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## Abstract
Risks associated with the management of groundwater in farming landscapes are at the forefront of public discourse in Australia and North America. There has been very little social research examining rural landholder attitudes to groundwater use and management. This is an important gap given the critical role social acceptability plays in resource access decisions, the important role groundwater plays in sustaining livelihoods, and the vital role it plays in maintaining groundwater dependent eco-...

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What lies beneath: rural landholder interpretation of the risks of aquifer exploitation in Australia

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ABSTRACT

Risks associated with the management of groundwater in farming landscapes are at the forefront of public discourse in Australia and North America. There has been very little social research examining rural landholder attitudes to groundwater use and management. This is an important gap given the critical role social acceptability plays in resource access decisions, the important role groundwater plays in sustaining livelihoods, and the vital role it plays in maintaining groundwater dependent ecosystems. This paper attempts to address that gap by exploring how rural landholders interpret risks associated with groundwater use for irrigated agriculture. We do that by using a case study from south eastern Australia where farmers’ livelihoods are increasingly dependent on groundwater. We draw upon spatially referenced survey data to investigate the general extent and nature of concern about risk associated with pumping groundwater. We also explore the factors influencing risk interpretation, including occupational identity and proximity to the aquifer. Survey results suggest that while there is concern about pumping groundwater for irrigated agriculture in the Wimmera region, there is also considerable confidence that negative outcomes can be avoided. The dimension of risk of most concern to respondents was the possibility that the benefits of pumping groundwater would not be shared equitably. Those reporting lower concern about the risks of groundwater pumping were more likely to own properties located above the aquifer, to exhibit a strong business orientation including prioritising economic values compared to environmental values, and to express attitudes indicating they thought private property rights should be protected. A substantial proportion of survey respondents indicated they were ‘Unsure’ on all the risk items in the survey. It seems the future social acceptability of groundwater exploitation in the Wimmera region will depend on the extent that those ‘Unsure’ shift to the ‘Agree’ or ‘Disagree’ cohorts. The survey data suggest that focusing on the economic
implications of declining water tables would be an effective way of engaging these rural landholders in dialogue about the sustainability of their groundwater resource.

**KEYWORDS**
Risk perception; groundwater management; Australia; social acceptability; agricultural landscapes

**1 INTRODUCTION**

With the rapid expansion of coal seam gas (CSG) mining, groundwater management is now at the forefront of public discourse in Australia and North America (Braisier et al., 2011). Those concerned about CSG often highlight potential negative impacts on the integrity of aquifers, including the quality of groundwater. The reality is that groundwater is a critical component of contemporary water supplies. In Australia, groundwater constitutes 17% of all water consumed and 33% of water used for agriculture (Marsden Jacob Associates, 2012; National Water Commission, 2012). In the USA, groundwater makes up 20% of all water consumed and 41% of the total water used for irrigation (Barber, 2009). It is estimated that groundwater supplies approximately half of the world’s drinking water, and it makes up a major proportion of irrigation supplies (Giordano, 2009).

There is now abundant evidence of the over-exploitation of this important resource, with implications for current and future generations. In many parts of the world, falling groundwater tables are causing draw downs, reductions in river base flows, saline intrusion and land subsidence. Additionally, it is contributing to the drying up of wetlands (Giordano, 2009). In the United States, groundwater depletion has increased markedly since 1950.
Maximum rates of depletion occurred between 2000 and 2008 when the depletion rate averaged almost 25 km$^3$ per year. Between 1900 and 2008, depletion rates averaged 9.2 km$^3$ per year (Konikow, 2013). Five major confined groundwater basins in the United States have recorded up to an 80% loss of storage space. Two unconfined aquifers have experienced declines in the tens of metres with little likelihood that natural recharge will restore levels in the near future (Narasimhan, 2009). These systems have essentially been mined (Narasimhan, 2009). In the western United States, urban and exurban developments have been partly supported by groundwater use. In some cases, ‘exempt wells’ have served as a substitute for developing municipal water supplies. This has raised concerns about the sustainability and quality of the resource. It has also created conflict between users, for example traditional users, such as farmers, and new suburban homeowners. These wells are exempt from permitting and monitoring, meaning it is difficult to know how many there are, their location, or how much water they extract (Tracy et al., 2012; Vinett and Jarvis, 2012). At present, the legal status of groundwater is different to surface water (despite scientific knowledge showing they are interconnected).

In 2005, 5% of Australia’s 367 groundwater management units (GMU) were over-allocated and a further 23% were highly developed (National Water Commission, 2011). In the Murray-Darling Basin (MDB) [Figure 1], Australia’s food bowl, around 65% of groundwater use is for irrigation (Murray Darling Basin Commission, 2007). State governments have over-allocated groundwater for irrigated agriculture in many parts of the MDB and provided licences to do so at minimal cost. As might be expected, farmers have expanded their areas under irrigation. In 2004/5, groundwater entitlements in the MDB amounted to 3,250 GL/year, compared with an estimated sustainable yield of 2,450 GL/year (Nevill, 2009).
In areas where groundwater entitlements are available, the adoption of centre pivot irrigation has aided the expansion of irrigated agriculture based on groundwater extraction. This has occurred in the Wimmera region in the state of Victoria, which is part of the southern MDB. The Wimmera region is the case study for this research. The Wimmera is also an interesting case study because of the large number of ecologically significant small wetlands on farming land that may be affected by changes in groundwater levels and quality.

There has been very little social research examining rural landholder attitudes to groundwater use and management. This is an important gap given the critical role social acceptability plays in resource access decisions, the important role groundwater plays in sustaining...
livelihoods, and the vital role it plays in maintaining groundwater dependent ecosystems. This paper attempts to address that gap by exploring risk interpretation by rural landholders in relation to groundwater use for irrigated agriculture. In the next sections, we provide an overview of key literature examining the social construction of risk and introduce the research approach. We then report the key findings from our case study. In our discussion, we reflect on the contribution of this research to the wider groundwater literature. We conclude with a discussion of the implications of this research for policy and management.

2 BACKGROUND

2.1 Water governance

The recent severe drought in south eastern Australia highlighted important water governance issues and led to a number of key reforms, including those intended to address pressures on groundwater resources. Those reforms have included establishing the National Water Initiative (NWI) and the National Water Commission (NWC) to implement the NWI, and the Murray-Darling Basin Authority (MDBA) to replace the Murray-Darling Basin Commission. The MDBA was charged with developing and implementing the Basin Plan. The Basin Plan involved establishing Sustainable Diversion Limits (SDL) for each watershed in the MDB (i.e. the amount of water that can be used by agriculture and urban areas without compromising ecosystem integrity) for both groundwater and surface water. An important change has been the consideration of surface water and groundwater as a single resource. While separate SDLs will be set for groundwater and surface water, they will take into account interactions between surface and groundwater systems to prevent double-accounting. Related changes to water governance have included: large reductions in irrigation
entitlements, the purchase of irrigation entitlements by government to provide additional water for the environment, and governments funding the costs of upgrading irrigation infrastructure and on-farm systems to improve water use efficiency. Water markets have also been established to enable water to move to higher value uses.

Most of the additional water for the environment under the Basin Plan will be held and managed by the Commonwealth Environmental Water Holder (CEWH). The majority of the water held by the CEWH is low security water, rather than high security water (Department of Sustainability Environment Water Population and Communities, 2011). While high security users can rely on receiving their full allocation except in severe drought periods, the reliability of low or general security water is less assured. Thus, there is currently debate about the extent that the environment will be compromised during dry periods when surface water allocations are reduced given that most of the water purchased is low security and may not be available during those times. At the same time, there has been widespread concern amongst irrigation industry stakeholders about the SDL process and outcomes. Many irrigators now think they are carrying increased risk as a result of governments cutting their irrigation entitlements to achieve what they believe are uncertain environmental outcomes.

2.2 The social construction of risk

A typical definition of risk is the combination of the probability of an event occurring combined with the magnitude of the consequences (Ben-Ari and Or-Chen, 2009). These elements have been combined as key components of formal risk assessment processes. Technical and rational calculation of risk can be successfully applied in some domains where shared knowledge and values are available (Zinn and Taylor-Gooby, 2006). However,
probabilistic risk assessments include subjective components and assumptions with inputs based on judgments. The calculation of probability is not a value-free activity. This is particularly true for events which have never occurred, or which occur rarely.

‘Lay’ and ‘expert’ interpretations of risk often differ. For example, the public is generally more averse to very unlikely but highly catastrophic or irreversible events than they are to more likely, everyday events. In that way, lay assessments of risk can be seen to deviate from what a technical risk assessment might consider as being rational. Important influences on public perception of risk include: having personal control over the risk; familiarity; perception of equitable sharing of risks and benefits; the opportunity to blame a person/institution for the creation of the risk; and beliefs and attitudes about the nature, consequences, history and justifiability of the risk (Slovic, 1999; Zinn and Taylor-Gooby, 2006).

There is evidence that people rely on a number of heuristics, or ‘rules of thumb’, to simplify their decision making when interpreting risk (Tversky and Kahneman, 1974). Those heuristics include: comparing a risk with other risks (representativeness); judging the frequency of a risk by the ease to which it comes to mind, which can be influenced by the media (availability); anchoring (where judgments are anchored to an initial value); and adjustment, where the initial value is adjusted according to present circumstances (Tversky and Kahneman, 1974).

Differences between the way people perceive and respond to risks are critical to understanding how best to manage and communicate about risk (Slovic, 1999). Older forms of risk communication tended to define the public as naïve. Risk communication was
perceived as a one-way process to increase the public’s knowledge to counteract irrational opinions (Gutteling and Kutscheruter, 2002; Rowan, 1994; Slovic, 1999). The end result of such approaches was often to reinforce public suspicion of the organisation or agency (Slovic, 1999). Newer models of risk communication emphasise the socially constructed nature of risk, the value of different forms of knowledge, and the need for greater levels of meaningful public participation in decision making (Slovic, 1999).

Risk interpretation influences the social acceptability of and, eventually, compliance with rules and regulations. Without social acceptability it is likely that institutional arrangements and organisations intended to improve groundwater governance will be less effective. Understanding how stakeholders and the broader community perceive risk can assist policy makers more effectively engage stakeholders (Trettin and Musham, 2000). It can also assist in the establishment of more socially acceptable policies and programs (Shindler et al., 2002).

2.3 Groundwater and risk

As with most natural resource management (NRM), groundwater governance is typically complex because cause and effect are often uncertain, effective intervention often requires substantial effort over a considerable period of time, and no single actor is capable of addressing the issues on their own. Groundwater governance is further complicated as the resource is largely invisible. There are often very substantial time-lags between recharge and discharge and these may occur over long distances, and hydrological zones often do not match management zones (Taniguchi and Shiraiwa, 2012). Additionally, groundwater is a common pool resource to which many people have direct access, either legally or illegally, and the concept of ‘sustainable yield’ is contestable (Mitchell, Curtis, Sharp and Mendham,
While in some areas there are still opportunities for the expanded use of groundwater, governance mechanisms have not kept pace with the changing groundwater situation. This has resulted in quality decline and aquifer depletion in some regions (Giordano, 2009). Time lags and the nature of groundwater mean that problems may be underway before they are perceived. Where substantial investments have been made in irrigation, users are often reluctant to give up access to the resource (Giordano, 2009). Water managers have ignored the interconnection between surface water and groundwater, exacerbating problems (Giordano, 2009; Narasimhan, 2009).

Groundwater research has generally neglected to focus on the actors who use and manage the resource (Mitchell et al., 2012). Several studies have examined irrigator behaviour, such as in response to drought (e.g. Mudrakartha, 2007). Other researchers have focused on water pricing as a way of limiting groundwater use (e.g. Abu-Madi, 2009; Shah et al., 2009) and the link between energy prices and groundwater use (Shah et al., 2008). Kuehne et al. (2008) classified irrigator types in an Australian case study to determine if the types of irrigators they identified had different intentions and attitudes to water trading. Other research has highlighted factors that are important in determining landholder attitudes and behaviour in relation to groundwater including: access to the resource (Bekkar et al., 2009); the nature of the groundwater resource (Albrecht, 1990); and the occupation, property/farm size and financial resources of the water user (Albrecht, 1990 & 1995; Bekkar et al., 2009). A body of work based on sound social theory explores the governance of groundwater and issues of power, influence and conflict (see Mitchell et al. 2012). For example, Birkenholtz (2009) highlighted that proposed reforms intended to conserve scarce water supplies can further entrench the power of wealthy landowners.
Albrecht (1995) compared the extent farmers and non-farmers were concerned about the Edwards Aquifer in Texas. He established that farmer respondents placed a higher priority on agricultural water uses and were more likely to oppose government involvement in management decisions. In an earlier study, Albrecht (1990) explored the influence of spatial location and the importance of farming occupation on the adoption of irrigation water saving technologies (centre pivot technology, bench terraces and furrow dikes) in response to groundwater resource depletion. He found that the location of a property in relation to the saturated thickness of the aquifer (i.e. extent of the groundwater resource and cost of access to it) influenced respondents’ uptake and commitment over time to irrigation and the adoption of irrigation technologies. The relative importance of farming (i.e. larger property size, more income from farming, larger farm debt) was also important. As expected, those located where there was a larger groundwater resource, and those for whom farming was more important, were more likely to irrigate and to adopt the new technology. More recent Australian research established that the social acceptability of managed aquifer recharge (MAR) amongst groundwater irrigators in the Namoi catchment of northern NSW, Australia, was higher amongst those who were more business-like, innovative, egalitarian and interested in collective action (Rawluk et al., 2013). Those who were less supportive of MAR were more concerned about the potential environmental impacts (Rawluk et al., 2013). Awareness and knowledge of groundwater also appear to be important influences on irrigator behaviour. Several studies indicate that a lack of knowledge or belief that groundwater is inexhaustible can lead to over exploitation (Bekkar et al., 2009; Birkenholtz, 2008; Zhen and Routray, 2002). Other research has found the adoption of water saving technologies is associated with positive recommendations by local authorities or the extent other farmers use them, rather than perception of groundwater depletion (Bluemling et al., 2010).
Social researchers examining unconventional gas development in the United States have explored risk perception amongst rural landholders (Brasier et al., 2013). Trust in the gas industry was strongly associated with perception of lower risk while greater trust in environmental groups was associated with higher risk perception (Brasier et al., 2013). This research also established that those expressing negative attitudes towards gas development had higher environmental concerns. More positive opinions of the industry were associated with having leased to the industry or having had experience with the industry. Proximity to the resource was not significantly correlated with specific attitudes although that finding may have been due to the even spread of gas wells throughout the area (Jacquet, 2012). However, differences at larger spatial scales were found with New York residents less supportive of gas development than Pennsylvanian residents (Stedman et al., 2011).

Groundwater management needs to be based on science, but as Narasimham (2009) emphasised, science can only provide information on how the resource will respond. Decisions about the allocation of groundwater are based on social values and are beyond the scope of science, “Thus, science, policy and management are inexorably interwoven” (Narasimham, 2009, p. 9-10).

In this paper, we explore how rural landholders who own a property located within the confines of an aquifer interpret risks of groundwater use differently from those with properties outside it (see Albrecht, 1990). We also expected the extent of a farming occupation or farming business orientation to be important influences on risk interpretation (see Albrecht, 1995; Rawluk et al., 2013). In part, our curiosity reflected our uncertainty about this topic. We hypothesised it was possible that those owning a property where they could directly access the aquifer would value it more highly. We considered whether these
landholders may value it more highly as it is an asset they are likely to be able to use (or sell) and they might therefore be concerned by the potential loss of access or capital value if the resource was degraded. We thought it likely that those owning a property further away from the resource, and with less ability to use the resource, would be more concerned that some are using a community or common pool resource for profit. We also thought these landholders may be concerned that over-exploitation by a few could negatively impact on groundwater dependent ecosystems. We expected there would be a positive relationship between pro-environmental values and several variables including: attitudes supporting a duty of care for the environment, less entrenched views about the sanctity of private property rights, and concern about the negative risks of groundwater use for irrigated agriculture.

3 METHODS

In this paper we explore risk interpretation by rural landholders in relation to the use of an aquifer by irrigators in an Australian region. We do this by examining:

1. measures of the overall level and nature of risk interpretation; and
2. the factors contributing to concern about risk, including farming as an occupational identity and spatial location of the rural property in relation to the aquifer.

3.1 The case study: The Wimmera region

We have defined the Wimmera region as the area managed by the regional NRM body, the Wimmera Catchment Management Authority (WCMA). The Wimmera is part of the MDB in the state of Victoria and covers approximately 30,000 square kilometres. The climate is typical of a Mediterranean type with relatively low total annual rainfall, most of which falls
in winter and spring. Average annual rainfall varies from up to 1000 millimetres in the Grampians to as low as 300 millimetres in the northern plains (Department of Sustainability Environment, 2008). The Wimmera River is the largest Victorian river that does not flow to the sea and the region includes a series of terminal lakes. Agriculture is the predominant land use. Approximately 85% of the region has been cleared of native vegetation. Broadacre cropping (cereal, oil seed and grain legume) is the principal agricultural activity, followed by meat, wool and dairy. The Wimmera’s regional population is around 50,000 and Horsham is the largest centre with a population of approximately 16,000.

In the eastern part of the Wimmera region, groundwater is mostly low yielding, poor quality, saline and of limited use for agriculture. However, towards the west, particularly within 40 km of the border with South Australia, groundwater is a significant, usable resource. A total of 52,850 ML of groundwater per year is allocated for use in the West Wimmera Groundwater Management Area (WWGMA). Most groundwater is extracted for irrigated agriculture. Other uses include stock and rural domestic, commercial use (intensive agriculture such as piggeries) and urban (small rural town) supply. Much of the area is experiencing population decline as properties expand in size. Groundwater use for energy development or urbanisation is unlikely to occur in the Wimmera, which is over four hours drive from the closest major city. The social and economic benefits and costs associated with groundwater extraction are primarily those associated with water use for irrigated agriculture, the flow on economic effects for local communities and the region, urban use (small town supply), and stock and domestic purposes. Extraction is focused on the Tertiary Limestone Aquifer (TLA) because the water is of a high quality and more readily accessible (< 80 metres). The TLA lies beneath the surface of most of the Wimmera plains, west of the Wimmera River [refer to Figure 2].
In the ten years preceding 2004, over 8,500 hectares of the southwest Wimmera was put under centre-pivot irrigation (WCMA, 2011b). There have been declines in the water table of up to a metre in the last 10 years in areas where groundwater extraction has been more concentrated (WCMA, 2011a). Away from areas of concentrated use, groundwater levels are generally stable (Grampians Wimmera Mallee Water, 2011). In 2001, a Permissible Consumptive Volume was declared for the Neuarpur Area (where use is concentrated), capping allocations at the current licence entitlement. New extraction bores are permitted, but using existing entitlement.

**Fig 2** Location and extent of the Tertiary Limestone Aquifer within the state of Victoria, Australia
The western part of the Wimmera is also a key area for biodiversity in the state with over a quarter of Victoria’s wetlands. Many of these wetlands are listed as nationally significant and are home to threatened species. Over 90% of the Wimmera’s 2,000 wetlands occur on private land (WCMA, 2011b). Approximately 17% of all wetlands in the region are groundwater dependent, but are generally not connected to the TLA. Many of these wetlands are fed by saline groundwater and appear to be less impacted by exploitation of the freshwater aquifer (TLA).

3.2 The mail survey

The results presented in this paper are based on the analysis of data from a survey of rural landholders commissioned by the WCMA in 2011. The survey data are spatially referenced, allowing for integration with other data sets. The survey was the third such survey in the region (following on from surveys administered in 2002 and 2007). A key aim of the survey was to inform development of the CMA’s Regional Catchment Strategy (RCS) by identifying issues of concern to rural landholders and providing explanations of landholder adoption of conservation practices.

In collaboration with the WCMA, the research team identified the topics listed in Table 1 for inclusion in the 2011 survey. In selecting those broad topics, the research team drew heavily on the widely accepted and related theories of planned behaviour (Ajzen, 1985); the value-belief-norm (VBN) theory (Stern, 2000); the theory and empirical research explaining the adoption of technology by rural landholders (Pannell et al., 2006; Rogers, 2003); and research conducted by the authors in the Wimmera region (Curtis and Mendham, 2011).
During survey development, WCMA staff relayed community concern about possible negative risks posed by increased use of the TLA groundwater resources as a result of the expansion of centre pivot irrigation. With the support of WCMA staff, the research team included items in the survey to explore this topic. To explore landholders’ attitudes towards risk regarding groundwater use, we adapted items used to explore risk interpretations towards natural gas developments in the USA (Brasier et al., 2013; Stedman et al., 2011). The six survey items exploring risk interpretation included one item asking if the benefits of groundwater pumping outweigh the costs, two items seeking respondents’ views about whether negative impacts of groundwater exploitation can be prevented or addressed, one item asking whether respondents believed the region will benefit from economic opportunities created by pumping groundwater, one item asking whether groundwater pumping will create long lasting problems, and one item asking whether respondents believed only a few people will benefit from pumping groundwater [Table 1]. Respondents were asked to select one of six response options ranging from one – ‘Strongly disagree’ to 5 – ‘Strongly agree’. ‘Not applicable’ was a separate response option.

Table 1 Principal survey topics, Wimmera social benchmarking survey 2011

<table>
<thead>
<tr>
<th>Survey topics</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Long-term plans for the property</td>
<td>Issues of concern at property and district scales</td>
</tr>
<tr>
<td>Beliefs and attitudes about roles and responsibilities of different NRM actors</td>
<td>Risk interpretations in relation to the management of wetlands and groundwater</td>
</tr>
<tr>
<td>Trust in the WCMA</td>
<td>Values attached to the property and held values</td>
</tr>
<tr>
<td>Knowledge of NRM processes and practices</td>
<td>Confidence in recommended practices for improvement in resource condition</td>
</tr>
<tr>
<td>Sources of information about NRM</td>
<td>Land use and enterprise mix</td>
</tr>
<tr>
<td>Implementation of CRP for sustainable agriculture and biodiversity conservation</td>
<td>Involvement in NRM programs</td>
</tr>
</tbody>
</table>
Background social and farming topics (e.g. occupation, place of residence, property size) 
On and off-property work and income, membership of Landcare and commodity groups.

To explore the influence of values we adapted scales (i.e. a series of items that, when 
measured together, explore different dimensions of a theoretical concept) from Stern et al.’s 
(1998) VBN theory. VBN theory underpins much of contemporary theory on landholders’ 
adoption of conservation practices. This theory explains an individual’s motivation for 
environmental behaviour. The elements of VBN theory include values, beliefs (awareness of 
consequences, ascribed responsibility beliefs and general environmental concern), personal 
norms and behaviour (Stern, 2000). VBN theory suggests that behaviour is derived from core 
elements of personality and belief structures. These inform people’s specific beliefs about 
human-environmental interactions, consequences and an individual’s responsibility for taking 
action. VBN hypothesises that pro-environmental behaviour is more likely if the individual 
feels there may be adverse consequences for something they value (Stern et al., 1993). To 
explore the influence of held values (guiding principles), the survey employed the 12 item 
scale developed by de Groot and Steg (2007) adapted from Schwartz’s value typology that 
distinguishes between biospheric, egoistic and altruistic values (Schwartz 1992; 1994). 
Values attached to the respondent’s rural property were assessed using items previously 
developed by the research team (Seymour et al., 2010).

To explore the influence of farming identity on risk interpretation, a single item was used that 
asked respondents to self declare their principal occupation (Groth et al., In press). This 
approach is consistent with that used by the widely accepted Ashmore et al. (2004) model 
based on collective identity theory.
The 2011 Wimmera survey process employed a modified Dillman (1978) *Total Design Method* (Curtis et al., 2005). Survey booklets were addressed to 1,243 of the approximately 12,000 rural landholders with properties greater than 10 hectares. Survey recipients were randomly selected from local government property owner lists. After removing multiple listings, return to senders and returned blank surveys with a valid reason for not completing the survey, the final N value was 1,003. With 495 completed and returned surveys, the response rate was 49%. To test for non-response bias, we compared survey respondents with the population of rural property owners in the Wimmera region using data from the Australian Farm Census. Comparisons using the area of landholding, age of landholders and membership of Landcare (locality-based sustainability groups) suggest that there are no significant differences between the survey respondents and the population of rural landholders in the region.

Grampians Wimmera Mallee Water (GWMW) provided the research team with a de-identified dataset of groundwater irrigation licence holders in the WWGMA, the volumes of their entitlements and the five year means and medians for actual use. That dataset indicated there were 166 licences within the TLA zone and 27 outside. That is, 84% of licences to pump groundwater occurred within the TLA. Those within the TLA had a median annual allocation (i.e. proportion of entitlement able to pump in any single irrigation season) more than five times larger than those outside the TLA (200 ML compared to 35 ML). Additionally, over the past five years those within the TLA had pumped a median four times more water per season (40 ML compared to 10 ML). GWMW also provided a GIS data layer showing the extent of the TLA. With the coordinates for each property we were then able to locate each survey respondent’s property in relation to the TLA (i.e. within or outside the aquifer) and examine the impact of spatial location on risk interpretation.
3.3 Data analysis

The research team first sought to establish whether the six items exploring risk interpretation could be combined to make a single scale. The final two items listed in section 3.2 were reverse coded to ensure that a higher score reflected less concern (i.e. stronger agreement that the benefits of groundwater pumping outweighed the costs). It was established that the six items created a valid scale with a Chronbach Alpha value of 0.78, which is above the accepted threshold of 0.7 (de Vaus, 2002). Not applicable responses were excluded from the statistical analyses reported in this paper.

Statistical analyses applied to the survey data included descriptive statistics (median, sum and total) and pairwise comparisons to explore relationships between risk interpretation and landholder characteristics. Kruskal Wallis Chi Square tests were used to test for differences on a continuous variable or a Likert scale based on a grouping variable (e.g. farmer/non-farmer). Spearman’s rho was used for correlation analysis to identify significant relationships between pairs of continuous variables. Multiple regression analysis using a stepwise process with Akaike’s Information Criterion (AIC) as the step criteria was conducted to further explore the relationships between risk interpretation and selected independent variables. Independent variables were checked for multicolinearity. In all analyses, the \( p \) statistic represents the significance level where a value below 0.05 is considered to be statistically significant. All statistical analyses were performed using S-Plus.

4 RESULTS
4.1 Attitudes to the risks of groundwater exploitation

There is a pattern across the items in Table 2 for those respondents concerned about negative risks of groundwater exploitation to outnumber those unconcerned. The exception is for the item *All in all, the benefits of pumping groundwater outweigh the costs*. On this item, there is symmetry between the proportions of those who ‘Agree’ and ‘Disagree’. A substantial (33%-56%) proportion of respondents indicated they were ‘Not sure’ for each of the six survey items listed in Table 2. These results suggest that in the longer-term, the social acceptability of groundwater exploitation in the Wimmera region will largely depend on the extent that those ‘Unsure’ shift to the ‘Agree’ and ‘Disagree’ cohorts.

Survey respondents appear more likely to express concern for the distributional (i.e. economic) impacts of groundwater exploitation compared to the long-term environmental or intergenerational impacts. For example, 51% ‘Agree’ (16% ‘Disagree’) that *Only a few in the Wimmera region will receive benefits from pumping groundwater*. In comparison, only 32% ‘Agree’ (18% ‘Disagree’) that *Pumping groundwater will create long lasting environmental problems* [Table 2]. Perhaps part of the explanation for the relatively higher concern about economic impacts is that only a small minority of respondents were pessimistic about the extent *Any negative impacts of pumping groundwater can be prevented if we proceed carefully* (15% ‘Disagreed’). Additionally, more agreed than disagreed that *Groundwater pumping creates economic opportunities that will benefit our district*. Nevertheless, this result should not be interpreted as indicating widespread acceptance that the negative risks are balanced by the economic rewards of groundwater exploitation. For example, only 10% of respondents ‘Agreed’ with the statement that *Any negative impacts of pumping groundwater can be fixed* [Table 2].
### Table 2 Views about groundwater, 2011 (N=494; n=453-455)

<table>
<thead>
<tr>
<th>Risk items</th>
<th>Disagree</th>
<th>Unsure</th>
<th>Agree</th>
<th>Mean</th>
<th>NA (n)</th>
</tr>
</thead>
<tbody>
<tr>
<td>All in all, the benefits of pumping groundwater</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>outweigh the costs&lt;sup&gt;b&lt;/sup&gt;</td>
<td>24%</td>
<td>51%</td>
<td>25%</td>
<td>3.02</td>
<td>52</td>
</tr>
<tr>
<td>Any negative impacts of pumping groundwater can be fixed</td>
<td>22%</td>
<td>56%</td>
<td>11%</td>
<td>2.72</td>
<td>45</td>
</tr>
<tr>
<td>Pumping groundwater creates economic opportunities that will benefit our district&lt;sup&gt;b&lt;/sup&gt;</td>
<td>19%</td>
<td>47%</td>
<td>34%</td>
<td>3.15</td>
<td>43</td>
</tr>
<tr>
<td>Pumping groundwater will create long lasting environmental problems&lt;sup&gt;a&lt;/sup&gt;</td>
<td>18%</td>
<td>50%</td>
<td>32%</td>
<td>3.16</td>
<td>41</td>
</tr>
<tr>
<td>Only a few people in the Wimmera region will receive benefits from pumping groundwater</td>
<td>16%</td>
<td>33%</td>
<td>51%</td>
<td>3.44</td>
<td>35</td>
</tr>
<tr>
<td>Any negative impacts of pumping groundwater can be prevented if we proceed carefully&lt;sup&gt;b&lt;/sup&gt;</td>
<td>15%</td>
<td>49%</td>
<td>36%</td>
<td>3.21</td>
<td>44</td>
</tr>
</tbody>
</table>
Those respondents owning a property outside the aquifer were significantly more likely to agree with this statement. Those respondents owning a property above the aquifer were significantly more likely to agree with these statements.

As stated above, a substantial proportion of respondents indicated they were ‘Not sure’ for each of the six survey items. It is possible that the ‘Not sure’ cohort are unconcerned about groundwater issues, lack sufficient knowledge to be confident about making an assessment of risk, or the groundwater topics covered were simply not very relevant for them. We were able to investigate these possible explanations using data provided about the extent of concern (the effect of existing groundwater extraction), knowledge (the existence of accessible groundwater underneath your property that is of sufficient quality to irrigate crops or water stock), and proximity to the TLA (located within/outside) as a surrogate for relevance. Of those responding ‘Unsure’ to the six items assessing risk interpretation, the majority (60% to 70%) were located outside of the TLA, a substantial minority said the issue was not important to them (from 41% to 51%), and a substantial minority indicated they had little knowledge (from 37% to 47%). To further unpack the high ‘Unsure’ response rate, we compared those who ‘Agreed’, were ‘Unsure’ and ‘Disagreed’ for the six risk items on each of the items for concern, knowledge and relevance listed above. The ‘Unsure’ cohort was significantly more likely to have self-reported lower levels of knowledge for the groundwater topic and to be located outside the aquifer. It seems that those attempting to engage the ‘Not Sure’ cohort in dialogue about the social acceptability of groundwater exploitation in the Wimmera region will need to establish the relevance of the issue by raising awareness of the value of the asset and knowledge of any threats posed to this community resource.
4.2 The influence of values, occupation and spatial location on attitudes towards the risks and benefits of groundwater exploitation

To explore the relationships between factors expected to influence risk interpretations, we tested for significant relationships between the single risk item (the scale combining the six risk items) and variables expected to influence risk interpretation. These included occupation as a farmer (using self-declared identity) and property location in relation to the aquifer. Drawing on those results, the research team suggest a plausible narrative to explain variance in risk interpretations for groundwater exploitation amongst the Wimmera survey respondents.

Less concern about the risks of groundwater exploitation was associated with being a farmer by occupation (p<0.01) and with social and farming variables expected to co-vary with occupation as a farmer. For example, there were significant relationships between less concern about the risks associated with pumping groundwater and the factors: owning a larger property (p<0.001), lower likelihood of earning an off-property income (p<0.05), and having owned the property for longer periods of time (p<0.05). There were also relationships between risk interpretation and land use. Again, those relationships were consistent with the farmer/non-farmer narrative. For example, those less concerned about the risks of groundwater exploitation were more likely to be involved in dairy, sheep and cropping enterprises (p<0.05).

Those less concerned about the risks associated with groundwater exploitation have a stronger farm business orientation and a weaker conservation/biodiversity value orientation. The single risk item was negatively correlated with the altruistic (p<0.01) and biospheric
(p<0.001) held value scales. No significant relationship was observed between the risk item and the egoistic held value scale. The risk item was also negatively correlated with a single variable exploring landholder commitment to a stewardship ethic (p<0.001). Indeed, those less concerned about the risks of groundwater exploitation were less likely to have placed part of the property under a conservation covenant (p<0.001). Less concern about the risks associated with groundwater exploitation was also associated with placing a higher priority on the economic values attached to a respondent’s property (five items, p<0.05). Less concern was negatively associated with holding stronger environmental attached values (four items, <0.001). A negative relationship was also observed between less concern about risk and three social values including valuing the property as a place for recreation, valuing the property for providing the opportunity to learn new things, and valuing work on the property for providing a welcome break from my normal occupation (p<0.05). A negative relationship was also observed between some beliefs and less concern about risk, including the belief that Clearing native vegetation since European settlement has substantially reduced the number and variety of native plants and animals in this district (p<0.001). These relationships are consistent with the influence of occupational identity on risk interpretation proposed in the previous paragraph.

Less concern about the risks of groundwater exploitation was also associated with a number of beliefs and attitudes, so that those respondents gave a higher priority to the sanctity of private property rights and lower priority to the protection of biodiversity. These included Landholders should have the right to crop floodplains or wetlands on their property regardless of the impacts on native plants and animals (p<0.001) and Landholders should have the right to harvest water that falls on their property, even if that action impacts on others (p<0.001). For example, a higher score on the risk item, indicating less concern about
the potential risks, was negatively correlated with agreement with the three statements exploring respondent commitment to a duty of care for the environment \( (p<0.001) \). A negative relationship was also observed between less concern about risk and the belief that the environment should have a specific allocation of water \( (p<0.001) \). Again, these positions are consistent with a stronger farm business orientation and weaker conservation/biodiversity value orientation.

There was a significant relationship between location of the property in or out of the aquifer zone and the risk item. The mean score was significantly higher (indicating less concern) for respondents owning a property inside the aquifer zone \( (3.08, n=164) \) than for those owning a property outside the TLA \( (2.82, n=261) \) \( (p<0.001) \). The mean score for all respondents on the risk scale was 2.92 \( (n=425) \). That is, those who owned a property within the TLA demonstrated less concern about the risks of groundwater exploitation. Those owning a property outside of the TLA were more likely to agree with the item *Pumping groundwater will create long lasting environmental problems* than those owning a property within the aquifer zone. One explanation for the higher level of concern expressed by those outside the TLA is the poorer quality of groundwater there, and possible issues that might arise from it extraction and use for irrigation (such as land salinisation).

A series of regression models was used to further explore the influences on risk interpretation and to test the validity of our narrative [Table 3]. The dependent variable used was continuous (the composite risk item). The independent variables included a mixture of categorical and continuous variables. In the first model the variables included were: biospheric and egoistic held value scales (altruistic values were excluded owing to multicolinearity); location in relation to the aquifer (inside/ outside); occupation (farmer/non-
farmer); two attitudes regarding property rights; a single item exploring landholder commitment to a stewardship ethic for the environment; and an item exploring landholder commitment to a duty of care for the environment. The model results confirm the importance of property rights, proximity to the aquifer and held values. Occupation was not included in the model (Adjusted $R^2$ 22%, $p<0.001$, F-statistic 22.65 on 5 and 372 degrees of freedom) [Table 3]. To further explore the impact of occupational identity, we developed a second model with self-declared occupational identity replaced with variables expected to co-vary with occupational identity including property size, days worked off property/year and hours worked on property/year. There was very little difference between the two models. The egoistic held value scale was no longer included in the second model.

Table 3 Regression results: index of risk interpretation (N=494, n=378).

<table>
<thead>
<tr>
<th>Coefficients:</th>
<th>Value</th>
<th>Std Error</th>
<th>T value</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept</td>
<td>3.1706</td>
<td>0.2318</td>
<td>13.6797</td>
<td>0.0000</td>
</tr>
<tr>
<td>Landholders should have the right to crop floodplains or wetlands on their property regardless of the impacts on native plants and animals</td>
<td>0.1460</td>
<td>0.0299</td>
<td>4.8901</td>
<td>0.0000</td>
</tr>
<tr>
<td>Biospheric values</td>
<td>-0.1391</td>
<td>0.0419</td>
<td>-3.3177</td>
<td>0.0010</td>
</tr>
<tr>
<td>Location outside aquifer</td>
<td>-0.1501</td>
<td>0.0577</td>
<td>-2.6004</td>
<td>0.0097</td>
</tr>
<tr>
<td>Stewardship ethic</td>
<td>-0.0790</td>
<td>0.0339</td>
<td>-2.3291</td>
<td>0.0204</td>
</tr>
<tr>
<td>Egoistic values</td>
<td>0.0879</td>
<td>0.0390</td>
<td>2.2558</td>
<td>0.0247</td>
</tr>
</tbody>
</table>

5 DISCUSSION AND CONCLUSIONS
In the Wimmera study, of those who had formed opinions, most respondents were concerned about the negative consequences of aquifer exploitation. Those concerned about the risks of exploitation were more concerned about the distributional impacts of the benefits of pumping compared to negative ecological impacts. However, most respondents were confident that those risks were preventable. A high proportion of survey respondents indicated they were ‘Unsure’ on all risk items. The high level of uncertainty in our study appears to be related to lower self-reported knowledge and salience (in our case, property location in regard to the aquifer).

Findings from the Wimmera study are consistent with, but extend on other research in the groundwater context. Results indicate that occupation, location, values and knowledge influence risk interpretation by rural landholders (Albrecht, 1995; Brasier et al., 2013). In the Wimmera study, the research team has been able to develop a coherent narrative that combines disparate threads identified in previous research to explain differences in the risk interpretations of rural landholders. Those less concerned about the risks associated with groundwater exploitation have a stronger farm business orientation and weaker biodiversity conservation orientation. While the self-declared measure of occupational identity was not significantly linked with risk perception in the multivariate analyses, there was a significant relationship in bivariate analyses. Other variables expected to co-vary with farming as an occupation were also significantly linked to risk perception. Respondents less concerned about the risks of exploitation operated larger, more profitable agricultural enterprises and exhibited values (held and attached) that reflected a business orientation. They were also more concerned about the sanctity of private property rights.
As in previous studies, location was an important influence. In this study, those owning properties within the aquifer zone were less concerned about the risks of exploitation. That finding was somewhat counterintuitive in that the research team had thought those with access to the aquifer would be concerned by the potential loss of access to water or reduced property values if the resource is degraded. In this study, it seems landholders are more confident in managing the risks associated with groundwater extraction for agriculture. Perhaps that optimism is a reflection of the relatively short period of time centre pivot irrigation has been used or the relatively small (i.e. one metre) decline in the water table to date. This optimism may also be due to the established cap extractions (new development may occur through the trade of existing groundwater licence entitlements, which is subject to rules and requirements) or confidence in current management. The research team also expected that those owning a property further away from the resource, and who have less ability to use the resource, would be more concerned about the potential negative impacts of the exploitation of what is essentially a common pool resource. Survey results provided some support for this hypothesis, while another explanation is that groundwater extraction in areas with poorer quality groundwater is seen as a risk.

Given the focus on surface water in the water reform process in Australia and the less visible nature of groundwater, the research team expected many respondents would report limited awareness and knowledge of groundwater. Despite that expectation, the high proportion of respondents who were unsure on each risk topic was surprising and was investigated further. Those analyses suggested that groundwater was less salient (their property was outside the aquifer) for the ‘Unsure’ cohort and that this group was less knowledgeable of groundwater. It may be that landholders utilising groundwater are more likely to have a greater understanding of the TLA, to understand current groundwater management issues that affect
them, and to be confident in current management. This confidence may be due to irrigators’
and stock and domestic groundwater users’ involvement in committees concerned with the
development of groundwater management plans within the WWGMA. Information regarding
the development of these plans has been sent directly to landholders, as well as via coverage
in the media, over a long period of time. Those attempting to engage the ‘Not Sure’ in
dialogue about the social acceptability of groundwater exploitation in the Wimmera region
will need to establish the relevance of the issue by raising awareness of the value of the asset
and knowledge of any threats posed.

This study suggests that those seeking to effectively engage rural landholders in dialogue
about groundwater governance need to be aware of the importance of a pro-farming business
mindset, including a relatively higher priority given to economic over environmental values
and a strong belief in the sanctity of private property rights. Given this finding, agencies
should emphasise the importance of declining water tables on pumping costs. They should
also highlight the potential damage to crops and livestock health and the potential negative
impact on the capital value of a property if the associated groundwater asset is degraded.
NRM managers should engage landholders in dialogue about the concept of sustainable yield.
Over the medium term, they should seek to establish collaborative arrangements or social
norms about “good farming practice” that will maintain aquifer integrity. Those efforts could
be embedded within established farmer networks that act as important platforms for the
delivery of training programs, including producer groups and Landcare groups.

It seems the future social acceptability of groundwater exploitation in the Wimmera region
will depend on the extent that the large proportion of ‘Unsure’ respondents shift to the
‘Agree’ or ‘Disagree’ cohorts. By comparison with the other cohorts, this group is less
knowledgeable about groundwater and that difference appears to present an opportunity to engage the ‘Unsure’ cohort before they have formed strong opinions. Again, effective dialogue should focus on the economic implications of any degradation of the aquifer, but this group is also likely to be receptive to information about the environmental impacts of the exploitation of a community resource.

ACKNOWLEDGEMENTS

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References


