Submission to the Standing Committee on Agriculture and Water Resources:

Inquiry into water-use efficiency in Australian agriculture

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Summary

The issue of water-use efficiency can only be answered by first looking at the reasons why the Australian Government is subsidising the uptake of water-efficient capital and water-efficient practices. The Murray-Darling Basin Plan (the Plan) is designed to rebalance consumptive extractions so that society benefits. To achieve the Plan's goals a set of water property rights (entitlements) is required to provide physical water resources for environment benefits (e.g. wetland watering events to support bird-breeding and fish habitat). Public finances have been used to recover at least 2,750GL (gigalitres) of water rights from farmers, through either the *Restoring the Balance* (buyback) or *Sustainable Rural Water-use Investment Program* (SRWUIP) programs. Another quantity of water may also been gained from investing in environmental capital works, but this is outside the scope of the inquiry.

The final portfolio of recovered water entitlements will have spatial and reliability characteristics providing environmental, economic, social and cultural benefits throughout the Murray–Darling Basin (Basin). One benefit includes reducing the level of salinity within Basin river systems, which provides irrigators with opportunities to expand their production choices.

Assuming the minimum 2,750GL of recovered water rights discussed above, a recent decision to cap buyback water recovery at 1,500GL means that the SRWUIP program must recover the other 1,250GL. Where that 1,250GL recovery cannot be achieved, and the government are unable to reach their sustainable diversion limit (SDL) objectives, Australia will experience a net reduction in expected national public benefits from tax-payer investments. The Plan may also need to be revised downwards, resulting in net environmental losses for the Basin.

Major Points:

Water Entitlements & Their Reliability

- Both irrigation and environmental water-users have access to the same entitlements.
- Water entitlements have spatial and reliability characteristics, and entitlements can be divided into three major reliability classes: high, general, and supplementary/low.
- Any water-user can hold a portfolio of entitlements.
- Future realised climatic events may reduce the reliability of water-users' entitlements.
- **There is a lack of clarity about how water-use efficiency gains are converted into water entitlements.**

Water-Use Efficiency

- Water-use efficiency by producing more crop yield with less water per hectare, may increase total Basin irrigated area, even when a share of water efficiency savings goes to the government.
- As efficiency increases, an irrigator's ability to adapt to future 'bad' (e.g. drought) shocks decreases, particularly if they invest in or already irrigate higher-valued perennial crops. Perennial crops require water every year to maintain capital investments.
- Growing global demand for high value perennial crops has been driving a structural change in the Basin at the same time as irrigation efficiency investment by the Commonwealth.
    - If entitlement reliabilities decrease in response to prolonged drought shocks, but the total area of perennials in the MDB has increased in response to growing demand and commodity returns, demand for water from high value perennials could be higher than in previous droughts; where loss to perennial capital stock in the Millennium drought (2000-2010) was already high.

    - If there is less water to trade in future, prolonged drought, and greater demand from more perennials then **the loss of private irrigation capital may be substantial**.
- Subsidising additional irrigation efficiency lowers cost and may encourage greater investment at risk in prolonged drought (see elaboration below).

Possible Outcomes from Subsidising Water-Use Efficient technology for existing inefficient irrigation

- A significant amount of water efficiency investment has focussed on existing "legacy" infrastructure; that is, publically built and increasingly dated irrigation infrastructure with inherent inefficiencies related to farm plot sizes, delivery inflexibility, and high costs associated with aging infrastructure retrofits and on-going maintenance.
- Public capital subsidisation lowers the private cost of adopting and adapting irrigation production systems. This lowers the rate of return on capital at which a farming enterprise breaks even, and increases farmer capacity to borrow money. This may incentivise a shift toward perennial cropping systems. If farmers transition towards perennial production systems that require water in all years and states of nature (i.e. dry, wet or average conditions):
    - Constant water requirements will reduce irrigator capacity to adapt to adverse climatic conditions (drought) through access to water trade supporting yield preservation;
    - Below yield preservation, if there is insufficient water to maintain the root stock, capital investments in perennial crops will rapidly become exposed to loss; and
    - If perennial crops are lost across an increased total area coverage, there is the potential for rural debt to significantly increase in a relatively short period.
- Such public capital subsidisation often does not target the most effective means of achieving water-use savings: e.g. through private transformation or agronomic/management changes, which studies show can be more effective (often more efficient, allowing benefits of more flexible delivery timing, large scale economics and other advantages).
- In order to maximise the gains from the SRWUIP, it may be necessary to target infrastructure investment at the least-efficient farmers/irrigation infrastructure operators (IIO), but this:
    - Rewards those farmers/ IIOs who do not value water at the same rate as the market
        - Thereby locking water resources into areas of low return, and preventing new farmers from entering the market and using all resources more efficiently
        - This leads to lower total farm productivity
    - Penalises those farmers/IIOs who previously allocated private capital to achieve water-use efficiencies
    - Crowds-out any current/future intended private capital investments during the life of the SRWUIP investment program, and

The Environment & Water-Use efficiency

- Water for the environment was originally recovered via both buyback and SRWUIP programs. By now capping buyback to 1,500GL:
    - SRWUIP needs to obtain 1,250GL, if the target is 2,750GL
    - SRWUIP needs to obtain 1,700GL, if the target is 3,200GL
- Under those objectives, SRWUIP has the following impacts:
    - Once SRWUIP farm or IIO investments occur, any saved water is shared equally (50-50) between the government and water user.
    - As efficiency increases, the total irrigated area can increase as farmers apply their 50% saving.
    - By increasing on-farm and/or IIO efficiency, less water returns to the river as run-off.
    - The combination of these two outcomes rapidly erodes any prior environmental gains.

  - SRWUIP thus cannibalises water recovery gains made from buyback, preventing the Plan from achieving its SDL objectives.
- The original motivation to shift toward less water buy back and more SRWUIP was that this should maximise environmental gain and economic returns in irrigation regions. But:
  - If public investment to offset impacts of reduced water is justified, the greatest return to the regions may not be from irrigation infrastructure.
  - Instead it could be advisable to consider a broader range of investments and choose other options where the multiplier gains from those investments exceed those from irrigation upgrades.

Wider Social Issues

- Horticultural producers in the MDB experience the highest psychological stress levels of all producer groups
- Irrigators who identify with high levels of psychological distress are much more likely to strongly agree that irrigation infrastructure investment had been wasteful, and that money should have been spent on rural health and/or education services instead

Introduction

Droughts and floods have shaped Australia, Australians, our ecosystems and our agricultural production systems. Irrigation is one solution to reduce the economic hardships incurred during drought. When water is available, it provides: economic growth; the capacity for healthy ecosystems to develop; opportunities to engage in cultural activities; and critical supplies for human needs. However, water supplies are finite, and investing in water-efficient technology allows society to maximise its welfare from any water resources that are available.

It is therefore important to understand that **water can be both a risk-increasing and risk-reducing input of irrigated production.**[1] Critically, Murray–Darling Basin (MDB) irrigation supplies are not guaranteed, and the MDB has the second-most variable inflows in the world. Water supply uncertainty in the MDB can be managed in part by the adoption of alternative water property rights (simplified as high, general and supplementary/low entitlements), where each right has different spatial and temporal reliability characteristics. For example, high reliability water rights may supply water in 95% of seasons, while general reliability rights may only supply water in 35% of years.

Additionally, the 'Millennium Drought' (2000-2010) highlighted that existing perceptions about future water reliability may underestimate the true risks associated with current and future climatic events. Consequently, any policy that encourages the adoption of increased private irrigator or public/private irrigated infrastructure operator (IIO) risk may have unintended consequences.

Private, IIO and Social gains from Water-Use efficiency

Water-use efficiency can be defined via agronomic, engineering or economic approaches. *Irrigation efficiency* is the ratio between water diverted and water consumed by crops; *field application efficiency* is the ratio of crop irrigation water requirements and water delivered to fields; *water-use efficiency* is crop yield per unit of water diverted (e.g. kg/m3); while *water-use productivity* refers to the dollar value of water produced per unit of water applied From an economic and farm perspective, water-use productivity is probably the most important measure as it represents the actual net dollar value earned by the farm(er).

The higher the application of water to actual crop usage, the higher the conveyance losses; hence, the greater the possibility to improve water-use efficiency savings. Irrigators can adopt a range of practices to improve water-use savings including agronomic (e.g. improved crop husbandry, changed crop mix, soil management), technical (e.g. irrigation infrastructure changes, laser-levelling) or managerial (e.g. irrigation scheduling, infrastructure maintenance) strategies.

Wheeler et al.[2] compared water-use efficiency/water-use productivity/water-use per hectare/water-use volume/water-use percentages between organic and conventional farms to highlight the complex issues attached to reducing irrigation water-use in the Murray-Darling Basin. It was found that:

- Higher irrigation infrastructure investment was positively associated with higher water-use volume (or was insignificant)
- Higher water charges were negatively associated with higher water-use volume (or was insignificant)
- Organic farms outperformed conventional farms in terms of water-use and water-use productivity overall, but the evidence is mixed on water-use efficiency.

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[1] Rothschild, M. and Stiglitz, J.E., 1971. Increasing risk II: Its economic consequences. *Journal of Economic Theory*, *3*(1), pp. 66-84.

[2] Wheeler S., Zuo A., Loch A. 2015. Watering the farm: Comparing irrigated organic and conventional farm water-use in the Murray-Darling Basin, Australia. *Ecological Economics*, 112, 78-85.

This study's highlights the complexities associated with water-use efficiency approaches to irrigator behaviour and farm outcomes, and that more efficient infrastructure may not necessarily be the most effective (or cost-efficient) way to improve/conserve water-use in the MDB.

Water-Use Efficiency and Droughts

The technical efficiency of investing in water-use efficiency can be illustrated in Figure 1, which shows the volume of water it takes to produce crop output Z per hectare under two production functions. PF represents an existing technology, requiring water WU to produce Z, while PF' is a new technology that only needs WU' of water to produce the same Z. In this case, WU' is the optimal amount of water the crop needs, and little to no water leaves the farm as a result of adopting the new technology (i.e. return flows to the river and surrounding environment are minimal).

The adoption of PF' saves $WU' - WU$ water per hectare, which in turn shows the efficiency gain. For simplicity in our argument, we will assume that the farmer then utilises all saved water in another productive capacity.

However, increased efficiency can reduce the irrigator's capacity to adapt. Let's assume that a drought occurs, and now only $WUd \text{ and } WUd'$ of water supply is available. Note, any reduction is proportional so that ($WU - WUd = WU' - WUd'$). In this case the old inefficient technology PF can only produce Zd with WUd water, while the new technology PF' produces Zd'. Where all other factors are held constant, the farmer's output reduces by $Zd' - Zd$, and that leads to a loss of income from the adoption of the efficient technology PF'. In other words, what may appear inefficient on face value, can sometimes be the better choice where inefficiencies provided a useful strategy for managing the supply uncertainty of a risky input (water).

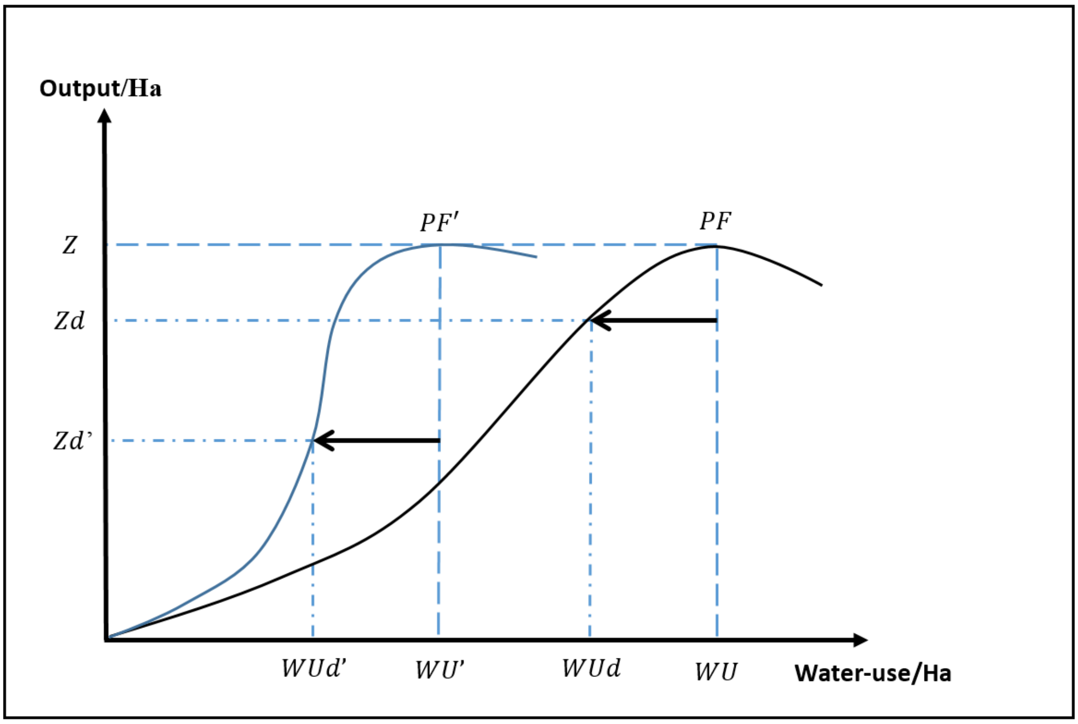

Figure 1 Water-use Efficiency[3]

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[3] Adapted from Adamson, D. and A. Loch (2014). Possible negative sustainability impacts from 'gold-plating' infrastructure. *Agricultural Water Management* 145(Nov), pp. 134-144.

Expansion of Irrigated area from Water-Use Efficiency

Another example based on stylized data to add transparency may help to clarify. The efficiency gain via technology adoption outline above—$WU' - WU$ of water per hectare from the adoption of PF'—provided farmers with surplus water resources that they could use elsewhere.

To produce five tons of a commodity per hectare, the old technology used 10 megalitres (ML) per hectare and the new technology uses eight ML/hectare. On the basis of current SRWUIP-shared water savings, both the government and the farmer would each get $(WU' - WU)/2$ ML = 1ML each. This provides the farmer with nine ML/hectare of total water, and the extra area they can plant is 1/8 hectare. This can be represented by Figure 2, where current area increases from IA to IA'.

SRWUIP capital subsidies thus provide the capacity to bring more irrigated area into production. This example applies equally if the IIO is upgraded, as more water is available to use. This is known as the Jevon's Paradox or the rebound effect.The question is: will this investment be placed into perennials or annuals, and what happens to the increased levels of private investments during droughts?

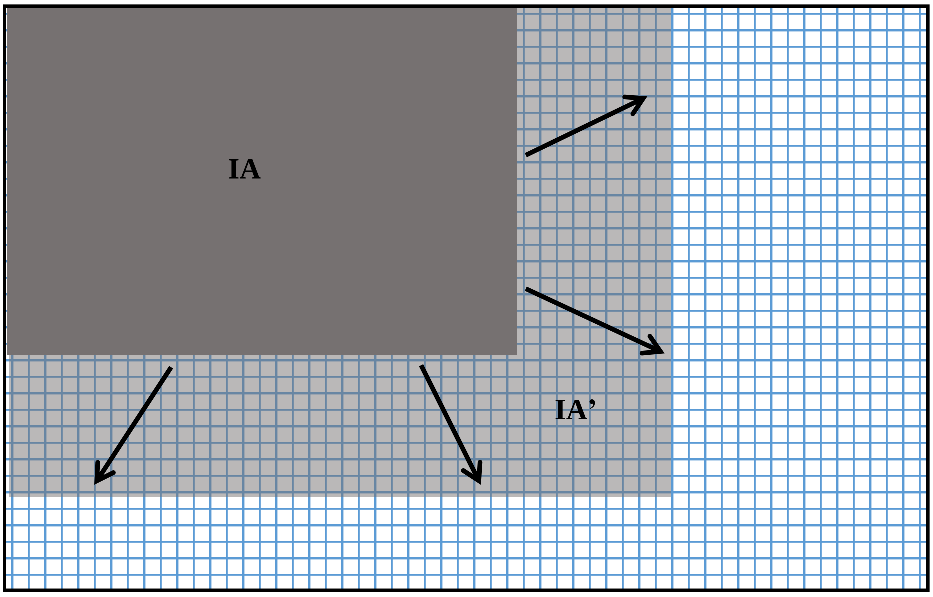

Figure 2 Possible Efficiency Gain Effects on Total Irrigated Area (IA)[4]

Water Supply, Water Prices and Choice Sets for Irrigators

In a forthcoming paper, the choice set for a perennial producer in preparation for and later response to drought and water price signals is explained in detail.[5] The following section simplifies the discussion contained in that paper, and Figure 3 below provides a graphical representation of a demand response by producers to a given supply of water.

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[4] Adapted from Adamson, D. and A. Loch 2014. Possible negative sustainability impacts from 'gold-plating' infrastructure. *Agricultural Water Management* 145(Nov), pp. 134-144.

[5] Loch, A. Adamson D. and Schwabe, K. (accepted). Adaptation responses to increasing drought frequency. *Australian Journal of Agricultural and Resource Economics*.

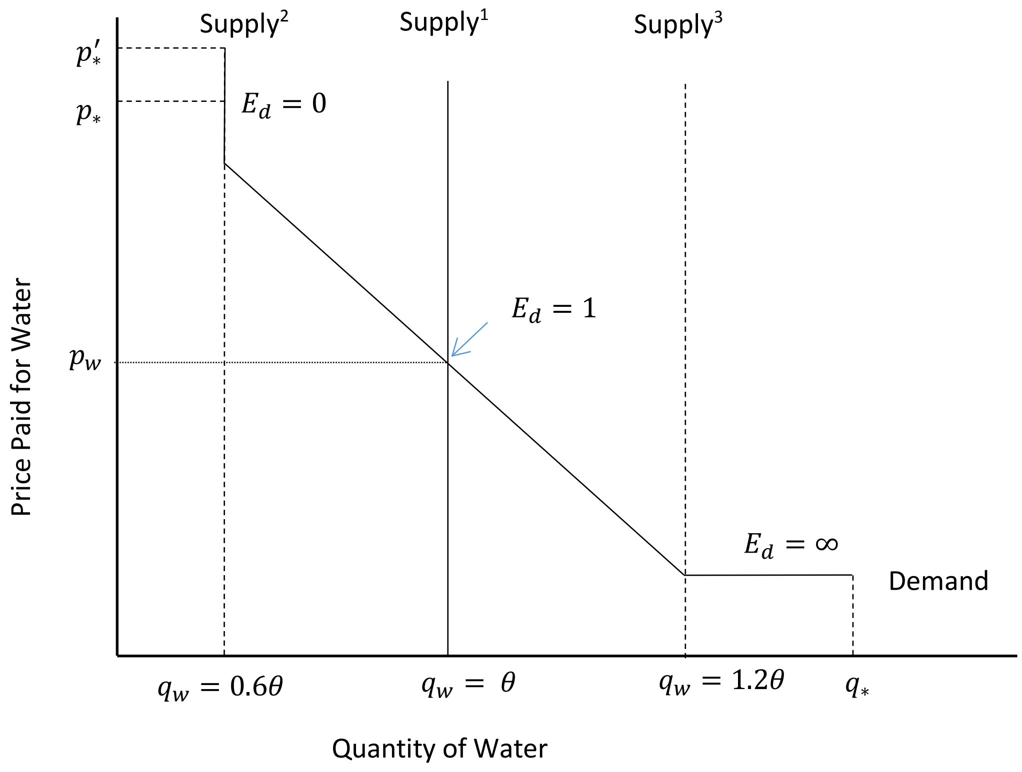

Figure 3 Producer demand response to water supply

At equilibrium (i.e. where water supply and demand intersect), the supply of water $q_w = \theta$ meets the demand or cropping needs of the producer, who is willing to pay p_w to access this water. When water supply contracts to the left (decreases such that $q_w = 0.6\theta$), then the producer is willing to pay $\geq p_w$ to obtain water from the market to meet their demand. Thus, when water becomes scarce, the price paid becomes relatively inelastic (Randall 1981)—particularly for perennial producers where their first priority is to keep commodities alive.

However, as water scarcity increases, prices may become perfectly inelastic until the water market value exceeds a user's ability to pay. This denotes the long-run choke price (P_*), or the point at which no further water is available on the market or from delivery systems. As shown in Figure 3, however, in the short-run perennial producers may be willing to pay above the long-run choke price—up to P_*'—to prevent irreversible capital losses. Irreversible capital losses (e.g. the death of perennial root stocks) will have multiple-year negative impacts, as investments to replace root stock capital have to be brought forward.[6]

In response to high P_*' water prices, annual producers with any seasonal allocation will elect not to crop, and instead enter the water market to generate revenue returns. In this way, water trade then keeps the perennial capital located in the Basin alive. **As such, water for the perennial producer is a risk-increasing input when supply is not guaranteed. In contrast, water is a risk-decreasing input for all annual producers.**

If future shocks are significant enough in impact, and/or prolonged in their duration, the fragile nature of the capacity for water markets to reallocate scarce water resources will become stark in a short period; especially where the amount of perennial cropping has grown in response to market/policy signals.

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[6] That is, all root stock has a finite life and will need to be replaced eventually (e.g. after 25 years). Early loss of immature capital (e.g. 10-15 year-old root stock) requires investment ahead of planned arrangements.

Water-Use Efficiency and Environmental Flows

But how can public water-use efficiency investments on a large-scale also be bad for the environment, particularly if the SRWUIP program is designed to recover water that is supposed to be held and later applied to things like wetlands and bird-breeding events?

The answer lies in our limited prior knowledge about water losses ahead of implementation of the SRWUIP incentives. Building upon the sections above, we know that SRWUIP has the capacity to:

- Reduce the amount of water needed to irrigate a commodity and reduce the amount of water being wasted (going into tail drains or returning to the river)
- Increase the area under irrigation

This section explores those consequences for the environment. Let's return to the example outlined previously where, to produce five tons of a commodity per Ha, the old technology used 10 ML/hectare and the new technology uses eight ML/hectare. When implemented, this efficiency gain reduces return flows to the river system from 30% to 10% for every ML used, as shown in Table 1 below.

Table 1

Technology	Water-use (ML)	Return Flow Rate (%)	Environment Receives (ML)
Old Inefficient	10	30	3.0
New Efficient	8	10	0.8

The efficiency gain is two ML, which as we know is shared equally between the government and farmer (one ML each). This provides the farmer with nine ML of water, so at the new rate of 10%, the total return flow is 0.9ML. Previously, the old technology returned three ML of water to the environment. However, under the new arrangements the environment now receives 1.9ML of water; that is, one ML from sharing the savings from subsidised upgrades and 0.9ML from any return flow.

Water-use efficiency can thus decrease the flow in the river. From this simple example, we can clearly see how the current investment from a base of ignorance with respect to prior losses coupled with the sharing arrangements under SRWUIP (50/50) can lead to reductions in total environmental water.

Buyback versus SRWUIP and the Environment

We can look at the argument above in some further detail. The key features of buyback and SRWUIP programs are provided in Table 2 below:

Table 2

Policy Option	Quantity of Water Recovered	Uncertainty in Supply	Price ($)
Buyback	☑ (100%)	Known (within boundaries)	Known + market specified
Efficiency	? (50%)	Unknown	Unknown + no market validation

The Buyback was a tender-based process where each right bought had known characteristics of supply, and delivery (reliability) by location. This process revealed a true market price and a known quantity of water with some historical basis of reliability. The SRWUIP is a process where submissions are made to upgrade water infrastructure (new or existing). Funded submissions will eventually share efficiency savings 50-50 between farmers and the government. Where nothing is known about prior losses, the true quantity of water recovered will be unknown. When combined with the rebound effect (i.e. where total irrigated area increases) and reductions in return flows, total river system flows decrease. This net reduction in flows means:

- The Plan goals are placed under increased risk; and/or
- There is downward pressure on the reliability of **all** water entitlements.

This can be explained by the following example. As buyback has now been capped at 1,500GL of water, SRWUIP needs to recover at least 1,250 GL of water for the environment. Assuming this recovery only came from irrigated farmland and efficiency gains of two ML/Ha could be achieved on average, over 2.5 million hectares of land would have to be upgraded to accomplish the current efficiency gain recovery target. If as described above, the net average reduction in river flows from investing in on-farm efficiency is 3-1.9ML = 1.1ML, then SRWUIP may reduce total flows by 125GL per annum (1,250*1.1=1,375GL). Consequently, SRWUIP cannibalizes water recovered from buyback investments that were made in the national interest, and decreases its own effectiveness at the same time.

In a normal or wet year, the Plan objectives and supply reliability of all entitlements (farm and environmental) may still be met. However, in a drought year this SRWUIP reduction impact (125 GL) **will place downward pressure on the reliability of all entitlements**.

Negative Externality Consequences– Impact on Irrigators' Stress and Mental Health

The previous discussion has provided a thorough discussion about why the SRWUIP has encouraged investment into perennial agriculture, and hence possibly encouraged lock-in and path dependency problems for the future. The following discussion summarises ongoing research by the University of Adelaide on current stresses experienced in the irrigation industry. The table below provides a summary of the results of a survey of 1000 irrigators randomly surveyed by telephone in 2015-16 (73% response rate) and illustrates that 75% of horticultural irrigators named electricity prices as their second main day-to-day stress (after commodity prices), far outweighing any other response from any other industry group. This is reflective of modernising irrigation infrastructure.

Table 3: Day-to-day farming stressors by industry (%)

Stressors	*Horticulture (n=315)*	*Broadacre (n=270)*	*Dairy (n=187)*	*Livestock (n=225)*	*Pearson Chi*^{2}
Financial	64.7	57.0	62.0	51.6	10.5^{**}
Time	61.5	58.2	62.0	51.1	7.2^{*}
Drought	59.9	73.0	72.7	69.3	14.6^{***}
Water availability	63.7	76.7	84.5	70.2	28.7^{***}
Community pressure	26.8	25.2	26.2	23.1	*1.0*
Labour supply/cost	52.4	36.3	44.4	37.3	19.4^{***}
Electricity irrigation costs	74.8	46.3	50.3	44.9	69.3^{***}
Commodity price	80.8	65.9	71.7	62.2	26.4^{***}
Bank pressure	36.0	30.0	24.1	25.3	10.9^{**}
Family succession	30.9	28.9	22.5	28.0	*4.3*

$^{*}p<0.10$; $^{**}p<0.05$; $^{***}p<0.01$

The survey also sought to measure psychological distress of irrigators, as large-scale measures of irrigator distress have never been measured before. They found that they distress levels of MDB irrigators were higher than Australian farmers in general, but they were also higher than the general population. Overall, horticulturalists had the highest distress levels (20.3% at high/very high levels), followed by broadacre (18.9% at high/very high levels) and then dairy irrigators. Livestock distress levels were the lowest. Many comments were also provided around water and the pain associated with uncertainty and regulation.

Irrigators who recorded high levels of psychological distress were much more likely to strongly agree that irrigation infrastructure investment had been wasteful, and should have been spent on rural health and/or education services instead.[7]

We suggest beneficial policies in the water space could include reforming termination fees in irrigation districts, supporting exit packages for small irrigators, eliminating irrigation infrastructure subsidies and supporting the buyback of water entitlements (because of the lock-in and path dependent nature of irrigation infrastructure and the flexible nature of the buyback of water entitlements that allows for farm exit), increasing water market information and conducting further research on value-adding opportunities for irrigated farming. Further research on the drivers of irrigators' mental health and their links with key social and economic infrastructure across the MDB is also clearly warranted.

Conclusion

We have outlined our thoughts and findings on the positive and negative private and public impacts for Australian tax-payers, farmers and environmental assets that may stem from the current water-use efficiency policy. These outcomes are also currently being identified and raised in other contexts. A very recent working paper examining the impacts of publically-funded agricultural water-use efficiency incentives and investments in Morocco outlines similar issues to those raised herein. The conclusions to that paper summarise our thoughts for the challenges in Australia very well:

> *Pressing political realities are understandable and may well encourage investments that are seen to provide employment and create wealth in rural areas. But these short-term political or private gains are a Faustian bargain. As Bouignane and Serrhini[8] put it: "we have sounded the alarm. We know it's a very complex problem, latent and invisible. We are procrastinating because we're not ready to sacrifice what we are gaining at present, and because there are conflicting interests. [...] the current trend follows the worst-case scenario." This is a wake-up call that political incantations mask the grim reality that in a closed basin you cannot 'create' new water by any technical fix or otherwise.*[9]

There is an opportunity for this Parliamentary Inquiry to understand the complex issues associated with agricultural water-use efficiency incentives, and its important role in returning water to the environment and achieving the national benefits possible under the Murray–Darling Basin Plan. A successful Basin Plan will benefit all: irrigators, environmental assets, urban and rural communities and cultural water users—and provide a lasting legacy for future generations.

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[7] Wheeler, S. Zuo, A. and Loch, A. 2016. Farm survey participant update letter. *Centre for Global Food and Resources*, the University of Adelaide, Adelaide South Australia 5005.

[8] Bouignane, A. and Serrhini, N. 2015. Enjeux et perspectives d'une gestion durable de la nappe de Fez-Meknès. *Alternatives Rurales*. Octobre 2015. http://alternatives-rurales.org

[9] Molle, F. 2017. Conflicting policies: Agricultural intensification versus water conservation in Morocco. *Institut de Recherche pour le Développement*, UMR-G-Eau working paper, March 2017.