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Feasibility Assessment: *Water Use Efficiency through Infrastructure Investment* Rural Program

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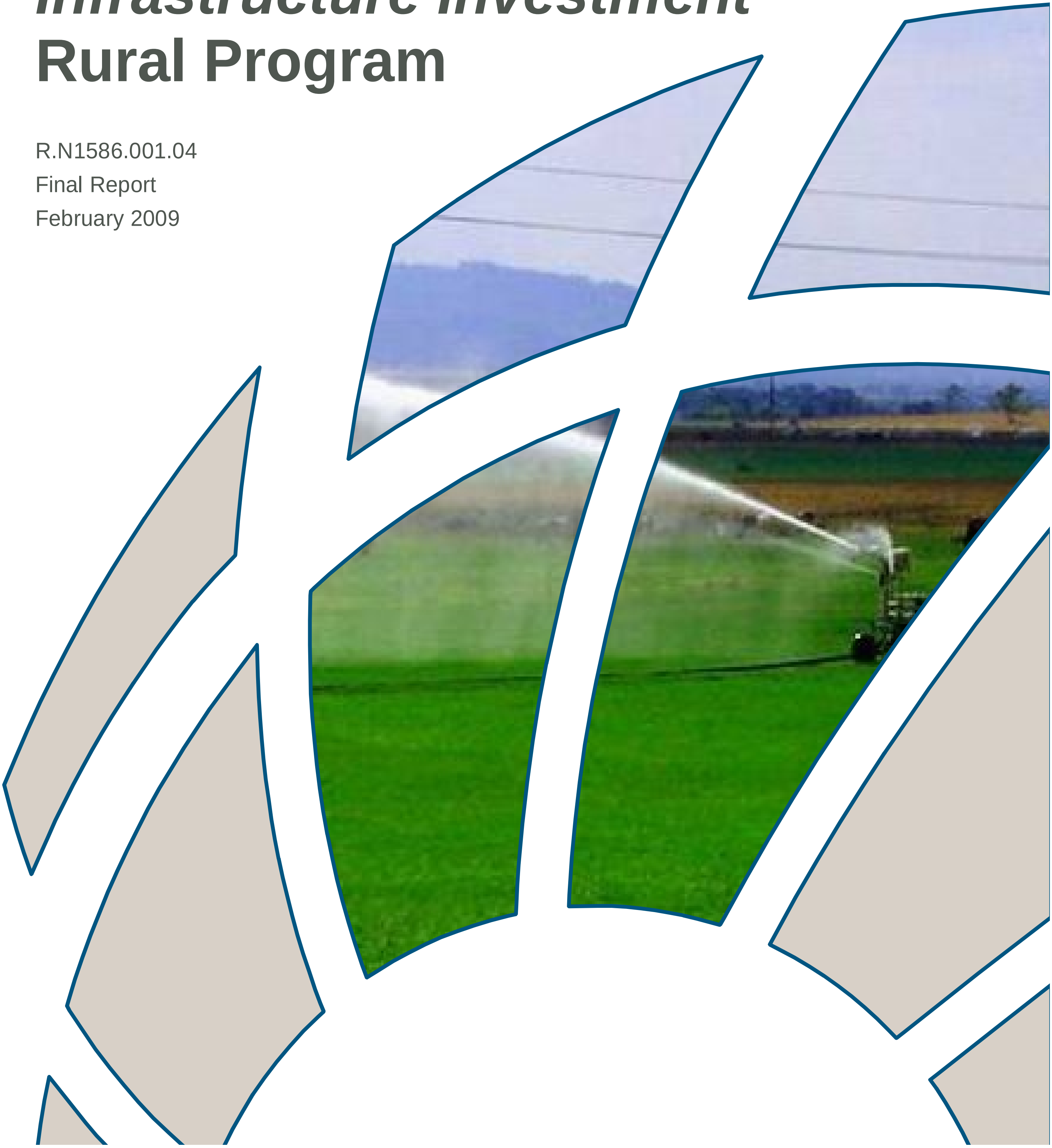

Feasibility Assessment: Water Use Efficiency through Infrastructure Investment Rural Program

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Title :	Feasibility Assessment: Water Use Efficiency through Infrastructure Investment: Rural Program
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Synopsis :	This feasibility assessment presents an overview of estimated water use efficiency gains associated with the Water Use Efficiency through Infrastructure Investment Rural Program proposed by the Queensland Murray-Darling Committee Inc. The cost effectiveness of the proposed water use efficiency measures is assessed in comparison with the Federal Government Water Entitlement Purchase (buy-back) scheme with respect to ensuring the sustainability of rural communities, maintaining growth in agricultural production in the face of a global food crisis and adapting to climate change and uncertainty.

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1 OVERVIEW

This report presents the outcomes of a feasibility assessment for the Water Use Efficiency through Infrastructure Investment Rural Program proposed by the Queensland Murray-Darling Committee (QMDC) Inc. The study area incorporates irrigated agriculture in the Condamine-Balonne, Border Rivers (Queensland), Moonie, Warrego, and Nebine subcatchments. The assessment involved analysis of current practices, water diversion/extraction, potential rural WUE measures applicable to the study area and the costs of implementation. An estimate of the potential WUE gains likely to result from successful implementation was made based on the best available information.

What is the Water Use Efficiency through Infrastructure Investment Program?

Water Use Efficiency through Infrastructure Investment is an initiative developed by the QMDC in co-operation with The Clean Waters Model (CWM) that aims to reduce agricultural demands for water without reducing net farm productivity. This partnership arrangement between Government and landholders is to be achieved primarily through WUE and other environmental works. Environmental works proposed as part of the Program incorporate a range of water quality and aquatic habitat protection activities such as riparian fencing, off-stream watering points and fish passageways. Funding for the Program is proposed to have equal contributions from Government and landholders.

How much water can be saved?

With a modest investment of approximately $190 million over six years it is estimated that total WUE gains of 200 gigalitres (GL) / year (+/- 20%) can be achieved as a result of successful implementation of this program (refer Figure 1). Greater WUE gains can also be achieved at greater cost. The rate of return on an investment of $190 million is comparable to the cost of direct buy-back as is being pursued under the Federal Government water entitlement purchase round (buy-back) scheme. Note, however, that no suitable offers were made or accepted from within the Queensland Murray-Darling region in 2006-7.

In addition to overall reductions in irrigator water entitlement, implementation of rural WUE would also make more water available for crop production. This potential of a ‘win – win’ outcome would therefore be expected to be more acceptable to existing irrigators compared to the alternative Federal Government buy-back scheme.

An increase in water availability for crop production will help meet increased demands for crops given expected increases in global food demand. Targets for growth in agricultural production are approximately 1.5% per annum globally (FAO, 2002). The existing Federal Government buy-back scheme effectively results in a reduction of crop production.

Further, climate change is likely to reduce water available for diversion by approximately 5% over the next 23 years in the Queensland Murray-Darling region (CSIRO, 2008) thereby requiring increased WUE simply to maintain current production levels.

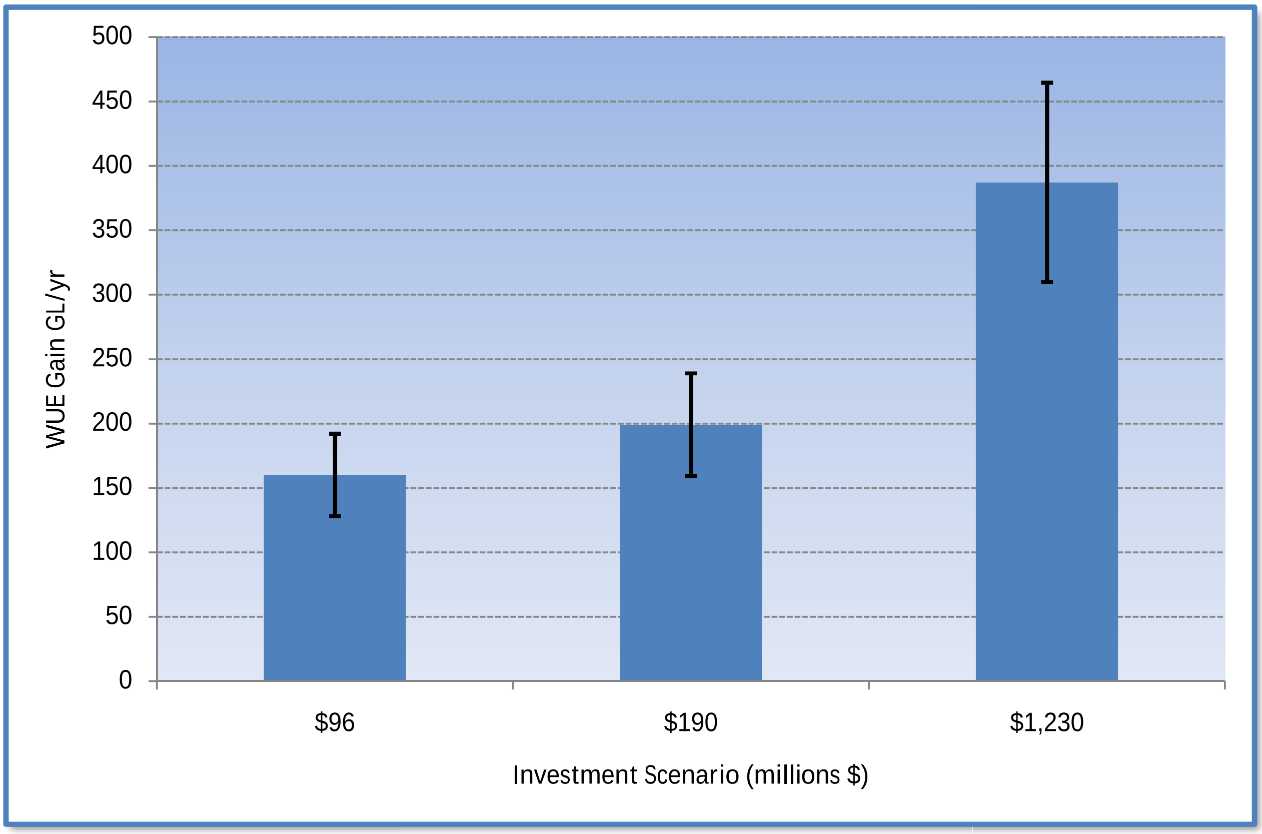


Figure 1 Potential Reduction in Water Entitlements following investment in Rural WUE: Queensland Murray Darling

Where can water be used more efficiently?

Less than 50% of water extracted from the river or groundwater in the Queensland Murray Darling region is eventually available for uptake by crops. Losses of water from the system are summarised in Table 1. Evaporation and seepage in off-farm channels is relatively minor, as only a small proportion of diversions and extractions pass through these channels.

Table 1 Estimated water savings within Queensland Murray-Darling region

Farm Component	Existing Loss	Investment Scenario and Water Savings					
		$96		$190		$1,230	
		$	GL/yr	$	GL/yr	$	GL/yr
Evaporation and seepage from dams and ring tanks	276	0	46	0	54	860	140
Evaporation and seepage from on- farm channels	61	2	12	6	16	10	28
Evaporation and deep drainage during crop application	302	94	102	184	129	360	219
TOTAL	639		160		199		387

The two main areas for potential improvement in WUE are crop application and water storage.

WUE is a rapidly developing field with research and trial activities already underway within the study area. While current losses and potential WE gains are highly variable and difficult to define, some reasonable estimates of typical rates and volumes have been developed based on existing literature.

What are the most effective WUE measures?

Potential gains can be achieved by addressing crop application losses and evaporation from storages. With respect to the latter, options for substantially reducing storage evaporation are all very expensive (in the order of $100,000/ha of storage). Therefore, the primary focus for delivering cost-effective WUE lies with application of irrigation water at the crop.

Conclusions

1. A $190 million investment in rural WUE has the potential to achieve WUE gains in the Queensland Murray-Darling region of approximately 200 GL/year (+/- 20%). Simultaneously the WUE program has the potential to increase water available for crop production thus helping to build resilience against potential future climate change and/or increases in global food demands.

   A $1.23 billion investment has the potential to achieve WUE gains of approximately 390 GL/year (+/- 20%).

2. The Water Use Efficiency through Infrastructure Investment Rural Program can deliver water savings at a cost that is comparable to the existing Federal Government buy-back scheme, and is more likely to be adopted by landholders given the potential for improved crop returns.

3. Total WUE gains of 200 GL/year (+/- 20%) can be achieved with adoption of best practice irrigation methods (including improved scheduling of irrigation and new more efficient infrastructure) by up to 50% of irrigators across the Queensland Murray Darling region.

2 BACKGROUND

2.1 The *Water Use Efficiency through Infrastructure Investment* Rural Program

The *Water Use Efficiency through Infrastructure Investment* Rural Program is an initiative of the QMDC and CWM. Specific details of the Program are not provided here, however, a basic outline is summarised in Figure 2.

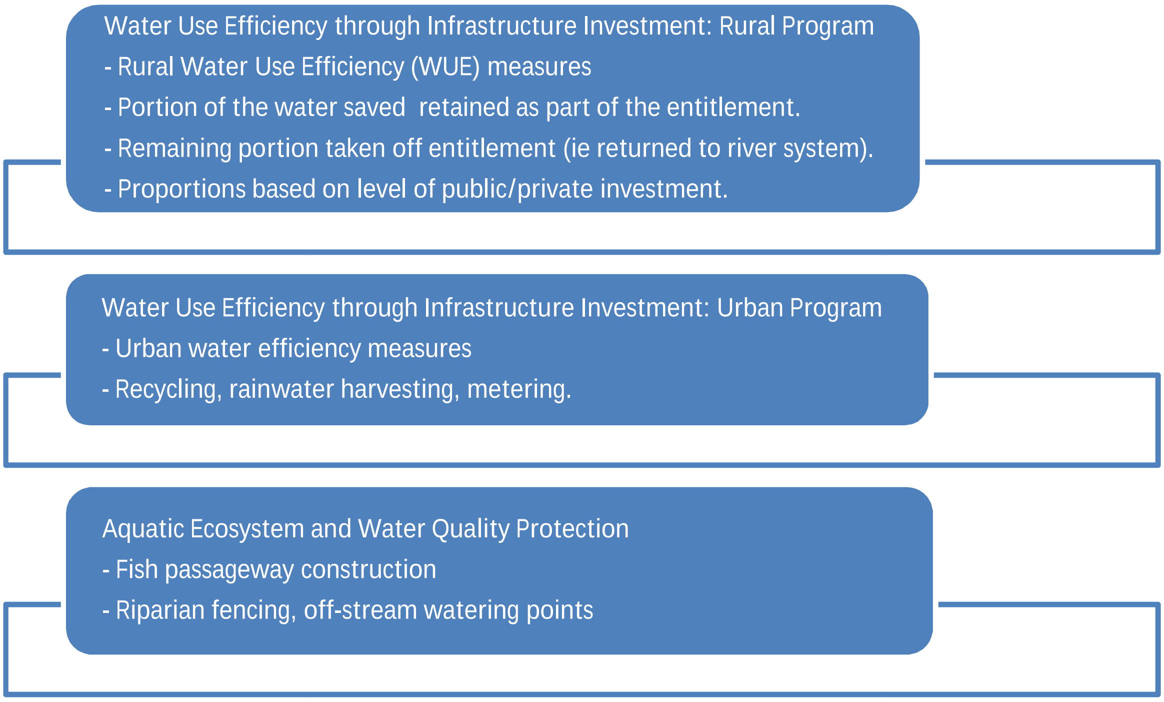
This feasibility assessment relates specifically to the *Rural Water* component of the project. The key aspects of the program that relate to this assessment are as follows:

- It is assumed that capital and in-kind funding will be provided to implement a range of currently viable on-farm WUE measures (as detailed by Baillie *et al.,* 2007) on water storages, distribution systems and in-field application systems;
- Implementation of the program will utilise existing regional extension, research and support networks provided by the Queensland Department of Primary Industry Rural WUE program, the National Centre for Agricultural Engineering, Cotton Catchments Co-operative Research Centre and a number of private consultants;
- A portion of the water gained through WUE measures may be retained as part of the individual entitlement. Improved WUE will result in a net increase in water available for crop uptake;
- In some cases, relinquished portions of existing entitlements may be provided as an environmental flow. This would involve the establishment of appropriate monitoring protocols that will enable adaptive adjustment of Resource Operation Plans (ROPs) to ensure water savings are not simply handed down to the next entitlement holder; and
- Some off-farm WUE measures will also be pursued, which have not been quantified as part of this study due to insufficient data.

2.2 Rural Water Use Efficiency Measures

Rural WUE has become a key focus in the effort to reduce water demand and improve productivity on the Murray-Darling River systems over the last ten years. Specifically for the Queensland Murray-Darling region, the Queensland Department of Primary Industries and the National Centre for Engineering in Agriculture (Baillie *et al*., 2002) have undertaken a range of research activities, trials and extension activities in this area. Similar work is being undertaken throughout the Murray-Darling Basin (MDB). Of particular relevance is work undertaken by Benyon *et al*. (2002) who undertook a similar, high-level feasibility assessment for in-field WUE improvement across the entire MDB.

This feasibility assessment has been developed using the information, data and guidelines developed by these organisations (in addition to other local, regional and national resources) to develop indicative investment scenarios for improved rural WUE.



Water Use Efficiency through Infrastructure Investment: Rural Program
- Rural Water Use Efficiency (WUE) measures
- Portion of the water saved retained as part of the entitlement.
- Remaining portion taken off entitlement (ie returned to river system).
- Proportions based on level of public/private investment.

Water Use Efficiency through Infrastructure Investment: Urban Program
- Urban water efficiency measures
- Recycling, rainwater harvesting, metering.

Aquatic Ecosystem and Water Quality Protection
- Fish passageway construction
- Riparian fencing, off-stream watering points

Figure 2 General Structure of the *Water Use Efficiency through Infrastructure Investment* Program

Some of the main WUE measures considered for this assessment include:

In-field Application System Measures

- Improved irrigation application efficiency through improved soil/plant/water monitoring, scheduling and control;
- Surface optimisation of furrow irrigation systems for improved distribution uniformity and application efficiency; and
- Improved application efficiency through replacement of irrigation infrastructure (e.g. surface furrow converted to centre pivot or drip).

On-farm Storage Measures

- Evaporation Mitigation Technologies (EMTs) for on-farm storages (e.g. monolayers);
- Evaporation mitigation in storages through partitioning or increasing depths;

Distribution System Measures

- Seepage mitigation in distribution channels and storages (e.g. lining and piping);
- Evaporation mitigation in channels through improved pump scheduling and control;

More detail on the nature of the WUE measures used in this assessment and the data source for parameter development is provided in Appendix A. The reader is directed to the abovementioned organisations and references for specific detail.

2.3 Methodology

This feasibility assessment has been undertaken by applying best available information from local, regional and national sources on surface water diversion, groundwater extraction and rural WUE to the proposed Caring for Our Rural Water program. A simplistic volumetric WUE approach was adopted given the scale of the assessment in an effort to maintain transparency. Given the limited amount of catchment and basin scale data on water use and WUE and the degree of uncertainty in the data that is available, a conservative approach was adopted. It is possible that estimated WUE gains and reductions in entitlements could be higher if more specific and detailed data is obtained and used in the volumetric WUE model.

Details of the methodology and data sources used are provided in Appendix C.

3 WATER USE EFFICIENCY GAINS

The results of an initial analysis of the potential range of WUE gains possible are presented in Figure 3. This figure represents the *maximum theoretical WUE gain* regardless of investment and feasibility limitations. Maximum theoretical WUE gains range between 70 and 390 GL/year, which represents an increased efficiency of up to 32% across the region (note existing average water allocations total approximately 1,200GL/yr within the Queensland Murray Darling region).

The level of investment (ie low, medium and high) in Figure 3 relates to the relative degree of implementation of new technology, infrastructure and best practice. Low investment relates primarily to improvements in existing irrigation practices (eg scheduling etc), whereas high investment relates to changes in both practice and infrastructure.

The investment required to achieve more than 25% adoption of WUE measures across all elements of the irrigation system (ie whole of farm) is well in excess of estimated budgets for this program. Furthermore, implementation of some of the measures may not be feasible for all farms. Typical adoption rates for similar programs are approximately 50% (Schmidt, 2003) with examples of higher levels of adoption limited.

Adding further complexity is the relative cost effectiveness of WUE measures at different elements in the irrigation system. For example, investment in WUE measures for in-field application systems is approximately 2.5 times more cost effective (in terms of dollars spent versus water saved) than an equivalent investment in WUE measure for on-farm storages.

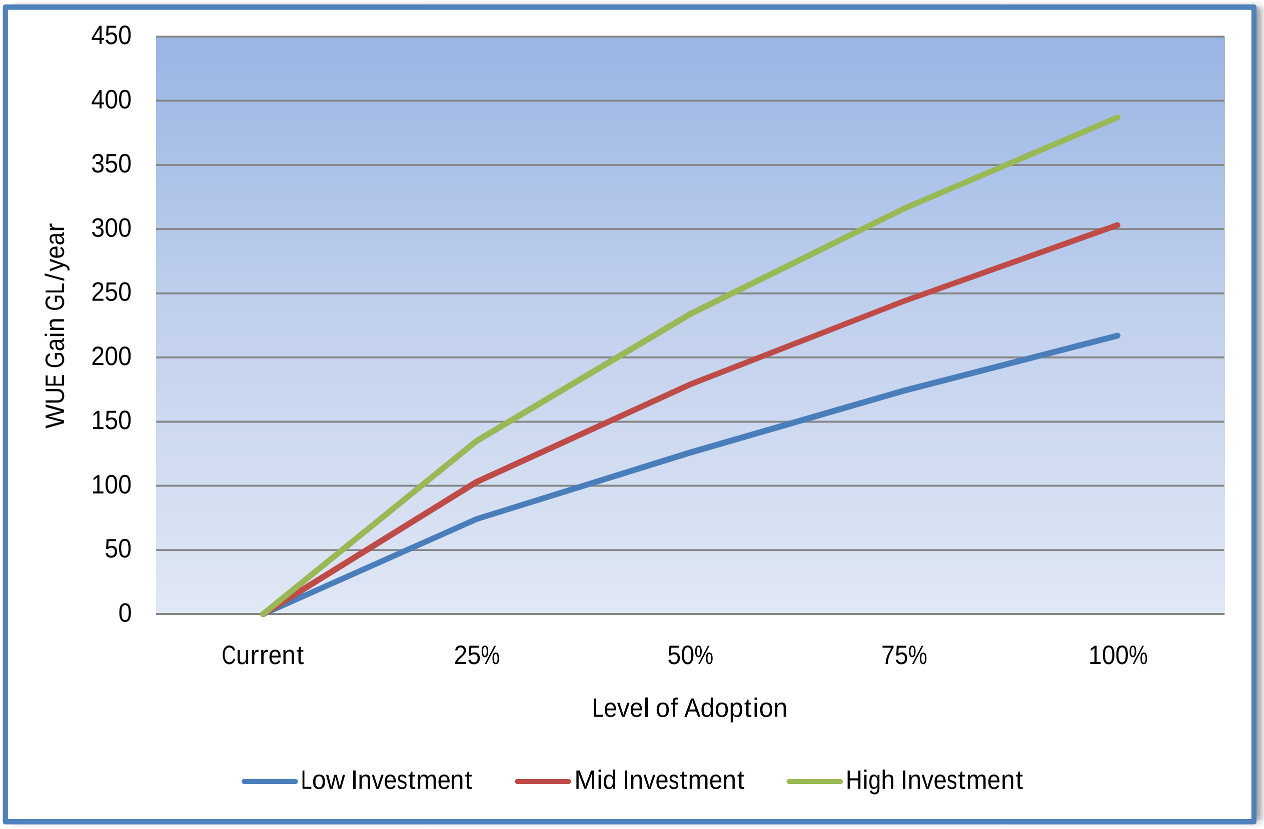


Figure 3 Estimated Total Water Efficiency Gains: Queensland Murray-Darling Basin

To address the issue of potential variability in investment and measures adopted, a series of *indicative investment scenarios* were developed that reflect a number of cost effective ways to invest prescribed amounts of capital and in-kind funding. Key aspects of the cost-effective investment scenarios are:

- Investment is focused on in-field application system WUE measures, which maximises cost effectiveness;
- The maximum level of adoption of any particular WUE measure is generally limited to 50% based on previous adoption rates for similar programs;
- Investment in on-farm distribution system WUE measures was limited to pump scheduling and control measures. Lining or piping of channels was found to be orders of magnitude less cost effective than in-field options and data on the amount of channels and their performance is limited; and
- Investment in on-farm water storage WUE measures was limited to “Low” investment options such as minor seepage reduction, monolayers and partitioning of a maximum of 25% of total storages in the region.

Cost estimates for the scenarios were developed using rates developed by Schmidt (2003), Baillie *et al.* (2007) and follows a similar methodology. Three (3) scenarios were considered adopting investments (capital and in-kind) of $96 million, $190 million, and $1.23 billion. The $1.23 billion scenario represented 100% adoption of high investment WUE measures (an unrealistic basis) and was included for comparative purposes only. Further detail on the structure of each investment scenario is provided in Appendix B. Relative cost effectiveness for the different investment scenarios are presented in Figure 4.

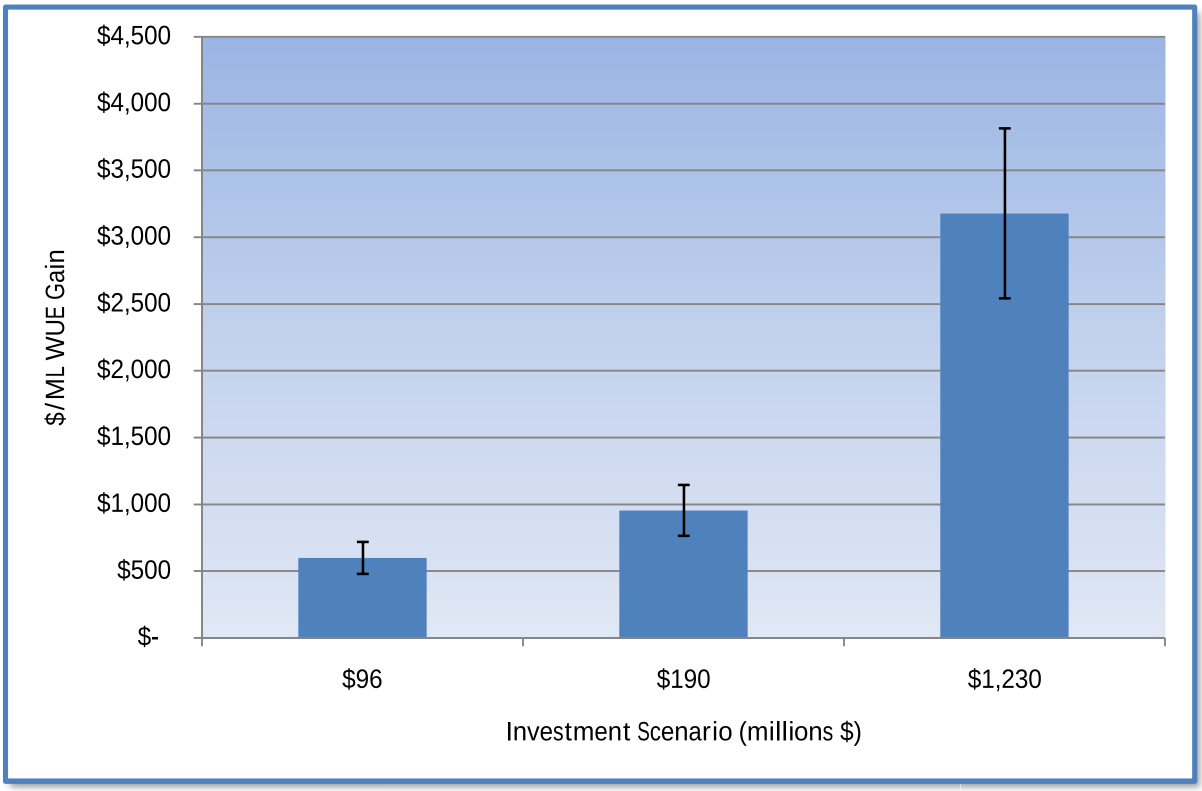


Figure 4 Cost Efficiency of Indicative Investment Scenarios

An analysis of the cost efficiency of the seven indicative investment scenarios (Figure 4) indicates that optimum investment (i.e. investment that strikes a balance between total investment and $/ML) in WUE measures in the region is approximately $190 million. This scenario has a cost efficiency of $940/ML which compares favourably with the Federal Government buy-back scheme.

4 COMPARISON WITH FEDERAL GOVERNMENT WATER ENTITLEMENT PURCHASES

To date, the Federal Government has purchased water entitlements of 34.4GL/yr for a value of $47 million (equivalent rate of $1,400/ML). For the investment scenario of $96m, a gain of 160GL gives a payback of $600/ML, while for the $190m investment scenario, a gain of 199GL gives a payback of $940/ML. For the $1.23b investment scenario, the payback would be $3,200/ML.

On a cost per ML basis the *Water Use Efficiency through Infrastructure Investment* Rural Program is marginally more cost effective (for lower quantities at least) than to the Federal Government Water Entitlement Purchase scheme, but it is the positive socio-economic and political outcomes from the *Water Use Efficiency through Infrastructure Investment* Rural Program that makes this proposal vastly different from the buy-back scheme. The Federal buy-back scheme results in a lost capacity to irrigate crops within the region. Irrigation within the study area produces between $400 and $600 million/yr in agricultural commodities, which constitutes approximately 27% of Queensland's, and 6% of the national, irrigated agriculture total. Whilst the follow-on economic impact of this reduced water availability is not quantified here, in comparison, the *Water Use Efficiency through Infrastructure Investment* Rural Program actually has the potential to increase the water available for crop production through increased efficiency at the same time as reducing entitlements by a comparable or greater quantity than the current buy-back scheme.

The 2006-2007 round of the Federal Government buy-back scheme failed to encourage any offers from irrigators in the Queensland Murray Darling region. Across the whole Murray Darling Basin, 3.2% of the total water entitlements were offered for buy-back by irrigators (totalling some 350GL). Of these entitlements offered, only 34.4GL/yr (ie ~10%) has been accepted by the Government.

Assuming that 3.2% of water entitlements are considered an acceptable level for relinquishment by most irrigators, the maximum reduction in entitlements within the Queensland Murray Darling region is unlikely to exceed about 38 GL/yr under the existing Federal Government buy back scheme. The *Water Use Efficiency through Infrastructure Investment* Rural Program could realistically achieve up to 160 GL/yr for an investment of $96 million, and up to 200 GL/yr for an investment of $186 million. Further water saving beyond 200 GL/yr are also achievable, however, costs would increase substantially thereafter.

5 BUILDING RESILIENCE FOR RURAL COMMUNITIES

Linked with the issues identified in Section 4 is the capacity for the *Water Use Efficiency through Infrastructure Investment* Rural Program to increase water security to rural communities thereby increasing their resilience to future climate change and market demands. Through implementation of WUE measures, less water is lost from the irrigation system (predominantly through in-field evaporation and seepage) which in turn results in a higher proportion of the irrigation water being available in the root zone for plant uptake.

A significant challenge facing irrigators in the Queensland Murray-Darling Basin is the potential impact of future climate change on water availability. The recently completed Murray-Darling Sustainable Yields Project (CSIRO, 2008) estimates a mid-range reduction in water availability of 4 - 6% for the Queensland Murray-Darling region by 2030. The increase in available water delivered by this Program would help mitigate against a loss of production as a consequence of climate change. For example, WUE gains of 100GL/yr can translate to an increase in crop production of 5 – 7%.

It is expected that WUE will become increasingly necessary to redress future water shortages. Also, national and global population growth and increases in global median income are expected to place increased demands on food and fibre production, in the order of 1.5% growth per year (FAO, 2002). Increasing water security associated with the *Water Use Efficiency through Infrastructure Investment* Rural Program would again assist with meeting the increase in production demand.

Where the *Water Use Efficiency through Infrastructure Investment* Rural Program can be seen as a positive for both climate change adaptation and future growth demands, the existing Federal Government buy-back program potentially increases vulnerability of the Queensland irrigation industry to these future conditions (possibly contributing to the absence of offers from the Queensland Murray Darling region).

6 POTENTIAL CUMULATIVE BENEFITS OF INCREASED ENVIRONMENTAL FLOWS IN THE MURRAY DARLING BASIN

This information provides a summary of key concepts and research relevant to the assessment of potential river flow and river health benefits attributable to increased environmental flows in the Murray Darling Basin (MDB). It outlines the potential positive benefits to the MDB associated with implementation of the *Water Use Efficiency through Infrastructure Investment Rural Program* proposed by the Queensland Murray Darling Committee (QMDC). It must be stressed that at this time only a simplified qualitative assessment has been provided for advisory purposes. Appropriate management of environmental flows in the MDB is a complex issue influenced by a range of regional and catchment specific considerations. There is capacity to provide a more refined estimate of the potential benefits of the program proposed by QMDC in the future, should this be desirable.

6.1 INFORMATION AND RESEARCH APPLICABLE

The following list of references is the principal sources of data upon which the details of this information has been based:

CSIRO (2008) *Murray-Darling Basin Sustainable Yields Project*. CSIRO, Canberra.

Webb, McKeown & Associates Pty Ltd (2007) *State of the Darling Interim Hydrology Report*. Murray Darling Basin Commission Publication Number 07/07, Canberra.

Dr Richard Evans (2007) *The Impact of Groundwater Use on Australia's Rivers*. Land and Water Australia.

6.2 KEY CONCEPTS

6.2.1 Impact of Development on River Flow Regimes

As outlined in the aforementioned references (particularly CSIRO, 2008 and Webb McKeown & Assoc., 2007), the development of irrigated agriculture throughout the MDB has significantly altered flow regimes. Average annual flow at the mouth of the Murray River is now 61% lower than pre-development flow rates. In the Condamine-Balonne catchment within the QMDC area current average annual flow is 55% lower than pre-developed rates. The interval between significant flow/flood events (wetting and flooding of river channels, billabongs and floodplain wetlands) has increased.

There has also been a change in the seasonal variation in river flows at a number of key points. Pre-development flows peaked in late winter/early spring following wetting up of the basin in the cooler winter months. The maximum monthly flow (September) was 5-10 times the minimum monthly flow (March). Since the development of substantial irrigation in the basin maximum monthly flows have mostly reduced (except for immediately downstream of Hume Dam) and are typically only 2-4 times the minimum flow.

Groundwater connectivity is another critical element of the MDB water cycle. The level of extraction in alluvial unconfined aquifers in irrigation regions has created average annual 'losing' conditions in a number of river systems including the Condamine-Balonne. Essentially, a river can be considered to be losing water when extraction of groundwater lowers the watertable sufficiently to create a groundwater flow out of the surface channels and into the aquifer. Prior to development of irrigated agriculture, unconfined aquifers in the MDB typically fed water to river systems (on an average annual basis). The losing status of river systems such as the Condamine-Balonne means baseflows are now reduced compared to pre-development.

6.2.2 Consequences of Altered River Flow Regimes

a) Due to the lack of baseflow and the losing status of most sections of river, a proportion of river flow is transferred directly to groundwater and is required to saturate river bed and wetland sediments (ie ‘wetting up’) prior to the movement of any flow downstream. These processes (in addition to evapo-transpiration) are generally referred to as transmission losses.

b) Increased intervals between high flow/flood events is allowing river channels, billabongs and wetlands/floodplains to dry out more thereby increasing flow requirements to establish baseflows.

c) high volume flows needed to establish baseflow conditions are less reliable

d) Lack of groundwater connectivity in river reaches results in a proportion of any flow seeping into alluvial aquifers

e) The change in seasonal variability in river flow is altering ecological communities and river geomorphology

f) The timing of flows has altered the ecosystem and hydrologic dynamics in the Coorong and Lower Lakes significantly.

6.2.3 Surface Flow Efficiency in the Basin

The MDB is a naturally inefficient hydrologic system. Using historical climate records, only 41% of total inflow to the basin is expected to have reached the Murray River mouth prior to catchment development. Transmission losses account for a large proportion of the inefficiency given the cyclic nature of flows. At the current level of development the efficiency has dropped further, with now only an estimated 16% of total inflow reaching the river mouth. This equates to a 61% reduction in average annual flow at the mouth of the Murray River.

As an example from the QMDC region, efficiency of water delivery to the end of the Condamine-Balonne system has reduced from 32% of total inflows down to 14%. Prior to irrigation development approximately 13% of total inflows to the Condamine-Balonne system flowed out of the Murray River mouth. This has now reduced to approximately 6%.

6.3 THE LEAPFROG EFFECT OF INCREASED ENVIRONMENTAL FLOWS

The implementation of programs that result in an increase in the volume and frequency of environmental flows (such as the QMDC project) will deliver incremental increases in river flow from one system to the next. Given the transmission losses associated with river systems such as the Murray Darling, however, a substantial proportion of the flows gained will initially just contribute to ‘wetting up’ of dry river channels, billabongs and floodplain wetlands rather than delivering immediate additional flows at the downstream end of the river system. This wetting up of the river and floodplains is crucial to river health and in the long-term is critically linked to an improvement in ecological condition and water quality. Importantly, the increased wetting of the river system reduces further transmission losses during high flow/flood events, thus increasing efficiency and the volume of water reaching the end of the system. As additional flows are delivered to the river, groundwater connectivity will improve and eventually rivers will once again start to gain water from aquifers on an average annual basis.

A preliminary estimate of the impact of the proposed QMDC program on the Condamine-Balonne catchment has been made. This estimate is indicative in nature and is based on a number of broad assumptions necessary at this scale and stage of the program. These estimates can be further refined and expanded to included potential implementation in other states within the MDB. Estimates have been developed using the catchment and river water balance delivered through the CSIRO *Murray Darling Basin Sustainable Yields Project* (2008).

Using the $220 million investment scenario as an example and assuming a 50% of the water saved is relinquished from entitlements, the following estimates can be made:

a) An average total surface water use efficiency gain (ie water that was previously lost from the system) of 121 GL/year (+/- 20%) is estimated for the Condamine-Balonne catchment (note that the gain from the whole QMDC area is approx. 200 GL/year total). Under an assumed 50:50 arrangement, half of this water gain from the Condamine-Balonne (60.4 GL/year) would be provided as environmental flows at different locations and times in the year. Of this 60.4 GL, approximately 26 GL/year (+/- 20%) is likely to reach the end of Condamine-Balonne system. This represents an 11% increase in average annual flow at the catchment outlet. An indicative estimate of the volume likely to contribute to flows at the mouth of the Murray River is 11.7 GL/year (+/- 20%). This equates to a 0.25% increase in flows at the Murray mouth. It is important to note that the Condamine-Balonne historically (pre-development) contributed only 2% and currently contributes 2.2% of total flow at the Murray mouth. Therefore the 0.25% increase in end of basin flow equates to an 11% increase in Condamine-Balonne contributions.

b) Implementation of the *Water Use Efficiency through Infrastructure Investment Rural Program* through New South Wales, Victoria and South Australia is highly likely to create a ‘leapfrog’ effect on downstream river flow and health. Implementation of the QMDC program is likely to deliver an additional 26 GL/year into the Barwon-Darling system. If the program was then implemented in the Barwon-Darling catchment additional flows (in addition to those coming from the Condamine-Balonne) could be transferred to the lower Murray River. Given the significantly larger volumes of water diverted for irrigation in NSW MDB catchments, the potential for water use efficiency gains and subsequent increase in end of system flow as a result of increased environmental flow are significantly higher than those presented for the QMDC.

It is important to recognise that a proportion of any additional water delivered to the downstream catchment will become a transmission loss and not make it to the end of the system. However, with each progression to the next river reach, the proportion of water lost will reduce. Essentially, the more downstream catchments that implement a program of this nature, the higher the proportion of Condamine-Balonne end of system flow that makes it to the mouth of the Murray River. It is also crucial to recognise that transmission losses do not necessarily represent wasted water. As previously described a large proportion of these losses provide important baseflow and event flow regimes for billabongs and floodplain wetlands.

In order for this to occur it is important that groundwater extraction from connected aquifers is also included in any water use efficiency program (as is the case for the proposed QMDC program). This will help increase groundwater connectivity with rivers, which increases the proportion of river flow that reaches the end of the system.

7 CONCLUSIONS

This feasibility assessment has identified potential WUE gains of 200 GL/year (+/- 20%) based on a relatively modest budget of approximately $190 million (over 6 years) utilising current available WUE measures. Water savings made by the *Water Use Efficiency through Infrastructure Investment* Rural Program can be potentially returned to the river, or potentially deliver an increase in water available for crop growth, or a combination of these.

This Program offers opportunities to achieve water savings comparable to the Federal Government buy-back scheme whilst increasing the resilience of rural communities to maintain agricultural production in response to growing demand for food and the need to adapt to climate change. A comparison of the *Water Use Efficiency through Infrastructure Investment* Rural Program and the Federal Government Water Entitlement Purchase Scheme is provided in Table 2.

Table 2 Comparison of *Water Use Efficiency through Infrastructure Investment* and Federal Government Water Entitlement Purchase Programs

Deliverable	***Water Use Efficiency through Infrastructure Investment***	**Federal Government Water Entitlement Purchase**
Estimated Water Savings	200 GL/year (+/- 20%) for $190 million	135 GL/year for $190 million(1)
Climate Change Adaptation	Increased capacity for adaptation	Reduced capacity for adaptation
Resilience in Rural Communities	Increased water availability	Decreased water availability
Agricultural Production	Best Management Practice Increased food production	Decreased food production

(1) Pro-rata cost based on purchases made to date.

Potential WUE gains and entitlement reductions were derived and adapted using data from existing literature from local, regional and national sources. As such the validity of estimated WUE gains and entitlement reductions is highly dependent on the accuracy and validity of these data. Effort has been made to ensure the best available information was used in this assessment, however, it is noted that there is limited basin scale information available on which to base many of the calculations. Estimates could therefore be refined if additional applicable data or information is made available.

This report focuses on the rural WUE component of the *Water Use Efficiency through Infrastructure Investment* Program. The urban and aquatic ecosystem components are assessed and documented separately.

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APPENDIX A: RURAL WATER USE EFFICIENCY MEASURES

A range of WUE measure have been considered and used for this project based on current research being undertaken by organisations such as the National Centre for Engineering in Agriculture, the Cotton Catchment Communities CRC, Queensland Department of Primary Industries and the Murray Darling Basin Commission.

Table A1: Potential WUE Measures for Irrigated Agriculture

Component	Investment	WUE Measure	Description
Storages	Low cost	Partitioning	Division of storages into smaller sections to reduce water surface area during times where the storage is not full.
	Mid cost	Monolayer	This technology has been in use for more than 50 years and consists of a fatty alcohol that is applied to the water surface that forms a one molecule thick layer that retards evaporation by restricting the flow of water molecules travelling through the water surface. They have no effect on the energy balance of the water storage, nor do they influence the wind speed above the water surface. Monolayer cost per application is low; however they need to be reapplied every few days. Various studies have shown an evaporation saving of between 20% and 55%, the reason for this variation is that the chemical is affected by wind and sometimes the application does not reach all parts of the dam surface. One advantage is that if the storage is empty then the chemical does not need to be applied.
	High cost	Floating cover	These are usually floating objects or modules on the surface of the dam. This design has some significant advantages as the shape of the storage is irrelevant and obstructions and intrusions on the dam can be easily accommodated. Rainfall can easily get into the storage. These covers do not attempt to make a complete seal over the surface of the dam. Instead they aim to restrict the air movement over the dam and the free water surface. One of the disadvantages of the system is if the storage is to be emptied then the modules need to be removed because they can get caught in the muddy dam floor and may not refloat. This system is effective and practical however they have limited availability and a high price. One advantage is that the modules can be bought progressively, reducing the initial cost to the farmer.
		Shade cloth	This system is usually suspended above the water surface by a permanent structure. The shade cloth works by reducing the net radiation flux and creating a zone of still air above the water surface and due to the permeability of shade cloth rainfall can easily enter the storage. The disadvantages of this system are that they can be susceptible to storm damage and UV degradation and compared to an impermeable layer there is comparably more evaporation. The cost of installation can also be high and is currently limited to storages with a surface span of 120m.
		Design	Innovative design of storages can also reduce water lost through evaporation and seepage. An estimation of the height of storages in Queensland is difficult. Until 2000 dam storages were not referred to dam failure analysis until the height of the Dam was 5m and the size of the storage was more than 20ML (Allen, 2008). This has now changed where the storage will only be referred if the height of the dam wall is 8m and the storage size is greater than 500ML or if the storage has a wall height of greater than 8 metres and a capacity of more than 250ML and a catchment area of greater than three times its maximum surface area at full supply level. Allen (2008) also suggested that storage dams were commonly built to be just under the triggering mechanisms.

Component	Investment	WUE Measure	Description
Distribution channels	Low cost	Improved control	Use of automated controls to deliver water to specific paddocks to maximise efficiency (minimise evaporation and time water spends in channel).
	High cost	Liners	The use of earth, hard surface (e.g. concrete) or membrane liners is expensive but can significantly reduce seepage.
		Piping	Replacement of channels with pipes.
Application Systems	Low cost	Improved scheduling	The use of more efficient irrigation scheduling and control mechanisms can provide significant reductions in deep drainage and evaporation. More sophisticated soil moisture monitoring equipment can also ensure application depths more closely match plant water requirements.
		Surface system improvement	This system works by evaluating surface irrigation events infield. It measures and logs an irrigation event which allows the irrigator to time and apply water to specific parameters.
	High cost	Low pressure overhead	In this design sprinklers are mounted on long wheeled towers that rotate around a centre point or progress through the crop. They are low pressure systems suited to many soil types. This includes lateral move machines or centre pivots. These machines are effective for a variety of soil types and are generally effective if designed and installed properly.
		Drip irrigation	Sub surface drip is the permanent placement of dripper tape between 200 and 400mm below the soil surface. Emitters in the tape allow water to enter the soil.

References Used to Develop Potential WUE Measures (refer to Reference list for full citation)

1. Baillie *et al.* (2007) *On-farm water use efficiency in the Northern Murray-Darling Basin*.
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6. *G.T. Barnes (2008) The potential for monolayers to reduce the evaporation of water from large water storages.*
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APPENDIX B: DESCRIPTION OF INDICATIVE INVESTMENT SCENARIOS

Table B1 Investment Scenarios for Feasibility Assessment

Investment Scenario	Distribution System WUE Measures	On-farm Storage WUE Measures	In-field Application WUE Measures	Land Area (ha)
$96 million	50% adoption of low cost measures.	None	50% adoption of a combination of low and high cost measures.	61,657
$190 million	50% adoption of a combination of low and high cost measures.	None	50% adoption of high cost measures.	
$1,230 million	100% adoption of a combination of low and high cost measures.	100% adoption of high cost measures.	100% adoption of high cost measures.	123,313

Refer to Table A1 in Appendix A for details of WUE measures.

Preliminary modelling of investment in on-farm storage WUE measures indicated very poor cost efficiency for all investment scenarios and as such storage measures were omitted from the scenarios considered. This primarily related to the large number of high surface area dams and ring tanks in the region and the current difficulty in delivering WUE measures at that scale. As an example, monolayers were the only EMT capable of installation on 83% of storages, and deliver only a relatively small improvement in efficiency.

APPENDIX C: FEASIBILITY ASSESSMENT METHODOLOGY

Provided below is an outline of the methodology and preliminary calculations used for this feasibility assessment. Full details can be obtained by contacting the authors. The assessment followed the simplistic volumetric approach adopted by previous authors of WUE assessments for the MDB (Benyon *et al*, 2002, Schmidt, 2003 and Baillie *et al* 2007). WUE was modelled on an average annual basis to provide an indication of the long-term potential for water savings and reduced entitlements.

Total River Diversion and Groundwater Extraction

A literature and statistical search was undertaken to determine the current best estimate of total river diversions and groundwater extractions for irrigated agriculture within the Queensland Murray Darling region. Three independent sources of water use estimates were available, and are detailed in Table C1. These estimates contain significant variation. Previous assessments (ie Baillie et al., 2007) have adopted an average of the estimates from these sources.

With an almost twofold variation in potential water diversion and extraction between monitoring data and modelled estimates, the potential to influence WUE gains is significant.

Table C1 Various Data Sources for Total Water Diversion/Extraction

Source	Method	Total Surface Diversions	Total Groundwater Extractions	Total Water Use
MDBC Water Audit Monitoring on the Cap on Diversions(1) (2000-2006)	Monitored	473.1	206.6	**679.7**
Baillie *et al.* (2007) (2)	Combination	645.6	205.6	**851.2**
CSIRO Sustainable Yields Project (2008)	Modelled	986.4	211.8	**1198.2**
Webb, McKeown & Associates (2007)	Modelled	1086.8	205.6	**1292.4**

(1) These data are based on the Australian Bureau of Statistics (ABS) *On-farm Water Use* Assessments.

(2) Baillie *et al.* adopted an average of the MDBC Water Audit Monitoring and the Webb McKeown and Associates modelling estimates.

A major contributor to the uncertainty in estimates is the volume of diversion occurring as waterharvesting and floodplain harvesting within the Queensland Murray-Darling system (Webb, McKeown & Associates 2007). Whilst metering of these diversions and inclusion in entitlements is in the process of being implemented, historically both of these activities have occurred in a largely unregulated manner.

As an investigation exercise, total diversions/extractions for irrigation were cross-checked against the average total irrigated land area and typical application rates (Schmidt, 2003, Baillie *et al.* 2007 and Dalton *et al.* 2001). Data was obtained for specific crops and applied to each subcatchment based on long-term average ABS statistical data on irrigated area (calculated by Baillie *et al.*, 2007). This cross-checking analysis indicated that the monitored water diversion/extraction estimates (MDBC 2000-2006) is most likely to be an underestimate of actual figures as the calculated total water applied to crops actually exceeded suggested diversion/extraction for a number of years and subcatchment. At best it suggested irrigation system efficiencies close to 100% (that is, there are no losses between the river extraction and the crop application), which based on available research (eg, Dalton *et al* 2001) is most unlikely.

Further evidence supporting the inference that monitoring data underestimates total diversion/extraction is provided in recent audits by Marsden Jacobs Pty Ltd (2005) and SMEC (2006) indicating the need for significant improvements in the measurement of bulk off-takes and pump diversions within the Murray-Darling Basin. It was suggested that river diversions are underestimated by up to 40% in some parts of the Basin (SMEC, 2006).

Recent preliminary hydrological assessments by Webb, McKeown & Associates (2007) attempted to estimate the volume of waterharvesting and floodplain harvesting occurring in the northern Murray-Darling Basin. Their estimate of total diversions is the highest available. Subsequent to the Webb McKeown assessment, CSIRO completed a more comprehensive modelling and calibration project to improve understanding of the hydrologic characteristics of the Murray-Darling Basin. The *Murray-Darling Sustainable Yields Project* (CSIRO 2008) involved comprehensive modelling of surface and groundwater hydrology and calibration against long-term climate and streamflow data. The relevant subcatchment assessments include the Condamine-Balonne, Border Rivers, Warrego and Moonie. Data from CSIRO (2008) was adopted for use in this assessment as it represents the best available information and matched well with expected volumes based on application depths and whole farm irrigation efficiencies. Estimates from CSIRO (2008) are presented in Table C2.

Assumptions and Limitations

- Inherent in this assessment is the assumption that average long-term river diversions and groundwater extractions from CSIRO (2008) are representative for the study area.
- Values for the Border Rivers (Queensland) catchment were split between states using statistical data on irrigated land and agricultural production within the various crops.
- It is assumed that water harvesting and floodplain harvesting will become increasingly more regulated and monitored under ROPs allowing more quantitative inclusion in entitlements.
- Average long-term irrigated area for various crops derived from ABS statistical data and Baillie *et al.* (2007) are representative.

- Average application rates (in ML/ha) published by Schmidt (2003) and Baillie *et al.* (2007) are representative of the study area.

Table C2 Summary of Adopted River Extraction and Groundwater Diversion (CSIRO 2008)

Subcatchment	**Surface Water**				**Groundwater**	**TOTAL**
	Regulated	***Unsupplemented***	***Floodplain Harvesting***	***Sub-total***		
Condamine	94.3	450.4	142	***686.7***	201	**887.7**
Maranoa-Balonne						
Nebine	0	5.6	0.7	***6.3***	0	**6.3**
Warrego	2.5	42	0	***44.5***	0	**44.5**
Moonie	0	33.1	0	***33.1***	0.03	**33.1**
Border Rivers (QLD)	36.3	179.5	0	***215.8***	10.8	**226.6**
TOTAL PROJECT AREA	*133.1*	*710.6*	*142.7*	***986.4***	*211.83*	**1198.2**

Note: Water harvesting (the diversion of river flows to water storages during high flow events) is included in the Unsupplemented portion.

Total Irrigation Volumes

The total volume of water applied through irrigation was required in order to estimate current water loss through irrigation systems in the study area. The National Centre for Engineering in Agriculture has data from a number of studies undertaken in the Queensland Murray-Darling region on typical application rates for the range of crops considered in this study. Adopted application rates were based on Schmidt (2003) and are presented in Table C3.

Long-term averaged irrigation areas were obtained from Baillie *et al.* (2007), which are based on ABS statistical data for the study area. Once application rates were applied to irrigated area the existing water demand was calculated for each crop and subcatchment.

Assumptions and Limitations

- Long-term averaged irrigation area for various crops derived from ABS statistical data and Baillie *et al.* (2007) are representative.
- Average application rates (in ML/ha) published by Schmidt (2003) and Baillie *et al.* (2007) are representative of the study area.
- Values for the Border Rivers (Queensland) catchment were split between states using statistical data on irrigated land, water use and agricultural production within the various crops.

Table C3 Adopted Application Rates, Irrigated Areas and Water Demand for Various Crops (Source: Baillie *et al.* (2007) and Schmidt (2003))

Subcatchment	Irrigated Crop	Area (ha)	Existing Application (ML/ha)	Existing Demand (GL/year)
Condamine-Balonne	Cotton	51428	7	360
	Broadacre	13303	5	67
	Pasture	15295	8	122
	Horticulture	3029	5	15
	TOTAL	**83055**	**6.8**	**564**
Border Rivers (QLD) including Moonie	Cotton	21583	6	129
	Broadacre	2013	5	10
	Pasture	4499	8	36
	Horticulture	5386	5	27
	TOTAL	**33481**	**6.0**	**202**
Warrego (including Nebine)	Cotton	1201	8	10
	Broadacre	0	7	0
	Pasture	5290	8	42
	Horticulture	286	6	2
	TOTAL	**6777**	**7.9**	**54**
TOTAL STUDY AREA		**123313**	**6.7**	**820**

Characteristics of On-farm Storage and Distribution Systems

Estimates of the number, volume and surface area of on-farm water storages were investigated through a literature search. There are a number of recent and current projects being undertaken through the MDBC to better quantify data on storages as the accuracy of existing information is uncertain. Key information sources include Dalton *et al.* (2001), Baillie *et al.* (2007), Craig *et al.* (2005) and Barnes (2008). A recent study was undertaken to estimate the surface area of on-farm water storages within the study area (MDBC, 2008). Data from this study was made available for use in the feasibility assessment, and is summarised in Table C4.

In contrast to other assessments, WUE gains and water losses from storages were calculated using average annual water volumes stored rather than storage capacities. This avoids a significant potential error given that the total storage capacity of most dams will not be fully utilised year to year. The use of total dam volumes would result in a substantial overestimate of both losses and gains.

Table C4 Summary of Irrigation Storages within the Study Area (MDBC, 2008)

Storage Size			
	0-2Ha	**0-5Ha**	**> 5Ha**
Count	7399	871	925
Area (ha)	2592	2689	26316
Average Water Depth (m)	2.6	2.2	3.1

Very limited information on the nature of on-farm distribution systems was available for the study area and the broader MDB. Common methodologies for estimating seepage and evaporation loss from channels use a percentage loss per unit volume of water distributed through the channels. This avoids the need to estimate channel lengths and characteristics, and better reflects the volumetric approach adopted for this assessment. However, channel characteristics are necessary in order to estimate the cost of implementing WUE measures.

Assumptions and Limitations

- Estimates of total storage surface area and volume from Dalton *et al.* (2001) and MDBC (2008) are representative.
- An assumed proportion of total diversion/extraction passing through distribution systems and stored in dams was used. The accuracy of these proportions is uncertain. They were derived through calibration of the WUE model using the current scenario.

Current and Potential Water Use Efficiency

Local and regional data on existing losses and potential WUE gains were available for a range of crops primarily through Baillie *et al.* (2007), Schmidt (2003), Dalton *et al.* (2001), Barnes (2008), Craig *et al.* (2005) and Smith *et al.* (2004). These data come from a range of individual field or whole-of-farm studies on WUE. These were then extrapolated to the entire study area, with conservative caution where appropriate. An estimated overall variation of +/- 20% was adopted to account for the potential for site specific characteristics or issues to influence outcomes. This is particularly true for WUE measures associated with storages and channels.

For this feasibility assessment, the WUE model used an efficiency factor to calculate loss from the system primarily through evaporation and seepage. Potential WUE gains associated with specific measures were applied to the model as an increase in the efficiency of each irrigation system component (channels, dams, in-field application). These efficiencies are shown in Table C5 for channels and storages, and in Table C6 for in-field application systems.

The limited improvement associated with channel and storage WUE measures reflects two factors:

- approximately 80% of storages in the study area are too large for implementation of the more effective WUE measures; and
- the high capital cost and low relative cost efficiency associated with implementing WUE measures on channels and storages compared to in-field application measures.

Table C5 Adopted Water Use Efficiency Factors for Channels and Storages

Scenario	Channel Loss	Storage Loss
Existing	0.06	0.3
Low Investment	0.06	0.288
Mid Investment	0.055	0.264
High Investment	0.05	0.228

Table C6 Adopted Water Use Efficiency Factors for In-field Application Systems

Scenario	Cotton	Broadacre	Pasture	Horticulture
Existing	0.6	0.6	0.7	0.75
Low Investment	0.74	0.7	0.9	0.87
Mid Investment	0.82	0.71	0.93	0.89
High Investment	0.9	0.74	0.97	0.91

Cost Estimates

Cost estimate were developed primarily using unit cost rates in combination with irrigated area and storage area. Given the constraints to cost effective implementation of distribution system WUE measures (see Table C5), a nominal level of investment in distribution system WUE was adopted. This nominal amount reflected low level investment in improved control and scheduling of channel pumping (see Appendix A for details). Costs associated with high level investment (eg piping and lining) are too high for realistic consideration in this feasibility assessment.

Unit costs were obtained from Baillie *et al.* (2007), Craig *et al.* (2005), Akbar (2001) and Schmidt (2003). All costs were adjusted for inflation to September 2008.

Costs for the *Water Use Efficiency through Infrastructure Investment* Program were based on capital costs plus the difference between six years of existing and WUE measure operating costs to reflect the full costs of implementation. This is particularly important for storage measures such as monolayers where operational costs are the dominant expense. No discount rate was applied and these estimates do not reflect life cycle costing which would normally be undertaken over a longer period using Net Present Value assessment.

The maximum potential for uptake of WUE measures was estimated using data on the proportion of existing irrigation methods within a region (e.g. furrow, centre pivot) for each crop with data from ABS and Schmidt (2003).

Initially, costs for whole-of-farm investment in WUE (i.e. equal level of adoption for distribution, storage and in-field application systems) were calculated (refer Figure C1). When assessed in combination with potential WUE gains (refer Figure 3 in main report) it is clear that investment in distribution system and storage WUE measures significantly reduces potential savings in comparison to investment in the in-field components alone.

A whole-of-farm investment of $190 million achieves approximately half of the WUE gains achieved by an equivalent investment in the in-field component only. Cost efficiency for the various farm components and levels of investment is shown in Table C7, and highlights the significant degree to which investment in the in-field component will lead to higher WUE gains.

A number of WUE model scenarios were considered to test potential combinations of investment to determine the most cost effective combinations of WUE measures. This analysis was the basis for the development of the indicative investment scenarios outlined in Appendix B.

The basis for cost estimates for the individual irrigation system components are presented in Tables C8 and C9, while a summary of Program costs for the different components and adoption levels is presented in Table C10.

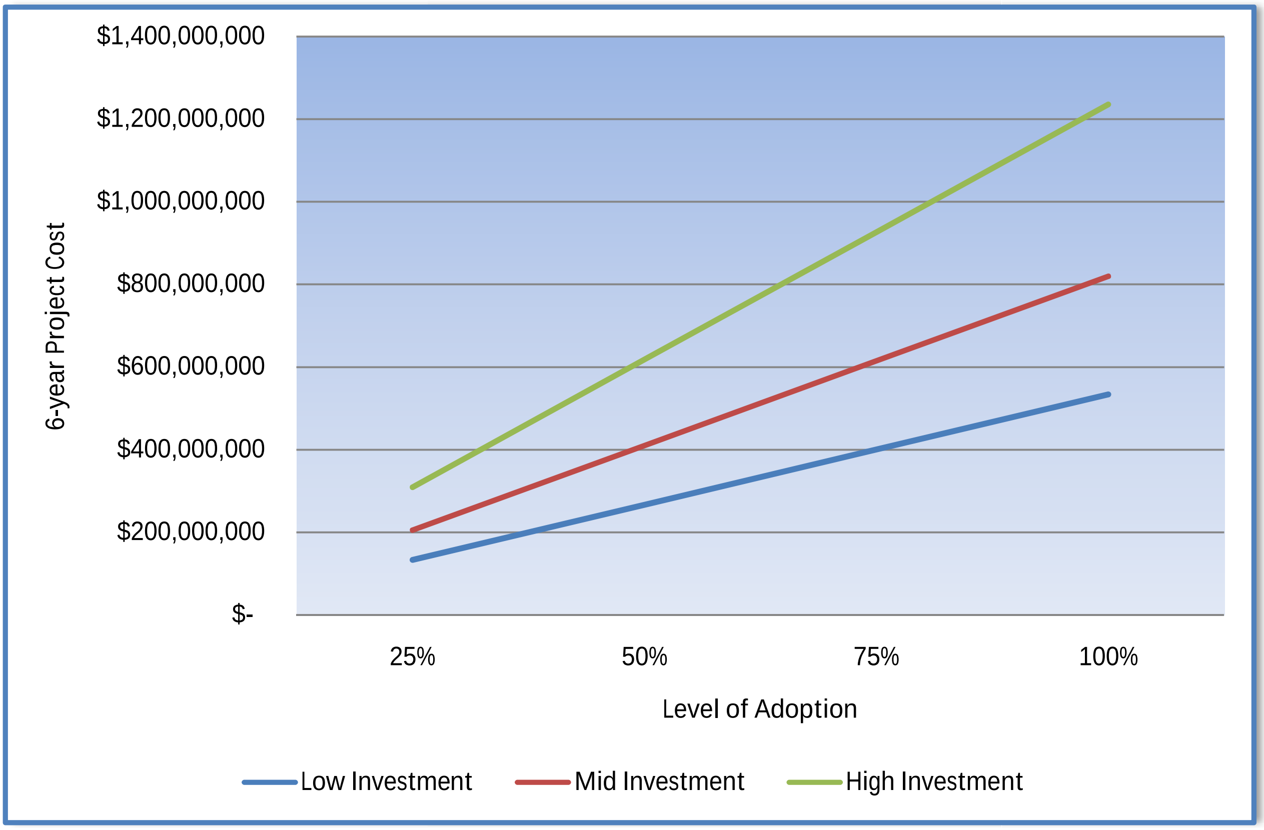

Figure C1 Program Costs for the Equal Adoption across all Farm Components for Various Investment Scenarios and Adoption Levels

Table C7 Cost Efficiency for Various Investment Scenarios and Farm Components ($/ML saved)

Farm Component	Low Investment	Mid Investment	High Investment
Distribution Systems	Cost effective implementation of WUE measures was not found to be practically feasible at present. This is compounded by a lack of information on distribution systems and the limited potential for WUE gains from channels.		
Storages	$3,400	$3,700	$4,600
In-field Application	$60	$800	$1,500

Table C8 6-year Project Unit Cost ($/ha) for In-field Application Components
(Baillie *et al* (2007) adjusted for Inflation and Maximum Adoption (Schmidt, 2003)

	WUE Conversion	Capital	Difference in 6 yr operational expenditure	Total 6yr Cost	Average	Maximum Possible Adoption	Adopted Unit Cost
Cotton	Furrow to Pivot	$2,535	$558	**$3,093**	**$3,879**	94%	$3,647
	Furrow to Lateral Move	$2,535	$570	**$3,106**			
	Furrow to surface drip	$5,282	$158	**$5,440**			
Broadacre	Furrow to Pivot	$2,535	$279	**$2,814**	**$2,814**	51%	$1,435
	Furrow to Lateral Move	$2,535	$279	**$2,814**			
Pasture	Travelling Gun to Boom	$2,535	-$520	**$2,015**	**$3,441**	80%	$2,212
	Travelling Gun to Lateral Move	$2,535	$2,332	**$4,867**			
	Handshift to Travelling Boom	$2,113	$241	**$2,353**			
	Handshift to Lateral Move	$2,535	-$1,572	**$963**	**$1,658**		
	Furrow to Lateral Move	$2,535	$665	**$3,201**	**$3,201**		
Horticulture	Travelling Gun to Boom	$2,113	-$298	**$1,815**	**$1,815**	41%	$419
	Solid Set to Drip	$2,113	-$488	**$1,625**	**$1,625**		
	Boom to Drip	$2,113	-$1,242	**$870**	**$870**		
	Gun to Drip	$2,113	-$1,540	**$573**	**$573**		
	Handshift to Drip	$2,113	-$1,109	**$1,003**	**$1,003**		

Maximum possible adoption % are averages.

Table C9 Unit Costs for Storage WUE Measures (Annual Costs)
(From Craig *et al* (2005) and adjusted for inflation)

EMT	**Cost Range**	**Capital $(\$/\text{m}^2)^{(1)}$**	**Operating $(\$/\text{m}^2)$**	**Maintenance $(\$/\text{m}^2)$**
Floating covers	*Low*	\$6.26	\$0.01281	\$ -
	Medium	\$7.97	\$0.02136	\$0.017085
	High	\$9.68	\$0.03673	\$0.028475
Shade Cloth	*Low*	\$7.97	\$0.01281	\$ -
	Medium	\$9.11	\$0.02136	\$0.011390
	High	\$11.39	\$0.03673	\$0.022780
Monolayer^1	*Small*	\$21,641	\$0.07404	\$0.000826
	Medium	\$60,367	\$0.11105	\$0.001866
	Large	\$91,120	\$0.16658	\$0.044034

(1) Monolayer costs are lump sum costs.

Table C10 Summary of 6-year Project Costs for Individual Components and Adoption Levels

	Adoption	**25%**	**50%**	**75%**	**100%**
Storage	**Low Investment**	\$130,706,401	\$261,412,802	\$392,119,203	\$522,825,604
	Mid Investment	\$156,781,972	\$313,563,944	\$470,345,916	\$627,127,888
	High Investment	\$215,700,754	\$431,401,507	\$647,102,261	\$862,803,015
Channels $^{(1)}$	**Low Investment**	Not considered			
	Mid Investment	\$1,250,000	\$2,500,000	\$3,750,000	\$5,000,000
	High Investment	\$2,500,000	\$5,000,000	\$7,500,000	\$10,000,000
In field	**Low Investment**	\$2,774,543	\$5,549,085	\$8,323,628	\$11,098,170
	Mid Investment	\$46,742,821	\$93,485,642	\$140,228,463	\$186,971,284
	High Investment	\$90,711,100	\$181,422,199	\$272,133,299	\$362,844,399

(1) Nominal levels of investment only, relating primarily to increasing degrees of improvements in channel controlling and distribution scheduling

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