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Revised indicators of community vulnerability and adaptive capacity across the Murray–Darling Basin

A focus on irrigation in agriculture

Nyree Stenekes, Robert Kancans, Lucy Randall and Kenton Lawson, Ian Reeve† and Richard Stayner†

Research by the Australian Bureau of Agricultural and Resource Economics and Sciences and †the Institute for Rural Futures, University of New England

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Australian Bureau of Agricultural and Resource Economics and Sciences (ABARES)
Postal address GPO Box 1563 Canberra ACT 2601
Switchboard +61 2 6272 2010|
Facsimile +61 2 6272 2001
Web daff.gov.au/abares

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

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Changes are occurring in rural and regional communities in the Murray–Darling Basin as a result of climate change, water availability, water trading, global markets, population movements and ongoing social change. Impacts of these issues and responses to them by Basin communities will be mediated by their adaptive capacity, resilience and vulnerability to change.

The Murray–Darling Basin Authority (MDBA) commissioned this project to measure the vulnerability, resilience and adaptive capacity of Basin communities to changes in water availability—due to a range of factors—in order to inform MDBA planning and decision-making.

The aim of the project was to increase understanding of community socioeconomic circumstances in the Murray–Darling Basin and to provide a readily accessible metric with which to compare the vulnerability of communities across the Basin. A set of measures of community vulnerability to changes in water availability was developed, drawing on and adapting the Intergovernmental Panel on Climate Change framework (Allen Consulting 2005). Composite indices were derived to spatially examine differences across regions and communities and these were mapped for the Basin.

The project reports on community vulnerability in two ways. First, community vulnerability before exposure to any water policy intervention (community vulnerability 'before exposure'); and second, exposure to a 2800 gigalitre sustainable diversion limit (SDL) water recovery scenario assuming 2005–06 commodity prices (community vulnerability 'after exposure').

Community vulnerability to changes in water availability before exposure to the proposed Basin Plan varies widely across the Basin. This is moderated by the different adaptive capacities and sensitivities of particular communities. The project identified two large areas where community vulnerability is relatively high. One is located in the north-east of the Basin in the Border Rivers, Gwydir, Moonie, central Condamine–Balonne and south Warrego Basin Plan regions; the other is concentrated in the southern Basin in the Murrumbidgee, Lower Darling, Murray and Lachlan Basin Plan regions. Communities in these areas have a combination of higher sensitivity to changes in water availability (that is, very high dependence on water for agriculture and high agri-industry employment) and limited levels of adaptive capacity (that is, low levels of human capital, social capital and economic diversity) in comparison with other areas in the Basin.

The analysis of relative community vulnerability with the addition of exposure to the proposed Basin Plan 2800 gigalitre SDL water recovery scenario shows a cluster of communities in the southern Basin that exhibit very high vulnerability rankings. This relates particularly to communities in the Murrumbidgee and upper Murray Basin Plan regions. Communities in these areas have a combination of higher levels of potential impact due to the 2800 gigalitre water recovery scenario and relatively low levels of adaptive capacity, which is a measure of the strengths and resources that communities have to manage and cope with changes (that is, levels of human capital, social capital and economic diversity). Community vulnerability to other water availability scenarios including 2400 gigalitre and 3200 gigalitre water recovery scenarios was also assessed.

A simple analysis was undertaken to determine which measures would have the most influence on the final community vulnerability index. The analysis considered the effect on the community vulnerability index of a 10 per cent departure from the median value of each constituent indicator, using the 2800 gigalitre water recovery scenario. The economic diversity index has the most influence on the vulnerability index because it is a single subindex that enters the

calculation relatively high in the hierarchy. Hence its influence is diluted the least by the process of standardising and addition that occurs in the hierarchy of calculations. The indicators of socioeconomic advantage and age advantage are the next most influential subindicators on the final community vulnerability index, followed by the social capital indicators (proportion of women in non-routine occupations and participation in volunteering) and the exposure subindex.

The concepts and methods used to develop the index of community vulnerability should be fully transparent and repeatable. Therefore, this report contains technical details relating to the statistical and procedural methods used to construct the index and subindices.

The outputs of the project can be used in several ways—to help policy decision-makers understand the potential impacts and relative vulnerabilities of Basin communities to the proposed Basin Plan, and to work with community decision makers in the Murray–Darling Basin to better understand their circumstances and the factors that contribute to changes in their communities. A process of science communication and community engagement could help incorporate community-specific knowledge into future analyses. The indices could also be used as a baseline of information to measure future socioeconomic changes and as part of a potential framework for measuring effects of the Basin Plan on communities.

1 Introduction

The Murray–Darling Basin Authority (MDBA) was established by the *Water Act 2007* and is responsible for developing and implementing the Murray–Darling Basin Plan. The Basin Plan is being developed to support integrated management of the Basin's water resources. It will identify key environmental assets and ecosystem functions of water resources for protection. The Basin Plan will also identify risks to the condition or continued availability of Basin water resources and provide strategies for managing those risks.

The MDBA is seeking to better understand the social and economic characteristics of Basin communities and to assess factors that may contribute to their ability to adjust more effectively to changes in water use (MDBA 2011). The MDBA commissioned the Australian Bureau of Agricultural and Resource Economics and Sciences (ABARES) to develop a range of indices to measure community vulnerability to reductions in water available for consumption across the Basin. ABARES developed indices to measure the exposure of communities to the change in water availability, the sensitivity of communities to changes in water access and their adaptive capacity, which is a measure of the strengths and resources communities have to manage and cope with change (ABARE-BRS 2010).

This document presents revised measures of community vulnerability, including refined subindicators of sensitivity and adaptive capacity that were previously developed for the MDBA to assess community vulnerability (ABARE-BRS 2010). A significant change is inclusion of a measure of exposure of communities to changes in irrigation water availability under the proposed Basin Plan. Exposure is a measure of how much external stress affected communities are likely to experience due to the SDL reductions specified in the proposed Basin Plan. This enables an assessment of relative vulnerability of communities to changes in water availability that would follow the proposed Basin Plan. Changes were also made to the adaptive capacity and sensitivity subindices, with the use of estimated irrigation water use data from the Australian Bureau of Statistics (ABS) for the year 2000–01, considered closer to an irrigation business-as-usual year than the 2005–06 data previously used.

Objectives

The objectives of the project as specified in the brief were to:

- update and refine the indicators of relative community vulnerability, including exposure, sensitivity and adaptive capacity, across the Murray–Darling Basin
- undertake validations of the indicators through, for example, comparison with ABS Socio-Economic Indexes for Area (SEIFA)
- measure and map the updated relative community vulnerability of communities across the Murray–Darling Basin.

This information will help the MDBA optimise the economic, social and environmental outcomes of the Basin Plan. This project complements other social and economic assessments underway that aim to optimise the outcomes of the Basin Plan (see the synthesis of social and economic analyses for the draft Basin Plan in MDBA 2011).

Approach

Vulnerability is an increasingly popular concept for describing the socioeconomic circumstances of communities undergoing change. It is a complex concept, which involves identifying the potential effects of a change and the ability of a community to respond or adapt.

Community vulnerability is used in this report to describe the degree to which communities in the Murray–Darling Basin (MDB) may be adversely affected by changes to water availability for consumptive use. The approach takes into account the inherent characteristics of the community, such as income, education levels, age structure and housing, as well as the likely sensitivity to changes in the availability of water. Many possible indicators could be used. The indicators selected in this analysis reflect the concepts being measured and the data available at a consistent scale and timeframe to populate the measures. 'Measures' is a generic term referring to indicators, subindices and indices.

Relative community vulnerability rankings can be significantly affected by including other indicators, such as the security of water entitlements for horticulture and broadacre farmers and the day-to-day mobility of people between regions for work or for shopping. These sorts of data were not available at the required scale and timeframe to populate the indicators for this project. However, further data items, data sources and methods could be identified to help refine the index of community vulnerability.

An indicator approach is a well-known method for tracking changes in socioeconomic circumstances of resource-dependent communities. For example, British Columbia Statistics developed socioeconomic indicators for measuring regional hardship (BC Stats 2009), the Canadian Forest Service assessed vulnerability of forest-based communities (Johnston & Williamson 2007; Parkins & MacKendrick 2007) and the United States Department of Agriculture published a number of indicator studies on forest community resilience (Donoghue & Sturtevant 2007; USDA Pacific Northwest Research Station 2008). Indicators of vulnerability have been used successfully in these, and other, policy contexts to identify where policy interventions are best directed.

ABARES and the Institute for Rural Futures (University of New England) jointly developed the index of community vulnerability and its components. The methods used in an initial project are detailed in ABARE–BRS (2010), which developed baseline indicators of community vulnerability. This project builds on that methodology, with a number of refinements of and updates to the indicators, as follows:

- included a measure of community exposure to different SDL reduction scenarios to take into account the implications of the proposed Basin Plan
- replaced the 'proportion of employment in agriculture, fisheries and forestry' with 'employment in agriculture'
- used global scaling to produce maps for the different exposure scenarios to allow comparison across maps
- assumed a baseline water use year of 2000–01 in the sensitivity subindex (replacing the ABS 2005–06 water use data used in the 2010 Indicator project), considered closer to a business-as-usual water use year
- undertook a simple validation that compared selected vulnerability subindices with the ABS SEIFA indices

- removed Canberra Census Collection Districts (CCDs) from the calculation of ranked scores.

In this updated analysis, an exposure measure has been included in the community vulnerability index. Exposure is a measure of how much external stress or change Basin communities are likely to experience due to the proposed SDL reduction, as specified in the Proposed Basin Plan (MDBA 2012).

The relative exposure subindex was constructed from the ABARES Water Trade Model (WTM) output. This enables a first pass assessment of the relative vulnerability of Basin communities to changes in water availability under the proposed Basin Plan. Updates were also made to the sensitivity subindex, with use of estimated irrigation water use data from ABS 2000–01, considered more representative of a normal irrigation year, to re-populate this subindex. This was because 2005–06 water use data were derived during a major drought and underestimated the dependence of Basin communities on consumptive water use.

A number of issues arise when developing a single index of vulnerability. A disadvantage is that complex concepts are reduced to a single index that to some extent masks local contextual differences. An advantage lies in the ability to synthesise a large amount of socioeconomic information across many diverse Basin communities into a single metric. Defining measures of community vulnerability is necessarily a balance between describing and representing the concept adequately and finding consistent datasets to populate the measures. This project reviewed recent theory on vulnerability and indicator development (see annotated bibliography in ABARE-BRS 2010, Appendix D), building on the work of Herreria and colleagues (2008) and Reeve and colleagues (2010), and has considered available datasets.

Structure of the report

The remainder of this report is organised into four chapters. Chapter 2 reviews some of the key concepts in the literature and evaluates their applicability to this project, providing an overview of the conceptual framework used as a basis for developing the index for community vulnerability. A more detailed discussion of the framework is presented in the previous vulnerability report (ABARE-BRS 2010). Chapter 3 describes the methodology and computations used to operationalise the key concepts and choose appropriate data items to populate the index of community vulnerability. Mapped outputs of community vulnerability for the Murray–Darling Basin are presented in Chapter 4 with a short discussion of how these outputs are to be understood. Chapter 5 outlines how the index of community vulnerability could be used to inform policy discussions.

2 Community responses to changes in water availability

This chapter presents an outline of the literature relating to the concepts of vulnerability, sensitivity and adaptive capacity as they relate to community responses to changes in water availability. It also describes the conceptual framework used in this project to explain the way in which the concepts are related. This has been extracted from a more extensive discussion and review of key sources in ABARE-BRS (2010 Chapter 2 and Appendix D).

The concepts reviewed here are the focus of active and fertile development in Australia and elsewhere, not only by researchers but also within government and community practice, so that useful insights and results are continually emerging. The literature has grown substantially in the past decade, especially as a result of the intense attention given to the effects of climate change. However, a feature of the literature, as noted by several authors (for example, Preston & Stafford-Smith 2009), is the inconsistent and confusing use of terminology. Apart from the terms used in this project, the literature refers to community robustness, vitality, viability, sustainability, resilience, health and others (see annotated bibliography in ABARE-BRS 2010, Appendix D). These synonyms have not always been used in ways that clearly convey their meaning. However, the concepts have gradually been clarified and the framework presented here has general support in the most recent literature.

Communities of place and interest

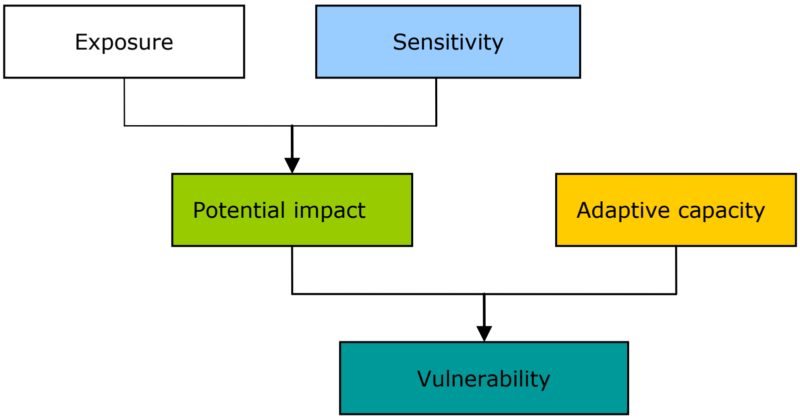
The relationships between individuals, households, businesses and other organisations in rural areas are spatially diffuse; people interact over often wide areas and long distances. They may live, work, spend and depend upon services in a range of different places. Communities are complex, adaptive, socioeconomic systems in continuous flux and have varying capacities to absorb and respond to stress or shock. The specification of a particular place-based community should not, therefore, be taken to imply that the wellbeing of that community is solely determined by the conditions within it. This becomes important when interpreting the maps of sensitivity, adaptive capacity and vulnerability: the geographic links between cause (the factors influencing access to water for irrigation) and effect (impacts on economic and social wellbeing) may not be well captured within a given place-defined community.

While this project emphasises communities of place and interest, it is acknowledged that communities of identity are also relevant. 'Communities of place' refers to people living within a defined geographical boundary, which in this project is the ABS Australian Standard Geographical Classification spatial unit, the CCD. A community of interest refers to people who share a common interest, such as an industry. A particular community of interest in this project is those who, because they are employed in agriculture or related downstream processing industries, may be more sensitive to changes in water availability.

Conceptual framework

The diagram or schematic the authors chose to illustrate the key concepts was that used by the Allen Consulting Group (2005), which in turn was based on Schröter & ATEAM consortium (2004). Other authors (such as Smit & Wandel 2006) have also used this framework, which suggests it has been found useful and relevant and ABARE-BRS applied it in the 2010 community vulnerability assessment work. It relates the concepts of exposure, sensitivity, potential impact, adaptive capacity and vulnerability as depicted in Figure 1.

Figure 1 Initial conceptual framework used in this project



Source: Allen Consulting Group 2005, based on Schröter & ATEAM consortium 2004.

Exposure is the amount of external stress or change a community is likely to be affected by; for example, a 90 per cent reduction in water availability is a greater stress than a 10 per cent reduction.

Sensitivity is a measure of how dependent a community is upon the thing that is changing; for example, a community that makes no use of water in a local river will be relatively unaffected by reductions in water yield and/or availability compared with a community that uses a lot of water.

Exposure and sensitivity together determine the magnitude of potential impact; for example, worse potential impact results from a community that is highly dependent on water availability and is facing a large reduction in water availability.

Whether this potential impact will cause lasting loss and harm depends on the community's **adaptive capacity**. Some communities may be able to adapt by reinventing themselves and so avoid loss and harm, whereas others may find it difficult to avoid social and economic damage. Whether a community is vulnerable depends on both the size of potential impacts and its adaptive capacity. Communities that are not vulnerable are often described as resilient; that is, their adaptive capacity enables them to minimise the social and economic damage that might have resulted from potential impacts.

The literature stresses that potential impacts, adaptive capacity and the resulting vulnerability depend on the specific nature and scale of the impacting event, and on specific local history and conditions. In the MDB, the potential impacts will clearly depend on the scale and local incidence of reduced water availability and on recent climatic conditions. For example, irrigators who have experienced recent drought are likely to have reduced financial capacity to adapt to further cuts unless rainfall returns to more normal patterns.

This suggests that analysis of community vulnerability should be based on information about specific places.

Adaptive capacity

The literature reflects considerable agreement that adaptive capacity is positively related to the resources available to the community. A common way of describing these resources has been to classify them as various forms of capital; namely, built, human, natural, social or financial capital

(Burnside 2007; Ellis 2000; Nelson et al. 2005; Yohe & Tol 2002). According to Ellis (2000) the five capitals are:

- human capital—labour and influences on the productivity of labour, including education, skills and health
- social capital—claims on others by virtue of social relationship
- natural capital—land, water and biological resources
- physical capital—produced by economic activity, including infrastructure, equipment and technology
- financial capital—savings and credit.

As noted, adaptive capacity appears to be positively related to the diversity of the resources (stocks of capital) available to a community. Another desirable characteristic of resources is that they should be mobile between uses, thereby increasing the flexibility with which they can be applied to new or alternative ends and facilitating community adaptation. In terms of human capital, for example, this means education and skills should be transferable between jobs. Similarly, the specificity of built capital (harvesting machinery, irrigation infrastructure, buildings) affects its reallocation to other uses.

While movement of labour (human capital) to another local job might be seen, from the perspective of the community, as a positive adaptation moving to a job elsewhere would presumably not. This illustrates the tension between the adaptive capacity of people, and the adaptive capacity of places. On the other hand, some rural towns are benefitting from the in-migration of new residents who embody desirable human capital characteristics (skills, attitudes, motivations, networks) and who tend to be attracted by a mix of social, cultural and environmental amenities. These amenities could also be seen as forms of capital.

Many variables have been suggested as indicators of adaptive capacity and resilience (and therefore, inversely, of vulnerability). However, little testing has been done of their predictive power to explain observed outcomes (that is, vulnerability) using cross-sectional and time series data. An exception to this is a recent paper (Alasia et al. 2008) that analysed the power of stressor and asset indicators to predict future vulnerability to declining population and employment in Canadian communities in 2001. More commonly, large area studies of adaptive capacity use recent data on proxy variables. One reason for this is that the intangible nature of the components of adaptive capacity makes it difficult to identify variables that might predict the outcomes in each sub-area. A second reason is the high cost of collecting primary data on context-specific variables for each sub-area. Another shortcoming of many studies is that the *a priori* justification for the choice of proxy variables, and of their weights, can be sketchy.

Walcott and Wolfe (2008) noted similar concerns about existing theory and measurement of adaptive capacity. These were that:

- many indicators are based on intuitive assumptions of the attributes underlying adaptive capacity
- the accuracy with which any indicator measures the attribute
- the strength of the relationship between an indicator and its attribute; that is, does a change in the indicator relate to a similar change in the attribute?

- some indicators are best gained from local qualitative studies
- matching the (spatial) scale of adaptive capacity to that of the driver of change is difficult
- there is a danger of conveying more precision than is warranted.

Sensitivity

Sensitivity is generally regarded as the degree to which a system is affected by a particular change without taking into account any abilities the system may have to adapt (Allen Consulting 2005). For example, a community or a region highly dependent on irrigation water to underpin economic activity would be more sensitive to changes in the availability of irrigation water than to rainfall patterns. Sensitive systems are more likely to be affected by the change under consideration and can be significantly affected by small changes (Allen Consulting 2005).

Many potential variables could be used to represent the concept of community sensitivity. However, few studies actually define a specific set of variables or test their predictive power. Several studies have linked community sensitivity to employment in industries that are likely to be affected by climate change. See, for example Cinner and colleagues (2012), where the sensitivity of coastal communities to the effects of temperature events on fisheries was defined in terms of households engaged in fisheries related occupations. The issue for defining sensitivity in those terms is that the linkages and directionality between temperature events and fishing activity are not well known.

In the context of irrigation water access, identifying indicators for the concept of sensitivity would require scoping of the ways in which a community or region depends on irrigation activity, including any pathways of economic or social dependence on this activity. The best measure of sensitivity would be the amount of irrigated primary production that occurs in the community or region and the proportion of the value of production retained there. But since a direct measure of this sort is difficult to obtain reliably at a fine scale, various proxy measures can be used, such as the amount of water applied, or the amount of employment in agriculture. The reasoning is that if not much water was applied there would not be much irrigated primary production, and likewise if not many people were employed in agriculture. If there were to be a change in irrigated primary production, the capacity for adaptation along the value chain would determine how this plays out and where the impacts fall.

Sensitivity could arise from reliance on economic activity related to the dairy or horticulture sectors, for example, which rely on irrigation water availability. These sectors may experience significant decline due to reduced access to water for consumptive use. Therefore, their sensitivity would result from direct reliance on irrigation water or through the proportion of employment in the irrigated agricultural sector and any processing sectors that use agricultural produce; for example, food or beverage manufacturing.

Vulnerability

These issues expose several implications for estimating adaptive capacity and vulnerability. Given the importance of taking into account both the nature and scale of the impacting event, and the context-specific nature of adaptive capacity and processes, the estimation of vulnerability would ideally involve scoping of logical linkages between exposure (in this case, reduced SDLs), sensitivity, potential impacts and adaptive responses, for each sub-area, and analysis of the relationships between context-specific variables in each. The analysis would also take into account the ways in which Basin communities have been affected by, and responded to, periods of very low water availability over the past 10 years.

The first stage in scoping and analysing use of consumptive water in irrigated agriculture would be modelling the farm-level responses, such as changes in enterprise mix (for example, increased proportion of dryland cropping); changes in technology (for example, substitution of built capital for water); reduced debt-servicing capacity; and impacts on financial viability and property sale.

Farm-level responses would include water trading, which has the potential to have major effects on the scale and geographic distribution of economic and social impacts. That is, the task of adaptation, and the ultimate vulnerability of particular sub-areas, could be intimately affected by the spatial pattern of water trade. ABARES modelling may generate important information on the spatial pattern of farm-level adaptation, including water trade. While irrigated agriculture accounts for the highest volume of water use, the potential impacts on urban water users, recreational users (such as fishing and tourism), and on-farm stock and domestic use should also be scoped and analysed.

The next stage of such an analysis would involve identifying the potential flow-on effects, both in the local community and in other communities linked by trade and other ways to irrigated agriculture. Next, the analysis would attempt to identify potential adaptive responses undertaken at several levels: that is, on-farm, in associated industries (input suppliers, output processors, transport and handling providers), in businesses serving farm households, in other industries (mining, tourism, the service sector, aged care) and in the community and non-profit sectors. The next stage would be to predict, estimate, or (in the absence of such models) make informed judgments about the likely success of the adaptive responses, based on an assessment of the resources (or capitals) available to the community. Finally, judgments would be made about the remaining negative impacts not dealt with by the local adaptive responses: community vulnerability.

This discussion outlines the thinking that informed decisions about the indicators used to represent the concepts of vulnerability, sensitivity and adaptive capacity in this project.

3 Developing the index of community vulnerability

The conceptual framework (Figure 1) was used to guide indicator selection in a number of studies of vulnerability and adaptation to climate change. This chapter considers the previously independent development of indices of adaptive capacity, vulnerability and resilience from the Institute for Rural Futures and ABARES.

The Institute for Rural Futures undertook a number of studies of community vulnerability in recent years, including:

- vulnerability to climate change of the New South Wales Central Coast and Hunter regions (Brunckhorst et al. 2009)
- vulnerability of communities in the Condamine–Balonne, Macintyre Brook and Border Rivers regions to reductions in water availability.

These studies employed and further refined a methodology that uses a statistical technique called Principle Component Analysis (PCA). PCA is a means of identifying relatively independent groups of census indicators to derive a reduced number of relatively uncorrelated subindices. PCA was first applied to demographic data by the Australian Bureau of Statistics for the 1971 Census, and expanded for the 1986 and subsequent censuses (see ABS 1998). The method has also been applied to the specific issue of natural resource availability (Fenton 1998) and to develop measures of socioeconomic disadvantage (Vinson 1999). This project used the method to identify a reduced number of composite indicators for community vulnerability to changes in water availability.

ABARES undertook a national assessment of community dependence on water and social resilience in 2007 as part of the *Water 2010: National Assessment of Community Dependence on Water and Social Resilience* project (Herreria et al. 2008). That project demonstrated how social theory can be used as a guide to identify a range of national datasets to help unravel the complex relationships between agricultural communities and the resources they depend on to maintain their livelihoods. *Water 2010* developed a composite index of susceptibility to changes in water access from indicators of dependence on water and social resilience, which was then spatially mapped at national and regional scales.

These measures provided a useful starting point to advance understanding of the intersection between biophysical phenomena and the social circumstances of agriculturally dependent communities.

Building on these studies, ABARES and the Institute for Rural Futures collaborated to develop measures of community vulnerability to changes in water availability in 2010. The results of that project were published in October 2010 as *Indicators of community vulnerability and adaptive capacity across the Murray–Darling Basin: a focus on irrigation in agriculture* (ABARE-BRS 2010), coinciding with release of the *Guide to the proposed Basin Plan* (MDBA 2010). When details of the proposed Basin Plan water recovery scenarios and modelling became available, MDBA approached ABARES to revise the Indicators project to include an exposure index in order to assess community vulnerability to the proposed Basin Plan scenarios. The measures used in the ABARE-BRS (2010) project are re-visited in this report and further validated in a continuing collaboration with the Institute for Rural Futures.

Choosing measures of community vulnerability

The concepts of vulnerability and adaptive capacity were applied to possible reductions in availability of water for diversion to irrigation in the Murray–Darling Basin (Figure 2). Numerical measures of the various concepts were developed and mapped for the Basin. These numerical measures are linear combinations of particular data items available from the ABS Population Census for 2001 and 2006 and from *A methodology for estimating regional agricultural water use* (ABS 2006).

An additional indicator representing the exposure of communities to various SDL scenarios was included since the publication of the 2010 Indicators report, in order to inform development of the proposed Basin Plan.

The rectangular boxes outside the concept clouds in Figure 2 represent application of the concept to the specific context of reductions in water availability in the Basin. Subject to the constraints of time and data availability for this project, it was possible to operationalise five of these as numerical subindices: SLA water dependence and SLA local economy agricultural dependence (which jointly determine sensitivity), and local economic diversity, human capital and social capital, which jointly determine adaptive capacity. Figure 2 also shows, in pale grey, other potential subindices that may be possible with further investigation of secondary data sources, or primary data gathering.

The exposure index was constructed from one measure—the proportion of reduced irrigation water available compared with the long-term average water availability as needed to implement an overall SDL. The MDBA specified the Basin SDL reduction scenarios. Regional level SDL reduction scenario figures were sourced from ABARES economic analyses (ABARES 2011). The contribution of each Basin Plan region to meeting the overall SDL was apportioned using output from the ABARES WTM.

The Economic Diversity Index, also referred to as the Hachman Index, provides an indication of the vulnerability of communities to changes in economic circumstances (Moore 2001; Pembina Institute for Appropriate Development 2005). The method of calculating the Economic Diversity Index is detailed in 'Economic Diversity Index'. A community with a diverse local economy is expected to be better able to adjust to changes that have a significant impact on a particular sector, as employment is available in a range of sectors. Conversely, in a less diverse economy, the community may be especially sensitive to change in certain sectors. For example, a community in which a large proportion of the workforce is employed in agriculture or related service and processing operations is particularly sensitive to events (such as drought, loss of irrigation water, increasing input costs, labour shortages) that have a negative effect on the quantity of agricultural goods the region is able to produce.

The elliptical boxes on the far edge of the rectangular boxes in Figure 2 refer to the various indicators used to calculate the subindices. As before, potential indicators not included due to constraints of time and data availability are shown in pale grey.

For local economy, agricultural dependence and human capital, many potential indicators, which according to the literature on community vulnerability and adaptive capacity, might be chosen as appropriate measures. In each case, principal component analysis was used to examine the relationships between the potential measures and a less numerous set of relatively uncorrelated indicators was chosen.

Spatial considerations in indicator selection

An issue to be considered when embarking on a study of a specific region is whether to use indices derived by analysis of a much larger region. The ABS SEIFA and Fenton's (1998) Community Sensitivity Indices, for example, were derived using PCA with demographic data at the CCD level for the whole of Australia. The study by Vinson (Vinson 1999) used postcode level data for New South Wales and Victoria.

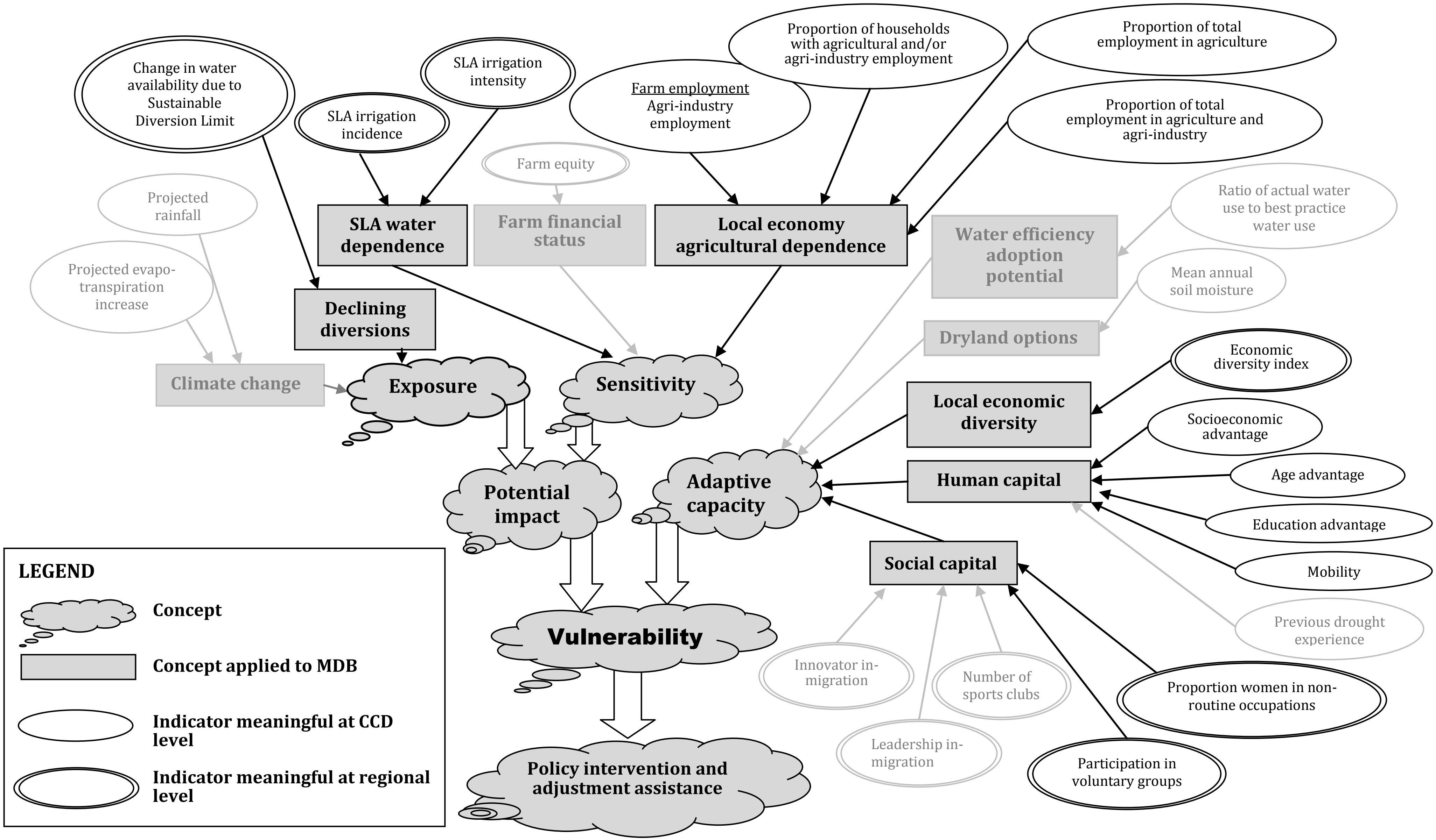
Using indices derived from larger regions than the region of interest has the advantage of enabling comparison beyond the specific region of interest. While such comparisons may be relevant in some policy circumstances, for water resource management within the Murray–Darling Basin, the ability to draw comparisons outside the Basin is likely to have little policy relevance.

On the other hand, analysis of data drawn only from the region of interest has the advantage of deriving indices that may reflect the unique circumstances of the region. This is a particularly important consideration when PCA is the method of analysis. Applying indices derived from analysis of larger regions assumes the same correlational relationships between demographic variables occur in the larger region as in the smaller region of interest. To the authors' knowledge, this assumption has not been tested.

Certainly, it is possible to point to plausible examples where this assumption will not be met. For example, in mining towns in north-west Western Australia, high incomes may be associated with single households in rented accommodation, whereas these households in some inner city areas and some coastal retirement communities might be more likely to be associated with lower incomes. PCA on data from a combination of such regions could find that income was uncorrelated with household size or tenure, and so allocate income to one component and household size and/or tenure to another component. However, PCA applied to just a single one of the three regional examples would be more likely to place income, household size and tenure in a single component. For these reasons, PCA solutions are likely to be scale-dependent. Components that are uncorrelated in larger regions may well be correlated in small regions.

Given that the aim of using PCA is to identify underlying components or factors that make a unique contribution to community vulnerability, and given that an understanding of these factors contributes to development of adjustment policies, these considerations suggest considerable merit in confining derivation of indices to analysis of data drawn from within the Basin.

Figure 2 Conceptual framework developed for this project showing measures used to populate the concepts



CCD = Census Collection District; MDB = Murray–Darling Basin; SLA = Statistical Local Area.

Note: Elements not used/unavailable for this project are shown in pale grey.

Data sources

The secondary data for this study came from the sources listed in Table 1. A list of CCDs was obtained from the ABS, based on previous work conducted by the ABS in which CCDs were concorded with the boundary of the MDB. A final list of 4600 CCDs was included in the dataset.

Relevant data items were extracted from the Census DataPack for each CCD in the Basin concordance using the Microsoft Excel lookup function, and aggregated into a single spreadsheet. Each indicator was then calculated from the data items, and the indicators exported for further analysis in the SPSS software package. Calculations included missing value substitution where appropriate (see Appendix C 'Missing values').

Table 1 Secondary data sources used to construct indicators

Data source	Supplier	Cat. no./identifier	Scale
2006 Census DataPack	ABS	2069.0.30.001	CCD
2006 Community Profile Series—Basic Community Profile	ABS	2001.0	CCD
Water Use on Australian Farms, 2000–01	ABS	4618.0 2000–01	SLA
ML water applied to irrigate farm establishments, 2000–01	ABS	na—data supplied by ABS direct using regional estimation methodology	SLA
2006 Census employment and household data relating to employment in ANZSIC Division A Subgroup 01 (Agriculture) and employment in Division C Subdivision 21 (Food Beverage and Tobacco)	ABS	na—data supplied by ABS direct	CCD
WTM, percentage change in water availability under three proposed Basin Plan SDL reduction scenarios: 2400gigalitre, 2800gigalitre, 3200gigalitre	ABARES	na—data supplied by ABARES water economics section	WTM region

ABS = Australian Bureau of Statistics; ABARES = Australian Bureau of Agricultural and Resource Economics and Sciences; CCD = Census Collection District; na = not applicable; SLA = Statistical Local Area; WTM = Water Trade Model.
Note: The scope of the ABS Agricultural Census includes all establishments undertaking agricultural activity with an estimated value of agricultural operations greater than $5000.

Agricultural water use data

The original maps ABARE-BRS published in 2010 used 2005–06 ABS data to populate the indicators of dependence on water for agriculture: SLA irrigation intensity and SLA irrigation incidence. This data had a number of shortcomings. First, it was recorded in a year when drought occurred in many parts of the Basin and, consequently, the amount of irrigation would probably have been less than a normal year. Therefore, many farms with infrastructure and entitlements to irrigate were not irrigating and dependence on irrigation water would have been underestimated.

Second, where the amount of irrigation in an SLA was not large, estimates in the 2005–06 data were either not given for confidentiality reasons, or have large relative standard errors. There were a number of missing data in the 2005–06 dataset, possibly resulting from less irrigation activity reported by irrigators in the ABS Agricultural Census, and imputations were made to estimate some of the missing data (see ABARE-BRS 2010, 'Missing data').

As a result, the current project assumed a baseline water use year of 2000–01 to better represent community dependence on irrigation water in a business-as-usual year. This should better reflect, for example, the significant increase in area planted with irrigated cotton, particularly in the north of the Basin in 2000–01, compared with 2005–06. The 2000–01 ABS Water Account, based on the Agricultural Census, provided indicators at the SLA level as: the number of agricultural businesses; the number of agricultural businesses irrigating; the area of agricultural holdings ('000 hectares); and the area irrigated ('000 hectares).

The first two indicators were used to populate the SLA irrigation incidence indicator in the sensitivity index. However, the ABS Agricultural Census form in 2000–01 did not ask landholders about the volume (megalitres) of irrigation water applied to grow crops on their holdings that year. However, megalitres of water used for irrigation at the SLA scale is a key data item in the SLA irrigation intensity indicator of the sensitivity index. Therefore, the dataset needed to be derived for 2000–01 from customised data supplied from ABS.

To generate the customised dataset, the ABS used a regional water use estimation methodology to obtain small area (that is, SLA level) water use data for 2000–01 as described by the ABS (ABS 2006). The method applies state-level water use averages to obtain water use for each SLA based on SLA cropping area data and water use rates for different crop types. Initially, the state mean application rate—megalitres of water per hectare—was calculated for each state and crop type. The application rate for each crop was assumed to be the same across the state. The SLA total irrigated agricultural water use was then calculated for a particular crop in an SLA. This was done by multiplying the mean application rate by the hectares of the crop within the SLA of interest. The total irrigated agricultural water use within the SLA was then calculated by summing the water use for each crop type (grapes, vegetables, sugar, fruit, cotton, rice, dairy farming and 'other', which includes livestock, pasture, grains and other activities) (ABS 2006).

The regional estimation methodology has advantages and disadvantages (see Appendix C 'Missing values'). One disadvantage is the accuracy of the assumption that the application rates for a crop are the same across a whole state when in reality, a range of factors such as climate, soil type and irrigation technologies, may influence application rates. Despite the problems in estimation, it was decided that the advantages of using the estimated 2000–01 data outweighed the disadvantages associated with using the 2005–06 data, particularly that of the large amount of missing data and in the ability to include a more accurate assessment of sensitivity.

Another reason for deciding to use the 2000–01 water use year was that the community vulnerability assessment would have the same baseline year as in the ABARES economic analyses of the impact of the proposed Basin Plan, where 2000–01 is the baseline year. (The WTM baseline scenario reflects 2000–01 water availability, with other data inputs such as gross value of irrigated agricultural production per hectare and land use based on 2005–06 data.) Map B10 shows the water use applied, divided by the number of irrigated farms (using the ABS 2000–01 custom data). The map shows high intensity water application rates as a proportion of farm establishments in some areas in the northern Basin reflecting a wet or business-as-usual year. The smoothing effects can clearly be seen across some areas due to the data being estimated at SLA scale.

Employment in agriculture data

Map B11 shows employment in agriculture as a percentage of total employment using ABS Population and Housing Census data 2006 across the Murray–Darling Basin. In the previous version of this project (ABARE-BRS 2010), the employment variable used in SLA Local economy agricultural dependence was the percentage of employment in agriculture, fisheries and forestry industries. This was replaced, in the revised indices, with the proportion of employment in agriculture only because this was considered more directly relevant to community vulnerability to changes in water for agriculture. As seen in the map, a number of CCDs in the central and west Murray–Darling Basin have significant proportions (more than 80 per cent) of their employment in agriculture. Agriculture employment is defined using ANZIC 2006 Industry of Employment, category 01 Agriculture.

Calculation of initial indicators

The data items and indicators initially assembled as potential constituents of a vulnerability index are listed in Table 2. This choice of potential indicators was guided by a review of the literature, available in ABARES-BRS (2010), which identified which phenomena appear to influence community sensitivity and adaptive capacity.

Table 2 Indicators, data used and scale at which data were available

Indicator	ABS data used	Scale
Adaptive capacity related		
% population >65 years old	Total persons aged 65 years old and over / total persons	CCD
% population <5 years old	Total persons aged 0–4 years old / total persons	CCD
% population 15–24 years old	15–24 year olds as proportion of total population	CCD
% couple families	Total couples without children + total couples with children / total families	CCD
% lone households >65 years old	Total lone householders aged >65 years old / total persons in occupied private dwellings	CCD
% lone person households	Total one person households / total occupied dwellings	CCD
% one parent	Total single parent families / total families	CCD
% separated and divorced	Total separated + total divorced / total persons >15 years old	CCD
% single parent with children <15 only	Total single parent families with children <15 years old / total families	CCD
% single persons >15 years old	Total persons not married / total persons >15 years old	CCD
% single persons 15–64 years old	Persons aged between 15 and 64 years not married as proportion of total persons aged 15–64 years	CCD
Average no. persons per household	Average household size	CCD
% 'ethnicity' (language spoken at home is not English)	Total other language spoken at home / total persons	CCD
% born overseas	Country of birth outside Australia / total persons	CCD
% over 15 years with no qualifications	% persons >15 years with no qualifications: certificate, diploma, undergraduate degree, postgraduate degree	CCD
% population <15 years old with management/commerce qualification	Total non-school field of study management, commerce etc. / total persons >15 years	CCD
% graduates	Total bachelor degree + total graduate diploma/certificate + total postgraduate degree / total persons 15+	CCD
Left school before Year 10	Total Year 9 leavers + total Year 8 leavers + total did not attend school / total persons 15+	CCD
% population 15–24 years old attending an educational institution	Full or part-time technical college or university students as proportion of persons aged 15–24 years – using Water 2010 'Youth educational engagement'	CCD
Household weekly income <$349	% houses with income between $0 and $349 per week – 2006 readjustment of Water 2010 indicator 'Low income households'	CCD
Income/mortgage differential	(Median household weekly income * 52 / 12) – median monthly housing loan repayment	CCD
Median household income as fraction of Australian median	Median household weekly income as proportion of the 2006 Australian median ($1026.80)	CCD
% 'need for assistance'	Total need for assistance (disability) / total persons	CCD
Dependency ratio	Persons aged <15 years and >64 years as a proportion of persons aged between 15 and 64 years	CCD
% voluntary work	Total volunteers / total persons >15 years	CCD
% dwellings no vehicle	No. dwellings with no vehicle / total dwellings	CCD
% population Indigenous	Total Indigenous persons / total persons	CCD
% visitors	Total visitors / total persons	CCD
% house 'being purchased'	Dwellings being purchased / total occupied private dwellings	CCD
% dwellings rented	Rented properties / total dwelling structures	CCD

(cont.)

Table 3 Indicators, data used and scale at which data were available (cont.)

Indicator	ABS data used	Scale
Median monthly housing loan repayment as a fraction of the Australian median	Median monthly house loan repayment as proportion of the 2006 Australian median ($1300)	CCD
Median weekly rent as a fraction of the Australian median	Median weekly rent as proportion of the 2006 Australian median ($190)	CCD
% households using the internet	Total households with internet / total occupied private dwellings	CCD
% of internet users with broadband	Total households with broadband / total occupied private dwellings	CCD
% different address to 1 year ago	Lived at different address 1 year ago / lived at different address 1 year ago + lived at same address 1 year ago	CCD
% different address to 5 years ago	Lived at different address 5 years ago / lived at different address 5 years ago + lived at same address 5 years ago	CCD
% new residents (≤1 year residing in SLA)	Persons living overseas or in different CCD one year ago / total persons >1 year old	CCD
% employed in public sector	Total employed in public admin sector / total employed persons >15 years	CCD
% labourer (employed >15 years old)	Total labourers / total employed persons >15 years	CCD
% 'tradespersons' (technicians and trades workers)	Total technicians and trade workers / total employed persons	CCD
Women in non-routine occupations	Female managers + female professionals + female technicians + female community and personal / total female employed persons	CCD
Economic Diversity Index	Diversity of local economy relative to Australian/MDB economy, calculated using employment by sector data	CCD
Total unemployment	Total unemployed / total labour force	CCD
Unemployment for 15–24 year olds	Unemployed persons aged 15–24 years / labour force aged 15–24 years	CCD
Unemployment 20–64 years	Unemployed persons aged 20–64 years / labour force aged 20–64 years	CCD
Sensitivity related (local economy agricultural dependence)		
% population >15 years with agriculture or environmental qualification	Total non-school field of study agriculture, environmental etc. / total persons >15 years	CCD
% work in agriculture	Total working in agriculture/mining/forestry sector / total employed persons >15 years	CCD
Agriculture and downstream agri-industries households	Households with at least one member employed in ANZSIC Division A Subgroup 01 (Agriculture) and Division C Subdivision 21 (Food Beverage and Tobacco) as % of all households	CCD
Ratio of agriculture and agri-industry employment to total employment	Ratio of persons employed in ANZSIC Division A Subgroup 01 (Agriculture) and Subgroup 02 Minor subgroup 05 to total employment	CCD
Ratio of employment in agricultural and downstream agri-industries to agricultural establishments	Ratio of persons employed in ANZSIC Division A Subgroup 01 (Agriculture) and Division C Subdivision 21 (Food Beverage and Tobacco) to number of farm establishments with an EVAO greater than $5000	CCD
Ratio of employment in agriculture to downstream agri-industries	Ratio of persons employed in ANZSIC Division A Subgroup 01 (Agriculture) to persons employed in Division C Subdivision 21 (Food Beverage and Tobacco)	CCD
Sensitivity related (Irrigation water dependence)		
SLA irrigation incidence	% of agricultural businesses irrigating	SLA
SLA irrigation intensity	Megalitres of water applied / no. irrigated farm establishments	SLA

CCD = Census Collection District; EVAO = estimated value of agricultural operation; SLA = Statistical Local Area.

All indicators, except SLA irrigation incidence and SLA irrigation intensity, were available at CCD level. The SLA values for these two water dependence indicators were assigned to the constituent CCDs in each SLA. However, SLA was retained in the indictor name to emphasise it is an SLA-level indicator that applies to a region around and including a CCD, and not just the CCD itself. This approach is less than ideal, but was necessary if the vulnerability index was to take account of water dependence.

Economic Diversity Index

The Economic Diversity Index was calculated for each CCD from Industry of Employment data available from the ABS Basic Community Profiles. The Economic Diversity Index compares the proportion of the workforce employed at the SLA geography in the 19 industry sectors identified by the Australian and New Zealand Standard Industrial Classification (ANZSIC) to that of a larger geographic unit (for this project, the entire Murray–Darling Basin). The closer an Economic Diversity Index score for a CCD is to 1.0, the closer its employment distribution is to the Basin as a whole, and the more diverse its economy is assumed to be. Conversely, a lower Economic Diversity Index score suggests a less diverse economy. Further details (including the method by which the index is calculated) are available in Moore (2001). The methodology this project used for calculating the Economic Diversity Index was developed by Frank Hachman at the Bureau of Business and Economic Research in Utah.

Technical development of indicators

A number of other technical procedures were used to develop the community vulnerability indicators. These included data quality checks, Principal Components Analysis (PCA) to obtain a reduced set of indicators, calculation of the indices and subindices, choice of weightings and class intervals used for mapping, population of the exposure indicator, global scaling of ranked scores and a comparison of the indicator results with ABS SEIFA scores. Details of these technical procedures are available in Appendix C 'Technical development of indicators'.

4 Interpreting the index of community vulnerability

This chapter provides analysis of the project outputs in two different ways. First, with a presentation of the indices of community vulnerability, sensitivity, adaptive capacity at the Basin scale without consideration of any exposure to the Basin Plan. This essentially updates the work presented in ABARE-BRS (2010) taking into account the refinements described in the 'Approach' section of this report. Second, it presents indices of community vulnerability when exposure to the proposed Basin Plan is factored into the conceptual framework (Figure 2). This includes presentation of the indices of relative exposure of Basin communities to changes in water availability, the resulting potential impact on Basin communities and the residual vulnerability of communities under the different water recovery scenarios.

Index of relative community vulnerability before exposure

Relative community vulnerability before exposure to the proposed Basin plan is shown in Map B1. Community vulnerability before exposure is a measure that combines the sensitivity of communities in the Murray–Darling Basin to changes in water availability with their adaptive capacity to manage and cope with stresses associated with changes in access to water for agriculture. The index takes into account refinements described in the 'Approach' section of this report and updates the community vulnerability mapped outputs presented in ABARE-BRS (2010). Community vulnerability before exposure assumes a water use year of 2000–01. Water use data from ABS for 2000–01 was used to populate the sensitivity index. Water intensity data for Canberra were unavailable so Canberra collection districts were removed from the analysis of community vulnerability, which influenced the rankings of other collection districts in the analysis.

Community vulnerability to changes in water availability varies widely across the Basin, depending on the different adaptive capacities and sensitivities of particular communities. Regions with the highest rankings of vulnerability include irrigation regions in the south of the Basin (that is, the Murrumbidgee, Lower Darling, Murray and Lachlan Basin Plan regions) and in the north-west of the Basin (that is, Border Rivers, Gwydir, Moonie, central Condamine–Balonne and south Warrego Basin Plan regions). Communities in these areas have a combination of higher sensitivity to changes in water availability (that is, higher ranked scores of dependence on water for agriculture and high agri-industry employment) and lower levels of adaptive capacity (that is, lower ranked scores of human capital, social capital and economic diversity) when compared with other areas in the Basin. This means communities in these areas are more likely to be vulnerable to changes in water availability.

A difference between the original vulnerability maps and those that use 2000–01 water use data are apparent in the northern part of the Basin where clusters of areas have higher vulnerability rankings, possibly associated with cotton growing in the 'wetter' years of 2000–01.

Subindex of relative adaptive capacity

Relative adaptive capacity is a measure of the different resources and abilities from which communities can draw to manage or cope with stresses or changes in access to water for agriculture.

Map B3 shows the revised index of adaptive capacity across the Murray–Darling Basin. The darker shaded areas on the map are those with relatively lower levels of adaptive capacity. That is, they have relatively lower levels of economic diversity, human capital and social capital compared with other areas in the Basin. Levels of adaptive capacity appear to be relatively low in some areas in the central and north-west areas of the Basin, including in the Barwon–Darling, Paroo, Warrego, Lower Darling, Lachlan, Murrumbidgee and Murray Basin Plan regions.

The index of adaptive capacity was revised to reflect updated economic diversity data and CCDs for Canberra have been removed for consistency with the other updated maps. The index is constructed from ABS demographic data from the 2006 Census of Population and Housing.

The revised map of relative adaptive capacity is constructed using five intervals defined using the Jenks natural breaks classification method (all other maps use the default five equal intervals). MDBA indicated it would prefer to use the Jenks natural breaks method to define class intervals for the relative adaptive capacity map to better visualise the 'tail' in the distribution containing census districts with relatively lower adaptive capacity rankings. The Jenks method of classification uses natural groupings inherent in the data to define the break points between classes. The class boundaries are set where relatively big differences in the data values exist. Natural breaks are data-specific classifications and not useful for comparing multiple maps built from different underlying information. Further technical explanation about the Jenks natural breaks classification algorithm can be found in de Smith and colleagues (2009).

Subindex of relative sensitivity

Relative sensitivity is a measure of the dependence of communities on employment in agriculture and downstream processing facilities combined with dependence on irrigation water across the Murray–Darling Basin. Communities with higher relative sensitivity rankings are located in the north of the Basin in Condamine–Balonne, Moonie, Border Rivers and Gwydir Basin Plan regions (Map B2). In the southern Basin, some communities in the Lachlan, Murrumbidgee, Murray and Wimmera–Avoca Basin Plan regions are ranked relatively more sensitive.

The major update in this subindex of sensitivity is the use of 2000–01 water data compared with 2005–06 water use data used in the previous Indicator project. The indicator of SLA irrigation intensity (Map B10), which makes up sensitivity, was generated using the 2000–01 estimated ABS data. Data from this year was used because it is closer to a business-as-usual year for irrigation and therefore represents a more conservative estimate of the sensitivity of communities to changes in the availability of water for consumptive uses. However, smoothing effects occur across some areas due to the water data being estimated at SLA scale (Map B11). More information about the method ABS used to generate the synthetic water use data is available in ABS (2006). All other ABS demographic data used in the sensitivity subindex was sourced from the ABS Population and Housing Census 2006 and was available at the finer CCD scale.

One of the measures used to determine sensitivity is the proportion of employment in agriculture as a proportion of total employment. This proportion is shown in Map B11 to provide some context to the sensitivity measure. The darker shaded CCDs have higher proportions of employment in agriculture relative to other industries and are therefore more reliant on agricultural industries. This includes areas toward the central and north western regions of the Basin which have a higher reliance on agricultural employment, particularly in parts of the Lachlan, Macquarie–Castlereagh, Barwon–Darling, Lower Darling, Condamine–

Balonne, Namoi, Gwydir, Border Rivers and Moonie Basin Plan regions. These areas are likely to be most sensitive to any changes in employment in agriculture.

Subindex of relative exposure

Exposure is a measure of the amount of external stress or change a community is likely to be affected by. The exposure measure was constructed from a single data item; that is, the proportion of reduced irrigation water available due to implementation of various water recovery scenarios. Exposure of areas in this case takes into account:

- the proposed SDL for the relevant catchment
- the amount of water acquired already in a catchment, such as through voluntary water buybacks or water savings through infrastructure investments
- the patterns of water trade within and between regions
- other factors, such as commodity prices.

Exposure is therefore the remaining change needed in the volume of water available for consumptive use after taking into account the water savings from infrastructure investments and entitlements already purchased.

Map B5 presents the subindex of exposure for the remaining change required to reach the 2800 gigalitre water recovery scenario. The exposure measure is presented as a percentage reduction in water use rather than as a ranked score since there is only one measure of exposure and there is no need to standardise and combine the indicators. This figure spatially represents the WTM 'main scenario' results for the 2800 gigalitre SDL reduction scenario assuming 2005–06 commodity prices. It shows that the Murrumbidgee, Goulburn–Broken and Wimmera–Avoca Basin Plan regions are more exposed to water use reductions in this water recovery scenario than other regions.

However, commodity prices are likely to significantly affect the modelled distribution of reductions in water availability across the Basin. Changes in commodity prices influence the relative profitability of differing industries, and hence alter the distribution of water between industries, as water is assumed to be able to be traded between users. As regions contain varying industry structures, this also affects the distribution of water between regions. To facilitate comparison after exposure under the main scenario, the subindex of exposure is also mapped for the 2800 gigalitre water recovery scenario using more recent commodity prices Map B6 shows that in the updated commodity price scenario, the regions relatively more exposed to water use reductions are the Lower Darling, Murray, Wimmera–Avoca and Goulburn–Broken Basin Plan regions. Exposure levels depicted in Map B6 and Map B5 can be compared as a comparable legend was used. Map B6 represents the WTM 'sensitivity analysis using updated prices' results, which assumes post-2005–06 commodity prices (average of 2006–07 to 2010–11 commodity prices). See ABARES (2011) and MDBA (2011) for further explanation of the influence of commodity price assumptions on the SDL reduction scenarios.

Smoothing occurs in the maps due to the coarse scale of the modelled water change results. Therefore, areas in a region that do not record any irrigation activity could attract a high level of exposure to the SDL reduction scenario even though it will have little relevance since no irrigation water was used in that specific area.

Subindex of relative potential impact

Potential impact is a measure of the consequences for a community of a change or stressor. The potential impact of proposed water recovery scenarios is influenced by both the sensitivity and the exposure of Basin communities to a change in water availability. For example, worse potential impact results for a community highly dependent on irrigation water and facing a large reduction in water availability. In this project, the relative potential impact is the relative degree to which areas are sensitive to changes in access to irrigation water or changes in employment in agriculture and agri-industries combined with their relative exposure to reductions in irrigation water to meet the SDL reduction scenario.

The subindex of relative potential impact for the 2800 gigalitre water recovery scenario is shown in Map B7. This potential impact scenario uses the WTM main scenario results for exposure, which assumes 2005–06 commodity prices. The darker areas on the map indicate areas likely to experience relatively higher potential impact than other areas under this scenario. Two main areas are likely to experience a higher potential impact relative to other areas in the Basin. One is located in the northern Basin in the centre of the Condamine–Balonne Basin Plan region and the other is concentrated in the southern Basin in the Murrumbidgee, Murray and Goulburn–Broken Basin Plan regions. These areas have a combination of being more exposed to the 2800 gigalitre SDL reduction scenario and/or are more sensitive because of their higher use of irrigation water and higher dependence on employment in agriculture and downstream processing industries. The areas ranked as having a lower potential impact—the lighter areas—are likely to be those areas that have already 'adapted' by giving up water through voluntary water buybacks, achieving water savings through infrastructure investments, through water trading activity and/or they are not exposed to SDL reductions according to the assumptions in the modelled water estimates.

Areas shown in white on the relative potential impact maps are unlikely to experience impacts resulting from the Basin Plan. These areas are ranked with the lowest relative potential impact due to the SDL reduction scenario giving an indication of where the relative potential impact is likely to be very small compared with other areas in the Basin. These areas are ranked zero because they have either:

- a raw exposure measure (that is, per cent reduction in water use levels due to the Plan) equal to or less than zero (which could mean there is no difference in water access under the SDL scenario or they are gaining water under the SDL scenario), or
- a sensitivity ranking equal to zero, which means it is unlikely that irrigation activity is occurring there.

According to this analysis, the maps show the Paroo, Ovens and Eastern Mount Lofty Basin Plan regions will experience negligible changes due to SDL reductions as reflected in their lower potential impact rankings. The Gwydir, Lachlan and Warrego Basin Plan regions gain water under the SDL scenario and therefore are ranked with zero relative potential impact. While several CCDs in the Paroo Region are not white, they would be expected to experience negligible change in water use due to the Plan because they are allocated to the Barwon–Darling region in the WTM and the region is losing water (3.7 per cent) under the SDL reduction scenario. The regions that exhibit a potential impact of zero because of their low sensitivity ranking of zero include the white areas in the Macquarie–Castlereagh, around the Broken Hill area, and the central Wimmera–Avoca Basin Plan regions.

A concordance of WTM regions was used to allocate the exposure scores to CCDs because this gives a better resolution than using Basin Plan regions. WTM region boundaries coincide with

CSIRO Murray–Darling Basin sustainable yield regions, except that some sustainable yield regions have been split into multiple regions. These include the Border Rivers region and the Murray region.

The potential impact maps should be interpreted with caution because the data are based on a limited set of indicators and are smoothed due to the coarse scale of available water data. For example, the Lower Darling region is large and contains large areas ranked with highest relative potential impact. However, irrigation only occurs in a small area of the region along the southern border. The map therefore indicates a large area of potential impact when it is really quite a small area. This analysis should be seen as indicative of the relative magnitude of potential impacts due to the Basin Plan rather than predictive of actual impacts.

Other potential impact scenarios

Relative potential impact for the 2800, 2400 and 3200 gigalitre water recovery scenarios using more recent commodity prices (average of 2006–07 to 2010–11) are depicted in Map B8. These maps have been global scaled so the ranked scores for the 2400, 2800 and 3200 gigalitre water recovery scenarios can be compared across maps. Even though global scaling is used to allow comparison across scenarios, the potential impact is still a ranked score and is therefore not an absolute measure of on-ground impacts.

The dark blue areas on Map B8 show areas ranked with higher potential impact scores under the SDL reductions. The lighter areas are likely to be those areas that have already 'adapted' by giving up water through the buybacks, infrastructure savings or water trading activity.

As with the 2800 gigalitre scenario using 2005–06 prices, white areas are zero ranked and signify those areas with the lowest relative potential impact scores due to the SDL scenario. These areas are ranked zero because they have either:

- a raw exposure measure (that is, percentage reduction in water use levels due to the Plan) equal to or less than zero (which could mean there is no difference in water access under the SDL scenario or they are gaining water under the SDL scenario), or
- a sensitivity ranking equal to zero, which means irrigation activity is unlikely to be occurring there.

Comparing the three scenarios shows that more areas in the southern Basin move into the top 20 per cent ranked CCDs as the diversion limit increases—that is, from the 2400 to the 3200 gigalitre scenario. This change is especially apparent for communities in the Murrumbidgee, Murray, Lodden, Wimmera–Avoca and Lower Darling Basin Plan regions which move into higher potential impact rankings. Potential impact rankings of areas in the northern Basin do not change significantly under the different SDL reduction scenarios. Paroo, Ovens and Eastern Mount Lofty Basin Plan regions will experience negligible reductions due to SDLs as reflected in their lower potential impact rankings. For an explanation of the different SDL reduction scenarios used in the relative potential impact maps, see ABARES (2011). The maps should be interpreted with caution because the relative potential impact is smoothed across regions.

Relative potential impact is a summary indicator that uses statistical data and does not constitute a full social impact analysis of the reduction scenario on Basin communities. Detailed contextual information about an area or a community is also required from other sources to fully understand potential impacts from a change in access to irrigation water. To understand the factors contributing to the potential impact index in this analysis, it is necessary to look at the sensitivity and exposure subindicators.

Index of relative vulnerability after exposure

Map B4 shows relative community vulnerability for the Murray–Darling Basin with the exposure subindex included. A significant proportion of Basin communities exhibit only a low to moderate level of relative vulnerability (lighter areas). These communities are in general less likely to be affected by the 2800 gigalitre water recovery scenario in the proposed Basin Plan and have relatively high levels of adaptive capacity, which lessens their vulnerability to changes in access to water for consumptive purposes. Some of these areas are likely to have already 'adapted' by giving up water through voluntary buybacks, infrastructure investment savings or water trading activity.

However, a cluster of communities in the southern Basin exhibit higher rankings of vulnerability (the darker areas). It can be seen that communities in the Murrumbidgee and upper Murray Basin Plan regions exhibit relatively high vulnerability to the 2800 gigalitre water recovery scenario. These communities generally have higher levels of potential impact due to the 2800 gigalitre water recovery scenario and have relatively low levels of adaptive capacity (that is, human capital, social capital and economic diversity) which increases their vulnerability to changes in access to water for consumptive purposes. These areas may be in a region that still needs to contribute substantially to meeting the Basin Plan SDL reduction.

The relative vulnerability of Basin communities, as presented in this map, takes into account any water already bought back by government, infrastructure savings and any water trade that has occurred in a region. It represents the remaining contribution of Basin Plan regions to meeting the relevant SDL as apportioned by the ABARES WTM.

Other vulnerability scenarios

Three additional vulnerability maps were generated using ABARES WTM results with updated commodity price assumptions from the post-2005–06 period (that is, average of 2006–07 to 2010–11) for the 2400, 2800 and 3200 gigalitre scenarios. These maps are depicted side-by-side in Map B9.

Comparison of the three maps in Map B9 shows that more areas in the southern Basin move into the top 20 per cent ranked CCDs as the diversion limit increases; that is, from the 2400 to the 3200 gigalitre scenario. This change is especially apparent for communities in the southern Basin in the Murrumbidgee, Murray and Lower Darling Basin Plan regions. Community vulnerability rankings for areas in the northern Basin do not change significantly under the alternative SDL reduction scenarios.

The ranked scores for vulnerability using the 2400, 2800 and 3200 gigalitre SDL reduction scenarios can be compared because global scaling was used to rescale the maps. Even though global scaling is used to allow comparison across SDL scenarios, vulnerability (after exposure) is still a ranked score using a limited set of indicators and therefore is not an absolute measure of community vulnerability.

Caveats and limitations

Several limitations arise when using summary metrics for community vulnerability. Principally, community vulnerability is a complex concept and a single metric cannot capture the full experience of specific communities undergoing rapid change. As well, using census data reveals only part of the story. To overcome this limitation, it is important to carry out further validation and scrutiny of the indicators to establish whether they represent people's experiences at a community level and to increase understanding of the community vulnerability index. Ways of overcoming this and other limitations are discussed in Chapter 4.

A number of general caveats and limitations emerged as relevant to interpreting outcomes of this project. In summary, they are:

- Relative community vulnerability is a composite index made up of data from a range of sources at different scales, including catchment level, regional level, SLA level and CCD level. Therefore, smoothing effects occur in the mapping process. This is particularly problematic for the modelled WTM water data, which were provided at the regional scale and used to populate the exposure measure, and for the estimated data used in the SLA irrigation intensity 2000–01 indicator, which was made available at the SLA level.

- Relative community vulnerability is a summary indicator and in order to understand the factors contributing to vulnerability, it is necessary to carefully examine the component indices and other information to understand what underlies a score. Analysis of the components of community vulnerability can help identify attributes that contribute to vulnerability and thereby identify opportunities to address any limiting factors.

- The analyses should be seen as indicative of the outcomes of proposed water use reduction scenarios, rather than predictive of actual impacts. They draw on data from a single point in time that can be readily quantified and therefore represent a snapshot of community characteristics.

- The indices in this project have been combined using the approach described in Appendix C 'Calculating subindices and indices'. The approach is in accordance with the Intergovernmental Panel on Climate Change framework and is informed by the literature; other ways of combining the data could produce different results.

- A range of changes was made to the baseline indices and maps. The authors checked and fixed anomalies on those maps and indices, so they will appear to be different from the maps produced in ABARE-BRS (2010). The main changes and updates to the baseline vulnerability maps are explained in 'Approach'.

- To construct the potential impact subindex, the potential impact was set to zero when there was no exposure to a particular water recovery scenario (reflecting that the region was not required to give up water to achieve an SDL) or sensitivity was zero (reflecting that zero irrigation water was applied or there was no employment in agriculture).

- The indices generated give a relative ranking only, and should not be interpreted as absolute values. Hence a score in the community vulnerability index of 1.0 does not mean that CCD is twice as vulnerable as a CCD with a score of 0.5, only that it is relatively more vulnerable. The ranked scores are comparable only to ranked scores in the same analysis and on the same map; they are not comparable across maps of different composite indices or scenarios, unless global scaling was used to standardise the scores (as was done for potential impact, Map B8 and vulnerability after exposure, Map B9). Even though global scaling was used to allow comparison for some maps, the indices generated are still ranked scores and therefore not absolute measures of impacts or community vulnerability.

- Despite the arrangement of CCD boundaries to obtain areas with approximately similar numbers of households, geography and settlement patterns can result in some CCDs having a low population. Among such CCDs, the degree of variability in the data tends to be higher than among CCDs with larger numbers of households (known as the modifiable aerial unit problem). The data may also be subject to random adjustments that ABS uses to protect confidentiality. This variability can strongly influence values for indicators, such as adaptive capacity, or sensitivity because it is calculated from a small number of people. Therefore the remoteness or population/employment size of an area should be considered when interpreting results drawn from 2006 Census data.

- The analysis in this project is based on place-of-usual-residence data for specific SLAs, so does not account for the potential movement of people within 'social catchments' across SLA boundaries (for example, movement of fly-in fly-out workers in mining regions). This movement could influence socioeconomic indicators, such as vulnerability and adaptive capacity, and should be considered when making comparisons across regions.
- This assessment provides insight into the drivers of community vulnerability. The analysis is based on a limited set of indicators available at the time. Other factors not included in the assessment may cause some areas to have different vulnerabilities than this analysis suggests. Other factors that might affect community vulnerability include security of water entitlements for horticulture and broadacre farmers, daily movement of people between regions, remoteness of areas, availability/access to services, changing financial markets, effects of natural disasters, or other specific local factors. Inclusion of other indicators representing these factors could significantly change the relative rankings.

5 Using indices and maps

The conceptual framework indices and maps could be used to:

- better understand relative vulnerability to changes in water availability across Basin communities
- communicate vulnerability to decision-makers in local communities
- form part of a monitoring and evaluation strategy to track socioeconomic circumstances of Basin communities.

Better understand relative vulnerability

The indices developed in this project could be used to compare community vulnerability, sensitivity and adaptive capacity across the Basin and to guide community and stakeholder understanding of socioeconomic context.

A single composite index was developed that summarises the complex socioeconomic circumstances of diverse local communities across the MDB in the context of dependence on water for agriculture. This effectively provides a summary metric of community vulnerability in an easily digestible form for decision-makers (with limitations, as discussed).

The output of this project provides measures of community vulnerability and adaptive capacity using consistent indicators across the Basin at a localised scale (CCDs). These measures enable an understanding, at a fine scale, of the likely differences in impacts and community and regional responses to changes in water availability for consumptive use. It should be remembered that people move within and through many CCDs in a single day for many reasons. Therefore, conditions in a CCD are not purely determined by conditions within its boundaries, but by socioeconomic conditions in nearby regions. The maps and indices need to be interpreted with considerable local knowledge of factors that account for local conditions.

This information could be used as input to considerations about potential socioeconomic impacts of the proposed Basin Plan. For example, the index of community vulnerability may be useful for highlighting particular combinations of circumstances, such as high potential impact and low adaptive capacity communities, or other combinations that may need more immediate attention. The information could also be used as input to discussions about the nature and extent of the structural adjustment likely across the Basin.

Communicate vulnerability to decision-makers in local communities

The indices developed in this project could contribute to incorporating local community knowledge, aiding communication with local communities and facilitating adjustment discussions with communities.

A potential advantage of maps and indices at a local scale is that communities ‘see themselves in the data’. The maps and indices could therefore play a communication role to help local communities understand the factors that could contribute to their vulnerability. Displaying a familiar area on a map would help an audience understand the adaptive capacity index in comparison with their experience of the social circumstances in their local area. This could build trust in the index, in what the maps show at broader regional scales, and in the legitimacy of the policy implications that result. A related use would be to incorporate community knowledge about whether particular indicators better represent their circumstances and if any other community knowledge or data could be brought into the analysis. The key question would be: what do local communities think are the factors that contribute to their circumstances, compared with those generated in this project? The PCA could be revisited for individual towns or regions in a series of interactive workshops to derive a unique set of independent indicators relevant to specific communities.

Verification of the maps and indices at the community level could stimulate discussion of responses to changes and incorporate community knowledge to strengthen the index of community vulnerability. Qualitative input and feedback from Basin communities on factors contributing to their vulnerability is important for increasing transparency and legitimacy of any decisions.

Form part of a monitoring and evaluation strategy

The indices developed in this project could be used as a baseline of information to measure future socioeconomic changes and as part of a potential framework for measuring effects of the Basin Plan on communities.

The community vulnerability assessment in this project represents a single point in time and relies on 2006 ABS Census data. This could represent a baseline against which to measure future changes to socioeconomic conditions from SDL changes.

The indices and indicators could form the basis of a framework for understanding long-term trends in community vulnerability and adaptive capacity. For example, the measures could guide the social and economic monitoring and evaluation framework—using 2006 ABS Census data as the baseline followed up with 10-yearly reviews—to track the impact of the Basin Plan on the socioeconomic circumstances of communities.

This would require populating the community vulnerability index with census data as they are released (for example, 2011 with release in 2012). A comparison of, for example, community vulnerability at two points in time would involve several potential challenges that derive from the social and economic changes that may have occurred in intervening years. The first is that if the PCA were to be repeated using future census data, the constituent indicators that make up the community vulnerability index may have changed. The second is that the values of the data items that populate the indicators would change. These changes would lead to differences in the rankings of community vulnerability of areas relative to each other. A change in relative rankings would reflect changes that had occurred in Basin communities between censuses, due to factors such as ageing of the population or migration of youth from an area.

The indicators could also be populated with data from previous census years to determine how communities responded to significant changes in water availability that may have occurred over the past decade. However, the problem arises that the ABS periodically alters the CCD boundaries and this would affect the consistency of the analysis and necessitate additional concordance of boundaries.

Many changes occur in communities between censuses. This raises a question of whether dedicated socioeconomic data, specific to the MDBA, should be collected more frequently than ABS censuses. There are opportunities to assess the utility of using alternative data sources that may be collected more frequently, such as social and economic data that local government authorities, state governments and non-government organisations collect.

Appendix A: Indicator specifications

This appendix provides specifications for the data used to populate the indicators of community vulnerability and its constituents.

Table A1 Indicator definitions for subindex of exposure

Subindex	Indicator name	Indicator definition	Scale
Exposure 2800 gigalitre scenario, 05-06 ('main scenario')	Change in water availability due to 2800 gigalitre sustainable diversion limit reduction scenario	Assumptions: 2800 gigalitre sustainable diversion limit reduction scenario 2005–06 commodity prices after buybacks to date and infrastructure water savings with inter-regional water trade	WTM regions

WTM = Water Trade Model
Source: Economic modelling data, ABARES

Table A2 Indicator definitions for subindex of exposure—other scenarios

Subindex	Indicator name	Indicator definition	Scale
Exposure 2800 gigalitre scenario, 06-11	Change in water availability due to 2800 gigalitre sustainable diversion limit reduction scenario	Assumptions: 2800 gigalitre sustainable diversion limit reduction scenario average of 2006–07 to 2010–11 commodity prices after buybacks to date and infrastructure water savings with inter-regional water trade	WTM regions
Exposure 2400 gigalitre scenario, 06-11	Change in water availability due to 2400 gigalitre sustainable diversion limit reduction scenario	Assumptions: 2400 gigalitre sustainable diversion limit reduction scenario average of 2006–07 to 2010–11 commodity prices after buybacks to date and infrastructure water savings with inter-regional water trade	WTM regions
Exposure 3200 gigalitre scenario, 06-11	Change in water availability due to 3200 gigalitre sustainable diversion limit scenario	Assumptions: 3200 gigalitre sustainable diversion limit reduction scenario average of 2006–07 to 2010–11 commodity prices after buybacks to date and infrastructure water savings with inter-regional water trade	WTM regions

WTM = Water Trade Model
Source: Economic modelling data, ABARES

Table A3 Indicator definitions for subindex of sensitivity

Subindex	Indicator name	Indicator definition	Scale
SLA water dependence	SLA irrigation intensity	Megalitres of water applied to agriculture production divided by number of irrigated farm establishments	SLA **a**
	SLA irrigation incidence	% of agricultural businesses irrigating	SLA **b**
SLA local economy agricultural dependence	% work in agriculture	Ratio of total working in ANZSIC Division A Subgroup 01 (Agriculture) to total employed persons 15+	CCD **c**
	Ratio of agriculture and agri-industry employment to total employment	Ratio of persons employed in ANZSIC Division A Subgroup 01 (Agriculture) and Division C Subgroup 11 (Food Product Manufacturing) and 12 (Beverage and Tobacco Product Manufacturing) to total employment	CCD **c**
	Proportion of households with agricultural and/or agri-industry employment	Households with at least one member employed in ANZSIC Division A Subgroup 01 (Agriculture) and Division C Subgroup 11 (Food Product Manufacturing) and 12 (Beverage and Tobacco Product Manufacturing) as % of all households	CCD **c**
	Ratio of employment in agriculture to agri-industry employment	Ratio of persons employed in ANZSIC Division A Subgroup 01 (Agriculture) to persons employed in Division C Subgroup 11 (Food Product Manufacturing) and 12 (Beverage and Tobacco Product Manufacturing)	CCD **c**

ANZSIC = Australian and New Zealand Standard Industrial Classification; CCD = Census Collection District; SLA = Statistical Local Area
Sources: **a** 2000–01 customised data, ABS (estimation methodology is available from ABS 2006); **b** 2001 ABS Agricultural Census; **c** 2006 ABS Census of Population and Housing

Table A4 Indicator definitions for subindex of adaptive capacity

Subindex	Subindex	Indicator	Data items	Scale
Adaptive capacity—human capital	Education advantage	% graduates	Total bachelor degree + total graduate diploma/certificate + total postgraduate degree / total persons >15 years	CCD
		% employed in public sector	Total employed in public admin sector / total employed persons >15 years	CCD
		% over 15 years old with no qualifications	% Of persons >15 years with no qualifications: certificate, diploma, undergraduate degree, postgraduate degree	CCD
		Median weekly rent as a fraction of the Australian median	Median weekly rent as proportion of the 2006 Australian median ($190)	CCD
		Median household income as fraction of Australian median	Median household income as proportion of the 2006 Australian median ($1026.80)	CCD
		Income/mortgage differential	(Median household weekly income * 52 / 12) – median monthly housing loan repayment	CCD
	Socioeconomic advantage	% one-parent	Total single parent families/total families	CCD
		% couple families	Total couples without children + total couples with children / total families	CCD
		% single parent with children <15 years old	Total single parent families with children <15 years old / total families	CCD
		Total unemployment	Total unemployed / total labour force	CCD
	Age advantage	% population >65 years old	Total persons aged 65 years and over / total persons	CCD
		% lone households >65 years old	Total lone householders aged >65 / total persons in occupied private dwellings	CCD
		Average no. persons per household	Average household size	CCD
		% lone person households	Total one persons households / total occupied dwellings	CCD
	Mobility advantage	% dwellings rented	Rented properties / total dwelling structures	CCD
		% different address to 1 year ago	Lived at different address 1 year ago / lived at different address 1 year ago + lived at same address 1 year ago	CCD
Adaptive capacity—social capital	Proportion of females in non-routine occupations	Women in non-routine occupations	Female managers + female professionals + female technicians + female community and personal / total female employed persons	CCD
	Participation in voluntary groups	% voluntary work	Total volunteers / total persons >15 years	CCD
Adaptive capacity—local economic diversity	Economic diversity index	Economic diversity index	Diversity of local economy relative to Australian/MDB economy, calculated using employment by sector data	CCD

CCD = Census Collection District.

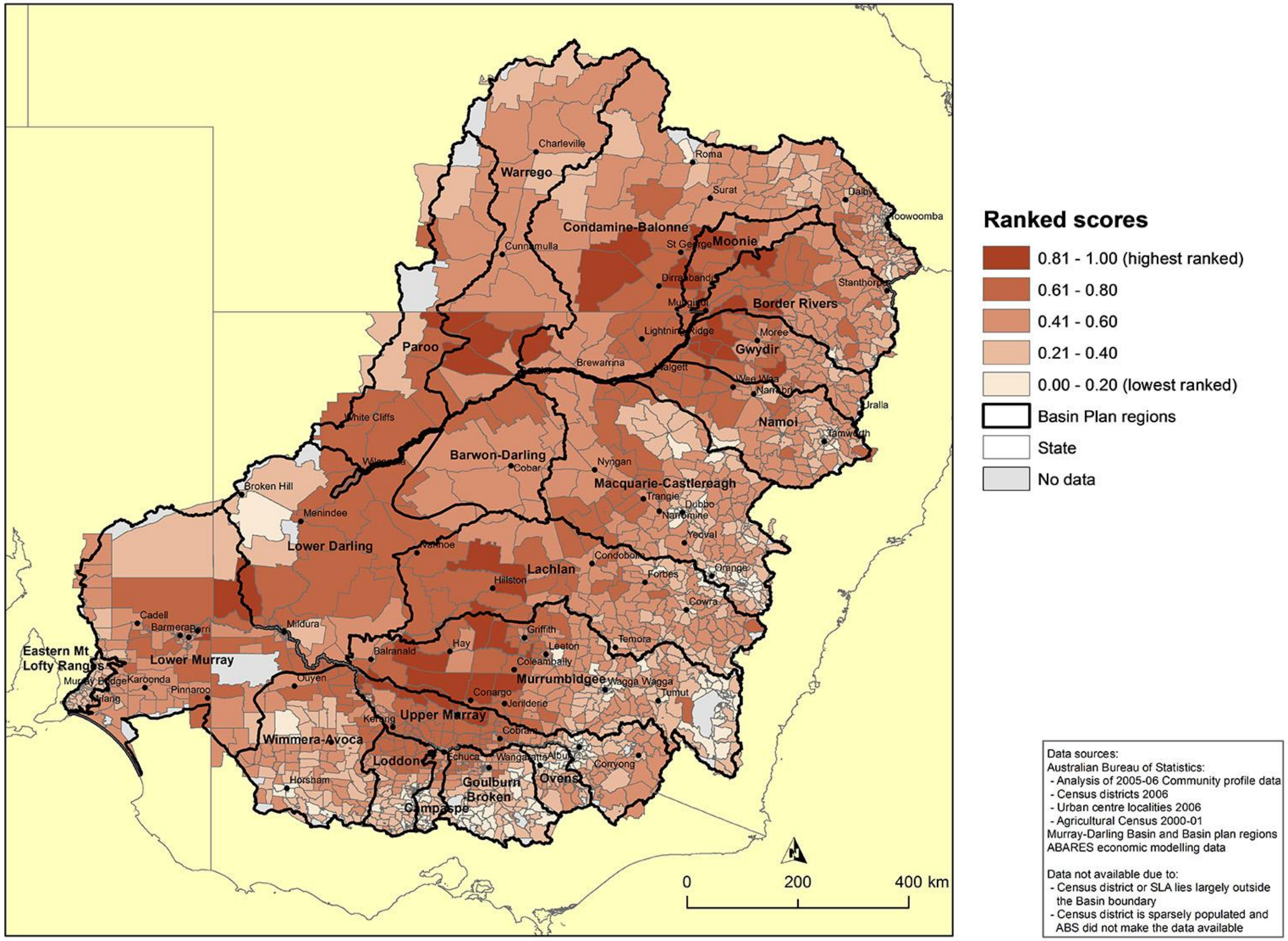
Note: Symbols in column 4 indicate a formula is used. Methodology for calculating Economic Diversity Index developed by Frank Hachman, Bureau of Business and Economic Research, Utah (Hachman 1995).

Source: 2006 ABS Census of Population and Housing

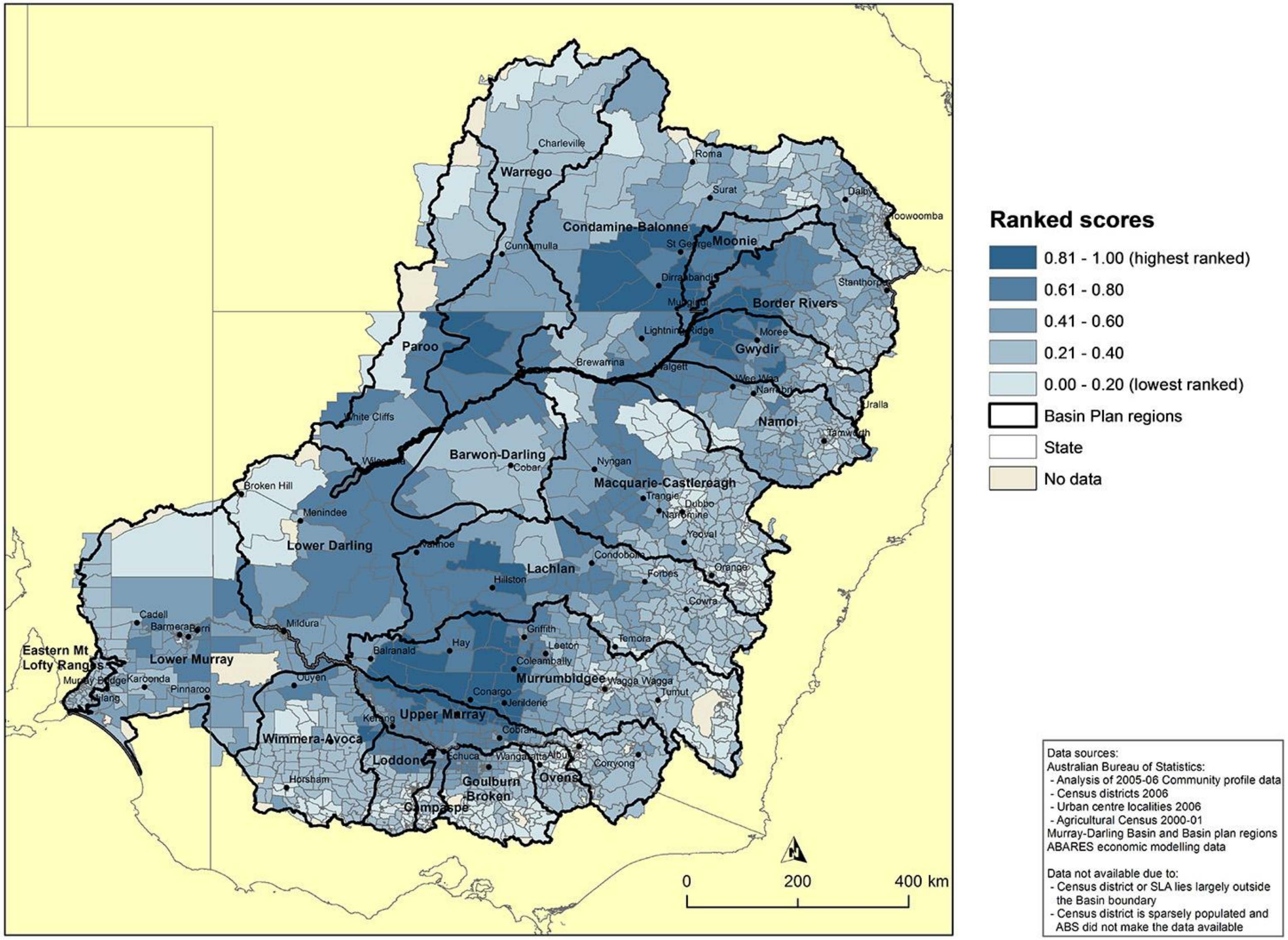
Appendix B: Indices mapped at the Basin scale

This appendix contains mapped outputs from the analysis of community vulnerability to changes in access to water across the Murray–Darling Basin.

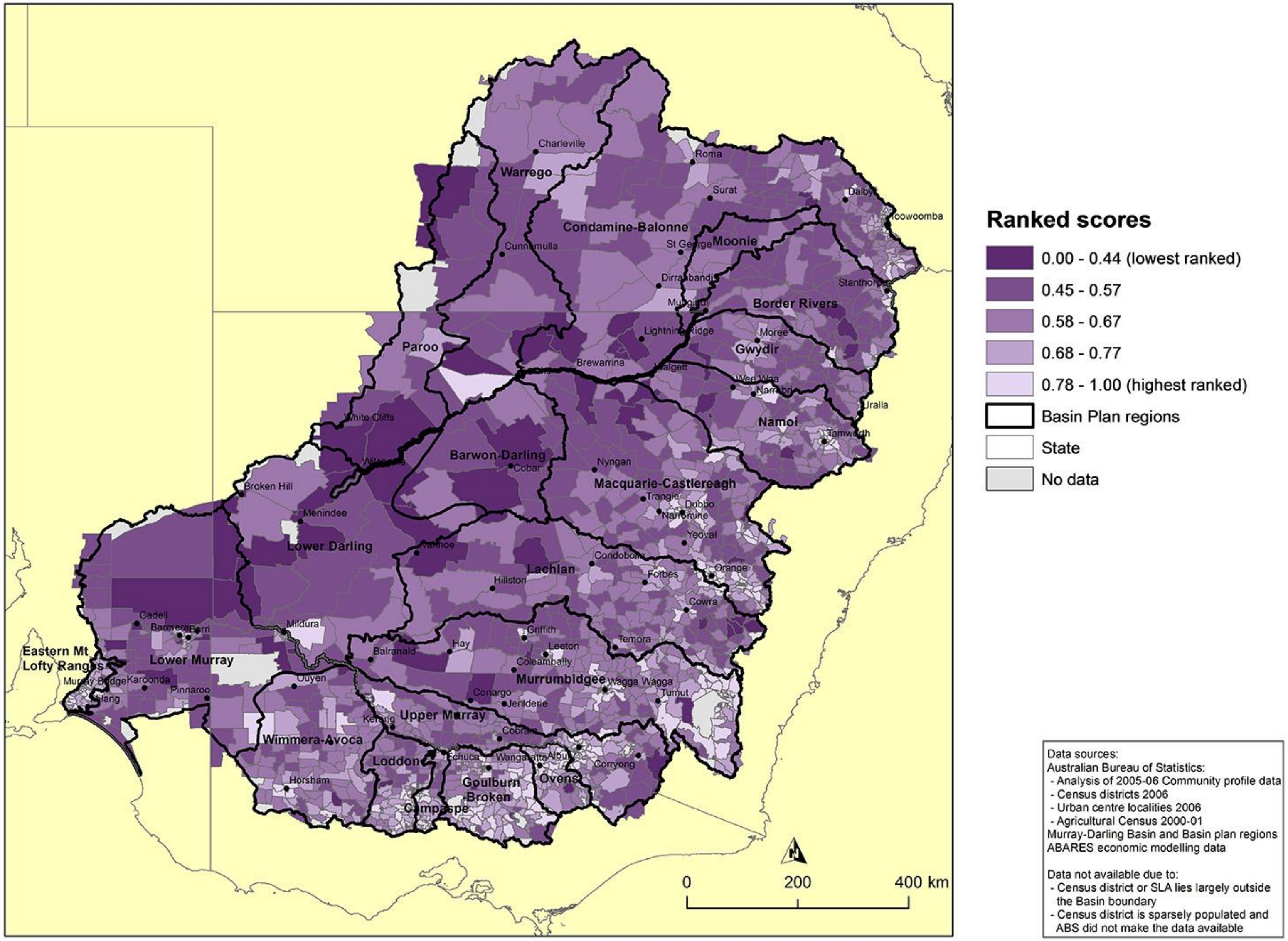
Map B1 Index of relative community vulnerability to changes in water availability before exposure to the proposed Basin Plan



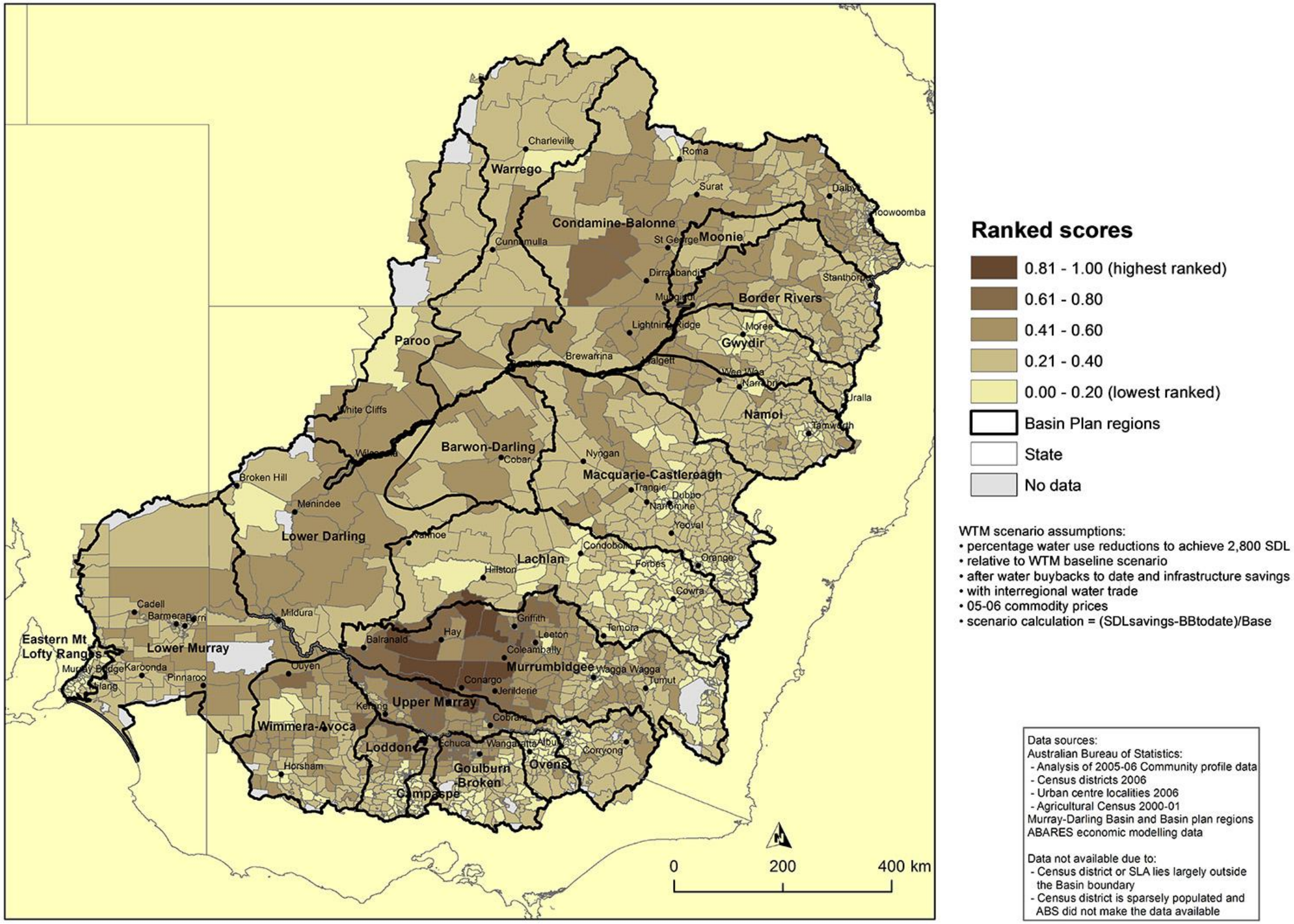
Map B2 Subindex of relative sensitivity to reductions in water availability for the Murray–Darling Basin



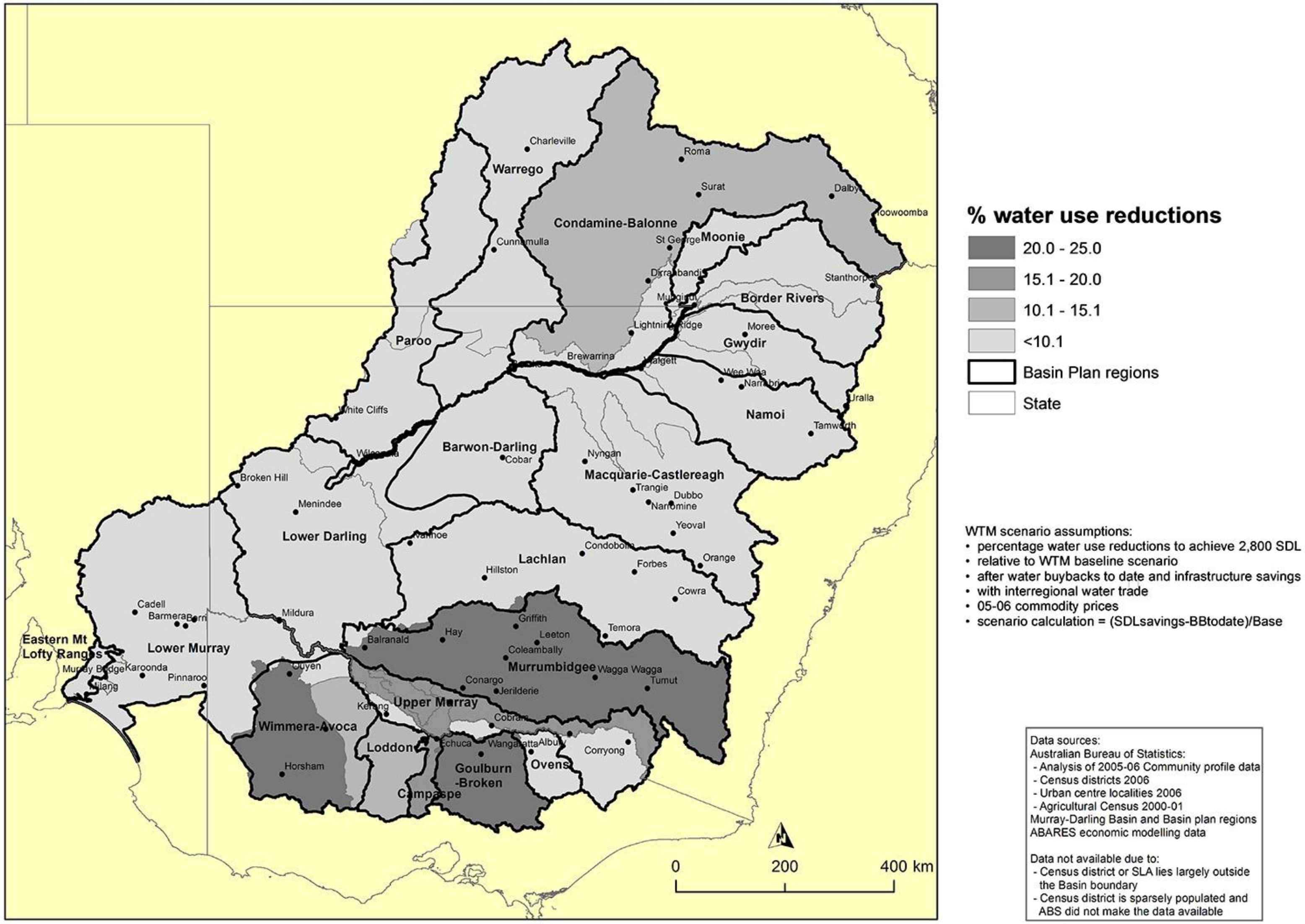
Map B3 Subindex of relative adaptive capacity for the Murray–Darling Basin



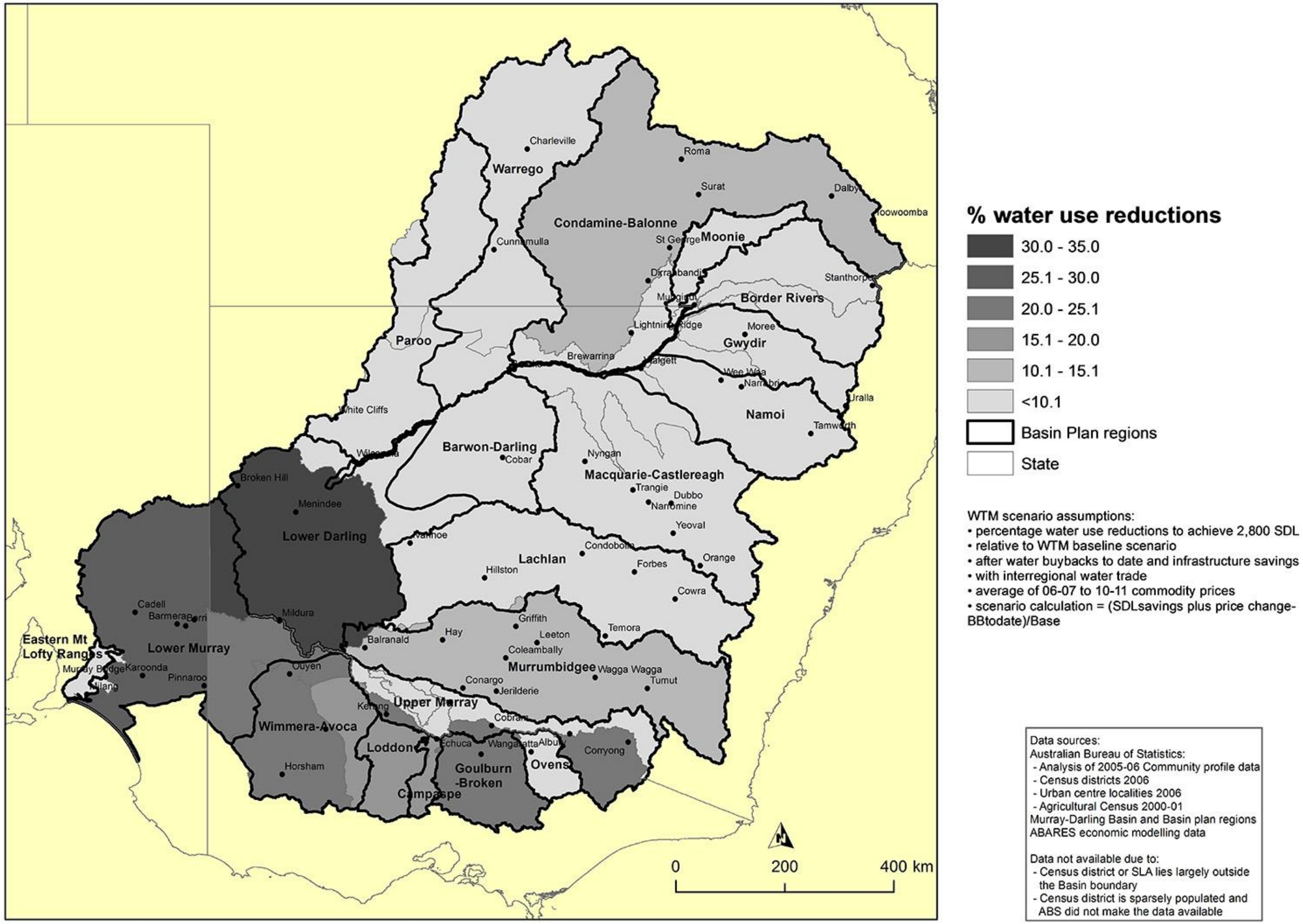
Map B4 Index of relative community vulnerability across the Murray–Darling Basin for a 2800 gigalitre water recovery scenario



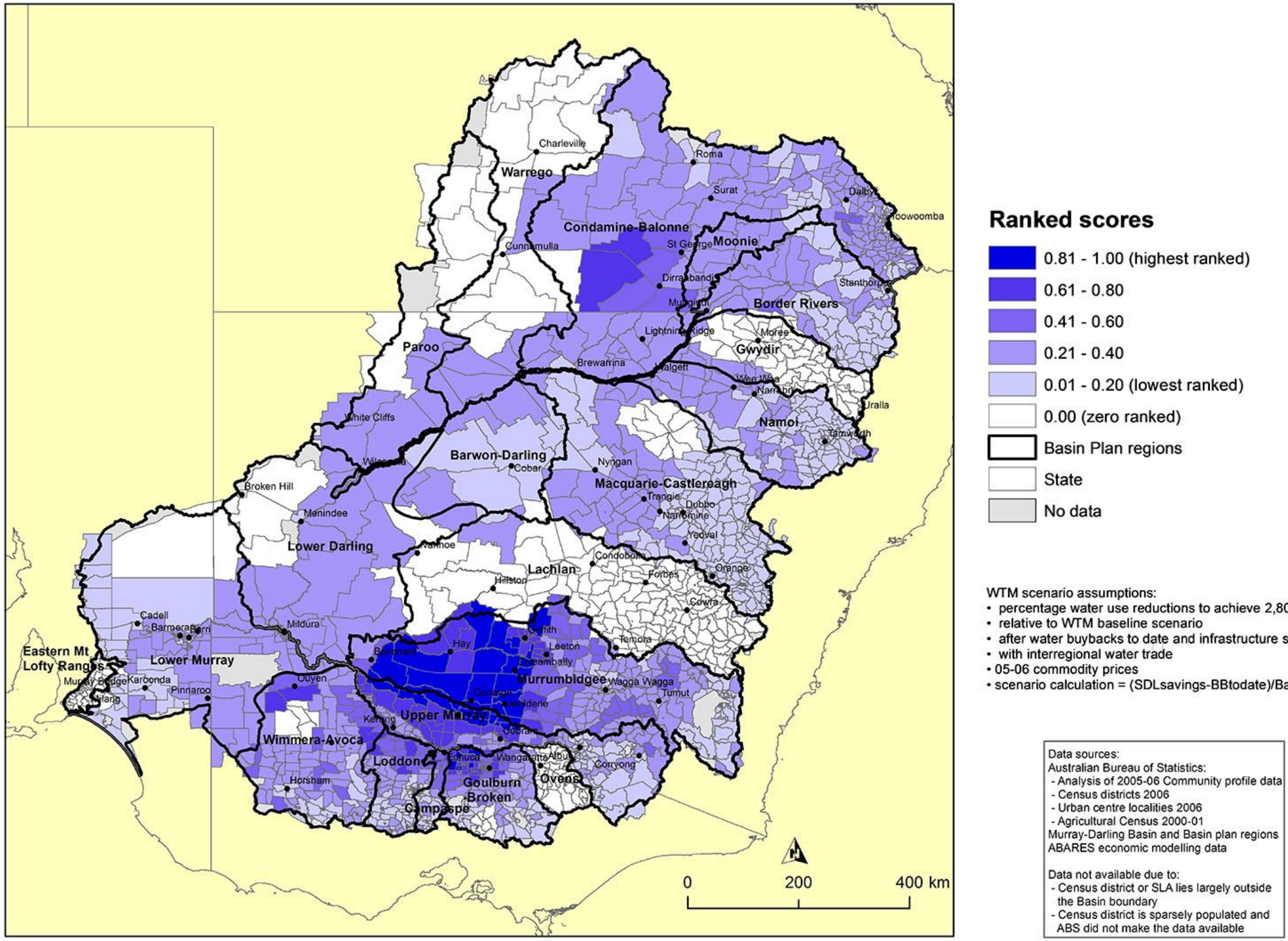
Map B5 Subindex of exposure to 2800 gigalitre sustainable diversion limit, percentage water use reductions required after modelled water trade for Basin Plan Regions, using 2005–06 commodity prices



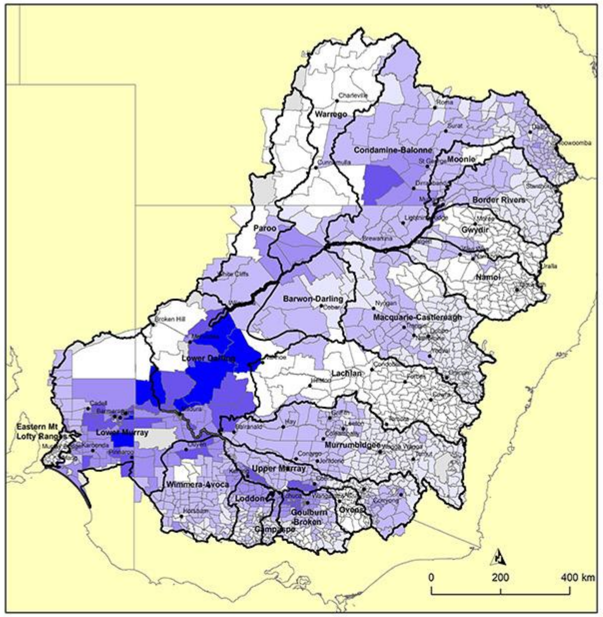
Map B6 Subindex of exposure to 2800 gigalitre sustainable diversion limit, percentage water use reductions needed after modelled water trade for Basin Plan Regions, using the average of 2006–07 to 2010–11 commodity prices



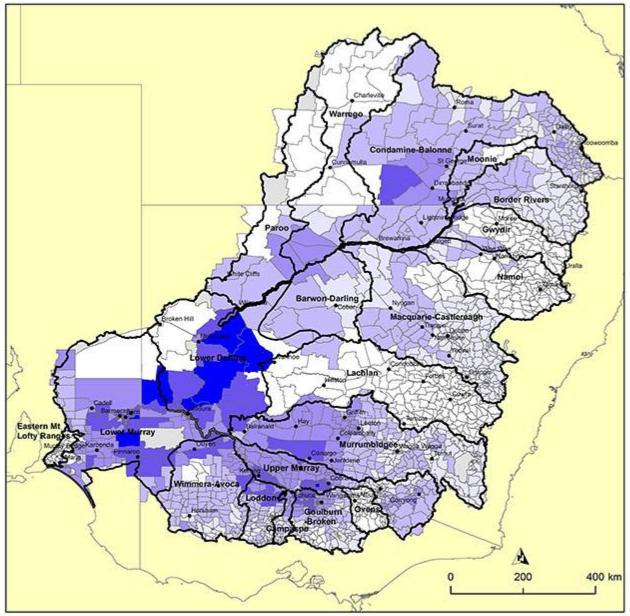
Map B7 Subindex of relative potential impacts for 2800 gigalitre water recovery scenario across Basin Plan Regions using 2005–06 commodity prices



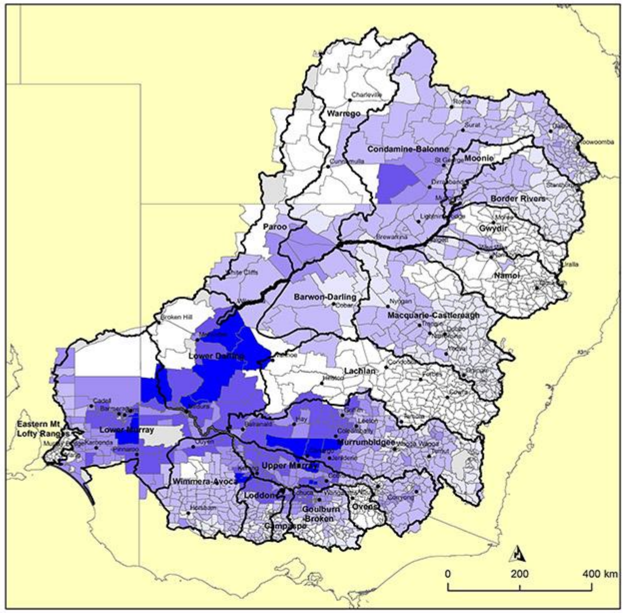
Map B8 Relative potential impacts of three water recovery scenarios (2400, 2800 and 3200 gigalitre) across Basin Plan regions using the average of 2006–07 to 2010–11 commodity prices



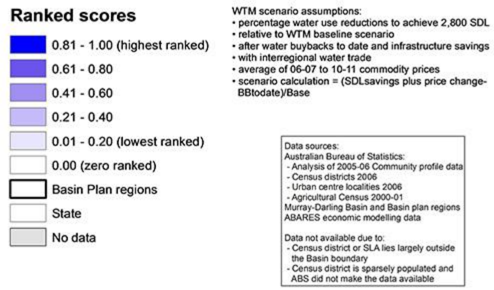
2400 gigalitre water recovery scenario



2800 gigalitre water recovery scenario

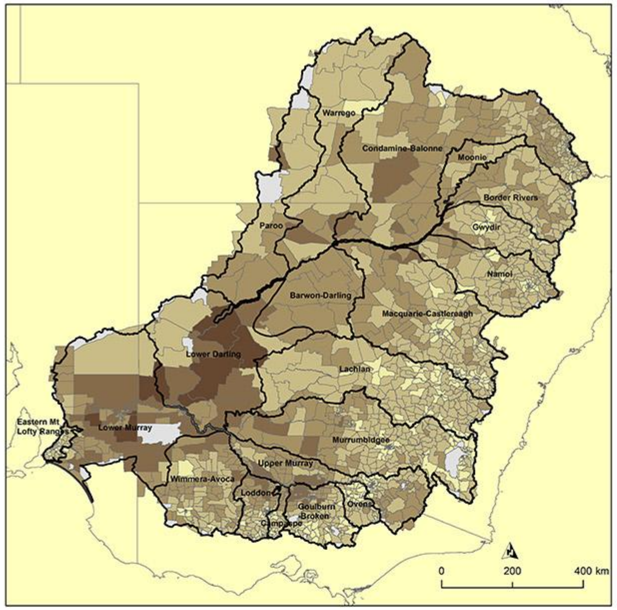


3200 gigalitre water recovery scenario

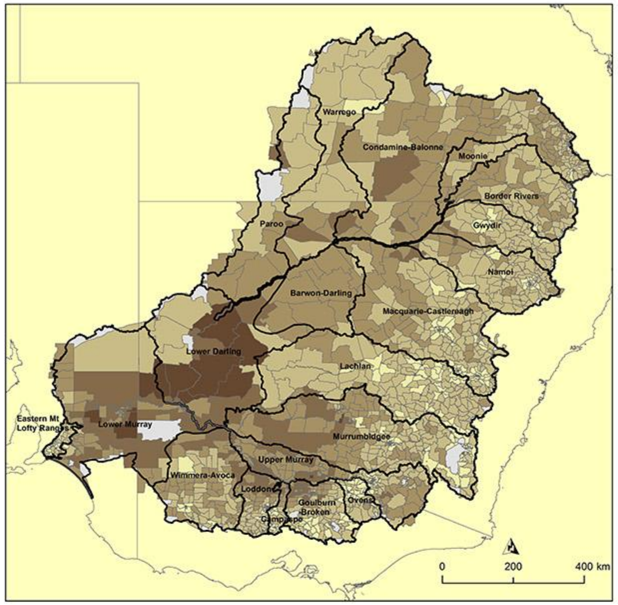


Note: These maps use global-scaled rankings so the relative potential impact scores can be compared across different water recovery scenarios.
Data sources: Australian Bureau of Statistics: Analysis of 2005–06 Community profile data; Census districts 2006; Urban centre localities 2006; Agricultural Census 2000–01; Murray–Darling Basin and Basin plan regions; ABARES economic modelling data.
Data not available due to: Census district or SLA lies largely outside the Basin boundary; Census district is sparsely populated and ABS did not make data available

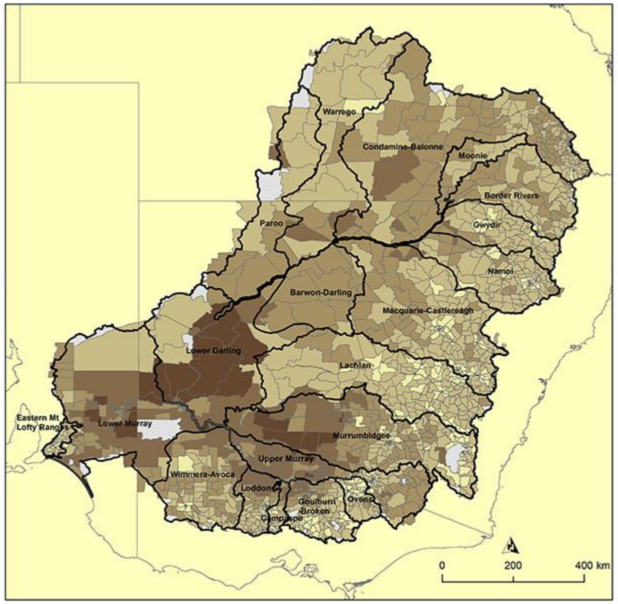
Map B9 Relative community vulnerability after exposure to three water recovery scenarios (2400, 2800 and 3200 gigalitre) across Basin Plan regions using the average of 2006–07 to 2010–11 commodity prices



2400 gigalitre water recovery scenario

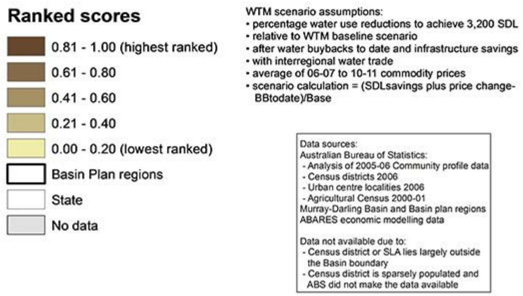


2800 gigalitre water recovery scenario

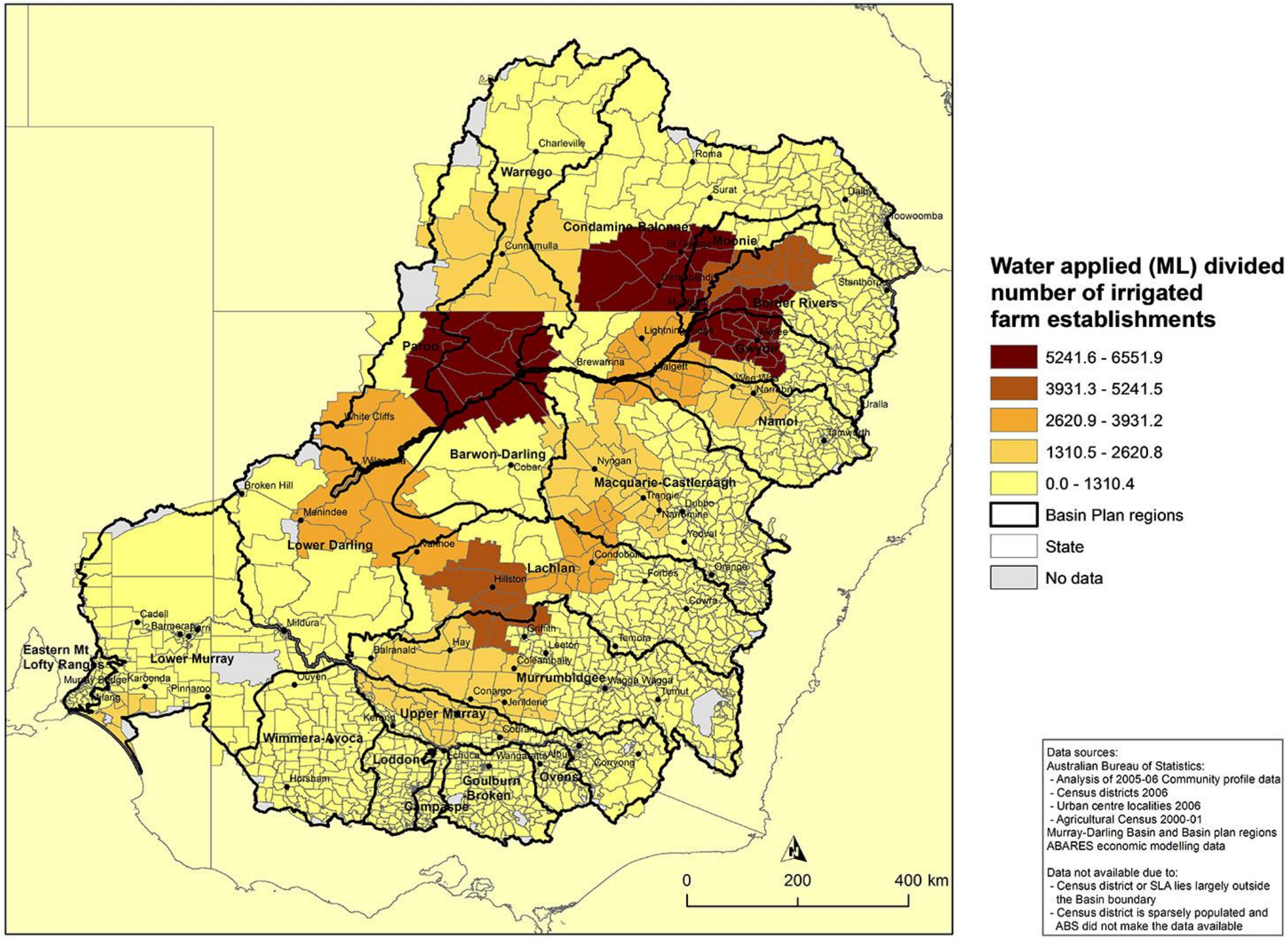


3200 gigalitre water recovery scenario

Note: these maps use global scaled rankings so the relative vulnerability after exposure scores can be compared across different water recovery scenarios.
Data sources: Australian Bureau of Statistics: Analysis of 2005–06 Community profile data; Census districts 2006; Urban centre localities 2006; Agricultural Census 2000–01; Murray-Darling Basin and Basin plan regions; ABARES economic modelling data.
Data not available due to: Census district or SLA lies largely outside the Basin boundary; Census district is sparsely populated and ABS did not make the data available.

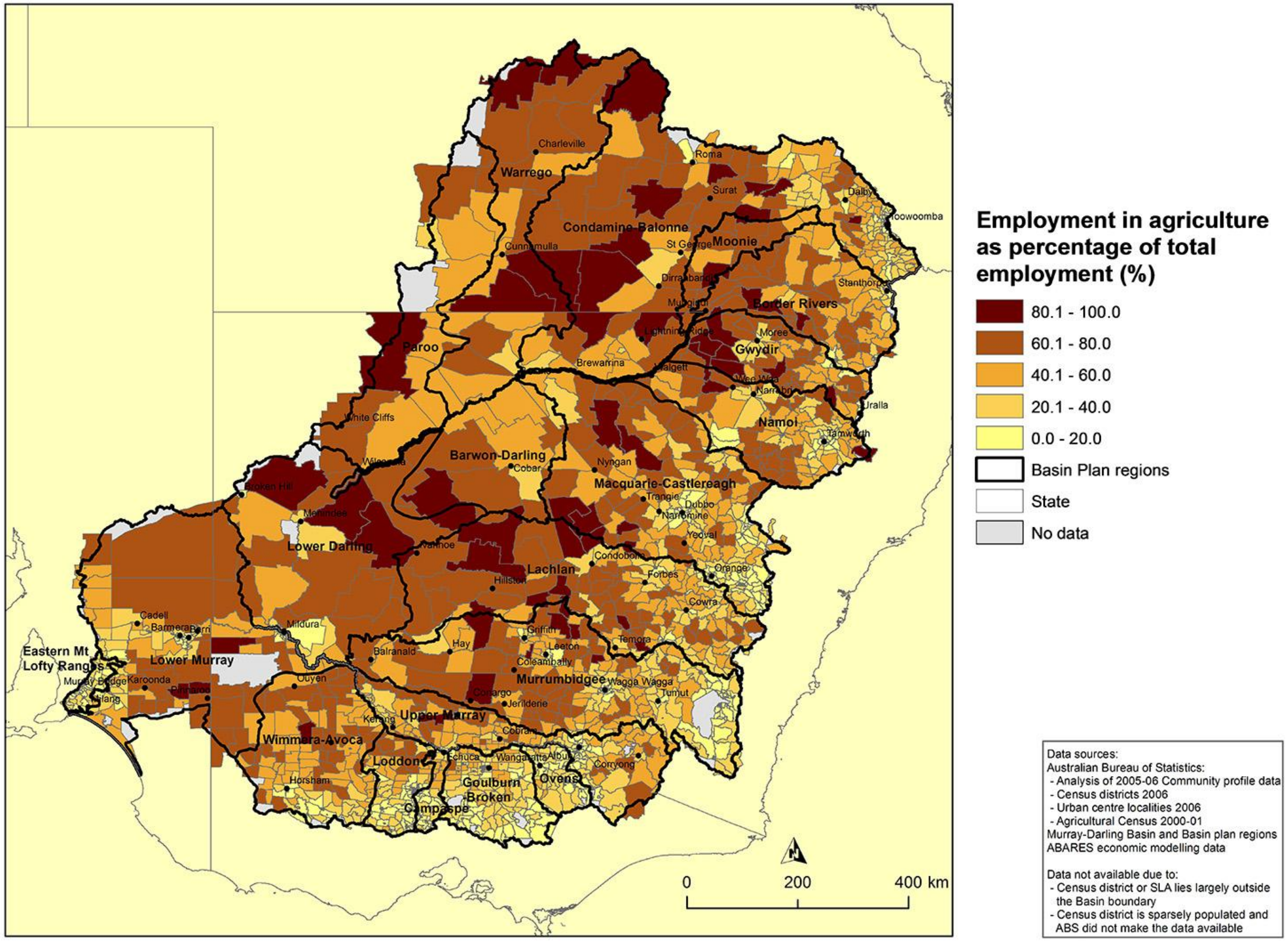


Map B10 Indicator of SLA irrigation intensity, water applied (ML) divided by number of irrigated farm establishments across Basin Plan regions



Data source: ABS 2000–01 custom data

Map B11 Employment in agriculture as a percentage of total employment by CCD in the Murray–Darling Basin



Data source: ABS 2006 data

Appendix C: Technical development of indicators

Data quality checks

Extreme values and distributions

The extreme values of all indicators were checked against corresponding data items to ensure miscalculations had not occurred. All extreme values were found to have plausible explanations; for example, high values of public sector employment occurred where CCDs were largely taken up by military establishments, and high values of the proportion of over 65s occurred where CCDs contained large retirement villages.

The histograms of indicators used in the PCA were also checked for excessive departures from a normal distribution. The distributions of SLA irrigation incidence and SLA irrigation intensity, at SLA level, were found to be too highly skewed and disjointed to consider including in PCA. Given there are only two available indicators for the SLA water dependence and one indicator for exposure, PCA is not required to choose a smaller set of composite indicators for those. All other indicator distributions were considered suitable for inclusion in PCA.

Missing values

A number of indicators, by their nature, were prone to creating a considerable number of missing values. For example, unemployment in the 15 to 24 year age group is a missing value for those CCDs where there were no people in this age group. Median weekly rent as a fraction of the Australian median is a missing value for those CCDs where there were no households in rented housing. If mapping of a vulnerability index across the Basin had been restricted to only those CCDs with non-missing values for all indicators, around half of CCDs would be omitted from the map.

Therefore, it was preferable to introduce some missing value substitutions where this could be done without compromising the validity of the vulnerability index. The substitutions made are listed in Table C, together with the justification for the substitution.

The main reasons for missing values were the CCD or SLA lies largely outside the Basin boundary, or CCDs are sparsely populated and the ABS did not make the data available.

While every effort was made with the substitutions and imputations described in Table C1 to provide plausible estimates where data is missing, several sources of uncertainty remain that may affect these estimates.

In the initial ABARE-BRS (2010) project, missing value substitutions were made for missing farm level water use data from the 2005–06 ABS Water Account. The ABS 2000–01 water use data used in this revised project had fewer missing data. This could be because more recorded irrigation activity was occurring in the Basin in the 2000–01 Agricultural Census year. In addition, ABS used a regional estimation methodology to estimate the farm based data—that is, water applied (in megalitres) at the farm level. Because of the methodology ABS used, the resulting dataset for water applied appears to have no missing data due to errors or reporting issues of this sort.

However, regional water use estimates are still subject to error. The regional water use estimation depends mainly on state level water use and cropping area data. The ABS in its methodology paper, states that most published state level estimates of the various commodities have relative standard errors of less than 5 per cent. However, for some states with limited production of certain commodities, relative standard errors for those commodities are greater than 25 per cent (ABS 2006). Another source of error, perhaps the most significant, is that the method does not account for region specific water application rates to crops. It assumes the rate of water use per hectare for any given crop type is the same for each SLA within a given state despite likely variations in climate, soil type and irrigation technology.

High values in a number of census indicators for Canberra, relative to the rest of the Basin, mean the process of scaling and addition of subindicators to produce the vulnerability index is likely to compress the index values for the rest of the Basin. As this can obscure the relativities in the indices in the rest of the Basin, Canberra CCDs were removed from the calculation, while retaining the standardisation used for the whole of the Basin. Removing this subset of CCDs slightly changes the rankings of CCDs compared with rankings generated in the initial vulnerability index reported by ABARE-BRS (2010). However, Canberra CCDs were retained in the PCA, so the analysis would produce a generic set of subindices that reflected the relationships between census variables for the whole Basin.

Table C1 Missing value substitutions and justification

Indicator	Frequency of missing value	Substitution	Justification
% unemployment in 15–24 age group	3.6% of CCDs had a zero workforce aged 15–24	Mean	It was assumed that, had there been people in this age group in the CCD, unemployment would be the same as the mean CCDs where there were people in this age group.
Median weekly rent as a fraction of the Australian median	10.4% of CCDs had no households in rented accommodation	0	This indicator is a proxy for disposable income. From this perspective, not renting at all is equivalent to renting for zero rent.
Median monthly housing loan repayment as a fraction of the Australian median	2.2% of CCDs had no households making mortgage repayments	0	This indicator is a proxy for disposable income. From this perspective, owning ones home is equivalent to having a home loan with a zero mortgage repayment.

CCD = Census Collection District.

Principal components analysis

Principal components analysis (PCA) is a statistical technique applied to a set of variables to discover which variables form coherent subsets, which are correlated with one another but largely independent of other subsets of variables (Tabachnick & Fidell 2007). The technique can summarise a large number of original variables into a smaller set of components, which are thought to reflect the underlying processes affecting the concepts of interest.

This project used PCA where a large number of potential indicators could be regarded as having an influence on the main conceptual components of vulnerability as shown in Figure 2. Of the list shown in Table 2, some 39 indicators could be regarded as having an influence on the level of human capital, and five upon the level of agricultural dependence. PCA was used with both sets of indicators.

In all cases, PCA was carried out on the correlation matrix, with orthogonal varimax rotation to aid interpretation of the components. The software used was SPSS.

An initial analysis was undertaken with the number of components set by the criterion that their eigenvalues be greater than one. The number of components to interpret was chosen by inspection of the scree plot, the interpretability of the components, and the presence of components with loading on only a small number of variables. Where these criteria permitted the possibility of several different solutions, each with a different number of components, each solution was examined and the solution providing the most readily interpreted components chosen. A conservative loading threshold of 0.7 was set for interpretation of components.

Multivariate outliers

All principal components analyses carried out were preceded by identification and removal of CCDs that were multivariate outliers, using the criterion: Mahalanobis distance > χ^2 for p=0.001, d.f. = number of variables (Tabachnick & Fidell 2007). Having used PCA to identify groups of relatively uncorrelated indicators—that is, subindices—the outlier CCDs were returned to the dataset for calculating the scores of individual CCDs on these subindices.

PCA on human capital indicators

Following the procedure and criteria described above, a four-component solution was chosen. This suggested that a little less than 63 per cent of the variance in the 39 census indicators was represented in the first four components (Table C).

Table C2 Variance and cumulative variance explained by components

Component	% of variance	Cumulative %
1	31.329	31.329
2	19.431	50.761
3	7.608	58.368
4	4.603	62.971

Using the rotated component matrix (Table C), these components were interpreted as educational advantage, socioeconomic advantage, age advantage and mobility advantage. A conservative loading threshold of 0.7 was set for interpretation of components (**above 0.7 shown in bold in Table C**). To make the pattern of loadings clear, variables with loadings between 0.7 and –0.7 on all components were omitted. Cross-loadings between 0.1 and –0.1 are shown as a blank cell for the same reason.

Table C3 Rotated component matrix for human capital census indicators

	Component loadings			
	Educational advantage	Socio-economic advantage (reversed)**a**	Age advantage (reversed)**a**	Mobility advantage
	1	2	3	4
% graduates	**0.842**	–0.264		0.103
Median weekly rent as a fraction of the Australian median	**0.835**	0.296		
% employed in the public sector	**0.828**			
% over 15 with no qualifications	**–0.794**	0.319	0.195	
Median household income as % of the Australian median	**0.783**	–0.248	–0.412	–0.204
Monthly income/mortgage differential	**0.749**	–0.214	–0.403	–0.248
% single parent families		**0.833**	0.111	0.331
% couple families		**–0.818**	–0.117	–0.369
% single parent families with children under 15		**0.816**		0.283
Unemployment rate (%)	–0.222	**0.752**	0.144	
% aged 65+	–0.175		**0.902**	
% lone households 65+	–0.119	0.194	**0.826**	0.209
Average household size	0.116	–0.168	**–0.739**	–0.493
% lone person households	–0.127	0.256	**0.703**	0.528
% dwellings rented		0.387		**0.777**
% living at a different address 1 year ago	0.237	0.287		**0.716**

Note: **a** Reversals—Census indicators were reversed for these components when calculating adaptive capacity. The reason for this is so that positive attributes go in the same direction as that component of advantage (for example, a higher proportion of couple families actually contributes to stronger socioeconomic advantage, instead of weaker as implied by a negative sign in component loading).

PCA on agricultural dependence indicators

PCA applied to the five agricultural dependence indicators suggested a one-component solution, with the component representing 84 per cent of the variance in the five indicators. The four indicators loading on the first component all had loadings greater than 0.78, which suggested that agricultural dependence could be represented with a simple unweighted sum of these four indicators. The four indicators were:

- percentage employed in agriculture
- ratio of agriculture and agri-industry employment to total employment
- agricultural and downstream agri-industries households
- ratio of employment in agriculture to downstream agri-industries.

Reduced set of indicators

The outcome from the PCA is a reduced set of indicators which provide a means of placing numerical estimates on the concepts shown in Figure 2. The reduced set of indicators is summarised in Table A3 and Table A4.

Calculating subindices and indices

The indices and subindices were calculated consistently, with the relationships between the concepts and their application shown in Figure 2. At the base of the hierarchy of calculations is calculation of educational, socioeconomic, age and mobility advantage from their constituent census indicators as shown in Table A4. This was done by the method of improper component scores, which involved multiplying the standardised values of each constituent census indicator by the component score coefficients yielded by the PCA, and adding up the resulting products. Values of the census indicators were standardised to a range of zero to one, instead of the usual z-scores. In a test of using both methods of standardisation of census indicator values, it was found the resultant improper component scores were highly correlated. Improper component scores (based only on the census indicators used to interpret components) were used in preference to proper component scores which use all the census indicators, so the scores were a better measure of the concept represented by each component. For some components, it was necessary to take the negative value of the component score coefficients to ensure the scores ran in the same direction as the concept they represented (see Table C note).

This method of improper component scores was used to calculate scores for each CCD for the educational advantage, socioeconomic advantage, age advantage and mobility advantage subindices. These scores were then added, unweighted, to form the human capital subindex.

- The exposure subindex is a calculated score based on the proportion of reduced irrigation water availability due to implementation of sustainable diversion limits.
- The sensitivity subindex was calculated as the unweighted sum of the local economy agricultural dependence and the SLA water dependence.
  - The agricultural dependence subindex was calculated as the unweighted sum of the standardised values of the census indicators listed in Table A4.
  - The SLA water dependence subindex was calculated as the unweighted sum of the standardised values of SLA irrigation incidence and SLA irrigation intensity.
- The potential impact is a subindex made up of standardised exposure multiplied by standardised sensitivity scores for each CCD in the MDB.
- The adaptive capacity subindex was calculated as the unweighted sum of the standardised values of the three subindices listed in Table A4, that is, the human capital, social capital and economic diversity subindices.
  - The human capital subindex was calculated by adding the unweighted standardised scores for the indicators (listed in Table A4) representing the subindices of education advantage, socioeconomic advantage, age advantage and mobility advantage.
  - The social capital subindex was calculated by adding the unweighted standardised scores for percentage of persons in voluntary work and percentage of female workforce in non-routine occupations.
  - The Economic Diversity Index was calculated from ABS employment by industry sector data using the method described by Moore (2001).
- The community vulnerability index was calculated by subtracting the standardised value of the adaptive capacity subindex from the standardised value of the potential impact subindex. The relationship between the measures is expressed as Potential Impact = Exposure x Sensitivity; Community vulnerability = Potential Impact – Adaptive Capacity.

In constructing the vulnerability index, when exposure or sensitivity was zero, it means there will, theoretically, be little or no potential impact. The reasons for this could include:

- no employment in agriculture and downstream processing industries was recorded in the area according to the ABS Population and Housing Census 2006

- no irrigation activity was recorded in the area in the ABS Agricultural Census 2000–01
- no further reduction will be made (or there will be an increase) in the availability of water for consumptive purposes under the Basin Plan in the region, according to assumptions made in the WTM.

Several areas in the Basin met one or more of these criteria, particularly in drier areas where hardly any irrigated agricultural activity was recorded. For example, the Warrego, Paroo, Lachlan, Gwydir, far western Murray and far western Lower Darling Basin Plan Regions are 'zero ranked' in the potential impact subindex for the 2800 gigalitre SDL reduction scenario (Map B7). A multiplication was then used to combine the exposure scores with sensitivity scores so that if either of these standardised scores was equivalent to zero, the resulting potential impact score would be zero. For the purposes of mapping the potential impact subindex, areas with zero ranked scores were depicted as 'white' areas in the maps. The assumption being that these areas are either not dependent on irrigated agriculture and/or are unlikely to be further adversely affected by any change in the availability of water for agriculture under the Plan.

Other ways of combining the data could produce different results. To investigate this, the authors explored the effect on the final community vulnerability index of adding (rather than multiplying) the exposure and sensitivity subindices. The effect was generally small and areas of relatively higher vulnerability remained similar using both methods of combining the subindices. This suggests the combination of the indicators is fairly robust.

The resulting index of community vulnerability provides a distribution of ranked scores between zero and one where an index score of one indicates the highest rank of vulnerability and an index score of zero indicates the lowest rank of vulnerability.

This hierarchy of calculations reflects the relationships shown in Figure 2.

Weightings and class intervals

A key consideration in developing a composite index is the relative weight of each component or indicator that contributes to the index (Herreria et al. 2008). Weightings on indicators reflect assumptions about the relative importance of underlying factors that contribute to a community's vulnerability. For this project neutral weightings (that is, of 1.0) were used and each indicator value was standardised to a value between zero and one based on the distribution of scores for all SLAs of interest in the Murray–Darling Basin.

The definition of the class intervals used to visualise the rankings on the maps is a subjective choice, based on the questions to be investigated or the focus of interest. Typically, in the community vulnerability project, five equal class intervals were used as a default method of defining intervals for all maps, except the adaptive capacity map which used the Jenks natural break classification method to define the classes. This was used, in consultation with the MDBA, because it enabled better visualisation of the 'tail' of the distribution, to better identify areas in the MDB exhibiting relatively low levels of adaptive capacity. More information about the Jenks natural break classification method is in Chapter 4 'Subindex of relative adaptive capacity'.

Populating the exposure measure

The conceptual framework in Figure 2 contains a measure of exposure, which is the amount of external stress or change a community is likely to be affected by; for example, from a reduction in irrigation water availability. The exposure measure in this case represents the shock or change in water availability due to the proposed Basin Plan that will affect Basin communities differently depending on the circumstances of the region in which they are located. The most appropriate measure of exposure to a change was thought to be the remaining water that would be needed for communities to reach a specified SDL, taking into account expected water savings from government infrastructure investment, the effects of water trade, and adaptations that have already taken place in the catchment, including water buybacks. This represents a realistic scenario for exposure to changes associated with the proposed Basin Plan expected to occur after 2011. Data from economic modelling analyses representing a decline in water use, by region, was included as the exposure subindex in the assessment of vulnerability. All estimates were provided for a long-term average year (for irrigation water use).

The main water recovery scenario used for the exposure measure in this project was the 2800 gigalitre SDL reduction scenario. The data to populate the exposure measure corresponding to the specifications were sourced from the WTM—a catchment-based economic model that estimates the direct hydrologic and economic effects on irrigated agriculture of proposed Basin Plan SDL reductions. The modelled estimates used represented the remaining contribution of each catchment to meet the overall Basin SDL reduction relative to an assumed baseline. This corresponds with Scenario 3 described in the ABARES economic modelling report (ABARES 2011, p.29). This scenario assumes:

- a 2800 gigalitre SDL reduction in water availability for consumptive use
- a composite baseline that reflects long-term average water availability
- ongoing Australian Government investment in water saving infrastructure
- water entitlement buybacks that have occurred
- inter-regional water trade is occurring
- 2005–06 commodity prices.

The WTM composite baseline reflects long-term average water availability and is constructed from 2000–01 and 2005–06 ABS data on water use, land use, and gross value of irrigated agricultural production by irrigated activity and region. For more information on this baseline, see ABARES (2011).

The WTM figures used to populate the exposure measure in this project therefore represent the remaining exposure after taking into account adaptations resulting from water government has already bought, and infrastructure savings and the effects of inter-regional water trade. For a full explanation of this modelled SDL reduction scenario and the assumptions involved, see ABARES (ABARES 2011, p.32, Scenario 3).

Assumptions relevant to this project are summarised in the indicator specifications in Table A1.

MDBA also asked ABARES to analyse community vulnerability if several alternative Basin Plan water reduction scenarios were assumed. The scenarios of interest were for three SDL reductions (2400, 2800 and 3200 gigalitres) using post-2005–06 commodity prices (average of 2006–07 to 2010–11 prices). The data used in these scenarios were sourced from additional model runs by ABARES (known as 'sensitivity analysis using updated prices'; ABARES 2011:75). Regional water availability change data from these scenarios were used to populate the exposure subindex. This scenario has similar assumptions as the main scenario described above, but with updated commodity prices, using the average of 2006–07 to 2010–11 prices. For a full explanation of these modelled SDL reduction scenarios and commodity price assumptions, see ABARES (2011, p.75).

The assumptions relevant to this project for data sourced from ABARES economic analyses for the alternative scenarios are summarised in Table A2.

Mapped results for potential impact and community vulnerability using alternative scenarios are reported in 'Other potential impact scenarios' and 'Other vulnerability scenarios' in Chapter 4 of this report.

Global scaling of ranked scores

A technique called global scaling was used to enable comparison of ranked scores across different SDL reduction scenarios. This was a useful interpretive tool for the maps of potential impact and community vulnerability (after exposure) in which several water recovery scenarios were investigated. Global scaling was undertaken for potential impact (Map B8) and community vulnerability (after exposure) (Map B9) under three water recovery scenarios: 2400, 2800 and 3200 gigalitres.

The approach used to rescale the ranked scores was to use the maximum and minimum (range) of values from the 3200 gigalitre scenario in the standardisation process rather than the actual maximum and minimum levels. The exposure index was the only change in input data between the scenarios and therefore this produces consistent indices across the three scenarios.

Without the application of global scaling, the rank of any single CCD is only relative to the other CCDs on the map of interest, not between maps. For example, the ranked scores of potential impact on communities resulting from the 2800 gigalitre SDL reduction scenario could not be compared to the ranked scores of potential impact due to the 3200 gigalitre reduction scenario. However, the global scaling technique enabled comparison across these scenarios.

Comparison with SEIFA index scores

The vulnerability indices can be compared with widely known and used indices to provide a degree of validation for the measures. A comparison was therefore undertaken between the ABS Socio-economic Index for Areas (SEIFA) indices and those developed in this project. The ABS developed four SEIFA indices which contain many of the same census variables as in the vulnerability index and its component subindices. Their development involves a similar process including a PCA to determine which variables cluster together. Differences with SEIFA indices would be expected because the geographies used in the development of the SEIFA indices are for the whole of Australia, whereas the vulnerability indices and subindices were developed using CCDs defined as within the MDB, which has the advantage that the indices derived better reflect the unique circumstances of the region. For more about this effect, refer to the discussion in 'Spatial considerations in indicator selection which explains how the choice of geographical boundary affects the selection and weighting of variables in the PCA process.

Correlations were investigated with all four SEIFA indices and the vulnerability (prior to exposure), adaptive capacity, sensitivity and socioeconomic advantage index and subindices. The results are shown in Table C. The closer the correlation coefficients are to –1 or +1, the closer the relationship between the two indices.

Table C shows a positive correlation of SEIFA Index of Advantage/Disadvantage and SEIFA Index of Disadvantage with the indicator of socioeconomic advantage. This would be expected because these indices share more variables than any of the others. There is a weaker positive relationship with the adaptive capacity subindex, which would also be expected since some census variables are shared.

The strongest correlation occurs between the SEIFA Index of Disadvantage and the socioeconomic advantage subindex where 76 per cent of the variance is explained. The shared variables include census items relating to income level, over 15 with no school qualifications, unemployment rate, household size, dwellings rented and single parent families. Note the direction of the component loadings in the PCA in Table C for socioeconomic advantage was reversed so the positive attributes go in the same direction as that component of advantage. Hence, there is a positive correlation with the SEIFA Index of Disadvantage.

Table C4 Correlations between SEIFA indices and vulnerability subindices using Pearson's r value

CORRELATIONS a	SEIFA indices			
Vulnerability indices/subindices	Index of Advantage and Disadvantage	Index of Disadvantage	Index of Economic Resources	Index of Education and Occupation
Vulnerability	–0.15	–0.04	0.07	0.07
Sensitivity	0.07	0.17	0.24	0.24
Adaptive capacity	0.45	0.39	0.25	0.25
Socioeconomic advantage (reversed)	**0.64**	**0.76**	**0.62**	**0.62**

SEIFA = Socio-economic Index for Areas
Note: **a** The Pearson product moment correlation coefficient, r, is a dimensionless index that ranges from –1.0 to 1.0 inclusive and reflects the extent of a linear relationship between two datasets. A correlation relationship is considered strong if r is roughly above 0.5 or below –0.5 (values meeting the criteria are shown in bold) (Cohen 1988).

SEIFA indices were developed at the scale of the whole of Australia, which includes metropolitan areas, while the vulnerability indices took in rural and regional areas within the MDB. As expected, this may explain why some variables are missing from the PCA for the vulnerability indices that are likely to be significant to metropolitan areas; for example, proportion of people who identified as being Indigenous.

The sensitivity index shows little correlation with any of the SEIFA indices which would be expected because the variables in the sensitivity index relate to agricultural industry characteristics in an area; for example, employment in agriculture; irrigation water use, which are quite different from those variables that make up any of the SEIFA indices. These differences follow through to the vulnerability index (which contains the subindex of sensitivity) which exhibits only a weak relationship with the SEIFA indices.

This analysis suggests that the vulnerability indices and subindices are relevant for the scale and purpose for which they were intended.

Influences on final vulnerability index

A simple analysis was undertaken to determine what indicators and subindicators have the most influence on the updated community vulnerability indices, including on relative community vulnerability (before exposure) and on relative community vulnerability (after exposure to a 2800 gigalitre SDL reduction scenario, using 2005–06 commodity prices).

For the purposes of this analysis, exposure was measured using the proportion of water each region would be required to give up to achieve the 2800 gigalitre SDL reduction scenario relative to water use levels in 2010–11. The exposure measure was populated using data from ABARES economic modelling of the 2800 gigalitre water recovery scenario. The scenario takes into account water buybacks to date, inter-regional water trading (an adaptation process) and water savings due to infrastructure investments.

The sensitivity analysis considered the effect on the community vulnerability indices of a 10 per cent departure from the median value of each constituent indicator (results are summarised in Table C). The influence of the measures was calculated by first setting all the input indicators to their median values. Each indicator was then separately increased by 10 per cent and the resulting changes in the community vulnerability indices were calculated.

Table C5 Degree of influence of subindices or indicators on the final relative community vulnerability index

10% increase from the standardised median of	Resultant change in community vulnerability index (%)	
	before exposure	after exposure
Statistical Local Area irrigation incidence	2.2	1.8
Statistical Local Area irrigation intensity	0.3	0.2
Farm employment/agri-industry employment	0.1	0.1
Proportion of households with agriculture or agri-industry employment	0.3	0.3
Proportion of total employment in agriculture	0.3	0.3
Proportion of employment in agriculture and agri-industry to total employment	0.4	0.4
Economic diversity index	–9.5	–10.6
Socioeconomic advantage	–5.2	–5.8
Age advantage	–4.5	–5.0
Education advantage	–1.7	–1.9
Mobility advantage	–1.2	–1.3
Proportion of women in non-routine occupations	–2.7	–3.0
Participation in voluntary groups	–2.4	–2.7
Exposure subindex		3.0

The values are as expected from a consideration of the hierarchy of calculations in the conceptual framework described in ABARE-BRS (2010). The economic diversity index has the most influence on the vulnerability indices because it is a single subindex that enters the calculation relatively high in the hierarchy. Hence its influence was diluted the least by the process of standardising and addition that occurs in the hierarchy of calculations.

Socioeconomic advantage and age advantage were the next most influential subindicators on the community vulnerability index (both before and after exposure), followed by the social capital indicators of proportion of women in non-routine occupations and participation in volunteering. The next most influential subindex on the final community vulnerability index was the exposure subindex.

The resultant changes in the community vulnerability index may not be representative of more vulnerable CCDs. For example, a 10 per cent increase in the median of the exposure subindex only changed the final community vulnerability index by 3 per cent. The reason is that the degree of influence was calculated using the median scores of constituent indicators rather than scores from the upper or lower end of the sample distribution. This means at higher levels of the sensitivity subindex, the degree of influence of the exposure subindex will be greater.

Glossary

adaptive capacity	Ability or potential of a system (such as a community) to modify or change its characteristics or behaviour to better cope with change or stress.
CCD	Census Collection District is an ABS standard geographic unit of collection covering on average around 150 to 250 dwellings. Urban CCDs are likely to have more dwellings than those in rural areas, which cover larger areas but contain fewer dwellings.
community	A community of place refers to people living in a given geographical area (such as Narrabri); a community of interest refers to people who share a common interest (such as an industry); a community of identity refers to people who take an important part of their identity from some characteristic (such as the Aboriginal community).
data item	A single number, such as number of people in the workforce.
exposure	The amount of external stress or change by which a community is likely to be affected.
GL	Unit of measurement for volume of water; a gigalitre =109 litres
index/indices	A single number representing a complex concept and obtained by combining subindices.
indicator	A single data item or a number derived arithmetically from more than one data item that is taken to indicate the level of simple concept; for example, the proportion of unemployed in the workforce is an indicator of the level of unemployment.
MDB	Murray–Darling Basin
MDBA	Murray–Darling Basin Authority
measure	A generic term referring to indicators, subindices and indices.
ML	Unit of measurement for volume of water; a megalitre = 10^6 litres
potential impact	Consequences of the change or stressor. Made up of a combination of exposure and sensitivity to change; for example, worse potential impact results from a community heavily dependent on irrigation water facing a large reduction in water availability.
resilience	An emergent property of an individual or community that is understood in three main ways in the literature: as recovery, as stability and as transformation (see Maguire & Cartwright 2008).
SEIFA	Socio-economic Index For Areas; an index the Australian Bureau of Statistics developed.

sensitivity	A measure of how dependent a community is upon the resource that is changing; for example, irrigation water.
SLA	Statistical Local Area is a unit of geography the Australian Bureau of Statistics uses for data aggregation. In most cases, SLA is identical to, or formed from, a division of whole Local Government Areas.
subindex/subindices	A single indicator or a number derived arithmetically from more than one indicator.
vulnerability	Potential for susceptibility to harm. The degree to which a system (such as a community) is susceptible to pressures and disturbances, such as climate change or socioeconomic processes.
WTM region	A unit of geography used in the ABARES Water Trade Model for economic analysis. The MDB is made up of 24 such regions. WTM region boundaries coincide with CSIRO Murray–Darling Basin sustainable yield regions, except that some sustainable yield regions have been split into multiple regions. These include the Border Rivers region and the Murray region.

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