

Water Availability in the Murray-Darling Basin

Summary of a report from CSIRO to the Australian Government

October 2008

Acknowledgments

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> The Molonglo River near Canberra, ACT (CSIRO)



> Cover: (left) Hume Dam near Albury, Vic/NSW (MDBC), (right) The confluence of the Darling and Murray rivers at Wentworth on the NSW/Victorian border (MDBC)

The Murray-Darling Basin Sustainable Yields Project

Following the November 2006 Summit on the southern Murray-Darling Basin (MDB), the then Prime Minister and MDB state Premiers commissioned CSIRO to report on sustainable yields of surface and groundwater systems within the MDB. This report from the CSIRO Murray-Darling Basin Sustainable Yields Project summarises the assessments for 18 regions that comprise the Basin. Separate reports for each of these 18 regions are available. Full technical documentation of project methods is also being provided. All these documents provide comprehensive citation details of materials used for the project.

The project is a world first for rigorous and detailed basin-scale assessment of the anticipated impacts of climate change, catchment development and increasing groundwater extraction on the availability and use of water resources. It represents the most comprehensive hydrologic modelling ever undertaken for the entire MDB including modelling of rainfall-runoff and groundwater recharge across the entire MDB, fully linked modelling of all major river systems and modelling of the major groundwater systems of the MDB and their connections to the surface water system. This work relied on existing river and groundwater models developed by state agencies and the Murray-Darling Basin Commission, and new models developed by the project. The river modelling results were compared against monthly surface water accounts for about 150 river reaches across

the MDB. The accounts integrate all available data on streamflow and water use and estimates of evapotranspiration losses from satellite imagery.

The project was led by CSIRO and used the expertise of government agencies in Queensland, New South Wales, Victoria, the Australian Capital Territory and South Australia. The Murray-Darling Basin Commission and leading industry consultants were also involved. The project relied on the cooperative participation of nearly 200 people from over 15 organisations. It established comprehensive and efficient quality assurance processes including the external peer-review of project methods and modelling. All modelling results were captured, documented and translated into project reports.

The Murray-Darling Basin

The MDB covers more than 1 million km² (one-seventh) of mainland Australia including parts of Queensland, New South Wales, Victoria and South Australia and all of the Australian Capital Territory. The landscape is dominated by vast plains and large areas of undulating hills. The Basin is bounded by the Great Dividing Range in the south and east. The Darling River (and its tributaries) drains southern Queensland and northern New South Wales, crosses the Darling Plain and joins the Murray River upstream of Wentworth. The Murray River and its tributaries harvest water from inland areas of southern New South Wales and northern Victoria. The Murray River dissects the Riverine Plain from east to west and flows to the Southern Ocean via the Lower

Lakes system in South Australia. The Darling (2740 km), the Murray (2530 km) and the Murrumbidgee (1690 km) are Australia's three longest rivers.

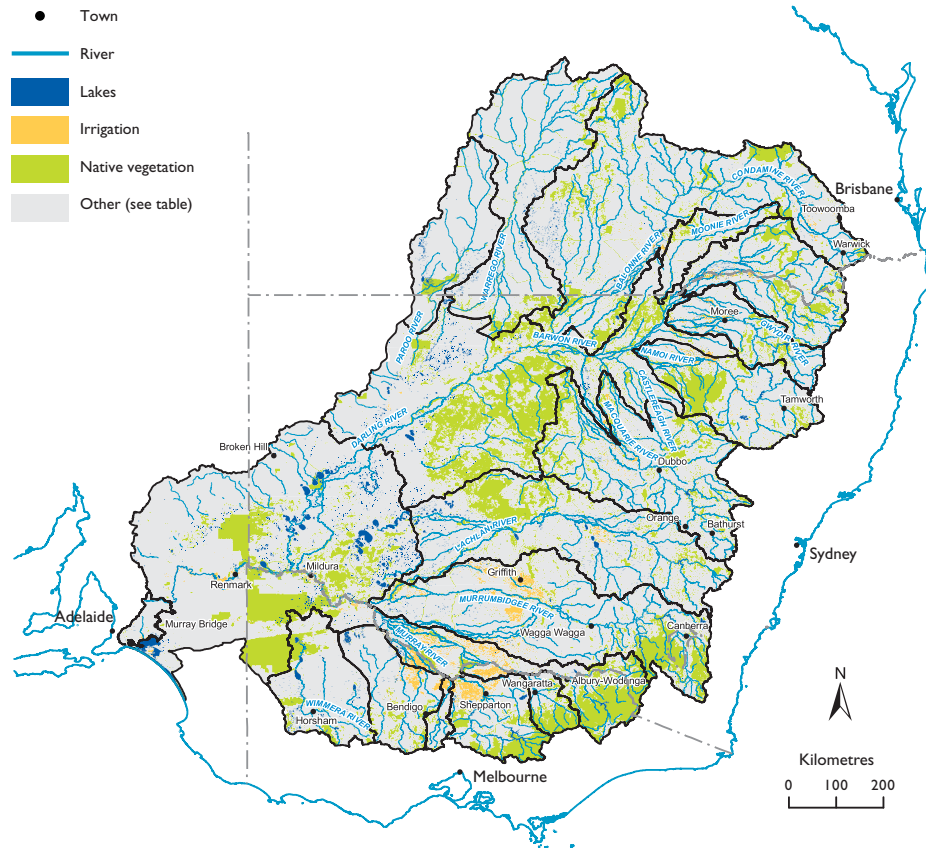
The MDB is home to around two million people including the national capital, Canberra, and the major centres of Toowoomba, Tamworth, Moree, Orange, Dubbo, Wagga Wagga, Griffith, Albury-Wodonga, Shepparton, Bendigo, Horsham, Mildura and Renmark.

Agriculture is the dominant economic activity in the MDB covering nearly 80 percent of the Basin and generating over 40 percent of the gross value of Australian agricultural production. The MDB uses 60 percent of all irrigation water in the country and is often referred to as Australia's 'food basket'. Agriculture also provides the raw materials for most of the manufacturing activity within the MDB and many processing companies located outside the Basin. Agricultural areas in the MDB are predominantly for livestock production, particularly dryland sheep and cattle production. Dairying is the main irrigated livestock industry. Important cropping activities include cereals (particularly wheat, barley and rice), oilseed, cotton, and horticulture (particularly citrus, stone and pome fruits, grapes and vegetables).

Remnant native vegetation covers around 20 percent of the Basin area. Agricultural and urban development has involved extensive clearing of native vegetation, disturbance of wetlands and other resource modification including construction of dams and the diversion of water for irrigation, stock and domestic uses.

There are some 30,000 wetlands in the MDB – most are on private land. Sixteen MDB wetlands are listed as internationally important under the Ramsar Convention on Wetlands and around 220 are listed in the Directory of Important Wetlands in Australia. Large wetland systems occur along the Darling River and its tributaries, including the Paroo Overflow Lakes, Narran Lakes, the Gwydir Wetlands, Macquarie Marshes and the Great Cumbung Swamp. There are also major floodplain forests along the Murray River including Barmah-Millewa, Gunbower, Koondrook-Perricoota, Chowilla Floodplain and Lindsay-Wallpolla Islands. Many of the floodplain wetlands and forests have been degraded and some have suffered significant loss of area over recent decades due to changes in flooding and land use. The Lower Lakes, Coorong and Murray mouth are at the terminus of the Murray River in South Australia. These wetlands are listed as internationally important under the Ramsar Convention and are important for breeding and feeding of many species of waterbirds and native fish.

Land use across the MDB



Summary of MDB land use in the year 2000

Land use	Area	
	percent	ha
Dryland crops	10.5%	11,001,881
Dryland pasture	66.7%	69,970,726
Irrigated crops	1.8%	1,916,256
Cereals	0.4%	467,178
Cotton	0.4%	426,519
Horticulture	0.0%	46,622
Orchards	0.1%	67,912
Pasture and hay	0.8%	820,890
Vine fruits	0.1%	87,135
Native vegetation	20.3%	21,242,551
Plantation forests	0.4%	445,048
Urban	0.3%	276,104
Total	100.0%	104,852,550
Water		943,861

Source: Bureau of Rural Sciences, 2005

Scenarios considered

Project results are framed around four scenarios of climate and development defined by 111 years of daily climate data.

The baseline scenario (for comparison with other scenarios) is the historical climate from mid-1895 to mid-2006 and the current level of water resource development.

The second scenario is based on the climate of 1997 to 2006. It is used to evaluate the consequences of a long-term continuation of the recent severe drought in south eastern Australia and provides a reference point for the climate change scenarios.

The third scenario considers climate change by 2030. A range of possible future climates is considered using three global warming levels and 15 of the global climate models included in the fourth assessment report of the Intergovernmental Panel on Climate Change. The reporting focuses on the median of the range and the uncertainty is reported as a 'wet extreme' and a 'dry extreme' in the range.

The fourth scenario considers likely future development and the 2030 climate. Development includes growth in farm dam capacity, expansion of commercial forestry plantations and increases in groundwater extraction. The projections of future farm dam and commercial forestry plantation development are 'best guesses' in the context of current policy and recent trends. The projections of future groundwater extraction represent maximum allowable use under existing water sharing arrangements.

Some results may be framed by a 'without-development' scenario. This scenario removes the effects of water management infrastructure and consumptive water use. Catchment characteristics such as vegetation cover are not adjusted and so this scenario does not represent 'pre-development' nor 'natural' conditions.

All these four scenarios assume the continuation of the existing surface and groundwater sharing plans implemented by states. In the future however, water sharing arrangements will need to comply with the Basin Plan to be developed under the *Commonwealth Water Act 2007*.

Key findings

- Water resource development has caused major changes in the flooding regimes that support nationally and internationally important floodplain wetland systems in the MDB. Integrating the flow impacts down through the connected rivers of the Basin shows that total flow at the Murray mouth has been reduced by 61 percent; the river now ceases to flow through the mouth 40 percent of the time compared to 1 percent of the time in the absence of water resource development.
- The south of the MDB was in severe drought from 1997 to 2006 and the catchment runoff in the southernmost parts of the MDB was the lowest on record. This event would occur once in more than 300 years without climate change. Such conditions will become increasingly common. The drought conditions in the south of the MDB have worsened in 2007 and 2008.
- The impacts of climate change by 2030 are uncertain; however, surface water availability across the entire MDB is more likely to decline than to increase. A decline in the south of the MDB is more likely than in the north. In the south of the MDB, a very substantial decline is possible. In the north of the MDB, significant increases are possible. The median decline for the entire MDB is 11 percent – 9 percent in the north of the MDB and 13 percent in the south of the MDB.
- The median water availability decline would reduce total surface water use by 4 percent under current water sharing arrangements but would further reduce flow at the Murray mouth by 24 percent to be 30 percent of the total without-development outflow. In volumetric terms, the majority of the impact of climate change would be borne by the environment rather than by consumptive water users.
- The relative impact of climate change on surface water use would be much greater in dry years. Under the median 2030 climate, diversions in driest years would fall by more than 10 percent in most New South Wales regions, around 20 percent in the Murrumbidgee and Murray regions and from around 35 to over 50 percent in the Victorian regions. Under the dry extreme 2030 climate, diversions in driest years would fall by over 20 percent in the Condamine-Balonne, around 40 to 50 percent in New South Wales regions (except the Lachlan), over 70 percent in the Murray and 80 to 90 percent in the major Victorian regions.
- Groundwater currently represents 16 percent of total water use in the MDB but under current water sharing arrangements groundwater use could increase by 2030 to be over one-quarter of total water use. One-quarter of current groundwater use will eventually be sourced directly from induced streamflow leakage which is equivalent to about 4 percent of current surface water diversions. Current groundwater use is unsustainable in seven of the twenty high-use groundwater areas in the MDB and will lead to major drawdowns in groundwater levels in the absence of management intervention.
- Expansion of commercial forestry plantations and increases in the total capacity of farm dams could occur by 2030. 'Best estimate' projections of these developments indicate only very minor impacts on the total runoff reaching rivers across the MDB. However, the volumes of surface water used by these developments, and the within-subcatchment streamflow impacts, may be significant.



> Castlereagh River at Coonamble, NSW (MDB)

> Wetland near Narran Lakes, Condamine-Balonne region, NSW (MDBC)



> Claypan depression, Nocolche Nature Reserve, Paroo region, NSW (WISE, NSW DECC)



Current climate and development

The MDB is naturally an inefficient hydrologic system. Surface water losses (via evapotranspiration and to groundwater) are naturally high and only 52 percent of the assessed total surface water resource of the MDB would reach the Murray mouth in the absence of flow regulation and consumptive water use. The surface water losses support floodplain and wetland ecosystems throughout the MDB (many are listed under the Ramsar Convention as wetlands of international importance) including the Coorong and the Lower Lakes on the Murray River. The losses are linked to the large but infrequent floods that characterise the highly variable natural flow regimes of the MDB – especially in the north-west rivers.

The relative level of current surface water use averaged over the historical climate sequence is high at 48 percent summed across the MDB, but varies widely between the 18 regions. Nearly two-thirds of the average annual consumptive surface water use across the MDB occurs in the Murray, Murrumbidgee and Goulburn-Broken regions. These regions collectively represent slightly over half the total MDB surface water resource. Consumptive water use across the MDB has reduced average annual streamflow at the Murray mouth by 61 percent. Water resource development has greatly reduced the frequency of flooding of many Ramsar sites and other key floodplains and wetlands across the MDB. Severe drought inflows to the Lower Lakes (annual inflow less than 1500 GL) – which would never occur in the absence of consumptive water use under the historical climate – prevail in 9 percent of years at the current level of water resource development. These hydrologic changes are linked to the significant levels of environmental degradation observed at numerous floodplains and wetlands across the MDB.

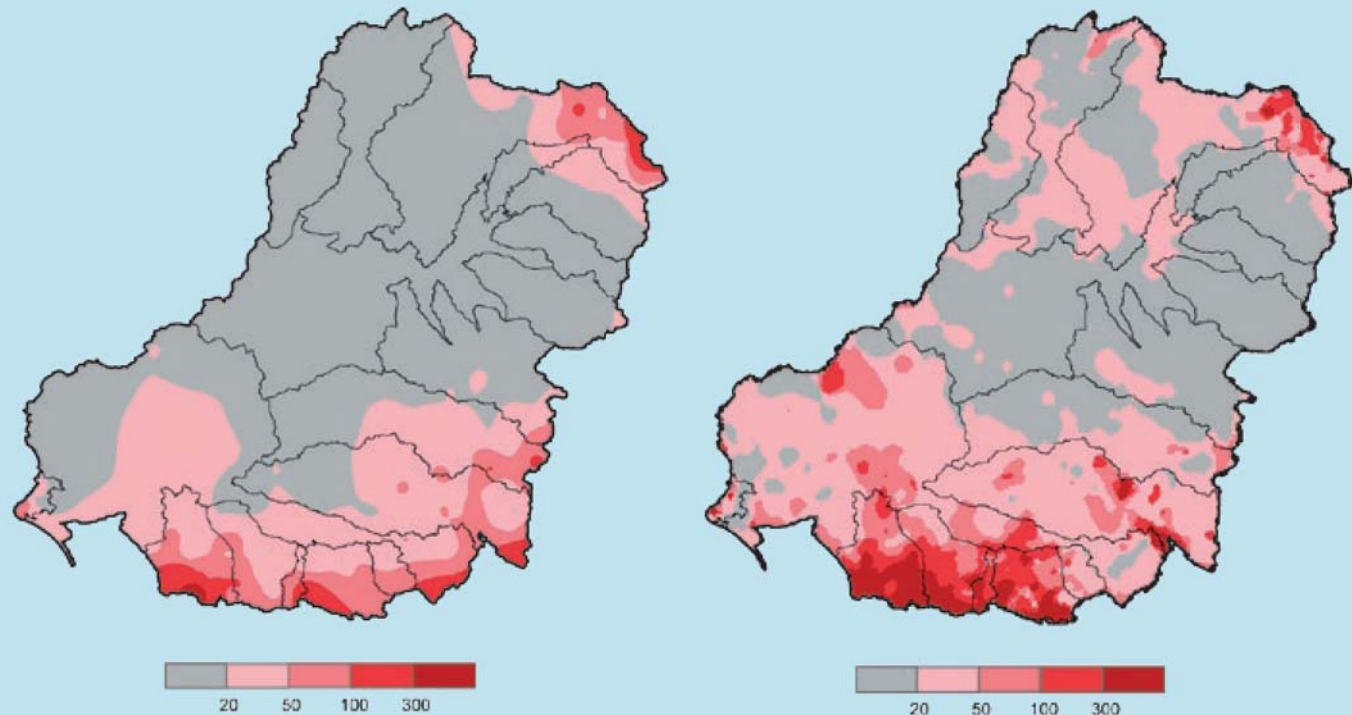
> The Murray River and the Snowy Mountains (MDBC)



The recent drought

Annual rainfall in the southern MDB for the ten-year period 1997 to 2006 was significantly lower than the long-term average but similar low-rainfall periods occurred in the 1890s and around 1940. Modelled annual runoff in the southern MDB (1997 to 2006) was lower than for any other ten-year period in the last 112 years and is less than half the long-term average in some areas. The low runoff in the southernmost parts of the MDB has an average recurrence interval of over 300 years. Related work by CSIRO and the Bureau of Meteorology indicates that these extreme climate conditions may be partly attributed to global climate change and that such conditions are likely to become more common. Rainfall and runoff averaged across the entire MDB (1997 to 2006) are not significantly different to the long-term historical averages.

These maps show the average recurrence interval (as number of years) of the 1997 to 2006 rainfall (left) and modelled 1997 to 2006 runoff (right) across the 18 regions of the MDB. The results indicate the average period between occurrences of 'ten-year events' similar to the 1997 to 2006 'event' and indicate that the drought was most severe in the southern Victorian regions



The impacts of climate change

Surface water availability across the entire MDB is expected to decline due to climate change. The future will be significantly drier on average but these conditions would be less severe than a continuation of the recent climate in the south of the MDB. The median of likely climate changes by 2030 would be an 11 percent reduction in average surface water availability across the MDB – 9 percent in the north and 13 percent in the south. The reduction would be greatest in the south-east where the majority of the runoff is generated and where the impacts of climate change are expected to be greatest.

This reduction in surface water availability would reduce surface water use by 4 percent overall under current water sharing arrangements. The impact on surface water use ranges from a maximum reduction of 10 percent in the Wimmera region to a 2 percent increase in the Barwon-Darling (in this case due to increased irrigation demand under a warmer climate). Use in dry years would be affected far more. The minimum one-year diversion volumes would be reduced by as much as around 40 to 50 percent in the Victorian regions (Goulburn-Broken, Campaspe, Loddon-Avoca and Wimmera).

The impacts of climate change on the reliability of 'water products' vary greatly between the products, regions and states. High reliability water products (including town water supplies) would generally not be affected. 'General security' and 'low reliability' type water products would be affected in terms of the average seasonal

allocation and the fraction of years of 100 percent allocations. The greatest reductions in reliability would occur in regions where the relative level of surface water use is already high and where the climate change is expected to have the largest impact on water availability, and for water products that are already less reliable. Some of the largest reductions in reliability would thus occur in the Murray, Goulburn-Broken, Campaspe, Loddon-Avoca and Wimmera regions, and under the dry extreme 2030 climate.

The reduction in surface water availability and the lesser reduction in surface water use would cause the overall relative level of use across the 18 regions (under the median 2030 climate) to rise to 54 percent. Outflows through the Murray mouth would fall from 39 to 30 percent of the without-development volume.

The reductions in surface water availability due to climate change would be focussed in the high water use Murray, Goulburn-Broken and Murrumbidgee regions. Under a continuation of current water sharing arrangements, much of the impact of reduced surface water availability would be transferred to the riverine environments along the Murray River including the Lower Lakes and the Coorong. Flow at the Murray mouth would cease 47 percent of the time and severe drought inflows to the Lower Lakes would occur in 13 percent of years. Current surface water sharing arrangements in the MDB would generally protect consumptive water users from much of the anticipated impact of climate change but offer little

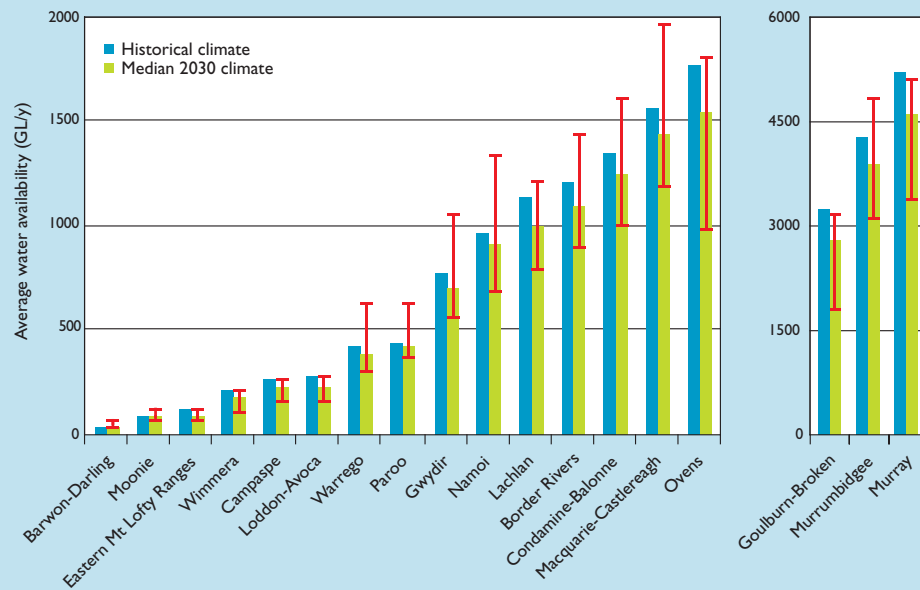
protection to riverine environments. This result should be considered in the development of future water sharing plans, as the National Water Initiative indicates that water plans should consider the risk of climate change on the size of the water resource and the implications for sharing. The Gwydir region is a notable exception as current arrangements would see the consumptive and non-consumptive water shares affected to a similar degree.

The hydrological impacts of climate change in the MDB remain very uncertain. For example, average surface water availability could reduce by as much as 34 percent by 2030 (more severe on average than the recent climate) or increase by up to 11 percent. Under the dry extreme 2030 climate (34 percent less surface water available on average), dry period use and allocation reliability are very greatly reduced. Uncertainty in the impacts of climate change is expected to reduce in the coming few years with improvements in climate change science. Projections further into the future become increasingly uncertain due to divergence in the range of possible greenhouse gas emissions trajectories. The median climate becomes increasingly drier further into the future and by 2070 the median climate under high global warming is expected to be broadly similar to the dry extreme 2030 climate. This highlights the need for far greater flexibility and adaptive capacity in water resources management in the MDB.

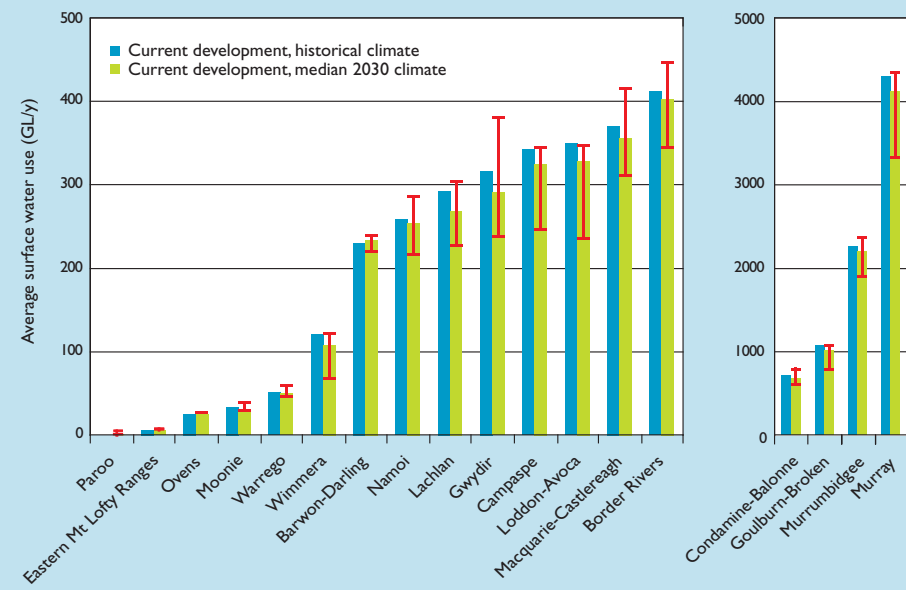
> Riverbank, Warrego region, Qld (QNRW)



Current and likely future surface water availability across the 18 regions of the MDB is summarised in the chart below. Red bars indicate the uncertainty inherent in the climate change projections for 2030. The current total surface water resource across the 18 regions is 23,417 GL/year on average. The total average surface water resource summed across the 18 regions under the median 2030 climate is 20,936 GL/year with a range from 26,047 GL/year to 15,524 GL/year



Current and likely future surface water use across the 18 regions of the MDB are summarised in the chart below. Red bars indicate the uncertainty inherent in the climate change projections for 2030. Current total surface water use summed across the 18 regions are 11,327 GL/year on average. Total average surface water use under the median 2030 climate and current water sharing arrangements would be 10,876 GL/year with a range from 11,686 GL/year to 8962 GL/year



Groundwater resources

Groundwater resources and use in the MDB are concentrated in twenty out of nearly one hundred groundwater management units (GMUs) that cover the MDB. Current groundwater extraction is assessed as unsustainable in seven GMUs (Condamine, Border Rivers, Lower Namoi, parts of the Lower Macquarie, parts of the Lower Lachlan, the Upper Lachlan and the Mid-Murrumbidgee). There are also indications that extraction in the Upper Murray may not be able to be sustained. The absence of management intervention to manage these high rates of extraction would eventually lead to large reductions in groundwater levels. Current groundwater use represents 16 percent of the total water use in the MDB but a far greater fraction of total water use during dry periods.

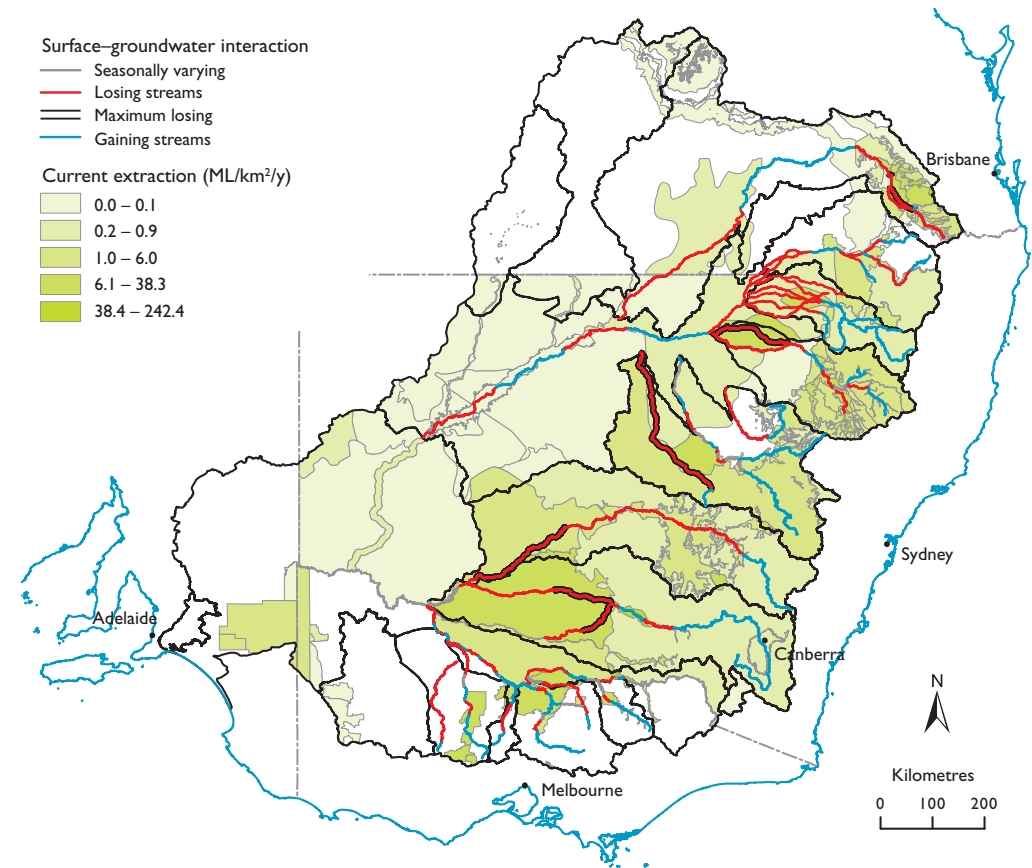


One-quarter of total current groundwater use will eventually be sourced directly from induced streamflow leakage which is equivalent to about 4 percent of current surface water diversions. Around 40 percent of the eventual streamflow leakage will occur in the Namoi, Lachlan, Murrumbidgee and Murray regions.

Groundwater use across the MDB, given current groundwater management arrangements, could more than double by 2030 to exceed one-quarter of total average water use. This is despite existing planning controls that will reduce groundwater extraction to below current levels in some areas. It highlights the need to bring all groundwater use into the water entitlement system. The projected future levels of groundwater use could not be sustained in the Border Rivers, Lower Namoi, parts of the Lower Macquarie and the Lower and Upper Lachlan due to large reductions in groundwater levels. Future increases in groundwater use are expected to significantly affect baseflow in small tributaries and turn many into ephemeral streams. Increased use is expected in some of the major alluvial aquifers leading to significant increases in streamflow leakage induced by groundwater extraction.

> Bore water irrigation near Narrabri, Namoi region, NSW (DEWHA)

This map shows (i) the current intensity of groundwater use across the MDB (the darker shades indicate greater volumes of groundwater extraction per unit area for each GMU); and (ii) the spatial patterns of surface–groundwater connectivity. ‘Losing streams’ naturally lose water to groundwater, while ‘gaining streams’ naturally gain water from groundwater.



Future development

Bureau of Rural Sciences projections indicate that (given current trends and current policy) MDB commercial forestry plantations could expand in area by 52,000 ha or 18 percent by 2030. The increases would be concentrated in the Eastern Mount Lofty Ranges (2000 ha), Murrumbidgee (17,000 ha) and Murray (33,000 ha) regions. These forestry developments would use a small volume of water in a MDB-wide context and the reduction in average annual runoff at the regional scale would be less than 1 percent (about 0.8 percent reduction in future average annual runoff over the Eastern Mount Lofty Ranges region and about 0.3 percent reduction in future average annual runoff over the Murrumbidgee and Murray regions). However, the expansion is likely to be concentrated in small areas and in these areas the local impact on runoff could be significant.

The current capacity of small farm dams across the MDB is estimated to be 2000 GL. Projections based on historical data for farm dam growth and current policy controls suggest a possible 10 percent increase in this total farm dam capacity by 2030. The increase in farm dam capacity would be less concentrated than commercial forestry plantation development and new farm dams would reduce average annual runoff by about 0.7 percent across the MDB. The biggest reduction would be in the Eastern Mount Lofty Ranges (3 percent). The projected farm dam development would reduce average annual runoff by 1.7, 0.8 and 0.4 percent in the Campaspe, Loddon-Avoca and Goulburn-Broken regions respectively. The projected farm dam development would reduce average

annual runoff in eastern New South Wales by 1.0 to 1.5 percent. The small projected farm dam development in Queensland would have negligible impact on future runoff.

These developments may have more impact at the local or subcatchment scale including environmental consequences for tributary streams. Streamflow impacts by 2030 of commercial plantation forestry (28 GL/year), additional farm dams (170 GL/year) and the streamflow leakage induced by additional groundwater extraction (177 GL/year) would collectively represent a volume of surface water use of 375 GL/year. This potential increase in surface water use (375 GL/year), together with the 451 GL/year average reduction in surface water use that would occur due to the median 2030 climate, would mean only a small net reduction (76 GL/year) in total surface water use as a result of the combined effects of climate change and possible future development. This is in spite of the considerable reduction in water availability expected with climate change. These increases in surface water use due to development and the reductions in surface water diversions due to climate change, would occur in different relative proportions in each region.

Project legacy

The project results provide a strong base to determine a new sustainable diversion limit for surface and groundwater use across the MDB as required under the *Commonwealth Water Act 2007*. The results should also be valuable in future assessments which may contribute to the development of the Basin Plan including consideration of (i) the consumptive and other economic uses of MDB water resources; (ii) conservation and sustainable use of biodiversity; and (iii) social, cultural, Indigenous and public benefit issues. The project has developed for the first time an integrated modelling capability for the entire MDB linking multiple river systems models together with multiple groundwater models. This capability should be invaluable in coming years for additional investigations including for example, scenarios of: (i) altered water sharing to guide determination of sustainable diversion limits; (ii) river system management that explores opportunities for greater efficiency in water delivery and use; (iii) the implications of temporary and permanent water trade; and (iv) altered environmental watering. The major challenge for future water resource management in the MDB is to achieve sustainable water resource use while optimising economic, social and environmental outcomes in the context of a climate which is highly variable and non-stationary. The approaches of the past which assume an 'equilibrium' climate are no longer adequate.

> Coombool Swamp upstream from Renmark, Murray region, SA (CSIRO)



> Wimmera River, Horsham, Vic (Wimmera CMA)

Enquiries

More information about the project can be found at www.csiro.au/mdbsy. This information includes the full terms of reference for the project, an overview of the project methods and all project reports, including the full version of this report.

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