (CPI), and potentially wages and employment, and have direct and indirect impact on other industries through sales and supply chains. CGE has become a key method applied to estimate the economic effects of environmental policies, such as measures to reduce greenhouse gas emissions and in biofuel policy analysis.

There are a number of types of CGE models.

Comparative-static CGE models estimate the reactions of the economy at one point in time. For policy analysis, results from such a model are often interpreted as showing the reaction of the economy to an external shock or policy change at a future point in time, although this is not strictly correct. That is, the results are interpreted to show the difference (usually reported in per cent change form) between two alternate future states (with and without the policy shock). The process of adjustment to the new equilibrium is not explicitly represented in such a model, although details of the model's closure[6] lead modellers to distinguish between short-run and long-run equilibria. Strictly speaking, as comparative static simulations have no explicit time dimension, it is fallacious to interpret results as representing any real-world point in time. Rather, results should be interpreted as deviations away from a representative point in time, in a simulation in which an economy adjusts instantaneously and costlessly to changes in a policy (or other exogenous) variable, without regard for dynamic concepts like flow-stock-accumulation relationships (for example, between investment and capital accumulation) or market frictions (for example, such as stickiness in wages and employment responses over time). Comparative static models are best at analysing the consequences of policy for allocative efficiency - the efficiency with which the economy allocates resources amongst productive uses. The ABARES-BRS CGE model falls into this category.

Dynamic CGE models explicitly trace variables through time - often at annual intervals. These models are better than comparative-static models (for example) in creating time-dependent projections for purposes such as forecasting, for policy analysis that involves phase-in or anticipation effects, and for economic shocks that impact on dynamic variables like investor expectations. They are, however, significantly more challenging to construct and solve. For example, truly dynamic simulations require specification of future changes for all exogenous variables, not just those affected by a possible policy change. The dynamic elements may arise from partial adjustment processes or from stock/flow accumulation relations for example, between capital stocks and investment, and between foreign debt and trade deficits.

[6] The mix of endogenous and exogenous variables. The values of endogenous variables are generated by the model via in a simulation, while the values of exogenous variables are told to the model by the modeller as means to determine the nature of the simulation. For example, in long run comparative static analysis, it is common to allow real wages to adjust but to assume that the aggregate level of employment is exogenous.

Recursive-dynamic CGE models are those that can be solved sequentially (one period at a time). They assume that dynamic behaviour depends on expectations about the future based only on current and past states of the economy. Alternatively, if an agent's expectations can be informed by information about the future state of the economy, it becomes necessary to specify expectations in the current period as dependent on all future periods of the simulation. This second type of dynamic model is usually referred to as involving a forward-looking or rational-expectations framework. Within this group, dynamic stochastic general equilibrium models explicitly incorporate uncertainty about the future. The Monash CoPS CGE model is a recursive dynamic CGE model.

As the Basin Plan is likely to result in reductions in the levels of water available for use in the agriculture industry, it is likely to have implications for agricultural production levels. The impact on agricultural production would have flow on impacts to the rest of the Australian economy. CGE models provide a structural representation of the economy. They are able to capture how particular policies impact the economy, how it responds, and how these responses flow through to socio-economic impacts.

4.1.2 Partial Equilibrium Approaches

In the studies commissioned from ABARES-BRS and UQ, partial equilibrium hydrological models were employed. These models are designed to enable detailed analysis of changes in Basin-wide irrigation activity, river systems and river health before and after the introduction of SDL reductions. They also enable detailed analysis of the effectiveness of water trading in mitigating economic losses that may result from reductions in SDLs, although this is also true of the water-modelling components of the TERM-H2O model applied by CoPS. The key findings of such analysis is useful in informing subsequent analysis of the economy-wide implications of SDL reductions.

5 Modelling Approaches

This section details the three modelling approaches undertaken in each of the three reports reviewed by KPMG.

Key points

- Three distinctive modelling approaches are used, although there are some common features.
- ABARES-BRS (2010 and 2011) used two modelling tools; a hydrological partial equilibrium region specific agricultural sector model (the "water trade model" (WTM)) and a comparative static CGE model. The outcomes of the partial equilibrium model (irrigated agriculture production impacts) were used as inputs to the CGE modelling analysis. The adopted two stage modelling approach could be combined into one if the underlying CGE modelling framework were further refined to accommodate the hydrological elements of the irrigated agriculture production. The integrated CGE modelling approach would have challenges, particularly in specifying the region-specific water trade channels and their capacity limits, but would pay dividends in terms of the consistency between the economic constraints imposed in the CGE model and the hydrological constraints of the WTM.
- UQ-RSMG (UniQuest 2010 and 2011) addresses the hydrological aspects of the irrigated agriculture sector with a particular focus on imposing uncertainty on producer decision-making. The application of state-contingent analysis to deal with uncertainty, and the specification of state-contingent production systems, is used to provide an additional layer of detail to agricultural production functions. However, this model is not designed to capture the economy-wide impacts in the way that a CGE model does. Nevertheless, this type of model can provide information on the localised impacts of the irrigation sector in the short to medium run, so these modelling results could be used to help develop structural adjustment strategies. From this perspective, this modelling has a common base with the WTM used by ABARES-BRS. In terms of the MDBA's need for socio-economic impact analysis, the UQ-RSMG framework should be viewed as potential input into a more comprehensive economy wide framework.
- CoPS-Monash (Wittwer 2010 and 2011) developed a dynamic, bottom-up multi-regional CGE model with a detailed specification of irrigated and dry agriculture production sectors. Irrigation water is explicitly introduced into the production process as a factor. This modelling approach is designed to capture all the feedback impacts of the SDL reduction scenarios and their flow-on economic impacts. From this perspective, the CoPS-Monash modelling has a common theme with ABARES-BRS CGE modelling. However, the key differences are that CoPS-Monash incorporates the use of irrigation water into the CGE modelling framework and allows for the time dimension to be explicit.

5.1 ABARES-BRS Approach

ABARES-BRS pursued a two-stage approach in its analysis of the impact of the SDL reductions on the Basin and sub-regions. Two models were applied sequentially and independently:

- the ABARES-BRS Water Trade Model (WTM); and
- a comparative static CGE model called AusRegion.

Water Trade Model (WTM)

The WTM is a comparative static, partial equilibrium, hydro-economic model. Irrigated agriculture production is modelled using a Cobb-Douglas production function with two inputs, water and land.

Water flows are modelled using a nodal framework, in which water flows between regions that are hydrologically connected are accounted for at specific points (or "nodes") in the system linked (or not linked, as the case may be) to other nodes. At any given point on a water course, water availability is given by the sum of local surface water run-off, surface water run-off from hydrologically connected areas upstream and local groundwater.

Given a significant degree of sophistication in its modelling of water, the WTM is more a hydrological model than it is an economic model. It shares this characteristic with UQ-RSMG.

The WTM distinguishes 24 regions producing 11 irrigated agricultural products. Quadratic (i.e. non-linear) cost functions are used to impose upward-sloping marginal cost functions (that is, supply functions) that enable producer optimisation decisions to distribute economic activity between sectors as they seek to maximise returns to land and water. The WTM treats the multi-product irrigated agriculture sector for each region as a single optimising agent.

The model allocates inputs (including land and water) in order to maximise returns to land and water. This is a fairly conventional treatment of economics in a partial equilibrium framework. The quadratic yield function implies diminishing returns to land and is a key mechanism that determines prices. As yields fall in response to a decline in water inputs and, therefore, marginal cost increases, the price of the agricultural product rises and puts a particular product produced on that unit of land at a competitive disadvantage. This, broadly speaking, is also a trait common with the UQ-RSMG model.

Production functions of this nature are likely to involve close to fixed-proportions technology – that is, there is likely to be very limited scope for changes in the mix of inputs (on a volume basis) used in production. Changes in the prices of water will influence cost shares and product prices, but the model treats production functions as having close to fixed proportions for most inputs. As a result, it is not ideal for detailing how farmers would substitute other factors of production in response to higher water prices. Hence, as water becomes more expensive (or less available) costs rise and farm outputs fall.

The WTM explicitly accounts for the "Barmah choke", through a component of the model that creates a physical water delivery constraint to regions downstream. It is this type of detail that would be useful in determining regional impacts to a finer level of detail. Explicit and dedicated hydrological modelling is an important component of Basin policy analysis, and the "Barmah choke" type of detail evident in the WTM falls in this category.

Simulations with the WTM can be run using different assumptions regarding water trade. When trade is assumed to be "unrestricted", water can be traded between hydrologically connected regions subject to various constraints relating to hydrological and environmental concerns. In the "restricted" trade version, water can be traded only within a region. The role of these assumptions in the economic outcomes relates to the determination of water prices:

- in the restricted region, a region-specific water price will emerge for each of the catchment areas; and
- in the unrestricted region, there should be a common price between hydrologically connected regions, assuming that water can flow freely between them (perhaps not the case, for example, for regions downstream of the Barmah choke).

This is a key determinant of the distribution of GVIAP between regions, and therefore of GRP in the AusRegion model once the WTM results are passed through. TERM-H2O makes similar assumptions, but these are handled by a more hands-on, exogenously determined set of assumptions about water flows and trade between regions, where as the WTM is a model designed specifically to capture these interactions. This is a strength of the ABARES-BRS approach, although it should be noted that, from a modelling point of view, it simply means that a slightly different set of assumptions must be brought to bear on the problem: in the end, how "good" the assumptions are is the key factor.

The ABARES-BRS approach focuses on irrigated agriculture. The WTM explicitly models irrigated agricultural production and changes in land use in these sectors are essentially assumed to free-up land to be used in dryland production. As dryland farming is not explicitly modelled, the land shift implied is a mathematical residual, and there is no interaction between the producers in competing for the land. The WTM assumes that all land that is removed from irrigated agriculture is converted to dryland agriculture, while maintaining each region's existing dryland production mix.

The ABARES-BRS (2011) study introduces a number of refinements to the methodology and assumptions employed in its 2010 study. Some of the key refinements include:

- a more detailed consideration of water supply variability;
- a more realistic relationship between water diversions and irrigation use;
- various refinements to WTM baseline data set;
- further considerations of other government policies, specifically Water for the Future; and
- a focus on both short and long run employment effects.

AusRegion

AusRegion is a bottom-up regional model of the Australian economy, historically based on the MMRF model that distinguishes the six states and two territories as distinct regional economies. This study has extended the database to incorporate data on seven Murray-Darling Basin regions and a further eight sub-state regions of interest. The version of AusRegion used in the Basin study distinguishes 31 commodities, 16 of which are agricultural products.

The AusRegion model has a long-run closure. Conventionally, this means that aggregate employment and rates of return on capital are exogenous. The assumption is that labour is mobile in response to relative wage rates, and implies that, in the long run, aggregate employment is determined by technological change, capital accumulation and population growth. This is a sensible assumption – in the long run, wages will adjust to return the economy to a "normal" level of employment determined by the ability of labour markets to clear as structural change occurs. Taking this further, the assumption is that water policy in the Basin can influence wage levels regionally and in the aggregate (although marginally), and it can influence the regional distribution of labour, but is unable to influence the aggregate demand for labour at the national level. Interpreting AusRegions results needs to be done in this context, and the assumptions that surround the long-run focus should be considered appropriate in the context of the scope and focus of the model.

The results from the WTM for GVIAP are used as exogenous shocks to regional output in AusRegion. While this approach is valid and will generate important and useful information, it has the limitation that substitution possibilities that could be well handled in the CGE model are diluted, and effectively dealt-with in the WTM in a framework less suitable to handle such effects. This type of informal linkage is a common practise in economic modelling, and these comments should not be construed as criticism. However, it must be said that a set of formal linkages allowing feedback between the models would likely lead to differences in some of the results.

A potential alternative for ABRES-BRS would be change the information transferred between the models. It would be a relatively simple task to add water to AusRegion as a factor of production, and then water price or supply information from the WTM could be brought into the CGE model as shocks. This approach would allow the relative strength of the CGE model - producer behavioural responses to changes in costs, both in terms of output levels and input choices - to be handled by AusRegion.

ABARES-BRS has also conducted some household level analysis of the impact of SDLs. Using a micro-simulation technique, data on household incomes and expenditure patterns that are linked to regional location and, therefore, exposure to water prices, is used to address the economic impacts of SDLs at finer level of detail than is possible with the CGE model alone. This household-level analysis is a very interesting exercise that could be taken further and provide useful estimates of economic impacts at a quite fine level of detail.

5.2 UQ-RSMG Approach

The UQ-RSMG model is a partial equilibrium framework of hydrology, water trade and irrigated agricultural costs. In common with the ABARES-BRS WTM, it is much more a hydrological model than an economic model. The approach used in 2010 was extended in 2011 to capture the inclusion of both social and environmental objectives; water trade within the basin; and modelling to capture varying states-of-nature on regional production. For completeness, this section begins with an outline of the approach used in 2010 followed by how the approach was extended in 2011.

5.2.1 2010 Approach

A distinguishing feature of this model is its use of a set of state-contingent parameter settings. A state-contingent framework links the value of certain variables within the system to a state in another variable or parameter. Such linkages are often referred to as complementarity relationships in economics.

The model accounts for three states of nature differentiated by the availability of water (normal, wet and drought) and each state carries with it an exogenously determined probability of occurring (0.5, 0.3 and 0.2, respectively). For example, rainfall in a region might be linked to one of these states of nature, making the availability of runoff in that region contingent on (or alternatively, complementary with) that state.

The model distinguishes 21 regions, comprising of 19 Catchment Management Regions (CMR), Adelaide and the Coorong (assumed to represent flows to the sea). The CMRs are based on 16 Natural Resource Management regions, modified to improve the representation of the flow of water through the MDB. Similar to the ABARES-BRS WTM model, the catchment area hydrological detail is a particular strength of this modelling approach.

The CMRs are linked to account for water flowing from one catchment to another. CMRs that do not share a border are not directly linked, and CMRs that share a border without water flow are not linked. This is, practically, very similar to the nodal approach used by ABARE-BRS.

Water accounting is impressively detailed. Several types of interaction are modelled:

Catchment flows refers to the total potential level of water that is directly sourced from each CMR, defined as the sum of local runoff, groundwater and water transfers. Runoff is linked to each state of nature by an adjustment factor. This adjustment factor assumes in normal years that 100 per cent of runoff is captured; in wet years, 120 per cent of runoff is captured; and in drought years, 60 per cent of runoff is captured.

The adjustment factor assumptions hold across the CMRs and the state of nature is assumed to be true for all CMRs in any one year. This approach also assumes that groundwater and transfers are unrelated to states of nature. This assumption leads to runoff capturing what might be considered direct rainfall effects on the basin's water supply.

The modelling approach also accounts for conveyance loss. This refers to the loss in water flow that occurs due to evaporation and seepage. Conveyance loss is not state-contingent, but it does vary across the CMRs. This treatment implies an assumption that conveyance loss is a geographical or technological variable and not a climate related variable.

Conveyance losses are used to modify catchment flows to determine net flows. The net flow is defined as the local catchment flows plus upstream net residual flows minus local conveyance losses. The net residual flow in any given CRM will be a function of catchment flows less conveyance losses.

The hydrological detail in this approach used to determine the water supply to irrigators in the UQ-RSMG model and this use of state contingent relationships is a distinct strength of this approach.

Production detail is captured in this approach by distinguishing production systems that account for how a hectare of land in a given CMR will switch between agricultural activities based on states of nature. This switching has implications for both the inputs and outputs – that is, as the availability and cost of water changes with the state of nature, a piece of land in a given CRM might change the commodity it produces and therefore, the particular mix of inputs that it uses to produce.

The UQ-RSMG model incorporates economic decision making via an optimization problem.

The objective function of the problem - that is, the variable that the economic agent is seeking to maximize - is "economic return" on irrigation. The economic return on irrigation for a given commodity under a given state of nature is defined by the revenue per hectare (given yield) minus total costs per hectare. The objective function is then defined as the sum across the commodity and state-of-nature dimensions (i.e. the total net revenue from all commodities in all states of nature), adjusted by the probabilities assigned to each state of nature. Effectively, then, the objective is to maximise the probability-weighted average of net revenue from irrigated activities. The net return, as will be explained below, is effectively a gross margin to irrigation services.

The agent in the UQ-RSMG is constrained by a number functions, some of which are sign constraints:

- A salinity constraint, applied as a water quality requirement that electrical conductivity in Adelaide's water is less than or equal to (i.e. this is an example of a sign constraint applied as an inequality constraint) 800 EC;
- A water use constraint measured against a CAP, where the probability-weighted average (by state) of water use in the basin must be less than or equal to the CAP, allowing for use to exceed the CAP under any one state as long as the average across states does not. With the exclusion of certain water requirements, the CAP applied is effectively a CAP on extractions only for irrigation use;
- Water use in each catchment must be less than or equal to total water flows in that catchment, for each state of nature;
- Constraints on irrigated land use not exceeding total irrigable land available, and a sub-constraint on horticultural land use;
- A requirement that operator labour applied to producing each commodity in a given catchment must not exceed the total available in that catchment. This implies that total operator labour is fixed in each catchment.

A cost constraint per hectare, defined by the sum of capital costs, operator labour costs and "variable" costs (contractor, machinery, chemical, water and "other" costs), defined for each commodity process in each catchment, with all components except capital costs varying across states of nature.

A production system is defined for each commodity produced in each catchment/region under each state of nature. As a catchment switches between states of nature, a hectare of land will face a different cost structure. Each cost structure is essentially fixed, but producers choose between cost structures, adding a degree of variability to the effective cost function for each producer.

Although the producer's ability to choose land-use options for given states of nature allows for a degree of the flexibility in the production functions, the economics in the UQ-RSMG model are largely subordinate to both the hydrological assumptions and the probabilities of states of nature occurring. This is true by design and is not intended to be a criticism.

Water impacts on the final calculation via its share in costs, which are fully determined by an assumption of fixed proportions and a fixed price, but which can vary in the levels for any given hectare of land as there can be multiple uses and multiple (fixed) production functions for the three different states of nature. In this case, and focused on the purpose at hand (socio-economic modelling of water restrictions), the strength of the state-contingent scenario analysis in this model is balanced by a relatively invariant and unresponsive production side.

5.2.2 2011 Approach

As noted earlier, the approach used in 2010 was extended in 2011 to capture the inclusion of both social and environmental objectives; water trade within the basin; and weighted average modelling to capture the varying state of nature to the regional production.

To achieve this extension, this approach involves employing a set or sequential sets of linear programming modelling which incorporate the three states of nature (normal, wet and dry). The modelling optimises the use of water subject to maximising economic returns from hydrological, environmental and agricultural production.

In 2010, three state contingent production sets were explicitly modelled. This reflected the possible production switch under the different state of nature. On the other hand, the stochastic approach introduced in 2011 does not have the explicit state contingent production, but rather allows the key variables such as yields and profit margins to vary subject to the stochastic state of nature.

Overall, the state-contingent modelling and stochastic approach attempt to take into account the variability or uncertainty of the water supply in the MDB. The state contingent approach in the 2010 report assumes all the regions in the basin are subject to a homogeneous state of nature, not allowing the possibility for different states of nature across regions at a given time. In the reality, this rarely occurs uniformly across regions. However, from this approach, the model attempts to capture the potential trade-offs of reallocating water for the environment and the likely optimised outcomes of the irrigation dependent production systems. To achieve this, the model computes the weighted average returns across different states on nature based on historical probabilities for each state. However, the average of the three state contingent results may not be a representative result for the Basin as a whole.

The stochastic approach adopted in the 2011 study addresses this shortcoming by allowing stochastic descriptions of these three states to examine the sensitivity of diversion limits for each region. The weighted sum of each regional outcome generated from such stochastic state (non-uniform across regions) of water variability provides an improved representation of the variability in water supply across regions.

However this stochastic approach has been achieved at the expense of some flexibility stemming from the production switching between the different states of nature. In the state-contingent approach, the water supply levels of the three states of nature are predetermined. However, in the stochastic approach, the water availability levels vary to capture all of the outcomes.

5.3 CoPS-Monash Approach

TERM-H2O is a specially modified version of the TERM model developed at the Centre of Policy Studies at Monash University. TERM is a bottom-up regional dynamic CGE model of the Australian economy. The TERM database is derived from a 206 region, 172 sector input-output database constructed by CoPS, and several other data sources including census data and ABS irrigation data. In this application, TERM-H20 distinguishes 35 production sectors in 23 regions including 18 MDB regions. These 18 MDB regions are further mapped to 163 top-down regions.

TERM-H2O has formal linkages between hydrological variables and economic variables in a single CGE framework, and the database and theoretical modifications are designed to allow behavioural modelling of water trade markets.

TERM-H2O modifications begin with changes to the production function.

Land is divided into irrigable land and dry land. In the production function for irrigated agricultural industries, irrigated production sectors can combine water with irrigable land (in fixed proportions, given technology) to create irrigated land. Dry land producers can use a combination of dry land and unirrigated-but-irrigable land in production, choosing this mix across a CES[7] nest according to relative land rental prices. The total supply of irrigable land is divided amongst irrigated and dry land operators, but only irrigated producers can combine it with water.

Once the effective land unit is determined, livestock producers can combine cereals with the "effective land" unit across a CES nest, capturing the idea that they can choose to grow or buy feed depending on relative cost - that is, the amount of land needed per animal can be reduced if the land is not required to grow feed, or indeed that feed can be brought in to compensate for dry weather as land becomes less productive in livestock production during droughts. Via this channel, changes in the ratio of irrigated and dry-land livestock production can occur when water prices increase.

Another interesting modification allows for a CES combination of land and operator labour to produce a "land and operator" primary factor, capturing (amongst several things) the impact of land prices on average farm acreages.

TERM-H2O is implemented as series of linearised equations, solved as a simultaneous system using GEMPACK. One of the benefits of this approach is the flexibility to change closure and to potentially shock any variable in the model. This means, for example, that a model like TERM-H20 is not a designated "long-run", "short-run" or any other "run" model – it can be used, via the proper choice of closure, to capture time in any way. For instance, the impact of variations in weather can be captured in the demand side of the water market in TERM-H2O by

[7] CES refers to "constant elasticity of substitution". These nests are functions that combine "inputs" to create an "output", and allow inputs to be substituted with another according to changes in relative prices and technology according to a "sensitivity" determined by the value of the elasticity. An elasticity is a parameter value that determines how a percentage change in one value (in this case, for example, it could be a price ratio) determines a percentage change in another (for example, demand for an input).

exogenously moving the values of technological-change variables in the production function. As an example, during dry years, dry land industries will see a fall in the productivity of their land, applied to TERM-H2O by shocks to the appropriate tech-change variable. This allows TERM-H2O to capture the idea that, as rainfall is reduced, not only does the environmental supply of water decrease, but the demand for it increases. This effect is not captured in the UQ-RSMG model, and while ABARES-BRS use an economic model based on the Monash modelling method, their simulations don't make use of this facility as they are comparative static in nature.

Irrigable land appears twice in the TERM-H2O production function – it is combined with water in fixed proportions to create irrigated land, and at a higher level of the production nest appears again as a substitute to irrigated land. This at first glance might seem counter-intuitive, but the purpose of this structure can be explained with an example. If the price of water increases, leading to fall in the demand for unwatered irrigable land by irrigators (via the fixed proportions combination of water and irrigable land), this in turn depresses rental values on the irrigable land itself and makes it more attractive to dry-land producers, causing this land type to move into dry land production during dry years.

A relatively large value for the substitution elasticity between land types is adopted. This created some controversy amongst MDBA workshop participants, but seems to be a sensible assumption that is perhaps not well understood. The consequences for the levels of (for example) land use implied by substitution possibilities in linearised equation systems are dependent on both the size of the elasticity and the initial shares of each land type in the database. For example, if industry X uses 1000 units of land type 1 and 1 unit of land type 2, a doubling in the demand for land type 2 and a reduction in demand for land type 1 by a single unit (so the sum of the two is unchanged) - essentially a halving of the land type 1 to 2 ratio - constitutes a large percentage change in the ratio of the two land types, but a relatively insignificant change in the levels of land use. In the TERM-H2O database, dry land and unwatered irrigable land is not used in significant quantities by irrigated production activities, and irrigated land (and therefore, water) is not used in significant quantities by dry-land industries. The dry land livestock industry, for example, can purchase feed that embodies water as a substitute for directly purchasing water to grow their own feed. Therefore, the high substitution elasticity between land types will not result in (for example) rice suddenly being grown on dry, unirrigated land.

Water prices are determined by the interaction of demand and supply. Demand for water is essentially handled via demand equations for irrigated land (which is a fixed proportions combination of water and irrigable land, but with the ability to exogenously change the relationship) flowing from cost-minimisation decisions made by producers subject to the technology in their production functions, relative input prices and the level of the industry's activity. On the supply side for water, supply to a particular industry in a given region is a function of water supplied through the irrigation system, water trade and the product of the amount of irrigated land used by that industry and rainfall. TERM-H2O accounts for rainfall on a per-hectare basis, and so total supply from rainfall to a particular industry in a particular region is a function of the amount per hectare multiplied by the number of hectares.

In simulations where inter-regional trade is not allowed, the equality between demand and supply, and the constraint that the sum across the "trade" variable for all industries within the region is zero, would jointly determine independent regional water prices. If inter-regional trade is allowed, then the sum across the trade variable is zero for the trading "group" of regions, and each trading group has its own water price. If trade were possible across all regions, there would be one zero-sum constraint and one water price, but this is obviously not allowed for hydrological reasons. The term "sum across the trade variable is zero" refers to the idea that if (for example) there are two producers, X and Y, using water, and the total amount of water available to both is fixed, that if X gives one unit of water away (i.e. the trade variable might take the value +1 for that producer) and Y takes that water to use in production (i.e. the trade variable for Y might take the value -1), the sum across the total trade is 0 (i.e. +1 + (-1)). In practise, this ability to change the tradability of water is shared by the ABARES-BRS "restricted" and "unrestricted" water trading approach.

An interesting feature of TERM-H2O is that, in the case where water trade can occur between regions but there are geographical or technical constraints on water moving in sufficient quantities to equalise water prices between those regions, a complementarity condition is used to constrain equalisation. In basic terms, the value of a parameter is set to produce an upper bound on the amount of water that can leave one region and enter another: when the constraint is slack, water prices between regions are equalised; when the constrain is binding, water prices diverge via a rent component that varies with the "pressure" on the constraint. This feature shares a conceptual similarities with the Barmah choke constraint in the ABARES-BRS WTM model.

Complementarity conditions can be thought of as state-contingent relationships between model variables, and so TERM-H2O shares this on a conceptual technical level with the UQ-RSMG model. However, they differ significantly in application: the UQ-RSMG model makes more extensive use of these relationships, but applies them in a more hard-wired way that relates to probability assumptions, while TERM-H2O solves for the state of the complementarity endogenously. Therefore, state-contingencies in the UQ-RSMG model are relatively determinant, while those in TERM-H20 are relatively responsive.

TERM-H20 has several strengths, described above, related in the main to the sophistication of the economic components of the modelling. An implication of this strength is that the model actively and explicitly allocates water between production uses based on the optimisation decisions made by the users of water. This is not a strength - at least for the purposes of socio-economic modelling - shared by the UQ-RSMG model. Due to the informal, sequential linkage in the ABARES-BRS approach (with water demand and water prices determined in the WTM and then passed through to AusRegion via GVIAP) the role of economic optimisation decisions in water allocation is diluted. However, TERM-H2O contains less hydrological detail than the WTM and UQ-RSMG, and contains a less sophisticated framework for internally determining water flows within and between regions. In the Basin water policy scenario simulation, TERM-H2O simulated an exogenously imposed water availability scenario, but does so with a high level of sophistication in its modelling of producer choice and intra- and inter-regional economic linkages. On the other hand, the hydro models of UQ-RSMG and ABARES-BRS and UQ-RSMG actually model the water flows themselves, and impose those answers on the economic model in different ways.

5.4 Summary of the Modelling Approaches

The key features of each modelling structure and approaches are summarised in the following table.

Table 5-1: Key Aspects of the Modelling Frameworks

	Monash-Cops (Wittwer 2010 and 2011)	ABARES-BRS (2010 and 2011)	UQ-RSMG (UniQuest 2010 and 2011)
General/partial Equilibrium	General equilibrium	Interfacing between partial (WTM) and general equilibrium (AusRegion)	Partial equilibrium[8]
Regional dimension	Based on statistical local areas, 23 regions focusing on 18 MDB regions[9]	24 WTM regions and 7 MDB regions for AusRegion	21 regions including 19 catchment areas
Agriculture product/sectoral details	35 industries including 17 farm and 10 irrigation sectors, producing 28 commodities	WTM:11 irrigated agriculture products/sectors AusRegion: 31 products including 16 agriculture products	23 sectors: 21 irrigated agriculture products/sectors, 1 dry land product, and Adelaide water supply
Comparative static/dynamic analysis	Year-by-year comparative dynamics	WTM: comparative static analysis (short run nature) AusRegion: Comparative static analysis for both short and long run	Comparative static analysis (short run nature)
Water trade	Implicit treatments of water trade	Explicit treatments of water trade in WTM	Explicit treatments of water trade
Uncertainty of rainfall	Explicit scenario of rainfall over the simulation periods	Sensitivity tests in terms of the variability of rainfall (2011)	Contingent based analysis

8 Key objective is to maximise the weighted average economic return from irrigation use across the three states of nature

9 The bottom up 18 MDB regions are mapped to 163 top-down regions.

Specification of dry land production	Explicit within a product, e.g. dry wheat and wet wheat	Irrigated sector only for WTM	Single dry land production State-contingent flexible[10] irrigated production technology
Role of water in irrigated agriculture production	Factor of production combined with irrigable land	WTM: volume of output depends on land and water use according to a Cobb-Douglas production function AusRegion: No specific role of water	Part of fixed costs along with operator labour cost and annualised capital payments
Key production substitutability	A wide range of substitutability between primary factors including water	WTM: little substitution among production factors including water AusRegion: a range of substitution between production factors – no water is explicitly specified in the agriculture production	Little substitution between water, labour and capital. However, the output mix is determined through a optimisation process
Reported major model outcome variables	Agricultural product output and key macro variables for each region	WTM: GVIAP and profit AusRegion: key regional macro variables	Irrigated areas and water used for each region, GVIAP and profits

[10] For example Wheat/Rice production involves dry land production of wheat in the normal and dry state, and rice in the wet state.

6 Modelling results

This section details the modelling results from each of the three studies reviewed for this report. It provides an interpretation of deviations from baseline path, and explains the reason for the results in terms of the underlying assumptions.

Key points

Scenarios

- 2010 modelling reports from CoPS-Monash and ABARES-BRS provided the economy-wide impacts of the SDLs reduction of 3,500GL, 3,000 GL and 4,000 GL while focusing on the 3,500 GL scenario. The UQ-RMSG did not focus on the SDLs policy scenarios. It compares to the irrigation sectoral impacts of the recent reduced water availability (based on 1998-2008) in comparison to 114 year historical water availability (1894-2008) in terms of GVIAP and profit levels.
- The 2011 updated modelling reports focuses on a SDLs reduction scenario of 2,800 GL. The updated CoPS-Monash and ABARES-BRS also include results for the 2,400 GL and 3,200 GL reduction scenarios.
- Generally, as the scenario specifications are subtly different between the three modelling analysis, direct comparisons of the modelling results generated from different approaches need to be undertaken with caution.

General Observations

- Modelling results from the ABARES-BRS and UQ-RSMG highlight that impacts are higher in New South Wales and Queensland and lower in Victoria and South Australia.
- The UQ-RSMG approach incorporates substitution of previously irrigated land to dryland farming and assumes that dryland farming would be undertaken on previously irrigated land. The ABARES-BRS WTM did not explicitly account for this as increased dryland farming is calculated as a residual of the model. Accordingly, the overall adverse impact of agricultural production would expectedly be lower under the UQ-RSMG assumption
- The CoPS-Monash report is the only report to include the economic impact of compensation, which result in smaller impacts. This also has an impact on the regional results.
- None of the modelling considered the correlation between irrigated commodity prices and the availability of irrigation water. If this were incorporated in the modelling it would be expected that the adverse impact of reductions in water availability would likely be lower.

This section is structured as follows:

- Sections 6.1 to 6.3 detail the results of from each of the three reports; and
- Section 6.4 compares these results in terms of the direct impacts to the agricultural sector and the flow-on impacts to the rest of the economy.

6.1 ABARES-BRS

6.1.1 Scenarios for economic analysis

The analysis considers the implications of the six Basin plan scenarios, namely SDLs of:

- 2,400 GL, 2,800 GL, 3200 GL (2011 update); and
- 3,000 GL, 3500 GL, 4000 GL (2010 report).

In the 2010 report, the focus of the study was on the analysis of the 3,500 GL scenario and the applicable long term reductions in water use (32 per cent decline in surface water use and 11 per cent decline in groundwater use). The 2011 report focuses on the scenarios covered in the draft Basin Plan; specifically, the 2,400 GL, 2,800 GL and 3,200 GL reduction scenarios. The focus of the economic analysis is on the direct economic effects of reductions in SDLs on irrigated agriculture including the effect on individual industries and regions.

6.1.2 Results (2010)

The effect of scenarios on irrigators' incomes and the value of irrigated activities were modelled using the ABARES-BRS Water Trade Model (WTM). Two sets of results were estimated, one assuming interregional trade and the other assuming no interregional trade. The direct effects of the SDL reduction scenarios were simulated in terms of annual average GVIAP and profit (essentially, farm income). The results for the 3,500 GL scenario are summarised in the following table.

Table 6-1: ABARES-BRS modelling results, annual average GVIAP and profit for 3,500 GL scenario

	Baseline	3,500GL scenario	% change	Value change
With interregional trade				
Water use (GL/year)	10,403	7,311	-29.7	-3,091
GVIAP ($m/year)	6,220	5,280	-15.1	-940
Profit ($m/year)	1,956	1,804	-7.8	-152
Without interregional trade				
Water use (GL/year)	10,375	6,952	-33.0	-3,423
GVIAP ($m/year)	6,207	5,030	-19.0	-1,178
Profit ($m/year)	1,955	1,762	-9.9	-193

Source: ABARES-BRS (2010)

The ABARES-BRS modelling assumes that these changes in irrigated agriculture production are associated with reductions in irrigated land use, and that this land reverts to non-irrigated (dry land) agriculture production. Accordingly, under the 3,500 GL scenario the value of dry land agriculture production is expected to increase by $68m/year (1.1 per cent) with interregional water trade and $69m/year (1.1 per cent) without interregional trade.

ABARES-BRS undertook a sensitivity analysis of the effect of reductions in water availability on the GVIAP. They found that there is likely to be a linear relationship between water availability and GVIAP. That is, as the volume of water decreases the economic cost increases. This is because irrigation activities with a lower profit margin are removed first (i.e. at lower volumes of reductions) and higher value activities are removed as the volume of water reduction increases.

The ABARES-BRS economy-wide modelling results for the 3,500 GL scenario are detailed in the following table.

Table 6-2: ABARES-BRS economy-wide modelling results, 3,500 GL scenario

	Change in GRP/GDP (%)	Change in employment (%)
Murray-Darling Basin	-1.30	-0.10
Australia	-0.13	-0.03

Source: ABARES-BRS (2010)

The ABARES-BRS economy-wide modelling results exclude the effects of government policies such as water entitlement purchases and irrigation infrastructure programs.

6.1.3 Results (2011)

The 2011 report focuses on the scenarios covered in the draft Basin Plan; specifically, the 2,400 GL, 2,800 GL and 3,200 GL scenarios. The report considered four main policy scenarios as outlined below.

- Water buybacks to date: the reduction in irrigation water availability due to government water purchases to date (2008 to 2011).
- SDLs reductions only: the total reduction in irrigation water availability as a result of the proposed SDL reduction outlined in the draft plan.
- SDL reduction after water savings: the reduction in water availability as a result of the SDL reductions, after accounting for offsetting water savings achieved through government investments in irrigation infrastructure.
- SDL reduction after water buybacks to date and water savings: the reduction in water availability as a result of the SDLs after accounting for water buybacks to date and projected water savings.

As the scenarios developed in the 2010 report consider the SDL reduction only case, the updated results under the 2,800 GL reduction scenarios are reported below for comparison.

Table 6-3: ABARES-BRS modelling results, annual average GVIAP and profit for 2,400 GL scenario

	Baseline	2,400GL scenario	% change	Value change[a]
With interregional trade				
Water use (GL/year)	9,868	7,608	-22.9	-2,260
GVIAP ($m/year)	6,040	5,364	-11.2	-676
Profit ($m/year)	1,950	1,719	-6.7	-131

[a] KPMG derived figures based on ABARES-BRS (2011).

Source: ABARES-BRS (2011)

Table 6-4: ABARES-BRS modelling results, annual average GVIAP and profit for 2,800 GL scenario

	Baseline	2,800GL scenario	% change	Value change[a]
With interregional trade				
Water use (GL/year)	9,868	7,312	-25.9	-2,556
GVIAP ($m/year)	6,040	5,273	-12.7	-767
Profit ($m/year)	1,950	1,790	-8.2	-160
Without interregional trade				
Water use (GL/year)	9,868	7,312	-25.9	-2,556
GVIAP ($m/year)	6,018	5,049	-16.1	-969
Profit ($m/year)	1,949	1,760	-9.7	-189

[a] KPMG derived figures based on ABARES-BRS (2011).

Source: ABARES-BRS (2011)

Table 6-5: ABARES-BRS modelling results, annual average GVIAP and profit for 3,200 GL scenario

	Baseline	3,200GL scenario*	% change	Value change[a]
With interregional trade				
Water use (GL/year)	9,868	7,648	-22.5	-2,220
GVIAP ($m/year)	6,040	5,188	-14.1	-852
Profit ($m/year)	1,950	1,761	-9.7	-189

[a] KPMG derived figures based on ABARES-BRS (2011).

Source: ABARES-BRS (2011)

The baselines used in the updated modelling differ slightly from the 3,500 GL scenario in the 2010 report. Though there are substantial reductions in the water use and GVIAP impacts under the 2,800 GL scenario when compared to the results of the 3,500 GL scenario, the impacts on profit levels are similar. The ABARES-BRS (2011) report also highlights the regional differences in the economic impacts. Generally, the impact on the Southern Murray-Darling Basin regions is much higher than for the Northern Murray-Darling Basin regions.

The following table summarises the impacts under the alternative scenarios.

Table 6-6: Comparison of ABARES-BRS modelling results

	% change			
	Buybacks to date	SDL reduction only	SDL reduction after water savings	SDL reduction after water buybacks to date and water savings
With interregional trade				
Water use (GL/year)	-6.8	-25.9	-18.8	-12.1
GVIAP ($m/year)	-3.2	-12.7	-9.0	-5.8
Profit ($m/year)	-1.6	-8.2	-5.7	-4.1
Without interregional trade				
Water use (GL/year)	-6.8	-25.9	-18.8	-12.1
GVIAP ($m/year)	-4.0	-16.1	-11.4	-7.3
Profit ($m/year)	-1.7	-9.7	-6.5	-4.8

Source: ABARES-BRS (2011)

Buybacks to date contribute a significant portion of the total SDL impacts. This implies that a significant proportion of any SDL targets have been already captured. According to the above table, the efficiency gains from infrastructure investment and the impacts of buyback to date explain around half of the total SDL reduction impacts.

The ABARES-BRS economy-wide modelling results for the 2,800 GL scenario are detailed in the following table.

Table 6-7: ABARES-BRS economy-wide modelling results, 2,800 GL scenario

	Change in GRP/GDP (%)	Change in employment (%)
Murray-Darling Basin	Short run: - 0.12% Long run: -1.13%	Short run: -0.05% Long run: -0.05%
Australia	not reported	not reported

Source: ABARES-BRS (2011)

As expected, the MDB region wide-impacts under the 2,800 GL reduction scenario are slightly lower than those under the 3,500 GL scenario. Though the national economic impacts are not reported in the updated report in 2011, they are expected to be similar to the national results under the 3,500 GL scenario.

6.2 UQ-RSMG

6.2.1 Scenarios for economic analysis

UQ-RSMG modelled two scenarios:

- a historical scenario based on 114 years of water availability (1895 – 2008); and
- a reduced water availability scenario reflecting water availability for the ten years from 1998 to 2008.

6.2.2 Results (2010)

The UQ-RSMG model assesses the impacts of reductions in water availability on the GVIAP. The modelling results using the global solutions taking into account three rainfall states (normal, dry, wet) are summarised for the entire Basin region in the following table.

Table 6-8: UQ-RSMG impact of reduction on water availability, 2,800 GL scenario

	Baseline	Scenario	% change	Actual change
Water use (GL)	10,560	6,814	-35.5%	- 3,746
GVIAP ($m)	9,170	7,725	-16.0%	- 1,445
Surplus from agriculture ($m)	2,325	1,954	-16.0%	- 371

Source: UQ-RSMG (2010)

Key results:

- The UQ-RSMG modelling results indicate that costs to irrigators would be higher if unrestricted water trading were not available. The results indicate that the ability to trade minimises the negative impact on regional incomes under the Basin Plan.
- The modelling also indicates that in the medium-term irrigators have the capacity to minimise loss in profits by changing production mix in response to reductions in water availability. The availability of water trading is important to irrigator's ability to change the production mix.
- UQ-RSMG estimates of the regional distribution of impacts suggest that irrigators in New South Wales and Queensland could be more adversely affected than those in Victoria and South Australia.

6.2.3 Results (2011)

The updated UQ-RSMG report develops the following eight scenarios:

- CDL: current diversion limits (base case).
- SDL: sustainable diversion limit reduction of about 2,703 GL.
- CDL + Trade: CDL and trading of water entitlements.
- SDL + Trade: SDL and trading of water entitlements.
- SDL + Environment Target: new sustainable targets (equivalent SDL reduction in terms of the modelling outcomes).
- SDL + Trade + Environment Target: SDL reduction with Environment Target, water trading (equivalent to SDL reduction andTrade in terms of the modelling outcomes).
- SDL + simulation: SDL reduction with Trade and Environment Target with stochastic water supply simulations.
- SDL + optimisation: SDL reduction and simulation with optimisation for the Basin.

For each scenario, the three states of water supply (normal, dry and wet) are separately applied.

The average results of the three states (normal, dry and wet) under the SDL reduction only scenario are summarised for the entire Basin region in the following table.

Table 6-9: UQ-RSMG average result, SDL reduction scenario

	Baseline	Scenario	% change	Actual change
Water use (GL)	9,162	6,459	-23%	- 2,703
Economic returns ($m)	2,240	1,911	- 13%	- 329

Source: UQ-RSMG (2011)

The above economic return results are quite different across scenarios as reported in the following table. Even though water use outcomes do not differ greatly across the alternate scenarios, the outcomes under each state of water availability are sensitive to the scenario specification.

Table 6-10: UQ-RSMG average results

% change	SDL	CDL+Trade	SDL+Trade	SDL+Stochastic
Water use (GL)	-23%	0%	-23%	- 23%
Economic returns ($m)	-13%	16%	5%	0%

Source: UK-RSMG (2011)

6.2.4 Implications of modelling method and key assumptions

The UQ-RSMG modelling assumes that water users will respond to reductions in water availability by reallocating water between different production systems to maximise profits. Water is treated as part of fixed factors along with operator labour and capital. The cost of each factor appears to be calculated separately without any consideration of substitutability between them in response to the price changes of the factors. If the factor substitution takes time, the results of UQ-RSMG should be regarded as short run impacts.

6.3 CoPS-Monash

6.3.1 Scenario for economic analysis

CoPS-Monash (2010) modelled the regional economic impacts of four SDL reduction scenarios, namely:

- SDL reductions of 3,000 GL (scenario 1), 3,500 GL (scenario 2) and 4,000 GL (scenario 3) whereby farmers sell permanent water entitlements to the government from 2011 to 2022 with sales suspended in two years of moderate drought.
- SDL reduction of 3,500 GL where no compensation is offered for reductions in water use (scenario 4).

Cops-Monash (2011) focuses on 2,400 GL, 2,800 GL and 3,200 GL SDL reduction scenarios. In the updated simulations, the simulation period of TERM-H2O was extended from 2026 to 2029 - 10 years after following the sales of the target water entitlements to the government.

All the SDL reduction targets take into account the buybacks already made from 2008 to the last observed year.

6.3.2 Results (2010)

The results of the CoPS-Monash modelling under SDL reduction only are summarised in the following table.

Table 6-11: CoPS-Monash results, 2010 report

	Target volume GL	Cost to Commonwealth $m (NPV 2010)	Real GDP (relative to 2026 forecast)
Scenario 1	3,500	4.1	-0.009
Scenario 2	3,000	3.0	-0.007
Scenario 3	4,000	5.3	-0.012
Scenario 4	3,500	0.0	-0.009

The Basin GRP impacts under scenario 2 (3,500GL) is reported at -0.25% in 2026 while the Basin employment impacts is -0.05%.

6.3.3 Results (2011)

The updated modelling results under the 2,400 GL, 2,800 GL and 3,200 GL reduction scenarios. These results are summarised below.

Table 6-12: CoPS-Monash results, 2011 report

	% change		
	National GDP	MDB GRP	MDB employment
2,400 GL (2020)	not reported	-0.14% for SDLs +buybacks -0.03% including upgrades	-0.01% for SDLs +buybacks 0.24% including upgrades
2,800 GL (2020)	not reported	-0.18% for SDLs +buybacks -0.05% including upgrades	-0.02% for SDLs +buybacks 0.23% including upgrades
3,200 GL (2020)	not reported	-0.21% for SDLs +buybacks -0.09% including upgrades	-0.02% for SDLs +buybacks 0.22% including upgrades

According to the above results, the infrastructure upgrades considerably offset the adverse impacts of the SDL reductions.

The contributions of buybacks in offsetting the SDL reduction impacts are considered to be less than the infrastructure upgrade contributions. Under the scenario where all buyback proceeds exit the Basin, the Basin GRP impact is -0.35% while the Basin employment impact is -0.18%.

6.3.4 Implications of modelling method and key assumptions

The CoPS-Monash modelling assumes that the sale of water entitlements from willing farmers is voluntary and as such, it proceeds slowly. This assumption implies that the permanent sale of water entitlements to the Commonwealth fits into the forward planning of irrigation businesses. For each scenario, CoPS-Monash assumed that target volumes were not reached until 2022. This assumption reduces the potential economic losses that may result if the reduction of water proceeded rapidly. The reduction in potential loss occurs for two reasons, namely:

- The slow process allows irrigators to take advantage of technological gains that are achieved over time and result in water savings. These water savings can be sold to the Commonwealth without a reduction in the volume of agricultural output (i.e. technological gains allow for output to remain the same while total water use falls).

- A large volume of water sales in a short time period would result in a significant fall in the volume of agricultural output. This would have implications for local manufacturing sectors.

CoPS-Monash assumed that the target volumes already include the 796 GL of entitlements that were sold to the Commonwealth prior to the end of January 2010.

6.4 Comparison of modelling results

6.4.1 Direct economic impacts

The UQ-RSMG model structure has some similarities to the ABARES-BRS WTM. Both models assess the impacts of less water on GVIAP and/or irrigation profits allowing for interregional trade. Comparing the direct impact results highlights some similarities and disparities between the results, as outlined below.

- The UQ-RSMG analysis modelled a target reduction in water use in the Basin and estimated that a recent reduced water scenario based on the period of 1998-2008 would result in a 16 per cent decline in profits compared to the 114 year historical scenario, and while a 2,800 GL reduction would lead to a 13 per cent fall in profits compared to the baseline.
- ABARES-BRS modelled a target reduction in water use. The direct impact of the 3,500 GL reduction on GVIAP and profit was a reduction of 15 per cent and 8 per cent respectively. The 2,800 GL reduction would lead to a fall of 13 percent and 8 per cent in GVIAP and profits respectively. The change in the target reduction does not make significant changes in the impacts on GVIAP and profits. Compared to the UQ-RSMG results, ABARES-BRS generated a lower percentage reduction in profit due to a greater decline in costs relative to revenues.
- The UQ-RSMG and ABARES-BRS results both highlight that the adverse impacts are higher in New South Wales and Queensland and lower in Victoria and South Australia.
- The UQ-RSMG modelling incorporates substitution of previously irrigated land to dry land farming, however the ABARES-BRS WTM does not explicitly account for this (dry land farming increases is a residual of the model). Accordingly, the overall adverse impact of agricultural production would expectedly be lower under the UQ-RSMG assumption.
- None of the modelling considered the correlation between irrigated commodity prices and the availability of irrigation water. If this were incorporated in the modelling, it would be expected that the adverse impact of reductions in water availability would likely be lower.

6.4.2 Economy-wide impacts

- The CoPS-Monash modelling accounts for government spending on purchases of water entitlements while the ABARES-BRS modelling does not. Holding other factors fixed, this would result in the adverse impacts being lower under the CoPS-Monash modelling than the ABARES-BRS modelling. It is expected that the government spending would offset the negative impacts on irrigators to some extent.

6.4.3 Summary – Comparisons of Simulation Approaches

The following table provides comparisons in terms of detailed simulation design aspects. The differences in the simulation approaches, which is closely related to the underlying modelling structure, leads to the different modelling outcomes.

Table 6-13: Summary of simulation design aspects

	Monash-Cops	ABARES-BRS	UQ-RSMG
Base year(s)	Wittwer (2011): 32 years from 2008 to 2029 Wittwer (2010): 27 years from 2010 to 2026	WTM: combined sources of 2005-06 crop and land use data set with 2000-01 water availability data (considered to be more representative of the long-run average levels of use) AusRegion: 2001-02 Australian economy	Water availability: estimated using the data from 2000-01 to 2009-10 Other underlying data is continuously updated
Major SDLs reduction scenario(s)	Wittwer (2011): 2,800GL reduction with financial compensation over the simulation period Wittwer (2010): 3,500GL, 3,000GL and 4,000GL reductions with financial compensation over the simulation period Note that all the targets include the buy back from 2008 to the last observed period	ABARES (2011): 2,800GL SDL scenario ABARES (2010): 3,000GL, 3,500GL and 4,000GL SDL reduction scenarios	UQ-RSMG (2011): 2,700 GL reduction on average between the three states of rainfall UQ-RSMG (2010): reduced water availability scenario based on 10 years from 1998 to 2008, while a base scenario (referred to as a historical scenario) based on complete 114 years water availability data set (1895-2008)

Key scenario variations	Witter (2011): all buyback proceeds exit the basin and infrastructure upgrades With upgrade on top of a buyback scheme Witter (2010): no buyback scheme	ABARES (2011): With/without interregional water trade with/without buybacks to date eand with/without infrastructure investment Separate sensitivity analysis in terms of water supply variability such as "good", "dry" and "very dry". ABARES (2010): with/without interregional water trade	UQ-RSMG (2011): trade and stochastic contingency
Buyback schemes	Witter (2011): sales of 2,800GL water entitlement by 2019 Witter (2010): sales of SDLs target entitlement by 2022	ABARES (2011): no specific timing	-

6.4.4 Summary – Comparisons of modelling results

The following table provides comparisons of key modelling results. Overall, the three modelling approaches provide somewhat different modelling results. At the broad regional level, the modelling results tend to converge. However, at the detailed sectoral levels, the modelling results tend to diverge slightly. In terms of the macroeconomic impacts, the CoPS-Monash modelling generates the least adverse impacts mainly due to the explicit treatment of the buyback scheme.

Table 6-14: Key modelling results under 2,800 SDL reduction target (2011 studies)

	Monash-Cops[a]	ABARES-BRS[b]	UQ-RSMG
National GDP	Year 2029:-0.013%	-	-
National employment	fixed by long run assumption	-	-
MDB GRP	Year 2020: -0.05% Year 2029: -0.16%	Short run: 0.21% Long run: -0.81%	-
MDB employment	Year 2020: 0.23% Year 2029:-0.02%	Short run: 0.33% Long run: -0.03%	-
MDB GVIAP	-	-5.8% (-12,7% for SDLs only)	-
MDB profit levels	-	-5.7% (-8.2% for SDLs only)	-13% for SDLs only 5% for SDLs + Trade

[a] With water buyback plus infrastructure upgrade.

[b] After interregional water trade and after water saving

Table 6-15: Key modelling results under 3,500 SDL reduction target (2010 studies)

	Monash-Cops	ABARES-BRS
National GDP	Year 2026:-0.01%	Long run: -0.13%
National Employment	-	Long run: -0.03%
MDB GRP	Year 2026: -0.25%	Long run: -1.3%
MDB employment	Year 2026: -0.05%	Long run: -0.10%
MDB GVIAP	-	-19.0%
MDB profit levels	-	-9.9%

7 Conclusions

Sections 5 and 6 of this report provided an overview of the differences in each of the modelling approaches under review and their respective results. This section of the report provides the key conclusions for the MDBA in terms of the approaches and results of modelling.

Key points

- The three models differ in their assumptions, approach and policy objectives.
- The three models provide the opportunity to analyse complementary aspects of the policy debate and identify areas for collaboration and further analysis.

7.1 Methodological differences

There are some fundamental differences in each of the modelling approaches which make them more or less comparable with each. These key differences related to:

- model structure;
- geographic coverage and regional disaggregation;
- economic coverage;
- baseline water availability; and
- scenarios modelled.

7.1.1 Model structure

Section 5 details the modelling approaches used in each of the reports. The modelling structure of each focuses on particular modelling strengths.

The structure of the ABARES-BRS model allows it to explicitly estimate hydrology and water trading separately. This is a strong feature of the approach and allows for the measurement of national, regional, and town impacts. This forms part of two step approach, where the WTM feeds information informally into a comparative static CGE model. The point of transmission is a reduction in the supply of agricultural products, that is, the response to the shock is calculated externally to the CGE model and then its impact through the economy is estimated by imposing this result on the CGE model. While a valid and commonly used method in policy modelling, this type of informal linkage does not allow for feedback effects and (in this case) has diluted the role of the CGE model in determining changes in production mix, something that the CGE model has a particular strength in.

The approach by UQ-RSMG is a stand-alone partial equilibrium analysis that uses detailed hydrological relationships and allowance for uncertainty in decision making to estimate the impacts on agricultural production. It includes a switchable agricultural production cost accounting system and switches production across agricultural industries depending on water availability. The UQ-RSMG approach is innovative in the way it estimates relative impacts on agriculture across the Basin catchment regions, however, the results are only a partial analysis of SDL impacts that cannot solely form the basis of a socio-economic impact analysis.

The CoPS-Monash approach is to incorporate water as a factor of production within the CGE model, and to also model some components of the supply constraints on water within the CGE model itself. The inclusion of water as a factor within the CGE framework allows the analysis to be completed inside a single model. The focus of the CoPS-Monash approach is to provide a complete economic assessment of the SDLs. A strength of the CoPS-Monash approach is that it includes the impact of compensation and includes macroeconomic affects, such as changes in investment decisions. Additionally, as the CoPS-Monash model is dynamic it can show how the economy is impacted as water rights are gradually sold. It can also include year-by-year rainfall scenario estimates which affect the level of water demanded by irrigators, allowing differing impacts on production between years.

7.1.2 Geographic coverage and regional disaggregation

All three reports model the impacts of SDLs across the all of the Basin. The Basin is a highly diversified region, covering over 1 million square kilometres, accommodating over 2 million people, generating over 100 different varieties of agricultural crops and having great variation in climatic conditions and landscapes. As such, capturing the impacts of SDLs at the regional level is important for the relevance and acceptance of the Basin Plan.

Each of the three reports disaggregate its results by region, with the number of regions ranging from 21 to 24. While obviously there is a high degree of uniformity, an accepted regional disaggregation of the results would improve comparability.

The reports do provide insight into some important regional issues across the Basin. For example, "...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" (UQ-RSMG, 2010).

This highlights the usefulness of a modified flow regime to alleviate the impact of water reductions for irrigators in the lower section of the basin, that is, in the Murray system. The Murray has a more regulated flow regime as it has more storages - 'offering the ability to pool resources' within the system - than the northern section of the Basin consisting of the Darling tributaries.

The UQ-RSMG modelling also highlights the benefits of removing barriers to trade for the northern region of the basin. In the first run ('global optimisation'), their model allowed for trade within regions for all regions in Queensland and down to Lachlan in NSW while allowing for trade across regions in the southern section of the basin, from Murrumbidgee to South Australia Murray. The model was also run with more restrictive trading arrangements, only allowing for trade within catchments across the basin. The second set of results, a 'sequential optimisation', resulted in a greater reduction in irrigated area and greater loss in the gross value of production (revenue) and regional surplus (profit) than the first for the same level of water reduction. This highlighted the effectiveness of water trading which is relatively freer flowing in the lower half of the system compared to the upper half.

In summary, UQ-RSMG (2010) has the strength of being a northern based model capturing the flow and trading arrangement differences across regions of the basin, drawing on their knowledge and experience of differences in the middle and northern and sections of the basin relative to the south.

7.1.3 Economic coverage

The reports present findings on the socio-economic impacts of SDL options for the Basin. However, each measures the impacts of these across different parts of the economy. The CoPS-Monash model provides the most comprehensive coverage, allowing for total direct impacts on all agriculture and the flow on impacts to the rest of the economy. While the ABARES-BRS model also captures the direct and flow-on impacts, the effects on only irrigated agriculture are exogenous shocks brought in from the WTM model. Lastly, the UQ-RSMG study covers only direct impacts and is not designed to inform flow-on effects.

7.1.4 Baseline water availability

Baseline water availability requires some deeper consideration going forward. The baseline is necessarily a 'snapshot' year. It needs therefore to reflect an average, representative year in terms of (for example) water use on-farm, activity structure, gross value of irrigated agricultural product (GVIAP) per activity to ensure that long-run policy ramifications are modelled most effectively. For example, authoritative data for key variables such as water use on-farm and GVIAP per hectare of irrigated land, activity, and region is scarce prior to about 2005/06. However, the period for which data exists is an outlier due to drought. Care needs to be taken when interpreting the data, particularly when compared across years.

It is possible that current estimates of pre-drought water use for the Murrumbidgee are significantly over-estimated (due to an outlier year in 2000/01) and GVIAP per hectare under-estimated (largely because the current methods seem to show results by crop areas rather than specific land used) – see Section 7.2.1 for further details.

In short, there are issues around data paucity and consistency. It would be useful to develop an agreed baseline based on the available data that is clearly explained.

7.1.5 Scenarios modelled

The reduction scenarios presented in each report, typically considered SDLs of 3,000 GL, 3,500 GL and 4,000 GL in 2010, and 2,400 GL, 2,800 GL and 3,200 GL in 2011. Differences in each approach arise from whether compensation for buyback purchases are included and consideration of the wet, dry and normal state factors is included.

Analysis of a broader range of policy scenarios would be informative. This would not only cover consideration of the volume of water entitlement to be recovered for the environment, but also the methods used to recover this water. In particular, the analysis could cover:

- the purchase of entitlements;
- the purchase of water allocations;
- investment in water savings within river systems; and
- improvement in management efficiencies.

A universally agreed set of scenarios should be part of the modelling process.

7.2 Model validation

There can be a tendency to evaluate model performance by comparison of modelled and actual observed outcomes. This 'ex ante' evaluation is seen to constitute a quality control test designed to provide evidence on a model's performance. However, such validation exercises have limited value and must be interpreted with caution.

Despite the intuitive appeal of this approach, considerable care is needed in interpreting socio-economic models. The modelling approaches reviewed in this report do not constitute 'forecasts' of the economy over a time horizon. Rather, the models are structural representations of regional and national economies that underlie simulations designed to measure the deviation resulting from a single policy impact from a baseline state. That is, they measure a marginal adjustment due only the scenarios modelled. This is particularly true of comparative static CGE models. It is likely that any attempt at forecasting or baseline generation will fail to capture many of the array of exogenous, unpredictable factors that will influence an economy's growth path over time. Baselines are not meant to make guesses at these variables, and so should not be held to account for failing to incorporate unpredictable things in an ex ante analysis.

It is important to consider the experiment that is being undertaken and its scenario design. Other important considerations include the data validation process, the model closure and model-consistent interpretation of the results. That is, the validation of the results should be carried in the context of the entire process of model development, simulation design, data validity and result interpretation.

It is also noted that dynamic CGE models can be used to generate detailed forecasts of output growth for commodities and industries. The main objective is to provide realistic baselines from which to calculate the effects of policy changes, and not to create a "crystal ball" through which the future can be predicted exactly. Dynamic baselines are business-as-usual approximations of the path of an economy over time, designed to allow the impact of flow-stock accumulation, market frictions and other dynamic variables to be incorporated in calculating the effect of a policy variables in deviation simulations. They do not claim to be, and should not be held to support, a "prediction" of a point in the future.

7.2.1 Comparator years

Additionally, the changes in water usage and its related agricultural production output between 2000/01 and 2005/06 may not be representative of average changes in water efficiencies. That is, 2000/01 represented a 'wet year' with high river levels, where annual inflow into the Murray River system was higher than the long-term median inflow. It has been suggested that opportunistic farming practices were undertaken, whereby highly water intensive crops were planted to capitalize on the seasonal conditions.

Conversely, while 2005/06 saw a limited improvement in water availability, it was a 'dry year' and represented a continuation of the below-average system inflows that have been observed each year since 2002/03.

Rainfall from July 2005 to June 2006 was average to slightly above average in the western part of the Basin. However, Murray River inflows for the year totalled about 6,200 GL (not including Snowy releases), which is 1,900 GL below the median (8,100 GL). The total system inflow for the five years from July 2000 to June 2006 had been the lowest on record. It is also noted, that 'water deals' between irrigators and Snowy Hydro Limited helped to meet some of consumptive requirements in the Murray River system in 2005/06 (MDBC 2006).

As such, the 2000/01 comparator year, may actually represent a relatively water-inefficient year, thereby overstating the increases in water efficiencies to 2005/06.

7.3 Common issues

Currently, there is a perceived gap between the expectations of stakeholders in the Basin Plan and the modelling reports. While the modelling reports are based on high quality socio-economic modelling, the reports focus heavily on the bottom line results at the expense of the underlying narrative and clear explanations around the model structures, assumptions, and inputs that drive the results. It is often difficult for stakeholders to accept the results if a path to those results is not fully revealed. In future, a benefit of an integrated modelling approach would be that more extensive stake-holder consultation could be pursued.

8 Next steps

Following on from the conclusions drawn in the section 7, this section sets out a possible path forward in relation to the managing the modelling requirements of the MDBA.

Key points

- Designate a modelling coordinator to implement a strategic focus to the modelling.
- Implement a short, medium and long term plan to enhance and improve the modelling undertaken for the MDBA and the reporting of results to key stakeholders.

8.1 Stock take

This report provides an initial stock take of selected economy-wide modelling that examines the socio-economic impact of SDLs scenarios.

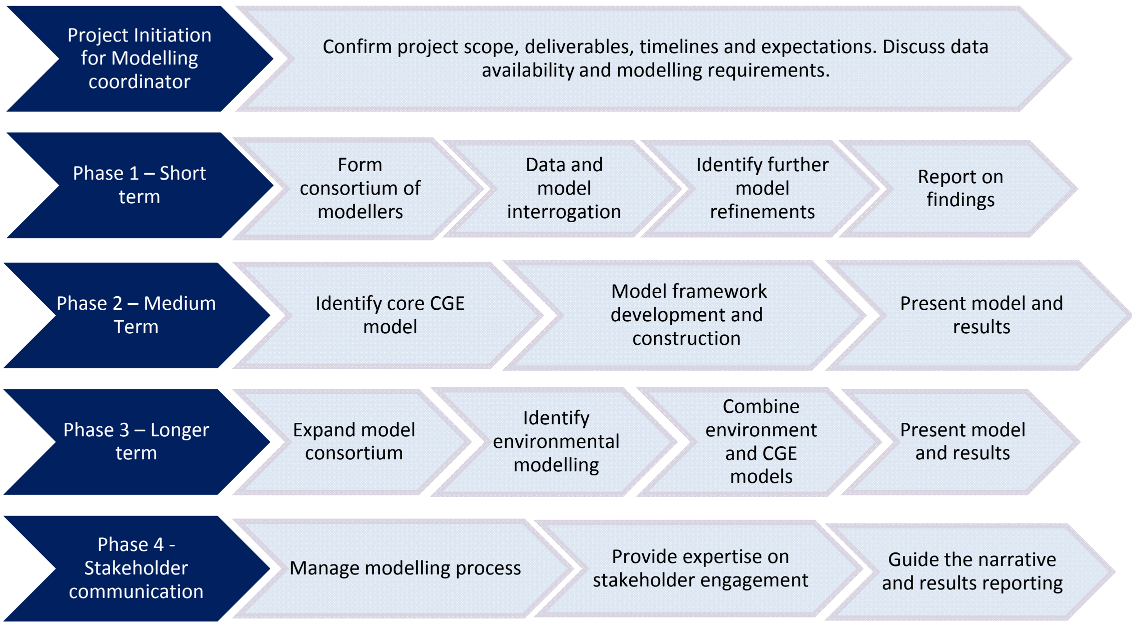
The modelling reviewed in the report has benefited from being independent in process and direction. That is, each modelling agency has been tasked with a modelling objective and allowed to meet this objective by managing its own modelling processes. This has allowed for innovative approaches, varied results and unique perspectives. However, we believe that in the future a more comprehensive socio-economic analysis will be feasible, and the path forward would involve a more cooperative, integrated approach that takes lessons from the studies already conducted. This variety of information has provided insight into the type of analysis that needs to be undertaken and the tools required to undertake it - all of which may not have been developed if a single agency was solely responsible for the modelling.

8.2 Moving forward

This report highlights that there is an opportunity to capitalise on the positive work and diversified approaches of the work carried-out so far, and bring these together under one framework. That is, in developing a path forward, the socio-economic modelling would benefit from a strategically agreed approach.

We have considered the requirements of the modelling objectives of the MDBA in designing the framework presented in Figure 8.1 as a possible path forward.

Figure 8-1: Project Framework



8.3 A Role for a Coordinator

In building on the strengths of the work already completed, we suggest that the MDBA establishes a coordinator or coordinating committee that is experienced in socio-economic modelling. This will assist in meeting stakeholder expectations and would be highly focused on client centric collaboration. The coordinator's role would be to set the strategic direction of the modelling and oversee the integration of modelling process and management. This would involve an oversight role of a consortium of modellers from ABARES-BRS, UQ-RSMG and Monash-COPS, and potentially others. This coordinator could be sourced from within the MDBA, or engaged externally. The key requirements for the candidate(s) are a high degree of experience in managing and conducting integrated policy modelling and policy-relevant research with diverse teams of researchers.

To best meet the needs of MDBA and the aims of Water Act 2007, the key objective of the modelling coordinator would be to develop and implement a well specified modelling framework based on bottom-up dynamic CGE modelling, but with the addition of model linkages - formal or informal - with other modelling frameworks with more utility in climate issues, agricultural land use, hydrology and micro-simulation issues, to name a few.

The framework would be designed to provide the MDBA with an enduring framework that would provide an ongoing capacity to analyse the socio-economic impacts of the Basin plan on regional and national economies. The model would provide estimates of the total direct and indirect impact of the government policy on key indicators that meet both the requirements of the Act and community expectations.

The project initiation process would provide the MDBA with the assurance that there is common agreement between all project participants about: project objectives; project methodology; project context and any critical issues; project protocols regarding communications, deliverables, risk management and project governance; and indicative project deliverables and timelines.

As part of the project initiation phase the coordinator would:

- confirm the broad scope of the project and activities;
- confirm the project roles and responsibilities for the project director and project manager;
- confirm project milestone dates and progress meetings; and
- receive any information held by the MDBA that is relevant to the project.

The project would be conducted in four broadly-defined phases (detailed below).

8.4 Phase 1: Short term

Phase 1 would assess the necessary components of the modelling framework, and the identification of those to be involved as subject matter experts. Discussion and debate amongst these experts would lead to consensus, at least at a high-level, on a plan to instruct the research program as it goes forward. The results of Phase 1 would be documented in a report that would form the basis of a project plan.

8.5 Phase 2: Medium term

The next phase would involve 2 broad three main tasks:

1. Constructing or modifying an existing CGE modelling framework to form the core of the socio-economic modelling system. It would ideally be a bottom-up regional, dynamic CGE model. The model and some results of indicative simulations would be documented at the conclusion of Phase 2. This would also involve the presentation of initial modelling results. We believe that, as a key component of this phase, an attempt to embed the detailed hydrological components of models like the WTM and RSMG models into the CGE model would bear fruit.
2. Constructing a (or identifying an existing) micro-simulation framework to enable regional impacts on variables like incomes and employment at a fine level of regional detail.
3. Creation of linkages between the two frameworks. A literature exists on linkages between CGE models and micro-simulation models, and such techniques have been used in several countries to address issues of regional importance.

8.6 Phase 3: Longer term

A linking of the socioeconomic model from Phase 2 with the MDBA's environmental models would be taken in this phase. This would build upon the theme of the cost-benefit analysis already undertaken, but would more rigorously analyse the linkages between the environmental watering plan and the socioeconomic impacts. The purpose of this approach would be to optimise environmental and socioeconomic outcomes from the allocation and use of water in the Basin but accounting for all of the relevant costs and benefits.

8.7 Phase 4: Stakeholder communication

The coordinator would develop a multidimensional stakeholder communication strategy aimed principally at addressing the perceived gap between the expectations of the stakeholders in the Basin Plan and the socioeconomic modelling reports.

As part of the communication strategy, there would be a focus on the clear presentation of the underlying narrative, methods and process used to derive the results from the modelling. This would involve, for example, presenting:

- the critical values used to assess welfare and the impacts on welfare;
- the key behavioural relationships and assumptions driving results;
- sensitivity analyses to test the risks association with key assumptions; and
- a finer level of regional results.

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