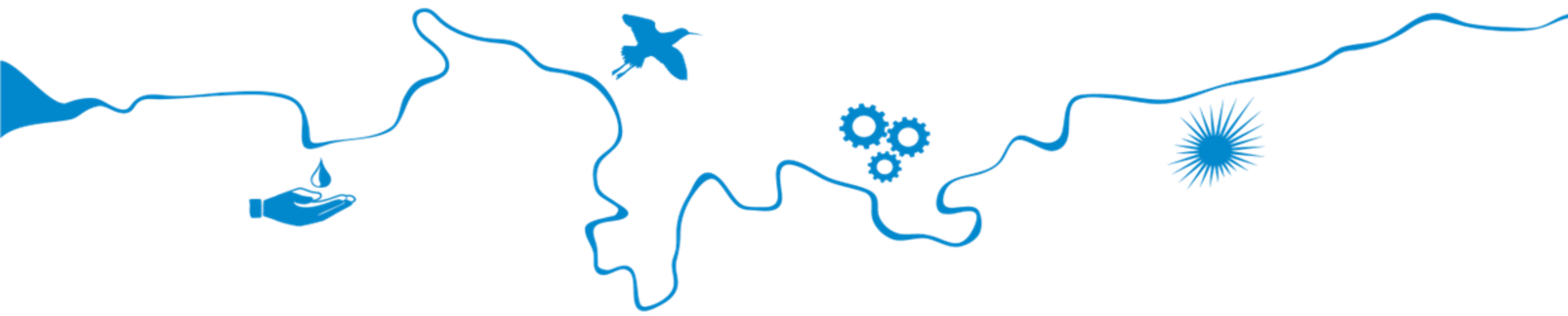
Adaptation of the South-Eastern drainage system under a changing climate

Quantifying the value of different water uses and future demands

Bethany Cooper, Lin Crase, John Kandulu and
Vandana Subroy



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The Goyder Institute for Water Research is a research alliance between the South Australian Government through the Department for Environment and Water, CSIRO, Flinders University, the University of Adelaide and the University of South Australia. The Institute facilitates governments, industries, and leading researchers to collaboratively identify, develop and adopt innovative solutions for complex water management challenges to ensure a sustainable future.

This *Adaptation of the South-Eastern drainage system under a changing climate* project has been jointly funded by the Australian Government through the National Water Grid Fund, the Limestone Coast Landscape Board, and the South Australian Government. The project was delivered by the Goyder Institute for Water Research partners: CSIRO, the University of South Australia, Flinders University and the University of Adelaide in collaboration with the Limestone Coast Landscape Board, South Eastern Water Conservation and Drainage Board (SEWCD Board) and the Department for Environment and Water. This report was prepared by Bethany Cooper, Lin Crase, John Kandulu and Vandana Subroy.

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First Nations Respect and Reconciliation

The Goyder Institute for Water Research and Limestone Coast Landscape Board, acknowledges the Traditional Custodians of the lands and waters of the Limestone Coast and South East region, where this project took place. Together we pay our respects to their Elders—past, present, and emerging—and recognise Aboriginal people as the First Peoples and Nations of South Australia, possessing and caring for these lands under their own laws and customs.

We respect the enduring cultural, spiritual, physical, and emotional connections that Aboriginal peoples maintain with their lands and waters. We recognise the diverse rights, interests, and obligations of First Nations and the deep cultural connections that exist between different First Nations communities. We seek to support their meaningful engagement and honour the continuation of their cultural heritage, economies, languages, and laws, which remain of ongoing importance.

We walk together with the First Nations of the South East and the Ngarrindjeri peoples through organisations such as Burrandies Aboriginal Corporation, Ngarrindjeri Aboriginal Corporation, the Ngarrindjeri Lands & Progress Aboriginal Corporation and South East Aboriginal Focus Group. For the work of generations past, and the benefit of generations future, we seek to be a voice for reconciliation in all that we do.

Project Summary

The Limestone Coast of South Australia is a highly modified landscape with an extensive cross-catchment drainage system converting what was once a wetland dominated landscape into one dominated by agricultural production. The region now has a diverse agricultural sector and extensive forestry plantations which are highly dependent on reliable rainfall and easy access to the region's substantial groundwater resources. However, as climatic conditions become hotter and drier it's important to understand impacts on ground and surface water resources and consequent risks to primary production and the environment to build a water secure future.

Achieving water security in the Limestone Coast region under a changing climate requires a more integrated and holistic approach to water resource management. In particular, the interactions between surface water and groundwater must be better understood, quantified, and managed to balance the seasonal demands—removing excess water from productive lands during winter while safeguarding groundwater-dependent agriculture and ecosystems during summer.

The "Adaptation of the South Eastern Drainage Network under a changing climate" project aims to inform opportunities to improve water management in the region - including potential use of water in the drainage network - to address risks to primary industries and groundwater dependent ecosystems. Delivered through the Goyder Institute for Water Research, research teams from the CSIRO, Flinders University and the University of South Australia have completed five separate but inter-connected tasks:

1. Quantifying the value of consumptive and non-consumptive uses of water
   This task assessed the value of additional water for key primary industries in the region, while also estimating the value of water for non-consumptive uses aimed at achieving ecological outcomes. Together, these valuations provide important context to the project's hydrological tasks, informing options to manage additional available water in the region.
2. Current and future water availability
   A water balance model for the region has been developed using the Bureau of Meteorology's Australian Water Resources Assessment – Landscape (AWRA-L) model. It integrates national and regional datasets to capture surface runoff, recharge, and soil moisture, while accounting for seasonal dynamics and regional variability. The model enables analysis of climate change impacts on the full water balance, providing insight into future water availability, supporting both short- and long-term water management decisions.
3. Groundwater and wetland modelling
   Site-specific models representing three-dimensional aquifer-wetland interactions have been developed for two key groundwater dependent sites. The models test the feasibility of changing the water distribution in the local landscape to improve ecosystem health and mitigate impacts of groundwater extraction. Options included redirecting / holding water back in drains, altering surface water inflows and reducing the extent of the wetland basin with levees. The learnings from modelling these two disparate sites will assist decisions to manage additional available water in the region.
4. Sea water intrusion risk
   The coastal area south of Mount Gambier is an area of high value irrigated agriculture and significant karst springs where the risk of seawater intrusion is of concern for both irrigators and environmental assets. This task set out to understand the extent and hydrodynamics of seawater intrusion in the region with an airborne electromagnetic survey of the south coast area, undertaken in October 2022, and construction of cross-sectional models to simulate seawater intrusion under different scenarios at different regional locations. This work provides the evidential basis to build on previous projects where reinstating wetlands by retaining water in drains appeared to effect some control over the seawater interface.

5. Groundwater, Ecology, Surface water and Wetland Assessment Tool (GESWAT)
   To enable opportunities to improve water management to be easily identified and investigated - including the potential use of water in the drainage network –a dynamic GIS tool (GESWAT) was built. GESWAT brings together outputs from the other project tasks integrating them in a tool with a range of other critical data (e.g. surface water flows, groundwater levels, and rainfall data, annual water use and allocation data, ecological information and other standard datasets). GESWAT provides the LC Landscape Board and its partner agencies a single platform with which to view, compare and interrogate the diversity of hydrological and ecological information available to inform policy and management decisions.

This report details results from Task 1 of the project.

Further results from this project are presented in the following reports:

Task 1
Cooper B, Crase L, Kandulu J, and Subroy V. (2025) Adaptation of the South-Eastern drainage system under a changing climate - Quantifying the value of different water uses and future demands. Goyder Institute for Water Research Technical Report Series No. 25/2

Task 2
Gibbs MS, Montazeri M, Wang B, Crosbie R, Yang A. (2025) *Adaptation of the South-Eastern drainage system under a changing climate - Water Availability for South East Drainage Adaptation*. Goyder Institute for Water Research Technical Report Series No. 25/3

Task 3
Gholami A, Werner AD, Maskooni EK, Fan H, Jazayeri A, and Solórzano-Rivas C. (2025) *Adaptation of the South-Eastern drainage system under a changing climate - Groundwater and wetland modelling*. Goyder Institute for Water Research Technical Report Series No. 25/4

Task 4
Davis A, Munday TJ, and Ibrahimi T. (2025) *Adaptation of the South-Eastern drainage system under a changing climate - Limestone Coast Airborne Electromagnetic Survey: Acquisition, Processing and Modelling*. Goyder Institute for Water Research Technical Report Series No. 25/5.1

Davis A, Munday TJ, and Ibrahimi T. (2025) *Adaptation of the South-Eastern drainage system under a changing climate - Limestone Coast Airborne Electromagnetic Survey:* Conductivity-Depth Sections. Goyder Institute for Water Research Technical Report Series No. 25/5.2

Gholami A, Werner AD, Solórzano-Rivas C, Jazayeri A, Maskooni EK, and Fan H. (2025) *Adaptation of the South-Eastern drainage system under a changing climate - Seawater intrusion risk*. Goyder Institute for Water Research Technical Report Series No. 25/5.3

Task 5
Gonzalez D, Werner A, Jazayeri A, Pritchard J, Fan F, Botting S, Judd R. (2025) *Adaptation of the South-Eastern drainage system under a changing climate - Groundwater, Ecology, Surface water and Wetland Assessment Tool (GESWAT) Spatial Data Dictionary*. Goyder Institute for Water Research Technical Report Series No. 25/6

Executive Summary

The Limestone Coast Landscape Region is known for its diverse and productive agricultural sector that supports the local economy. It is also home to several regionally, nationally and internationally important wetlands.

Currently, groundwater is used to support a range of agricultural and forestry activities in the Limestone Coast region. There are also significant groundwater dependent ecosystems. Climate change and increased water demand are expected to impact existing water sources with predictions noting a 42% reduction in water availability by 2050.

There is limited understanding of some of the key values that would accrue from having additional freshwater available in the Limestone Coast region and its value in different uses. The estimated demand for additional future water supplies is also unclear, although the prospect of climate change would likely see increases in demand across multiple fronts. A better understanding of water demand and the value of water in different contexts will help managers prioritise investments and optimise the allocation of water in the region.

The purpose of this project was to better understand the range of values that accrue from water in agriculture and forestry and establish the value of water when it delivers ecological or environmental benefits.

A critical concept in analysing management choices through an economic lens is the notion of marginality – that is understanding change at the margin. This is particularly important in the case of this project, where the management questions hinge on the benefits of *extra* water being available to support changes in different activities.

In the case of agriculture and forestry, primary and secondary data covering hardwood, softwood, dairying, winegrapes, onions and potatoes were collected and used to estimate the 'residual value of water' – that is, the dollars generated from having an additional megalitre (ML) of water available, minus other input costs. Our analysis is primarily based on a recent, localised business-level survey conducted in the Lower Limestone Coast, which reflects current conditions but lacks long-term trends and future projections. The purpose was to understand what commercial value would be generated from an extra megalitre (ML) of water in each of these activities. Since input and output prices vary over time, this information can also be used to show how profitability can vary within and across the different agricultural and forestry activities.

The results show considerable variability in the case of the Limestone Coast, with some industries generating negative values, partly due to low current output prices. The results also show sizable variability within each activity, supporting the view that some enterprises will be doing much better than others even within generally profitable sectors.

Table: Water values and cost sensitivity (in $/ML) of five key agricultural and forestry sectors in the Limestone Coast region.

STATISTIC	SOFTWOOD	HARDWOOD	DAIRY	POTATOES & ONIONS	WINEGRAPES
Minimum	160	176	-161	272	-1,588
Maximum	620	703	411	1,333	1,297
Mean	320	319	136	688	-161
Median	310	311	140	684	-179
Standard deviation	77	71	108	168	457

To gain an understanding of the value of water from an ecological perspective, the well-established survey technique known as choice modelling (or discrete choice experiments) was used. This technique is particularly helpful when people value the existence of an ecological asset, even if they never visit it. A choice modelling survey was designed with input from ecological experts in the region. The purpose was to understand what environmental changes would likely occur if different amounts of water were available to a specific site. The survey focussed on Bool Lagoon, a large and diverse freshwater lagoon system that is an important remnant wetland in the Limestone Coast region. The Lagoon has been dry more often and for longer periods since the Millennium Drought and this is changing what species can survive and thrive in the system. An online survey was distributed to just over 1,100 respondents across South Australia covering both metropolitan and regional areas. Each respondent answered a total of six choice questions, each containing three options. Each option described the likely changes to native species and an extra amount to be paid as part of the landscape levy (collected for one year only). By making repeated choices respondents implicitly reveal the trade-offs they make between the benefits to the environment with the costs they incur.

The choice modelling results show that average households in the state have a significant willingness to pay to preserve and restore systems like Bool Lagoon. The average marginal willingness to pay for 3,000 ML, 12,000 ML and 20,000 ML of extra water in 2 years out of 10 is $288/household, $513/household and $540/household, respectively. There is, however, a diminishing marginal utility for additional water. For 564,147 households across the state who are willing to pay for ecological improvements in Bool Lagoon, the average marginal value of water per ML is $54,158 for 3,000 ML, $24,258 for 12,000 ML and $15,232 for 20,000 ML. More specifically, the lowest ecological value is around $15,000 per ML.

To gain insights into the preference for different ecological outcomes, the choice experiment was followed by a best-worst scaling task. Respondents were presented with a set of five questions, each with six options containing a subset of the ecological outcomes and asked to select which outcome they most and least prefer. The outcomes include various potential levels of population change for five key species at Bool Lagoon. An 'importance score' (a relative probability measure that an item will be selected as best from among the options presented) is assigned to each ecological outcome level. Results of the best-worst scaling task show that respondents weigh increased species' populations more highly while local extinctions are least preferred. A 50% or greater increase in visiting population of Brolga was estimated to have the highest positive impact on choice, followed by a 30-49% increase in the Southern Bell Frog population, while a 100% decline (local extinction) of the Australasian Bittern population and a local extinction of the Southern Pygmy Perch population were scored very low.

This project was undertaken between July 2022 and April 2025.

Acknowledgements

This report covers one of five tasks undertaken as part of the "*Adaptation of the South-Eastern drainage system under a changing climate*" project. The project has been jointly funded by the Australian Government through the National Water Grid Fund, the Limestone Coast Landscape Board, and the South Australian Government. The project was delivered by the Goyder Institute for Water Research partners: CSIRO, the University of South Australia, Flinders University and the University of Adelaide in collaboration with the Limestone Coast Landscape Board, South Eastern Water Conservation and Drainage Board (SEWCD Board) and the Department for Environment and Water. This report was prepared by Bethany Cooper, Lin Crase, John Kandulu and Vandana Subroy.

1 Introduction

1.1 Background

The Limestone Coast Landscape Region has a diverse and productive agricultural sector that supports the local economy. It also contains several regionally, nationally, and internationally important wetlands. The benefits that stem from both agriculture and wetlands partly derive from the availability of good quality groundwater. However, increased demand for good quality water coupled with climate change is putting additional pressure on existing water sources. Observations suggest that the Limestone Coast has already experienced a 1-5mm/year decrease in rainfall since 1960. Fu et al. (2019) and Crosbie et al. (2013) established a 1 mm/year decline in groundwater recharge over the period 1970-2012, which is expected to continue under future climate scenarios. Under an extreme wet scenario there may be no change to recharge, but under an extreme dry scenario there may be a 42% reduction by 2050, with similar patterns of scarcity for surface water (Crosbie et al. 2013).

Given these issues, the Lower Limestone Coast Water Allocation Plan (LLC WAP), which covers the southern part of the region, has come under scrutiny. Consequently, there has been exploration of reduced allocations for some management areas to mitigate risks associated with the over-allocation of water resources and to achieve the broad environmental and social goals of the plan.

Simultaneously, questions have arisen about the prospect of other water that might be rediverted in the landscape to generate value and/or offset reduced availability from existing sources. This has led to an extensive investigation about the feasibility of managing surface water differently – particularly drainage water - in parts of the Limestone Coast region.

There is, however, limited understanding of some of the key values that would accrue from having additional freshwater available in the Limestone Coast region and its value in different uses. The estimated demand for additional future water supplies is also unclear, although the prospect of climate change would likely see increases in demand across multiple fronts. A better understanding of water demand and the value of water in different contexts will help managers prioritise investments and optimise the allocation of water in the region. This project sought to shed light on the value of water in different uses and was undertaken between July 2022 and April 2025.

1.2 Aims

The overall aim of this project is to identify whether there are opportunities to manage water from the extensive drainage network in the Limestone Coast region differently to address risks to primary industries and groundwater dependent ecosystems and thus generate value. This report details results from Task 1 of this project that focusses specifically on quantifying the value of different applications of water. The outputs from this task will help the Limestone Coast Landscape Board contextualise the biophysical analysis of water availability and any possible redeployment. The objective of this task is to understand and measure the economic value of additional water being made available to alternative uses (including consumptive and non-consumptive) in the Limestone Coast region. Specifically, this task addresses two key management questions:

1. What is the marginal value of water in different consumptive uses including alternative agricultural settings (e.g. different agricultural enterprises)?
2. What is the marginal value of water in different ecological settings (e.g. ecological restoration or preservation)?

2 Methods

To answer these important questions, it is necessary to clarify two main dimensions of economic value.

Value

In terms of value, economists have developed several frameworks to help conceptualise and disaggregate this construct. Commonly, economic value is construed by many as solely the dollar value revealed in an exchange between two parties – the price at which something is traded. While a useful starting point for some valuation exercises, this approach falls short of more comprehensive techniques to capture overall value. The typology presented in Figure 1 provides one way of positioning the tasks involved in this project.

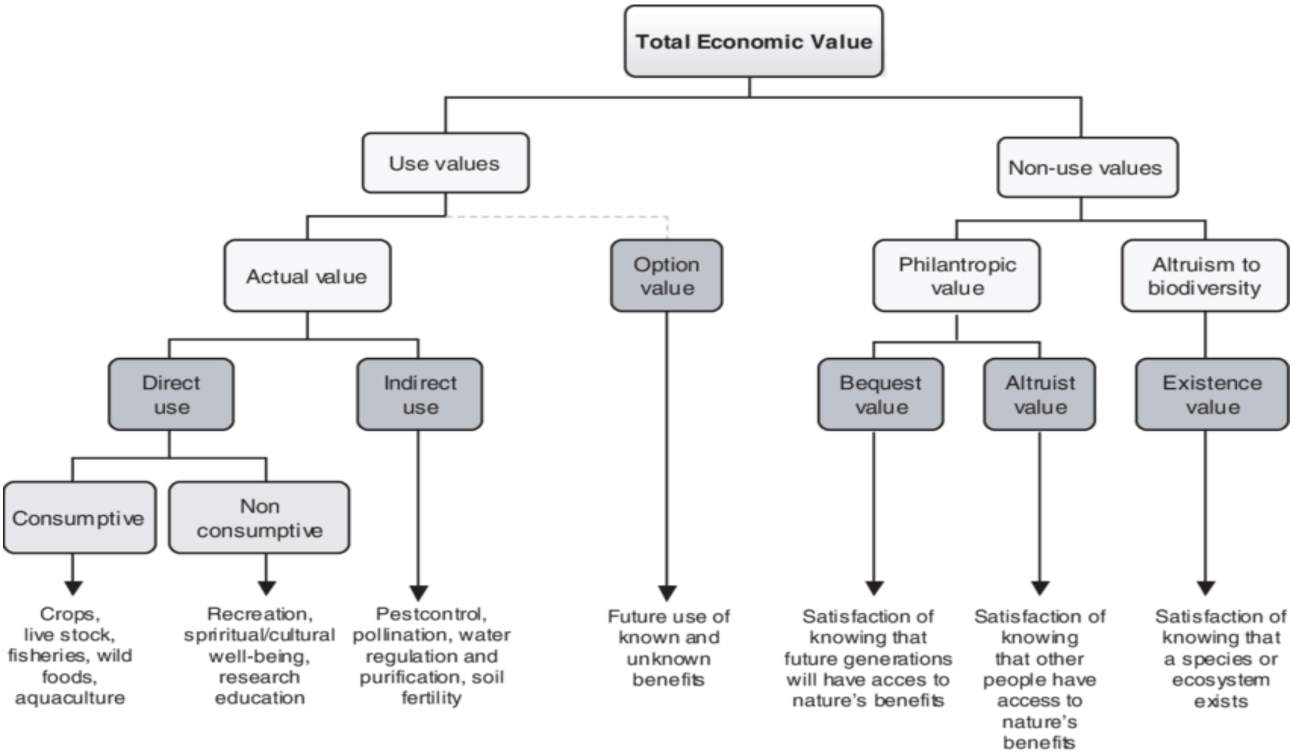


Figure 1. The Total Economic Value Framework from Pascual et al. (2010).

The total economic value (TEV) of a resource being evaluated is expressed as the sum of its use value (Bateman et al., 2002) and non-use value (Krutilla, 1967, Smith, 1987, Cameron, 1992). As the name would suggest, use values denote the benefits that individuals derive from using the resource while non-use values denote the worth that individuals attach to the resource, even if they do not use it themselves (Remoundou et al., 2009). Consumptive values accrue directly to individuals and are ultimately tied to some form of use. For example, the value of water in growing a farm crop is partly encapsulated in the price paid for that crop and that, in turn, is tied to the value of that output to food production/consumption. For this type of valuation exercise, market prices act as a proxy for value. The logic is that rational individuals would not pay a price that was greater than the value of the good/service/resource and, provided the exchange is relatively competitive, the final price in the market will be close to the reservation price at which buyers and sellers are willing to exchange. Put simply, the market price represents the approximate consumptive value. Thus, for use values (like those that attend agriculture or forestry) the task reduces to understanding how water relates to the various inputs and outputs exchanged in a market.

Unlike consumptive values, ecological values have a more complex range of dimensions and many of these are articulated in the non-use values and option value depicted in Figure 1. Ecological values also tend to be more dispersed and cover a broader population. For example, an individual living in Adelaide might gain satisfaction (i.e., value) from knowing that a wetland is preserved in the south-east of the state, even if they never visit the area. Arguably, some ecological values also spill over into indirect and non-consumptive use values and accrue closer to the site of interest: for example, an ecologically valuable wetland might provide a site valued for its recreation opportunities as well as ecosystem services to adjoining agriculture (e.g. pollination). Generally, many ecological values are not fully expressed in a market setting[1]; that is, ecological sites are usually not bought and sold in a competitive market, so we do not have prices to act as a proxy for capturing the full suite of these values. Economists have developed a range of non-market techniques to quantify these values.

Marginality

A critical concept in analysing management choices through an economic lens is the notion of marginality – that is understanding change at the margin. This is particularly important in the case of this project, where the management questions hinge on the benefits of *extra* water being available to support changes in different activities. While seemingly straightforward, there are some nuances to marginality that require noting.

First, water is only one input into the different activities being analysed in this project. In the case of an ecological asset, for instance, the change in ecological condition might also be influenced by other factors and there may be both positive and negative feedback effects between any extra water and those factors (e.g. the interactions between invasive species and the sequencing and extent of wetland watering). Similarly, in the case of agriculture, the prospect of additional production resulting from water availability might be impacted by access (or lack thereof) to extra land, labour or other inputs.

Second, there may be some instances where the marginal changes are non-linear. In the case of an ecological site, the extra water may not reach a sufficient threshold to prompt bird breeding or fish migration, for example. Similarly, in the case of agriculture, the price of the final output may be so low as to cause a cessation of production altogether, regardless of the availability of extra water.

Third, (and to help deal with the above challenges), marginality can only be enumerated if the status quo is clearly articulated. That is, if we are to understand the value of extra water being made available to either consumptive or ecological uses, we must first understand how the water currently available impacts value.

Sections 2.1 and 2.2 below detail the methodologies used for tackling these valuation challenges.

[1] Non-consumptive use values, like recreation, can be estimated using market data. For example, the costs paid in a market for reaching an ecological site to undertake birdwatching can be used to estimate these types of values. Similarly, indirect use values, like pollination or pest control can be estimated from the market cost of using alternatives.

2.1 Methodology for estimating the marginal value of water in various consumptive uses

2.1.1 Conceptual overview

To understand the benefits, costs, and risks of water management and investment options of consumptive water uses, water values were estimated using the "residual value" method to determine the reservation price of water at which key industries would remain profitable. This is calculated as profit per megalitre after accounting for all other input costs (Berbel et al., 2011; Muchara et al., 2016; Qureshi et al., 2018; Rodrigues et al., 2021). By attributing the residual economic value exclusively to water, the method quantifies water's unique role in sustaining profitability in each industry.

Residual value is similar to "resource rent" calculations used to estimate the value of scarce natural resources (e.g. Ganhae and Stage, 2024; Krevel and Peters, 2024). Resource rent is the difference between the market price of a scarce natural resource and the total per-unit production costs plus "normal" profit. The "super profits" or producer surplus represent the extra profits made after all costs are accounted for.

The residual value method assumes that water, as a critical input, captures the residual value of production after accounting for all other costs. As noted, the residual value of water is like a resource rent but in this instance, we are isolating the economic contribution of water, showing its importance and scarcity in generating profits and revealing the minimum price at which water would be sold. This approach, is particularly useful when direct market prices for water are absent or imperfect, as is the case when water markets have not fully developed. The approach provides a proxy for water's economic value by isolating its contribution to the total value of the product. It is also suited, though not exclusively, to contexts where water is a limiting factor, as it allows for an estimation of the maximum price producers would be willing to pay for water without incurring losses.

The residual value method for water valuation can be expressed mathematically as:

$$\boldsymbol{RV_w = TVP - \sum_i C_i} \qquad \textbf{[1]}$$

Where:

RV_w = Residual value of water

TVP = Total value of production

C_i = Cost of non-water input i

We used gross margins data at the business level, including yield, output prices, and operating costs (e.g., transport, labour, chemicals, energy, operating and servicing machinery), to estimate water values for five key industries: softwood, hardwood, dairy, winegrapes, and a combined category of potatoes and onions, grouped due to their shared agricultural and economic characteristics. Industries were selected for analysis based on their significant reliance on groundwater, data availability, water-sensitive production processes, and high economic value within the region. Industries like broadacre cropping, livestock, and citrus were excluded due to limited groundwater dependence or alternative water sources, insufficient data (see next section for sources).

To provide a more accurate and nuanced understanding of the relationship between water value and other economic factors in agricultural production, our farm enterprise models quantified the sensitivity of water values (or the proxied cost of purchasing water from producers' perspective) relative to fluctuations in other variable input costs (costs that increase with increasing scale of production). Specifically, we: 1) simulated changes in each variable input cost, varying it by ±20% of its median value while holding all other variable input costs constant; 2) mapped the resulting changes in water values across the different industry types; and 3) ranked variable input costs from most to least sensitive in terms of their impact on water value estimates. Further technical details of the simulation method are outlined in Kandulu et al. (2012) and Kandulu et al. (2018).

Water values were estimated under current land uses and water allocations within each Groundwater Management Area (GMA) using a snapshot of ABARES' 2023 catchment scale land use data – the latest and highest resolution land use data available for the Lower Limestone Coast region (ABARES, 2023). Figure 2a provides a map of the South East region of South Australia and Figure 2b illustrates spatial distribution of primary industries and water use patterns in the Lower Limestone Coast region. Water use was calculated by multiplying average water application rates (ML/hectare) by area of production (hectare). To calculate water application rates, historical data on the total watered area, yield per hectare and total volume of water applied were used (ABS, 2017). Variability in application rates was quantified by fitting best-fit probability density functions to historical data, treating application rates as probabilistic variables (ranging between minimum and maximum observed values) with some values more likely than others. This approach, following Kandulu et al. (2018), accounts for differences across years, locations, and water use efficiency levels, avoiding reliance on simplistic averages.

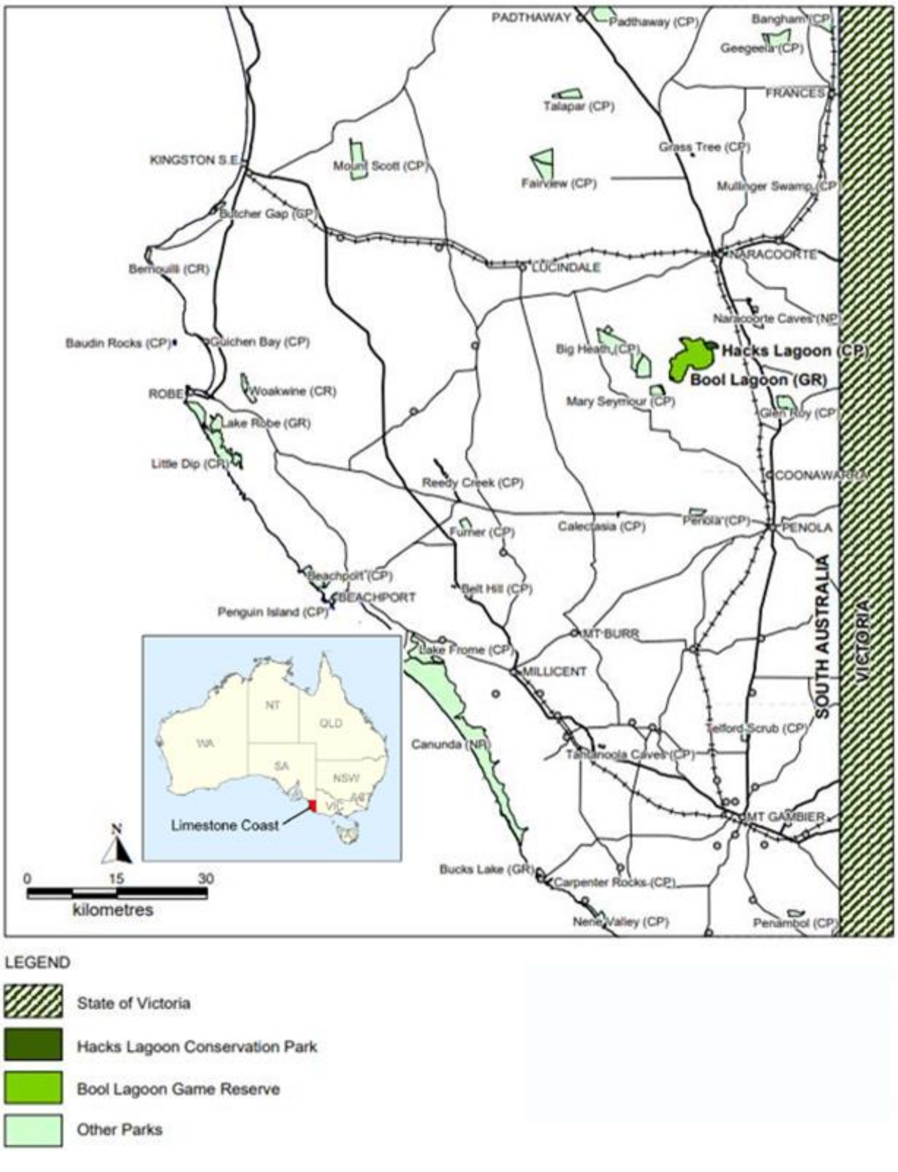


Figure 2a. South East region of South Australia (Source: adapted from Department for Environment and Heritage 2006).

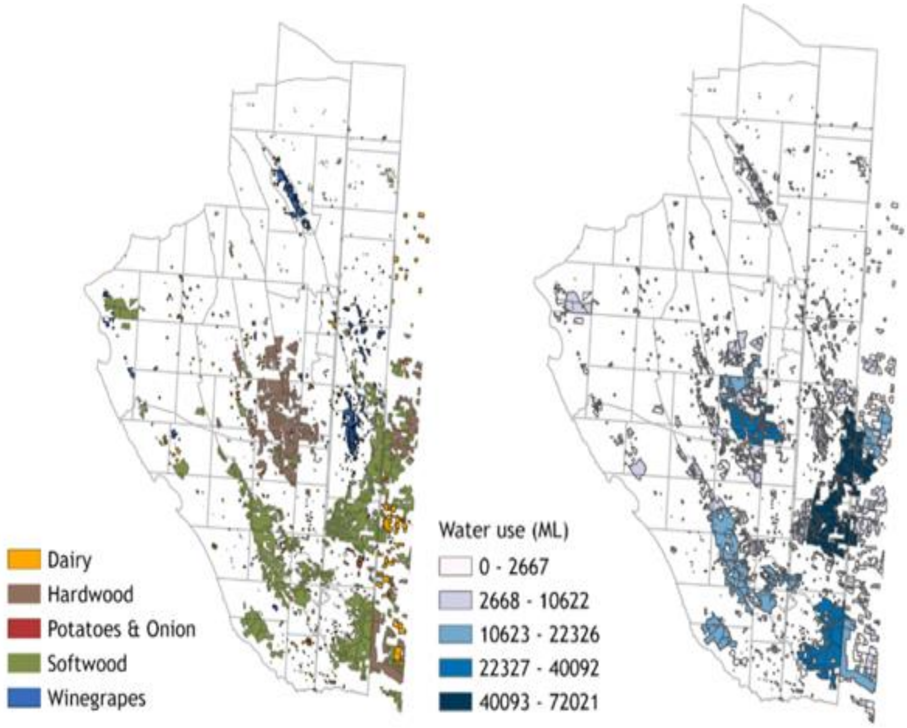


Figure 3b. Spatial distribution of primary industries and water use patterns in the Lower Limestone Coast region from ABARES (2023).

2.1.2 Data sources

Residual water values were calculated using gross margin financial data from publicly available sources and industry surveys. The data collection and analysis methods varied across sectors due to their unique characteristics and data availability. Costs and prices were specified in real terms (i.e. constant 2024 dollars).

For the dairy industry, we used time series gross margin data from 2013/14 to 2022/23, sourced from the Dairy Farm Monitor Project and historical DairyBase data to establish ranges of values (Dairy Australia, 2023). This survey of South Australian dairy farms provides business-level financial cashflow and gross margin data on production costs and profit. Table A 1 in Appendix A details the parameters, data values, and sources used to estimate dairy residual water values.

To account for the long-term investment cycle in forestry, we calculated annual equivalents of Net Present Values (NPVs) of costs and profits over a 15-year rotation from 2023 to the projected harvest year of 2038 for hardwood and softwood, adjusting future income to present value equivalent values using a discount rate of 7%. To capture the variability in profitability, ranges of gross margin data were obtained from a survey of 61 businesses across 33 GMAs. It is important to clarify that these 33 GMAs refer to regions where forestry businesses operate and are not necessarily coincident with individual managed aquifer zones. For hardwood, we used E. globulus (blue gum) production costs obtained by Regan et al. (2023) through industry consultation (Winkley, N., Dobson C., personal communication, 2020). A representative forestry estate was constructed using the Australian National Forest Inventory (ANFI) Forests of Australia 2018 data set (ABARES, 2018a). The hardwood estate age distribution was derived from the Australian National Forest Inventory (ABARES, 2018b), which provides statistics for areas planted over the past two decades. Table A 1 in Appendix A lists the parameters, data values, and sources used to estimate softwood and hardwood residual water values.

For winegrapes and potato and onion industries, we used business-level income and production data provided in Table A1 in Appendix A. To define broader ranges of possible values for production costs and income, we incorporated production and income data from Nordblom et al. (2018), who used data from

South Australian Winegrape Crush Surveys from 2006 to 2017 (Wine Australia, 2017) and business-level data on production costs. Our analysis, primarily based on a recent, localised business-level survey in the LLC reflecting current conditions, lacks long-term trends and future projections, especially for cyclical industries like winegrapes facing export market volatility. While incorporating data from other South Australian regions provides a broader sensitivity analysis, it may reduce LLC specificity. A more comprehensive dataset tracking long-term trends and incorporating price projections is needed for a full understanding of water's economic value in winegrape production.

2.2 Methodology to estimate the marginal value of water for non-consumptive (i.e. ecological) uses.

To understand the economic value from assigning additional water to protect and improve the ecological condition of important assets in the Limestone Coast, a stated preference experiment was iteratively developed and applied in the study region and across the state. As noted earlier, stated preference techniques are particularly useful to evaluate the value of goods and services that are not traded in regular markets or for which markets do not exist; this includes most environmental resources. Stated preference methods are also helpful for capturing non-use values, like existence values (i.e. a household might value simply knowing that a wetland is preserved, even if they never visit it), which are often held by individual geographically remote to the site in question. In this instance, the values held for an ecological site in the state's south-east by those living across the state were considered pertinent, since the South Australia's water planning instruments seek to optimise value to the state.

2.2.1 Stated preference methods

Stated preference methods use surveys where hypothetical scenarios and theoretical markets are developed to estimate individual preferences for and willingness to pay (WTP) for marginal changes in the supply of goods and services being evaluated. Stated preference surveys usually have three main parts (Banzhaf, 2010). These mainly comprise: (1) development of a specific policy scenario/program to achieve a certain objective (e.g. restoration of a section of a river/wetland), including a realistic "payment vehicle" to collect funds to attain the objective; (2) a series of questions where respondents are asked to either indicate their willingness to pay for the program, hypothetically vote in favour or against the program, or choose among alternative programs; (3) questions related to the respondents socio-demographic and often attitudinal perspectives. This additional information can be helpful when trying to understand the range in willingness to pay responses. The third section of the survey can also collect other information that can explain what aspects of the choice were most important to respondents.

Stated preference surveys generally fall into two groups: contingent valuation and discrete choice experiments. Contingent valuation surveys describe a single program and evaluate value by asking respondent to indicate their willingness to pay. This can be done through either open-ended questions, "payment cards" or "dichotomous choice" questions, where respondents simply vote yes/no on a hypothetical referendum.

In contrast, discrete choice experiments (DCEs) are a well-tested stated preference technique widely used in market research and behavioural economics to understand and predict how individuals make choices (Alamri et al., 2023). In DCEs, individuals are presented with a series of hypothetical choices, each having two or more alternatives (or options). Each option has several characteristics of the environmental resource being valued (called attributes) but with differing levels. For example, one attribute might be 'fish' and the levels represent the population or diversity of fish species. One of the attributes in a DCE is the cost to the individual to achieve the levels in the alternatives. Individuals are asked to choose their preferred option in each question, implicitly expressing the trade-offs they make between the different attributes, their levels and cost.

Since respondents answer a series of choice questions, public preferences for the various attributes can be inferred. DCE surveys thus provide greater information than contingent valuation surveys and are useful to evaluate the importance of various characteristics of environmental and other resources, which can be beneficial in decision making. DCEs also tend to be more realistic and have been widely used in Australia and abroad to value environmental assets (e.g., Chen et al., 2017; Cooper et al., 2023; Dissanayake & Ando, 2014; Tempesta & Vecchiato, 2013).

DCEs are usually developed iteratively to ensure that respondents in the experiment can comprehend choices and that the data are ultimately useful for decision making. Key tasks include:

- Detailed individual interviews with experts to understand the context and what information is needed from the DCE;
- Open-ended focus groups to broadly explore the topic from a layperson perspective;
- Structured focus groups to refine the DCE and other related information, including testing media;
- Piloting to understand how many choices can be tackled before fatigue sets in;
- Development of a design so that choices are systematically offered to respondents without bias (not every respondent will face every choice);
- Creation of an online pilot to test the instrument;
- Preliminary modelling of pilot data to establish 'priors' so that the design can be optimised;
- Reconfiguration of the design based on priors to optimise the final design;
- Main data collection and monitoring of DCE data to ensure modelling efficacy.

In addition to the practical steps and for completeness, the underlying theoretical elements and common estimation models for discrete choice experiments are summarised below.

2.2.2 Discrete choice experiments - Theory and common statistical models.

Lancaster's Characteristics demand theory (Lancaster, 1966) and the random utility maximization (RUM) theory (Luce, 1958; McFadden, 1974) form the economic frameworks for discrete choice experiments. Lancaster's (1966) theory states that individuals obtain utility (value) from the characteristics (attributes) that make up a good. Altering these characteristics allows changes in preferences to be measured.

Simultaneously, RUM theory considers individuals as rational decision-makers functioning to maximize their utility, including when selecting alternatives in a choice set. Collectively, these theories allow us to assume that consumers will select the alternative where the characteristics that make up that option lead to the greatest satisfaction for the individual. However, since an individual's choice cannot be identified with certainty, the utility (U) of respondent (i) for alternative j is assumed to be the sum of a deterministic or observable part (V) as well as a stochastic or random part (ε) (McFadden, 1974; Hoffman and Duncan, 1988):

$$\boldsymbol{U_{ij}} = \boldsymbol{V_{ij}} + \boldsymbol{\varepsilon_{ij}} \qquad \textbf{[2]}$$

Where V_{ij} is a function of the explanatory variables as:

$$\boldsymbol{V_{ij}} = \boldsymbol{\beta'} \ \boldsymbol{Z_{ij}} \qquad \textbf{[3]}$$

Where, $\boldsymbol{\beta'}$ is a vector of coefficients of the matrix of $\boldsymbol{Z}$ for individual i and alternative j.

The conditional logit model is commonly used for discrete choice data, which assumes the ε_{ij} to be independent and identically distributed (IID) random variables with mean zero and extreme value type 1 (Gumbel) distribution. The probability (P) that individual i will choose alternative j (among J alternatives) in a conditional logit model is given by (McFadden, 1974; Hoffman and Duncan, 1988):

$$P_{ij} = \frac{\exp(\beta' Z_{ij})}{\sum_{k=1}^{J} \exp(\beta' Z_{ik})} \quad [4]$$

Respondents' marginal willingness to pay (MWTP) for an attribute is calculated as the ratio of the negative of that attribute's coefficient to the cost coefficient as:

$$MWTP = \frac{-\beta_{attribute}}{\beta_{cost}} \quad [5]$$

Beyond the conditional logit approach, researchers have used a range of alternative statistical specification to derive willingness to pay estimates, including models that allow for individual heterogeneity. Given the primary interest of this project is to understand the ecological value of water and draw comparisons with other consumptive water uses, we limit our analysis to the more conventional statistical methods.

3 Results

3.1 Consumptive values

Overall, significant variations of residual water values across the five key industries were found (Figure 2). In the forestry sector, both softwood and hardwood demonstrate positive values with similar means ($320/ML and $319/ML). Relatively low standard deviations in both industries suggest relative stability in the economic value of water. The dairy industry has a wide range of values, from -$161/ML to $411/ML and a mean of $136/ML, suggesting an overall positive value but with considerable variability. The potato and onion sector consistently showed high positive values, with a mean of $688/ML and the highest minimum value among all industries. The winegrape industry has the highest variability, with a large negative mean of -$161/ML and the widest range, from -$1,588/ML to $1297/ML.

Negative residual water values, particularly in winegrapes and dairy industries, suggests that non-water input costs exceed output value in these cases. As noted earlier, our analysis is primarily based on a recent, localised business-level survey conducted in the Lower Limestone Coast, which reflects current conditions but lacks long-term trends and future projections[2]. Regardless of these future possible refinements in data, the prospect of assigning additional water to winegrape production in the current context would not generate positive marginal returns.

The sensitivity of water values (or the perceived cost of purchasing water from producers' perspective) to fluctuations in variable input costs were quantified by simulating changes in each variable input cost by ±20% of its median value, while keeping all other input costs constant and calculating residual water values. This approach ostensibly reveals the drivers of risk in each sector.

Tornado diagrams in Figure 4a and 3b visually represent these sensitivity analyses, illustrating the variability of cost components within each industry and highlighting the factors most significantly contributing to variability in water value estimates. In the softwood and hardwood industries, harvesting and transport costs emerged as the primary drivers of variability in residual water values. The important role of transport costs likely explains the spatial clustering of these industries near timber processing facilities, as observed in the land use map (Figure 1). For dairy, feed purchases dominated the cost structure, followed by fertiliser and irrigation. The potatoes and onions industry shows a broader range of cost variability, with fertiliser, seed and planting costs, and land rent being the most influential drivers of variability in water value estimates. In the winegrape industry, contract operators and fertiliser costs were the primary drivers of variability in water value estimates. Understanding the key drivers of variable water residual values across various industries is important for determining a realistic reservation price for water that supports the economic viability of different sectors while acknowledging their varying sensitivities to water costs.

[2] Suggested improvements are noted later in this report.

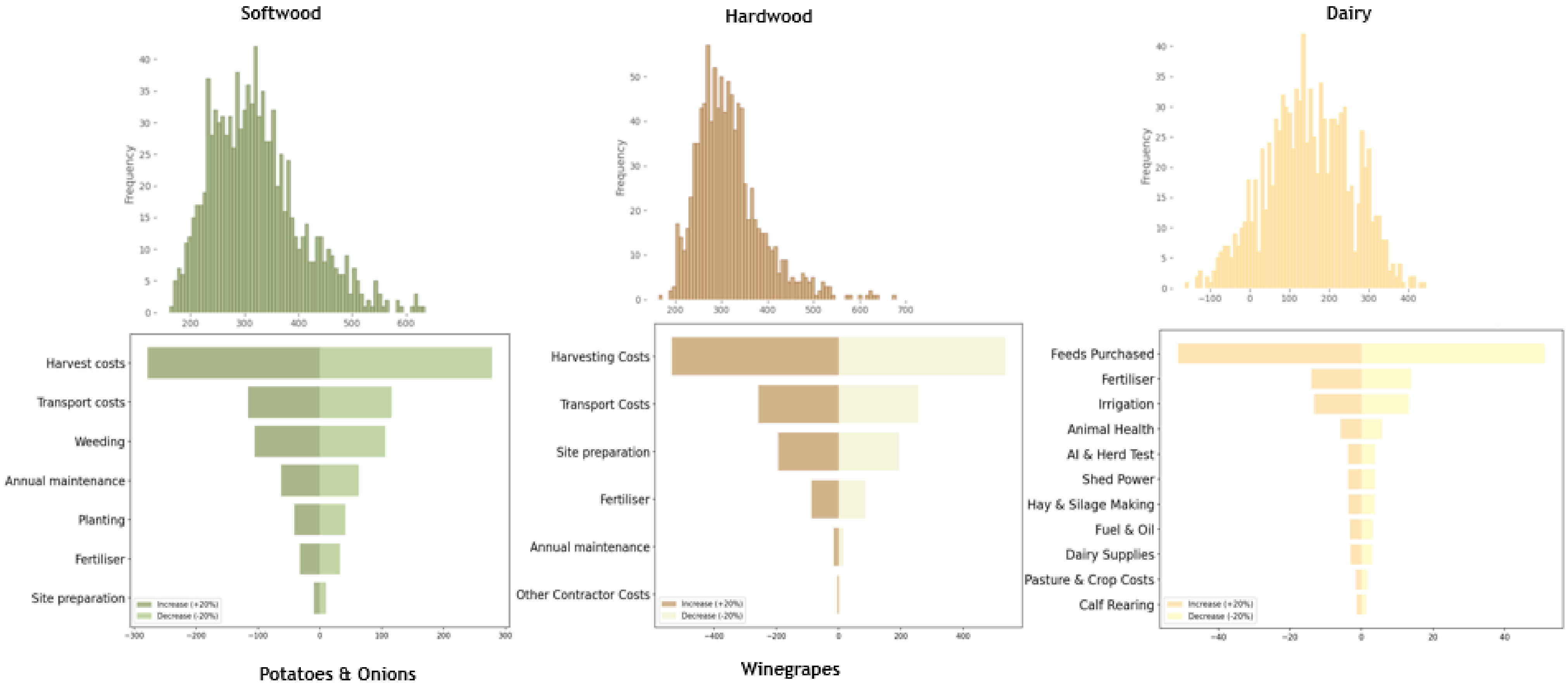


Figure 4a. Water values and cost sensitivity ($/ML). Irrigation costs include energy consumption and maintenance of pumping infrastructure.

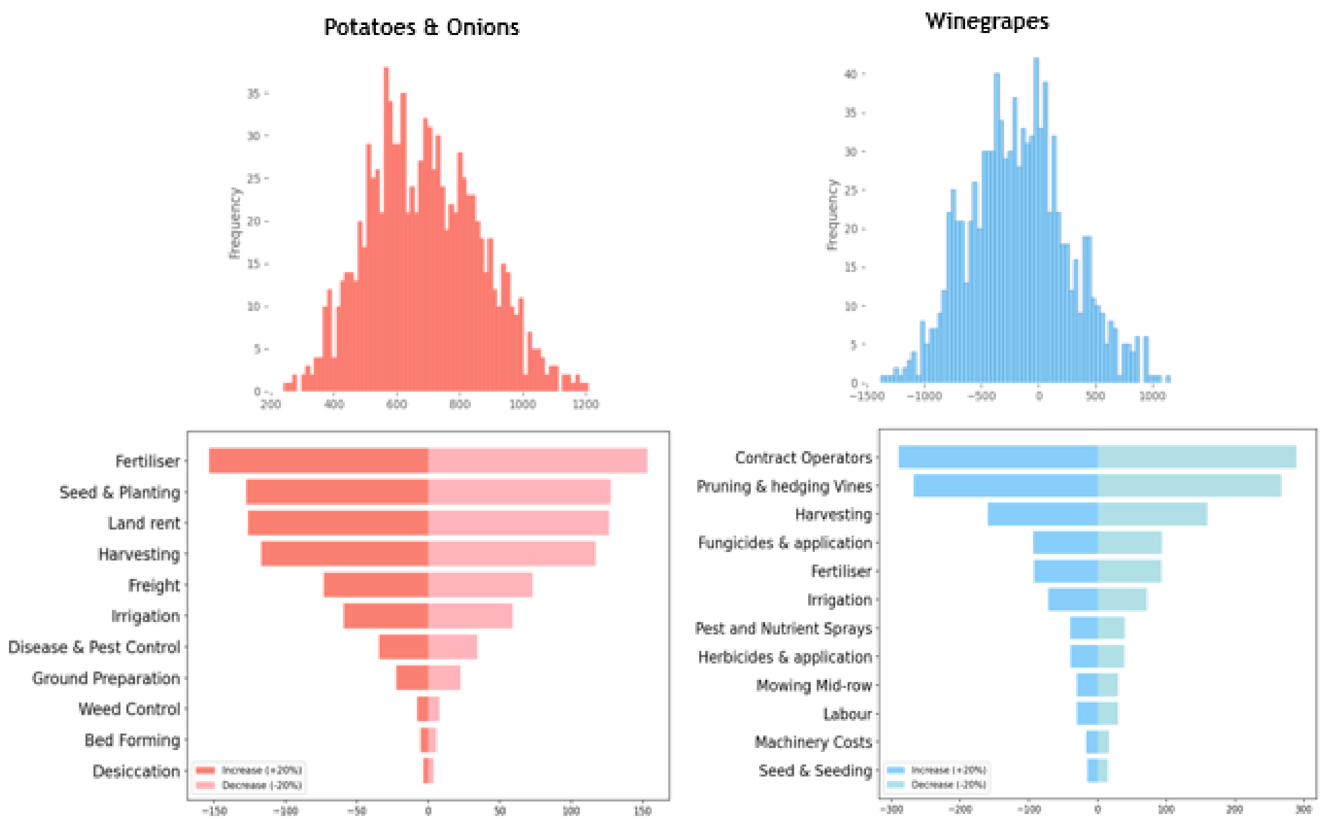


Figure 5b. Water values and cost sensitivity ($/ML). Irrigation costs include energy consumption and maintenance of pumping infrastructure.

3.2 Ecological values

3.2.1 Representative environmental asset — Bool Lagoon

In the context of non-consumptive or ecological uses of water, the valuation of changes in the condition of Bool Lagoon was identified as being important and offering useful insights for the region generally. Bool Lagoon was selected by representatives of the Limestone Coast Landscape Board partly because of its regional significance and its proximity to other consumptive water uses. In addition, there are possible engineering works that could be undertaken at the Lagoon to modify its operation to preserve some values.

Bool Lagoon is an important remnant freshwater lagoon system in the Limestone Coast region in the Southeast of South Australia. It provides a critical breeding habitat and drought refuge for a variety of birds including several rare and endangered species. Together with the adjoining Hacks Lagoon Conservation Park, Bool Lagoon was included on the List of Wetlands of International Importance (the “Ramsar List”) in 1985 (Figure 6). The site meets eight Ramsar criteria for listing. Seventy nine species of waterbirds have been documented at Bool Lagoon, with 48 of these known to have bred there (RSIS, 1998).

The lagoon system is mainly fed by Mosquito Creek but also relies on groundwater recharge. At full capacity the system covers over 2,500 hectares. Figure 4 includes a map of Bool Lagoon.

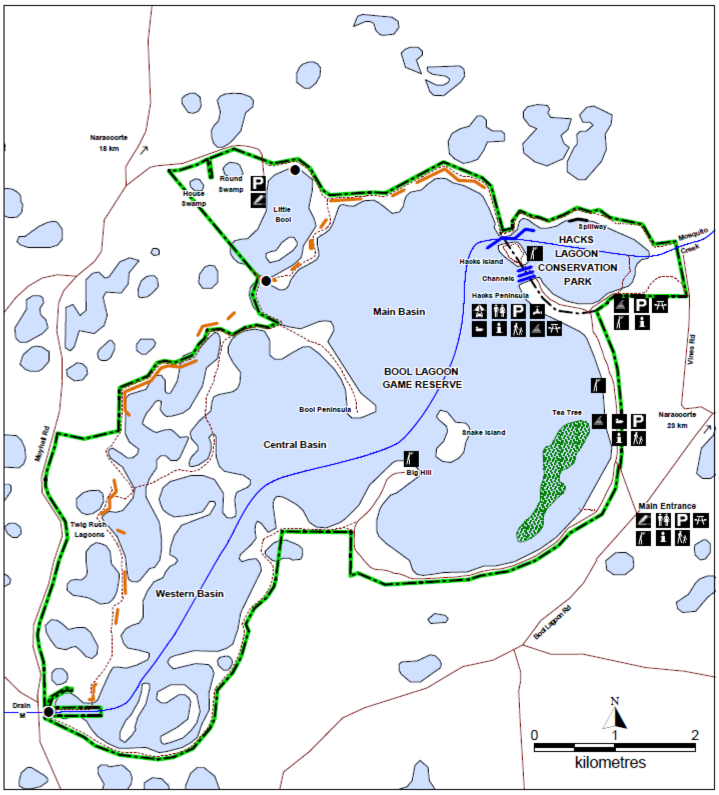


Figure 6. Bool and Hacks Lagoons Ramsar Site (Source: Department for Environment and Heritage 2006).

Bool Lagoon relies on having wet and dry periods to support a diversity of habitats. The Lagoon’s Main Basin requires seasonal inundation for at least six years out of ten, while the Central and Western Basins require four years out of ten. Although frequently full in the 1980s and 1990s, Bool Lagoon has been dry more often and for longer periods since the Millennium Drought.

Under a changing climate and land uses, the Limestone Coast region is experiencing lower rainfall, less groundwater recharge and increased groundwater use. This has decreased inflows from Mosquito Creek and reduced groundwater levels underlying Bool Lagoon. Owing to these changes, Bool Lagoon is expected to become more episodic and have insufficient water available to maintain the current habitat and ecology that the flora and fauna rely on. Data shows that drier years and reduced flows from Mosquito Creek have impacted fish species with the Yarra Pygmy Perch and Little Galaxias now locally extinct, and the endangered Southern Pygmy Perch in decline. The population of the Southern Bell Frog in Bool Lagoon also declined during the Millennium Drought and is expected to be impacted if flows into the Lagoon system continue to decline (Department for Environment and Heritage 2006).

This part of the study focussed on the possibility of diverting water from other parts of the region and providing extra water to Bool Lagoon to improve the Lagoon system and preserve its key habitat and functions.

3.2.2 Scenarios – Extra water for Bool Lagoon

To design a discrete choice experiment, it is first important to understand what potential scenarios of provisioning extra water may be feasible and what impacts are likely for the ecology (flora and fauna) in the Lagoon system. This was required because (a) the comparison data with other uses is expressed in dollars per megalitre and (b) individuals involved in responding to the DCE were shown to have limited understanding of water volumes per se but were interested in and engaged with the ecological outcomes as expressed through species.

Three scenarios involving extra water to Bool Lagoon were proposed after extensive consultations with experts from the Limestone Coast Landscape Board. Each sets out a volume of water, additional to any existing flows, and describes ecological responses that would be expected in the next 10 years. The scenarios were derived from observations based on the last 20 years of water levels in Bool Lagoon and is admittedly a simplification of a very complex system. Three levels of extra water were deemed feasible to provide to Bool Lagoon every 2 years in 10:

- Extra 3,000 ML
- Extra 12,000 ML
- Extra 20,000 ML

As well as scenarios on providing extra water, experts also provided information on a status quo (or "do-nothing") scenario. In each scenario, the ecological changes were described in terms of change in the population of a few indicator species as determined by experts. These included two species of birds (Brolga and Australasian Bittern), one species of fish (Southern Pygmy Perch), one species of frog (Southern Bell Frog), and one type of aquatic vegetation (Water ribbons).

These changes in population were described as either:

- a decline in population
- an increase in population
- no decline in population (i.e., maintain population)

The magnitude of the change was described numerically and in words (see Figure 5).

CHANGE IN POPULATION

Decline					Increase			
Local extinction	Large	Medium	Small	No decline	Small	Medium	Large	Very Large
Decline by 100%	Decline by 30-49%	Decline by 16-29%	Decline by 1-15%	No decline	Increase by 1-15%	Increase by 16-29%	Increase by 30-49%	Increase by 50% or over

Figure 7. Scale describing the extent of change of the indicator species for the scenarios on providing extra water to Bool Lagoon for two years in 10.

3.2.2.1. Status quo scenario – No extra water to Bool Lagoon

In the status quo scenario, no additional water would be sourced from available surface and groundwater to augment Mosquito Creek inflows and Bool Lagoon would be reliant only on rainfall and natural inflows. There will be no changes to land use or water use in the catchment. Bool Lagoon would not be modified to retain higher water levels and there are unlikely to be permanently inundated areas in the Lagoon. Areas of seasonally deeper water where aquatic plants grow will occur less often and reeds, sedges and tussocks which need occasionally wet conditions will suffer in longer periods of dry weather.

Under the status quo, as Bool Lagoon experiences longer dry periods, it is expected that in the long term this will result in less breeding and feeding habitat for birds such as the Brolga and the internationally endangered Australasian Bittern (Figure 8). The Southern Pygmy Perch is also likely to be lost from the system, numbers of the EPBC-listed vulnerable Southern Bell Frog are also expected to decline, and Water Ribbons are also likely to contract and decline.

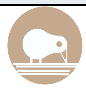
0 ML (No extra water)				
				
Brolga 16-29% decline in visiting population.	**Australasian Bittern** 100% decline in population.	**Southern Pygmy Perch** 100% decline in population.	**Southern Bell Frog** 30-49% decline in population.	**Water Ribbons** 1-15% decline in area.
Medium decline	Local extinction	Local extinction	Large decline	Small decline

Figure 8. The impact of providing no additional water to Bool Lagoon on the change in population of indicator native fish, frogs, birds, and aquatic vegetation under the status quo scenario.

3.2.2.2. Extra water scenario 1 – Extra 3000 ML

Under this scenario, an extra 3,000 megalitres (ML) of water will be provided to augment natural flows, in two years out of every 10 years. However, Bool Lagoon will not be modified to retain higher water levels. It is expected that there will be sufficient water to seasonally inundate deeper areas more regularly and to keep mud flats wet for longer. But the additional water provided will not permanently inundate any areas nor will it provide for the occasionally wet conditions needed by reeds, sedges, and tussocks.

The extra water will meet the minimum ecological needs for Water Ribbons. This in turn will provide nesting materials and sites for Brolgas and feeding and breeding habitat for the Southern Bell Frog (Figure 9). Breeding and foraging habitat for the Australasian Bittern is not expected to be improved significantly. Although the habitat will be suitable for the Southern Pygmy Perch, the lagoons will still need to be connected to refuge sites in Mosquito Creek to repopulate following dry periods.

Extra 3,000 ML in 2 years out of 10				
Brolga	**Australasian Bittern**	**Southern Pygmy Perch**	**Southern Bell Frog**	**Water Ribbons**
No decline in visiting population.	30-49% decline in population and no breeding occurring.	16-29% decline in population.	1-15% decline in population.	No decline in area.
No decline	**Large decline**	**Medium decline**	**Small decline**	**No decline**

Figure 9. The impact of providing an extra 3000 ML of water to Bool Lagoon on the change in population of indicator native fish, frogs, birds, and aquatic vegetation.

3.2.2.3. Extra water scenario 2 – Extra 12,000 ML

Under this scenario, an extra 12,000 ML of water will be provided to augment natural flows, in two years out of every 10 years. The Lagoon will not be modified to retain higher water levels. This extra water will increase water levels in Bool Lagoon for up to six months in the year, providing wet conditions for reeds and sedges and maintaining seasonally deeper water for Water Ribbons, and in turn, provide breeding habitat for the Australasian Bittern and feeding and refuge habitat for Brolgas. As water is retained in the lagoons for a longer period, there will be the opportunity for frogs and fish to breed to maintain populations (Figure 10). An increase in populations of frogs and fish will, in turn, provide important food sources for many foraging bird species.

Extra 12,000 ML in 2 years out of 10				
Brolga	**Australasian Bittern**	**Southern Pygmy Perch**	**Southern Bell Frog**	**Water Ribbons**
30-49% increase in visiting population.	No decline in population and breeding occurring.	No decline in population.	No decline in population.	No decline in area.
Large increase	**No decline**	**No decline**	**No decline**	**No decline**

Figure 10. The impact of providing an extra 12,000 ML of water to Bool Lagoon on the change in population of indicator native fish, frogs, birds, and aquatic vegetation.

3.2.2.4. Extra water scenario 3 – Extra 20,000 ML

Under this scenario, an extra 20,000 ML of water will be provided to augment natural flows, in two years out of every 10 years. The Lagoon is not modified to retain higher water levels, but this scenario aims to provide sufficient water to maintain the ecological character of Bool Lagoon and, for some species, act as a buffer against climate change impacts. Although the period of inundation is shorter (less than four months), it will increase water levels and so wet the feet of reeds, sedges and tussocks and create protected, hidden refuge and foraging areas for birds. It will also assist in retaining water in the lagoon for longer allowing frogs and fishes to breed and potentially increase their populations (Figure 11).

Extra 20,000 ML in 2 years out of 10				
Brolga	**Australasian Bittern**	**Southern Pygmy Perch**	**Southern Bell Frog**	**Water Ribbons**
Increase in visiting population by 50% or more.	16-29% increase in population and breeding occurring.	1-15% increase in population.	30-49% increase in population.	No decline in area.
Very Large increase	**Medium increase**	**Small increase**	**Large increase**	**No decline**

Figure 11. The impact of providing an extra 20,000 ML of water to Bool Lagoon on the change in population of indicator native fish, frogs, birds, and aquatic vegetation.

3.2.2.5 Cost attribute

To maintain the parsimony of the discrete choice experiment other attributes relevant to the site were excluded. For example, varying levels of access to the Lagoon could be included as an attribute but this would further complicate any comparisons with use values of water. In order to extract a willingness to pay estimate from these data, a payment vehicle is needed as another attribute. Landowning households in South Australia currently pay a landscape board levy as part of their annual rate payments to local government. To retain the plausibility of the experiment, a one-off annual increase in the landscape levy (divided into 4 instalments) was chosen as the cost attribute. Standard practice with choice experiments is to explore all attributes with focus groups to identify any potential areas of bias in advance.

3.2.2.6 Best worst scaling follow-up

While the choice experiment can help us understand the value of changes in the condition of Bool Lagoon, it does not always reveal what aspects of the environment are most important to individuals. To gain insights into this, the choice experiment was followed by a best-worst scaling task. This is a reduced form of choice modelling where individuals are given a list of attributes and must indicate which is most and least preferred. Essentially, the best-worst scaling experiment provides a statistically robust ranking of the ecological outcomes and assigns an 'importance score' to each level. The statistical treatment of the type of data yielded by this approach is described in Cooper et al. (2024).

3.2.3 Discrete choice experiment survey

3.2.3.1. Discrete choice experiment survey – focus group testing and online piloting

Once feasible baseline and alternate scenarios were developed by experts, a discrete choice experiment survey was developed and tested through a series of focus groups with members of the general public in South Australia. Ethics approval was received from the UniSA Business Negligible Risk Ethics Committee (Approval number: 047-2024) to conduct the focus groups and the survey.

The first two focus groups were held in person at the University of South Australia's City West Campus on 31st October 2024 and 4th November 2024 with a diverse cross-section of people (11 in total) from the Greater Adelaide Region. Individuals were recruited through a third-party proprietary recruitment company *Pureprofile*. These focus groups assessed feedback on the scenarios developed, including the ecological outcomes and the scale indicating the degree of change. The focus groups also tested the payment vehicle, which was also informed by prior research (e.g., Cooper et al. 2023). Feedback from these focus groups helped refine the presentation of information about the scenarios.

The full survey was then developed and tested through two more focus groups, which were conducted on 12th and 13th December 2024, respectively. The focus group on 12th December was conducted in person at Naracoorte with members of community groups and included nine participants. The focus group on 13th December was held in person at the University of South Australia's City West Campus with a diverse cross section of 13 participants from the Greater Adelaide Region, recruited through the online panel of respondents (*Pureprofile*). Collectively, these focus groups tested the full survey for clarity, ease of understanding the information presented, choice experiment and best-worst scaling questions and survey length.

As part of the survey, two videos were also created to (1) present the background information on Bool Lagoon and the issue, and (2) introduce the choice experiment survey. These two videos were also tested with focus group participants and any changes for improvements noted. Six levels of cost in the form of an increase to the landscape levy, payable quarterly for one year only, were also tested in the focus groups. The cost ranged from $10 ($2.5/quarter) to $400 ($100/quarter). The higher costs ($300, $400) were considered as unaffordable to participants in the regional focus group, even though metropolitan participants did not consider the payment excessive. However, given the current inflation and high cost of living, the survey was further tested using lower cost levels. The final choice experiment design consisted of 3 alternate scenarios and 6 payment levels (i.e., a total of 18 alternatives) (Table 1).

Table 1. Attributes and levels for the discrete choice experiment.

ATTRIBUTE	DESCRIPTOR	STATUS QUO	LEVEL
Additional environmental water	Additional megalitres of environmental water for Bool Lagoon in 2 years out of 10	**0 ML** of additional environmental water	• **3,000 ML** • **12,000 ML** • **20,000 ML**
Cost ($)	An increase to the landscape levy (issued quarterly) for 1 year only.	**$0**	• **$20 ($5/quarter)** • **$60 ($15/quarter)** • **$100 ($25/quarter)** • **$160 ($40/quarter)** • **$240 ($60/quarter)** • **$300 ($75/quarter)**

The 18 choice alternatives were assigned to three blocks using a specialist statistical software program (*NGene*). This generated six questions per respondent, such that each participant would only answer six choice questions (thus, three respondents would be needed to answer the full design).

The survey was programmed online in the survey platform Qualtrics. The survey included four sections: socio-demographic questions, attitudinal questions, the choice experiment and the best-worst scaling experiment[3].

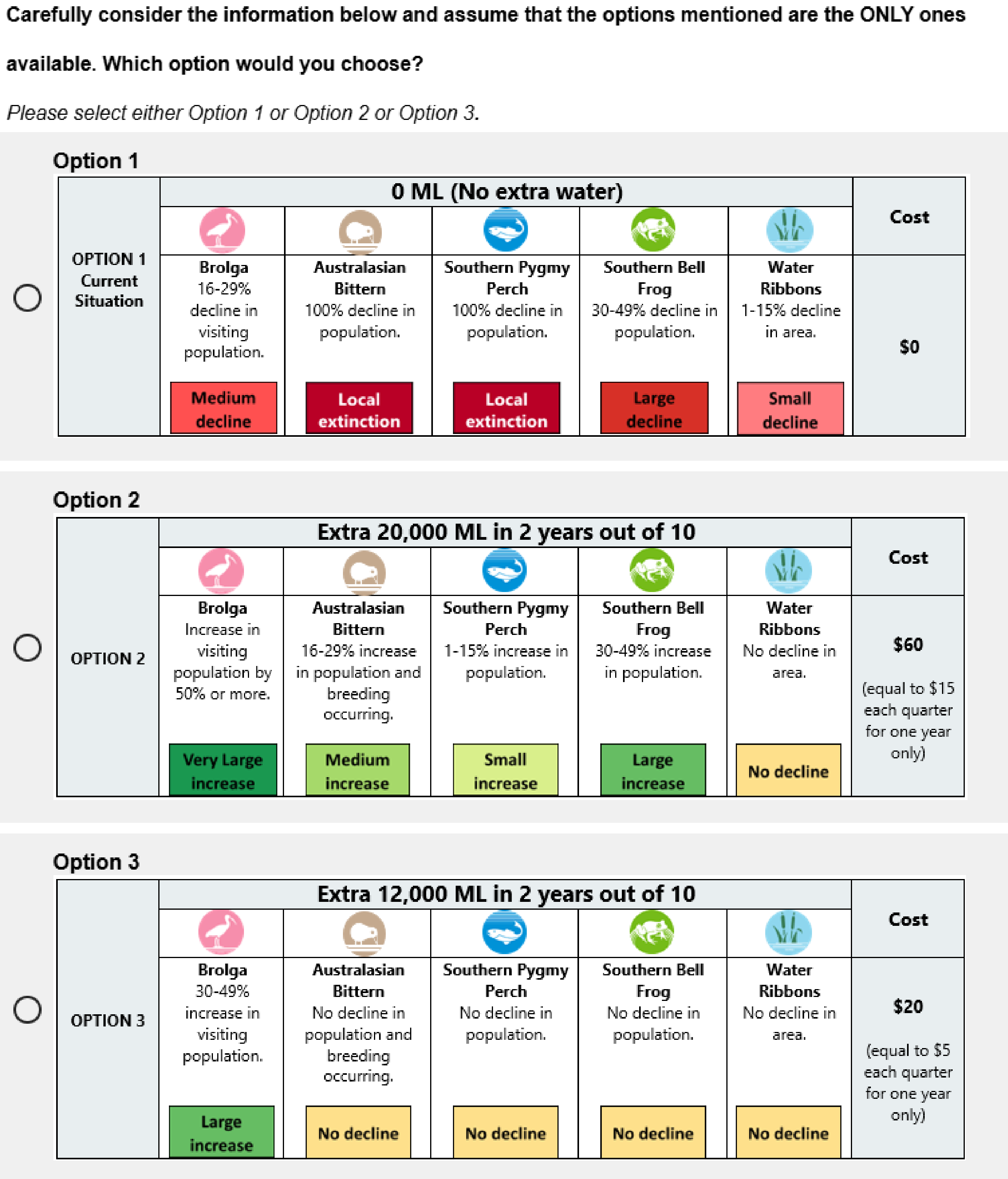
Section A requested demographic information including a respondent's postcode, age, educational status, gender, residency length in South Australia and in Australia, family type, household size, and number of children and personal and household income. The response options for socio-demographic questions reflected Australian Bureau of Statistics (ABS) categories and can thus help adjudge the representativeness of the sample. This section also included questions on whether respondents were jointly or solely responsible for paying bills, whether they had a lawn or garden, visitation to Bool Lagoon in the last 10 years, and if yes, the recreational activities at the site, and membership of environmental groups.

Section B included questions on respondents' opinion and attitudes towards the natural environment and were based on the New Environmental Paradigm scale (Dunlap, 2008). Respondents were asked to rate a series of statements on a five-point scale ranging from 'Strongly disagree' all the way to 'Strongly agree'.

Section C presented information about Bool Lagoon (through text and short video clips) and introduced the choice experiment. Respondents were provided information about the baseline and alternate scenarios and the payment vehicle. Some simple quiz questions followed to (a) ensure respondents remained engaged and (b) provide data that can help capture and isolate non-attentiveness. An example choice experiment

[3] Initially, each choice question had only two options – the current situation/status quo that was always shown at zero cost and an alternative scenario that was presented at a cost to the respondent. Respondents had to select either one of the options and could not opt out of making a choice. After piloting the survey the choice question was changed to include 3 options.

question was also shown (



Carefully consider the information below and assume that the options mentioned are the ONLY ones available. Which option would you choose?

Please select either Option 1 or Option 2 or Option 3.

Option 1

OPTION 1 Current Situation	0 ML (No extra water)					Cost
	Brolga 16-29% decline in visiting population.	**Australasian Bittern** 100% decline in population.	**Southern Pygmy Perch** 100% decline in population.	**Southern Bell Frog** 30-49% decline in population.	**Water Ribbons** 1-15% decline in area.	**$0**
	Medium decline	Local extinction	Local extinction	Large decline	Small decline	

Option 2

OPTION 2	Extra 20,000 ML in 2 years out of 10					Cost
	Brolga Increase in visiting population by 50% or more.	**Australasian Bittern** 16-29% increase in population and breeding occurring.	**Southern Pygmy Perch** 1-15% increase in population.	**Southern Bell Frog** 30-49% increase in population.	**Water Ribbons** No decline in area.	**$60** (equal to $15 each quarter for one year only)
	Very Large increase	Medium increase	Small increase	Large increase	No decline	

Option 3

OPTION 3	Extra 12,000 ML in 2 years out of 10					Cost
	Brolga 30-49% increase in visiting population.	**Australasian Bittern** No decline in population and breeding occurring.	**Southern Pygmy Perch** No decline in population.	**Southern Bell Frog** No decline in population.	**Water Ribbons** No decline in area.	**$20** (equal to $5 each quarter for one year only)
	Large increase	No decline	No decline	No decline	No decline	

) and respondents were randomly assigned to one of three blocks, each containing six choice questions. Before being shown the questions, respondents were told to answer the choice questions as if they would have to pay, keeping in mind their available income and as if this was a real vote to determine a new policy, noting that these results would help in future water policy and planning in South Australia. Those who always selected the status quo option or who always selected the alternate option in all choice questions were also asked a series of follow-up question to help understand their reasoning. In the case of those who always selected the status quo, the follow-up question would help assess if respondents genuinely could not pay, or if they were protesting about some aspect of the payment[4]. Those who always selected away from the status quo option were also asked about their reasoning and attention to levels and attributes.

The final section of the survey (Section D) presented respondents with five best-worst scaling questions, each containing 6 ecological outcomes drawn from the 18 available and asked to identify the one that they would MOST like to see happen, and one that they would LEAST like to see happen. Table 2 lists the ecological indicators and their levels. The combinations of 6 items were drawn from an experimental design that had 150 questions in total. An example BWS question (Figure 13) and a short video on how to answer the question was also shown to respondents. For both the choice questions and the best worst scaling questions, respondents were asked to answer each question independently.

Table 2. Ecological outcomes used in the discrete choice experiment.

BROLGA	AUSTRALASIAN BITTERN	SOUTHERN PYGMY PERCH	SOUTHERN BELL FROG	WATER RIBBONS
16-29% decline in visiting population.	100% decline in population.	100% decline in population.	30-49% decline in population.	1-15% decline in area.
No decline in visiting population.	30-49% decline in population & no breeding occurring.	16-29% decline in population.	1-15% decline in population.	No decline in area.
30-49% increase in visiting population.	No decline in population & breeding occurring.	No decline in population.	No decline in population.	NA
Increase in visiting population by 50% or more.	16-29% increase in population & breeding occurring.	1-15% increase in population.	30-49% increase in population.	**NA**

[4] We discuss the treatment of protesters in the results section.

Carefully consider the information below and assume that the options mentioned are the ONLY ones available. Which option would you choose?

Please select either Option 1 or Option 2 or Option 3.

Option 1

	0 ML (No extra water)					Cost
OPTION 1 Current Situation	**Brolga** 16-29% decline in visiting population.	**Australasian Bittern** 100% decline in population.	**Southern Pygmy Perch** 100% decline in population.	**Southern Bell Frog** 30-49% decline in population.	**Water Ribbons** 1-15% decline in area.	**$0**
	Medium decline	**Local extinction**	**Local extinction**	**Large decline**	**Small decline**	

Option 2

	Extra 20,000 ML in 2 years out of 10					Cost
OPTION 2	**Brolga** Increase in visiting population by 50% or more.	**Australasian Bittern** 16-29% increase in population and breeding occurring.	**Southern Pygmy Perch** 1-15% increase in population.	**Southern Bell Frog** 30-49% increase in population.	**Water Ribbons** No decline in area.	**$60** (equal to $15 each quarter for one year only)
	Very Large increase	**Medium increase**	**Small increase**	**Large increase**	**No decline**	

Option 3

	Extra 12,000 ML in 2 years out of 10					Cost
OPTION 3	**Brolga** 30-49% increase in visiting population.	**Australasian Bittern** No decline in population and breeding occurring.	**Southern Pygmy Perch** No decline in population.	**Southern Bell Frog** No decline in population.	**Water Ribbons** No decline in area.	**$20** (equal to $5 each quarter for one year only)
	Large increase	**No decline**	**No decline**	**No decline**	**No decline**	

Figure 12. An example discrete choice experiment question shown to respondents.

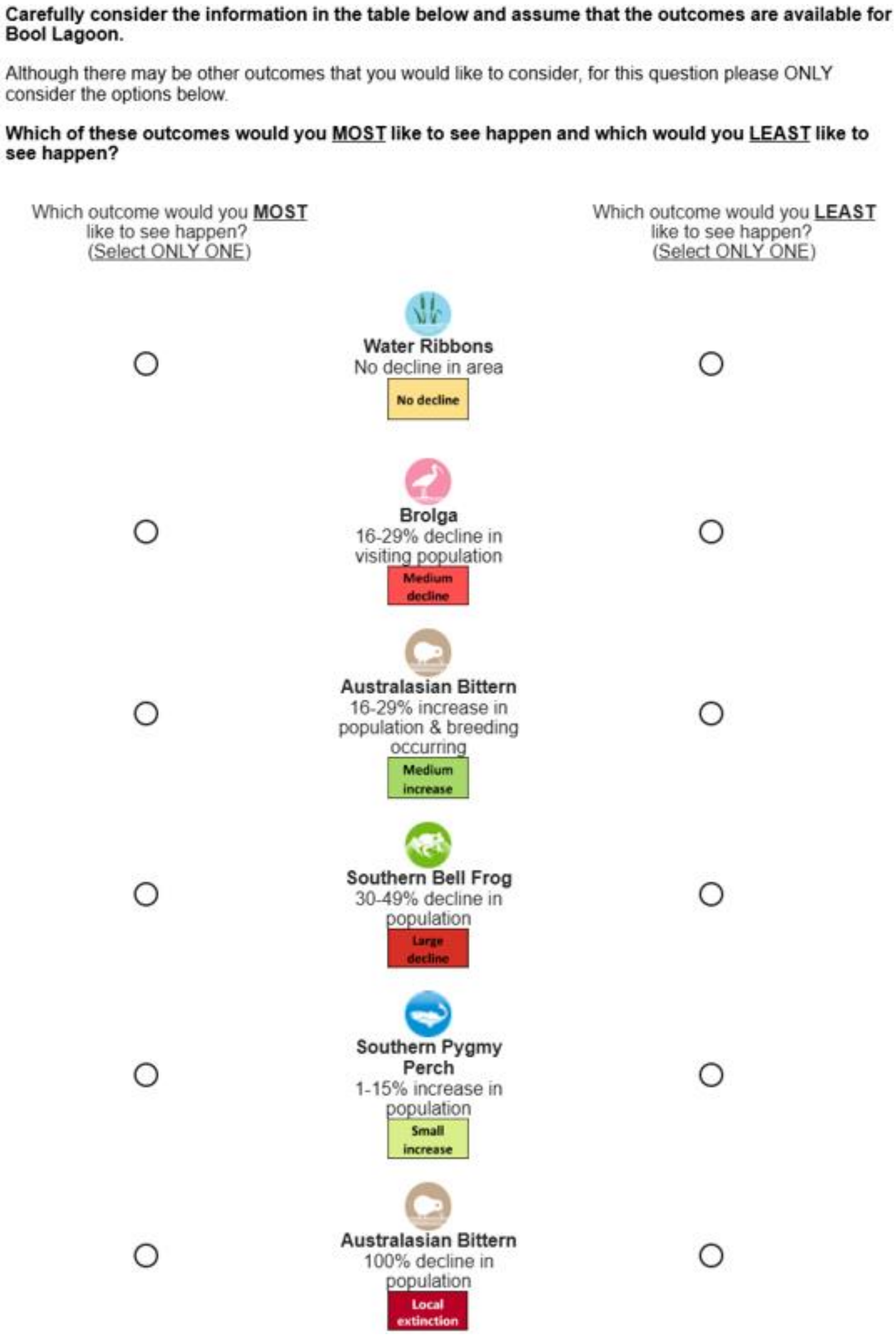


Figure 13. An example best-worst scaling question shown to respondents.

An online pilot of the survey was opened on 14th March 2025. This was intended to ensure that the data collected would generate an appropriate statistical model. The initial pilot (n=approx. 50) indicated that the cost attribute was significant and had the expected coefficient sign (negative) but the water attribute was not statistically significant. Respondents would systematically opt away from the status quo (i.e. they did not want the current situation to continue), but did not systematically discriminate between the ecological improvements. To overcome this concern, the choice sets were adjusted to (a) include 3 options in each choice, as illustrated in Figure 12, (b) increase the cost attribute to encourage more discriminating responses and (c) take account of the priors revealed in the pilot. The statistical design was regenerated in *NGene* and an example choice task that was included in the final survey is shown in Figure 12Figure 1. A copy of survey is available on request.

3.2.4 Survey results

As noted earlier, an online survey was administered for this project. Participants were screened to ensure:

- They were over 18 years of age;
- Were involved in paying household bills.

Participants completed the survey (including piloting phases) between 14th March and 14th April 2025.

This section of the report provides a description of the sample data from the first two parts of the survey along with some analysis of representativeness against the state's population.

3.2.4.1. Sample

Overall, the sample consisted of 1,305 completed[5] respondents. The response rate was 71 percent, and the median completion time was 21 minutes. Following protocol to deal with fast respondents, those who completed the survey in less than a third of the median completion time (i.e., 7 minutes) were removed from the data analysis. Responses with a ReCAPTCHA Score below 0.7 were also removed from data analysis, thereby reducing the risk that the survey was completed by a bot. The usable responses were, therefore, 1,151.

The sample was stratified on the basis of postcode in an effort to ensure a degree of representativeness. Of the total 1,151 respondents who completed the survey, 935 (81.2%) were from the Greater Adelaide Region, 12 (1%) were from the Limestone Coast Region and the remainder 204 (17.7%) resided in other regions in South Australia. Given that about 80% of the population of South Australia resides in the Greater Adelaide Region, our sample distribution by region is comparable to the distribution in population across the state[6].

3.2.4.2. Socio-economic and demographic comparisons of sample to population

Differences between the sample and the population of South Australia were assessed by comparing relevant socio-demographic characteristics (Table 3). The Australian Bureau of Statistics (ABS) 2021 Census data was used for comparisons. Chi-square tests of difference were employed for this assessment.

[5] There were also 60 respondents who did not consent to participate and 89 who were not involved in paying household bills. These respondents were screened out. Two respondents from out of state were also removed.

[6] Recall that the rationale for conducting the DCE outside the Limestone Coast region was to capture the option, existence and bequest values - collectively known as non-use values – often held by people located away from the ecological site.

Table 3. Selected socio-economic and demographic comparisons.

FEATURE	SAMPLE	POPULATION
Median age (years)[a]	54.5 years	41 years
Median household income [b]	\$78,000–\$103,999	\$114,061
Proportion of males	37.5%	49%
Proportion Aboriginal and/or Torres Strait Islander	3.5%	2.4%
Proportion with highest educational level Bachelor Degree or above	35%	23%
Household composition		
Couple family without children	31%	41%
Couple family with children	28%	41%
One parent family	9%	17%
Other family[c]	31%	2%
Dwelling tenure		
Owned outright	38%	33%
Owned with mortgage	36%	36%
Rented	26%	28%
Other	1%	3%
Dwelling type		
Separate house	78%	78%
Flat, unit, or apartment	11%	7%
Semi-detached, row or terrace house, townhouse etc.	10%	17%
Other	1%	0%

[a] Sample included those 18 years or older only; [b] From https://www.abs.gov.au/articles/snapshot-sa-2021. Value adjusted for inflation; [c] Those who did not fit in the other given categories and instead described the type of household that they were part of.

There was a statistically significant difference in the distribution of age groups (p<0.01) between the sample and the population and this was likely due to differences in the proportions of those between 20–24 years and all groups between the ages of 35 and 79 years (

Table 3). The median age of the sample (54.5 years) was higher than the population (41 years). This was not unexpected as the sample only comprised respondents 18 years or older. The sample also had a greater proportion of females (62.5%) compared to males (37.5%).

Participants were asked to select their highest education level. In this case, there is a difference between the sample and the population. Around 14% of the sample did not have a higher level of education than Year 11 or below (including Certificate I/II) compared to 29% in the population in the 2021 census. Also, while 35% of the sample achieved a Bachelor Degree level or higher (Graduate Diploma/Certificate or Postgraduate Degree), this proportion was 23% in the population (

Table 3). Participants responding to online surveys are usually found to be more educated than the general population (Reinikainen et al. 2018, Spitzer, 2020).

In addition to fundamental socio-economic information, the survey collected a range of attitudinal and behavioural data about participants. This is often done with choice experiments as it can help with more sophisticated modelling of respondents. Given the key focus of this project, data on visitation activities, environmental attitudes and responses to test questions is presented in Appendix B.

3.2.5 Discrete choice experiment survey

3.2.5.1. Modelling approach

In the case of the choice data 15,696 observations were included in the modelling. In the majority of choice experiments, there will be participants who offer a protest to the alternatives presented. For instance, this might be in the form of a refusal to offer a bid because of a lack of trust in authority or an objection to the payment vehicle (see, for instance, Cooper et al. 2023). In this case, the choice sets were followed by a series of questions that appeared automatically if a respondent always selected the status quo or only chose the alternative option in each choice set. Respondents who answered positively[7] to these types of questions were considered to be protestors and were excluded from the analysis. This equated to about 279 respondents or 24% of respondents. Removing these respondents leaves 872 respondents in the sample[8].

Econometric estimation was conducted using conditional logit models to test for the statistical significance of the attributes. Additional modelling was undertaken to investigate heterogeneity (e.g. Latent Class modelling) but this is not reported here as it has no significant bearing on the WTP for non-use values.

Table 4 provides variable definitions of attributes and variables used in the models.

Table 4: Attribute definitions for the discrete choice experiment

ATTRIBUTES	DESCRIPTION	UNIT
cost	Cost attribute $ in one off annual payment.	**$**
water	Quantity of additional water for the environment	**ML**

3.2.5.1. Modelling results

Since the levels of the attributes (cost, water) are zero in the status quo option, the implied marginal utility associated with the status quo would be zero. A conditional logit model was generated from the data to understand the probability of a respondent selecting away from the status quo to one of the alternative water scenarios. As the choice experiment comprises only two attributes (cost and water) each of the water levels is represented in the model as a separate parameter.

[7] For those who always selected the 'Current situation', respondents who selected one or more of the following reasons were deemed protestors: (a) I would like Bool Lagoon to be improved, but the government should pay for it, (b) I would like Bool Lagoon to be improved, but I don't think I should have to pay for it through my landscape levy, (c) I would like Bool Lagoon to be improved, but I don't trust government to deliver it, (d) I found it too hard to compare the options, so I selected 'current situation'. For those who never selected the 'Current situation', respondents who selected one or more of the following reasons were deemed protestors: (a) I didn't consider the cost, (b) I don't think I will be asked to pay the cost, and (c) it's important to send governments a message about improving natural wetlands.

[8] "The rationale for excluding protestors is that the respondents are not 'engaged' in a market and the experiment is premised to replicate a market setting. It is important to note that respondents who claim to never offer a bid because they cannot afford to do so are not excluded, since this is consistent with a market response" (Cooper et al. 2023, p.6).

Several key findings can be drawn from the model results (Table 5. Conditional logit results for the discrete choice experiment.5). First, cost is significant at the 1 per cent level and negative such that options with a higher cost are less preferred. Second, each level of the environmental water attribute (water) is statistically significant at the 1 per cent level and positive such that respondents prefer additional water for the environment. Overall, the results support the view that participants responded systematically to the choices presented to them.

Table 5. Conditional logit results for the discrete choice experiment.

ENVIRONMENTAL WATER ATTRIBUTE	COEFFICIENT	STANDARD ERROR	Z VALUE	P >|Z|	95% CONFIDENCE INTERVAL	
Extra 3,000 ML water	1.446	0.066	21.960	0.000	1.317	1.575
Extra 12,000 ML water	2.573	0.062	41.730	0.000	2.453	2.694
Extra 20,000 ML water	2.707	0.087	31.250	0.000	2.537	2.877
Cost	-0.005	0.000	-13.310	0.000	-0.006	-0.004

3.2.6 Best-Worst Scaling results

3.2.6.1. Best-worst scaling approach

In the best-worst scaling experiment, respondents were asked to rate the ecological attributes that were used to describe the outcomes from the purchase of environmental water (i.e., change in populations of key species at Bool Lagoon: Brolga, Australasian Bittern, Southern Pygmy Perch, Southern Bell Frog, and Water Ribbons).

3.2.6.2. Best-worst scaling results

A convenient way to represent best-worst-scaling data is using a relative probability measure, or "importance score". This is a relative measure of the likelihood that an item would be selected as best from a set of 6 items. The scores are scaled, so they sum to 100.

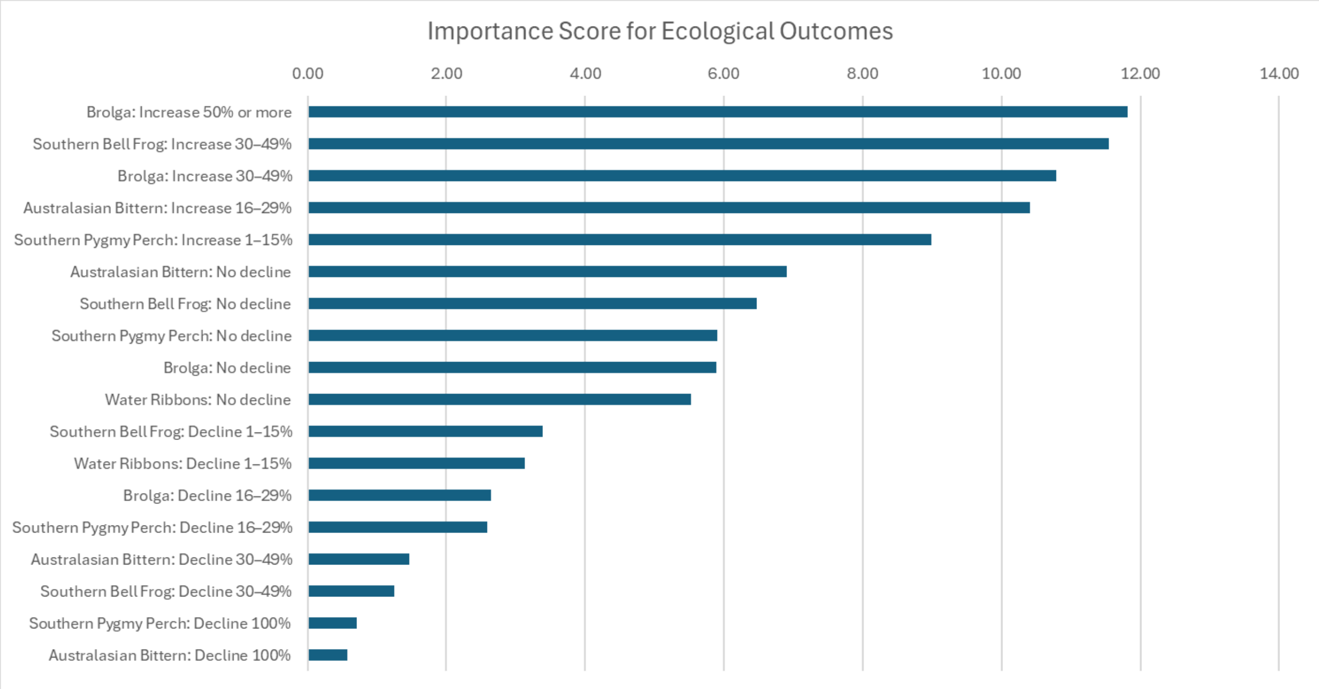


Figure 14 illustrates the "importance score" for each of the items.

The results show a logical progression with item types (i.e. improved values of species are weighted more highly while local extinctions are least preferred). They suggest that a 50% or greater increase in visiting population of Brolga has the highest positive impact on choice, followed by a 30-49% increase in population of the Southern Bell Frog. A 100% decline (local extinction) of the population of the Australasian Bittern and a local extinction of the Southern Pygmy Perch population are scored at very low levels. Maintaining population (No decline in population) of species was ranked in the middle.

Although one cannot identify a monetary value associated with these items, the best-worst scaling analysis indicates what aspects of the ecological outcomes from the ecological water will likely have influenced respondents' choices.

For completeness, Table 6 reports the conditional logit results analysed in Stata18, using "1-15% decline in area of Water Ribbons" as the baseline.

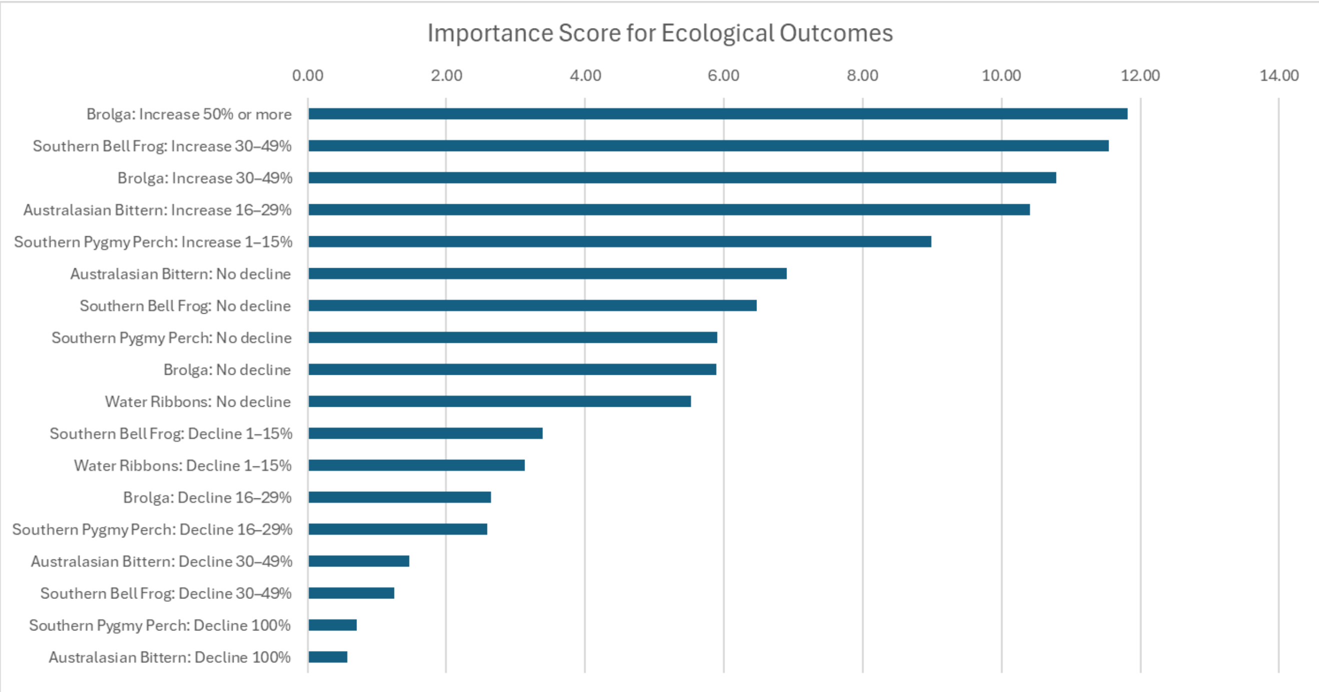


Figure 14. Importance scores of 18 ecological outcomes.

Table 6. Conditional logit results for best-worst scaling analysis.

ECOLOGICAL OUTCOME	COEFFICIENT	STANDARD ERROR	Z VALUE	P >|Z|	95% CONFIDENCE INTERVAL	
Brolga: Increase 50% or more	1.807	0.067	26.96	0.00	1.676	1.939
Southern Bell Frog: Increase 30–49%	1.766	0.067	26.24	0.00	1.634	1.898
Brolga: Increase 30–49%	1.647	0.067	24.49	0.00	1.515	1.779
Australasian Bittern: Increase 16–29%	1.585	0.068	23.29	0.00	1.451	1.718
Southern Pygmy Perch: Increase 1–15%	1.351	0.068	19.86	0.00	1.218	1.485
Australasian Bittern: No decline	0.969	0.070	13.93	0.00	0.833	1.106
Southern Bell Frog: No decline	0.884	0.070	12.67	0.00	0.748	1.021
Southern Pygmy Perch: No decline	0.762	0.070	10.90	0.00	0.625	0.899
Brolga: No decline	0.760	0.070	10.82	0.00	0.622	0.898
Water Ribbons: No decline	0.676	0.069	9.78	0.00	0.540	0.811

Southern Bell Frog: Decline: 1–15%	0.090	0.070	1.28	0.20	-0.048	0.227
Brolga: Decline 16–29%	-0.190	0.070	-2.72	0.01	-0.327	-0.053
Southern Pygmy Perch: Decline 16–29%	-0.214	0.070	-3.08	0.00	-0.351	-0.078
Australasian Bittern: Decline 30–49%	-0.833	0.067	-12.38	0.00	-0.965	-0.701
Southern Bell Frog: Decline 30–49%	-1.002	0.066	-15.22	0.00	-1.131	-0.873
Southern Pygmy Perch: Decline 100%	-1.593	0.066	-24.09	0.00	-1.723	-1.463
Australasian Bittern: Decline 100%	-1.797	0.066	-27.07	0.00	-1.928	-1.667

4 Discussion

The overarching goal of this project was to shed light on the value of water in alternative uses in the Limestone Coast region, including non-consumptive uses. The range of consumptive uses was reported in detail in section 3. Key information gleaned about consumptive values is summarised here along with computed non-use values generated from the choice modelling data detailed earlier.

4.1 Consumptive values

Insights into consumptive values were gained using the residual value method and a range of simulation approaches. As noted, the consumptive industries covered 5 sectors – softwood forestry, hardwood forestry, dairy, onion/potatoes and winegrapes. The key value parameters are summarised in Table 7.

Table 7. Key water values and cost sensitivity ($/ML)

STATISTIC	SOFTWOOD	HARDWOOD	DAIRY	POTATOES & ONIONS	WINEGRAPES
Minimum	160	176	-161	272	-1,588
Maximum	620	703	411	1,333	1,297
Mean	320	319	136	688	-161
Median	310	311	140	684	-179
Standard deviation	77	71	108	168	457

4.2 Non-consumptive values

To generate non-consumptive values, part-worth estimates[9] of willingness to pay are generated using the outputs from the conditional logit model reported in Table 5Table 6. These are shown as a per household amount in Table 8.

[9] Part-worth estimates represent how much each attribute level contributes to overall perceived value.

Table 8. Part-worths evaluated at mean of normal distributions ($).

	PART-WORTH ($/HOUSEHOLD)	95% CI
Extra 3000 ML	**$288**	**[$241–$335]**
Extra 12000 ML	**$513**	**[$442–$584]**
Extra 20000 ML	**$540**	**[$480–$599]**

There are several additional steps that are required to convert this information into values that can then be meaningfully compared with consumptive values.

First, the part-worth estimates show a positive but diminishing marginal utility for additional water. Put differently, households generally prefer more water for an ecological site, like Bool Lagoon, but are not willing to pay the same unit amount for the last 20,000 ML ($0.027/ML) as they are for the first 3,000 ML ($0.096/ML). There are a variety of explanations for this, including the relative keenness of households to avert local extinction of some species, as supported by the best-worst-scaling results, and thus bidding strongly away from the status quo. To deal with this non-linearity, we report upper and lower mean willingness to pay estimates per ML per household.

Second, the treatment of protestors needs to be resolved. In some cases, protestors are assigned the mean willingness to pay on the assumption that they are objecting to the survey and not the ecological change. However, in this case we have adopted a more conservative approach and assume that protestors have a zero willingness to pay and thus reduce the total number of households with a positive willingness to pay in the state by the proportion of protesting households.

The total number of households in the state is taken from the 2021 census[10] and estimated at 742,298. Setting aside 24% protestors, leaves 564,147 households with a positive willingness to pay. The upper and lower bound willingness to pay for per ML of additional water to restore ecological health at the state level is reported in Table 9.

Table 9. Willingness to pay per ML of additional water at the State level ($).

	MEAN	95% CI	
Extra 3000 ML	$54,158	$45,132	$655,539
Extra 12000 ML	$24,258	$20,873	$642,563
Extra 20000 ML	$15,232	$13,540	$626,203

4.3 Interpretation, caveats and future work

The ecological restoration values have been estimated at the state level, focussing attention on the non-use component of values for households. In contrast, the use values in agriculture relate solely to the first-round benefits derived from deployment of additional resource in water-abstracting industries. To make the analysis manageable we have reported those values in equivalent $ per ML terms.

We do not include second-round values in any of these comparisons. More specifically, we do not include any impacts on local employment either (a) as a result of agriculture activity or (b) the potential behavioural

[10] https://www.abs.gov.au/census/find-census-data/quickstats/2021/4

impacts for households' utility from a restored ecological site. This is not to say that some of those impacts might not be meaningful or that distributional considerations should not be given attention by decision makers. Rather, we contend that first-round impacts are a clear basis for initial analysis and predicting community or state-wide flow-on effects is beyond the scope of this research.

As a general rule, economic analysis is agnostic about the source of welfare benefits and economists would generally recommend assigning scarce resources to the highest value. This is seen as maximising the welfare to society generally. In a related vein, economists would also generally recommend assigning scarce resources away from activities that generate negative welfare/value.

On that basis alone, there is evidence from this project that would support consideration of measures that saw additional water being allocated to non-consumptive activities, since these yield the highest benefit. There is also evidence produced as part of this research that would support efforts to reduce the use of water resources by some consumptive users, where that use adds to economic losses.

Where an active water market is in place and infrastructure existed to move water resources between users, this might act as the means for moving existing and additional resources to the highest value. Where this is not the case, decision makers may need to rely on other mechanisms to optimise the use of the resources. For example, we noted earlier that ecological sites are not usually bought and sold in a marketplace. Nonetheless, there is a body of experience in Australia and South Australia where market mechanisms have been used to reallocate water for environmental or ecological benefit.

Important caveats attend these findings. First, and has previously been noted, the analysis of consumptive values has been hindered by data availability with our analysis of winegrapes being primarily based on a recent, localised business-level survey conducted in the Lower Limestone Coast. This reflects current conditions but lacks long-term trends and future projections. While the incorporation of data from other South Australian regions informs a comprehensive sensitivity analysis, it may reduce specificity to the Lower Southeast region. To fully understand the economic value of water in winegrape production, a more comprehensive dataset is needed, ideally one that tracks long-term trends. This dataset should incorporate price projections reflecting the anticipated decline in winegrape prices with future prices likely trending towards the lower end of the estimated range.

Similar data limitations affected the analysis of the other industries. Specifically, the dairy, potato, and onion industries also presented challenges due to a scarcity of comprehensive, long-term data, limiting the ability to fully assess the long-term economic value of water use. While supplementary secondary data from other regions was considered where possible, this approach compromises the specificity of the analysis to the Lower Southeast region. Future research should prioritise the development of comprehensive datasets that track production, costs, and market prices over extended periods. These datasets should also incorporate realistic price projections, reflecting anticipated market trends, to provide a more accurate nuanced understanding of water's economic value across these industries. Put simply, in the absence of these long-term data we have relied on current information to estimate use values, and this requires a degree of caution.

Nonetheless, the trajectory of change in the region points to less water availability not more. From an ecological standpoint, choices will need to be made about the extent of habitat that can be preserved, although the community as a whole has expressed a high value on avoiding local species extinctions. This preference is evident, regardless of the limited visitation to the site by most survey respondents. This is further supported by the results of the best-worst scaling exercise.

In the context of agriculture in the region, future research should also assess the relative profitability of dryland farming as an alternative to groundwater-based irrigation to better inform decisions regarding investment in additional water supply infrastructure. Regan et al. (2023) used PIRSA data for dryland pasture grazing in the region, which is considered the most likely land use after conversion and found profits ranging from approximately $52/ha for cattle fattening to $266/ha for breeding, with some scenarios showing up to $300/ha after conversion costs. These figures offer a baseline for comparing dryland profitability to residual water values for irrigation. This research needs to be expanded to directly compare these dryland returns with the returns from irrigated agriculture, accounting for factors like water costs, crop yields, and trends in market prices. Incorporating this information with capital expenditure and ongoing operational costs of new water infrastructure can help policymakers make informed, economically sound decisions about future water resource investments.

5 Concluding remarks

This project aimed to establish the value of water in different applications in the Limestone Coast region. The motivation for the work was a broader project investigating the scope for managing drainage water in the region differently against a background of declining water availability and aquifer decline.

Residual water values were calculated for 5 consumptive water uses. This revealed significant value variability between enterprises and within them. This supports the view that some consumptive uses may be currently generating negative marginal values.

Non-consumptive values were estimated using a choice experiment centred on an ecologically significant site – Bool Lagoon. The valuation includes existence values, which capture the benefits non-visitors and non-residents gain from knowing an ecological site is being improved. Overall, the results from the valuation exercise reveal significant ecological values that surpass those generated from consumptive activities.

The data generated support a reconsideration of the current allocation of the resource and provide guidance to how any additional 'new' water could be allocated to maximise welfare.

List of shortened forms and glossary

ABARES	Australian Bureau of Agricultural and Resource Economics and Sciences
DCE	Discrete choice experiment
GMA	Groundwater Management Area
LLC WAP	Lower Landscape Coast Water Allocation Plan
ML	Megalitres
NPV	Net Present Value
RV	Residual Value (of water)
TEV	Total Economic Value
TVP	Total Value of Production
WTP	Willingness to pay

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Appendix A – Data to calculate residual water values

Table 10. Input parameters and values used to calculate water values

Parameter	Value	Unit	Source
Dairy			
Gross Farm Income	4,046-6,776	$/ha	(Dairy Australia, 2023)
AI & Herd Test	44-86	$/ha	(Dairy Australia, 2023)
Animal Health	75-121	$/ha	(Dairy Australia, 2023)
Calf Rearing	16-29	$/ha	(Dairy Australia, 2023)
Other Herd Costs	0-17	$/ha	(Dairy Australia, 2023)
Shed Power	53-95	$/ha	(Dairy Australia, 2023)
Dairy Supplies	29-65	$/ha	(Dairy Australia, 2023)
Other Shed Costs	0-16	$/ha	(Dairy Australia, 2023)
Feeds Purchased	489-1,179	$/ha	(Dairy Australia, 2023)
Hay & Silage Making	42-76	$/ha	(Dairy Australia, 2023)
Agistment	0-15	$/ha	(Dairy Australia, 2023)
Fertiliser	185-331	$/ha	(Dairy Australia, 2023)
Water Purchase	186-316	$/ha	(Dairy Australia, 2023)
Irrigation Costs	0-14	$/ha	(Dairy Australia, 2023)
Pasture & Crop Costs	21-31	$/ha	(Dairy Australia, 2023)
Fuel & Oil	34-68	$/ha	(Dairy Australia, 2023)
Other Feed Costs	0-11	$/ha	(Dairy Australia, 2023)
Application rate	2.33-4.30	ML/ha	(ABS, 2017)*
Softwood			
Rotation length	15	Years	(Regan et al., 2023)
Harvest costs	478-892	$/ha	(Regan et al., 2023)
Average travel costs	0.07-0.14	$/m3/km	(Regan et al., 2023)
Average distance travelled	31-72	km	(Regan et al., 2023)
Transport costs	173-387	$/ha	(Regan et al., 2023)
Land preparation	18-33	$/ha	(Regan et al., 2023)
Weeding	222-327	$/ha	(Regan et al, 2023)
Planting	79-138	$/ha	(Regan et al., 2023)
Fertiliser	56-118	$/ha	(Regan et al., 2023)
Annual maintenance	98-211	$/ha	(Regan et al., 2023)
Application rate	0.9-2.75*	ML/ha	(Regan et al., 2023)
Hardwood			
Rotation length	15	Years	(Regan et al., 2023)
Average travel distance	150	km	(Regan et al., 2023)
Transport cost	0.12-0.19	$/t/km	(Regan et al., 2023)
Site preparation	640-1154	$/ha	(Regan et al., 2023)
Planting costs	238-558	$/ha	(Regan et al., 2023)
Establishment fertiliser	116-270	$/ha	(Regan et al., 2023)
2nd Year fertiliser	170-320	$/ha	(Regan et al., 2023)
Annual Maintenance	61.6-92	$/ha	(Regan et al., 2023)
Other Contractor costs	14-23	$/ha	(Regan et al., 2023)
Harvesting costs	28-46.9	$/t	(Regan et al., 2023)
Application rate	1.20-3.00*	ML/ha	(Regan et al., 2023)
Yield	135-259	t/ha	(Regan et al., 2023)
Chip price	89-135	$/t	(Regan et al., 2023)

Parameter	Value	Unit	Source
Winegrapes			
Yield			
Coonawarra	4.1-6.2	t/ha	2024 business survey
Mount Benson	5.6-11.4	t/ha	2024 business survey
Mount Gambier	3.5-8.4	t/ha	2024 business survey
Padthaway	5.0-10.1	t/ha	2024 business survey
Wrattonbully	3.9-8.1	t/ha	2024 business survey
Net return			2024 business survey
Coonawarra	-872 - -1,446	$/ML	2024 business survey
Mount Benson	-1,266 - -2,398	$/ML	2024 business survey
Mount Gambier	-	$/ML	2024 business survey
Padthaway	1,114- 2,685	$/ML	2024 business survey
Wrattonbully	-608- -1,347	$/ML	2024 business survey
Irrigation rate			2024 business survey
Coonawarra	0.9-1.5	ML/ha	2024 business survey
Mount Benson	1.4-2.9	ML/ha	2024 business survey
Mount Gambier	-	ML/ha	2024 business survey
Padthaway	1.2-1.8	ML/ha	2024 business survey
Wrattonbully	0.7-1.7	ML/ha	2024 business survey
Average price	360-645	$/t	(Anderson and Puga, 2023; Vinehealth Australia, 2024)
Pest and Nutrient Sprays	154-288	$/ha	(Nordblom et al., 2018)
Seed and seeding	50-87	$/ha	(Nordblom et al., 2018)
Herbicide & application	143-245	$/ha	(Nordblom et al., 2018)
Fungicide & application	273-588	$/ha	(Nordblom et al., 2018)
Mowing mid-row	87-203	$/ha	(Nordblom et al., 2018)
Fertiliser	302-646	$/ha	(Nordblom et al., 2018)
Pruning & hedging	911-1901	$/ha	(Nordblom et al., 2018)
Irrigation	259-418	$/ha	(Nordblom et al., 2018)
Harvesting	656-976	$/ha	(Nordblom et al., 2018)
Contract Operators	912-1,824	$/ha	(Nordblom et al., 2018)
Machinery Costs	56-101	$/ha	(Nordblom et al., 2018)
Labour	115-209	$/ha	(Nordblom et al., 2018)
Potatoes & Onions			
Land Rent	1,759-4,029	$/ha	2024 business survey
Ground Preparation	307-715	$/ha	2024 business survey
Seed & Planting	2,150-3,441	$/ha	2024 business survey
Fertiliser	2,521-4,662	$/ha	2024 business survey
Bed Forming	82-172	$/ha	2024 business survey
Weed Control	146-201	$/ha	2024 business survey
Irrigation	1,078-1,557	$/ha	2024 business survey
Disease & Pest Control	588-936	$/ha	2024 business survey
Desiccation	46-116	$/ha	2024 business survey
Harvesting	1,686-3,820	$/ha	2024 business survey
Freight	1,053-1,992	$/ha	2024 business survey

Appendix B – Bool lagoon visitation, activities and environmental attitudes

Respondents were asked about their use of Bool Lagoon in terms of frequency and activity. Figure 15 shows the breakdown of visitation frequency. Of the 1,152 respondents, 831 (72%) stated that they never visited Bool Lagoon in the last 10 years. Of the remaining 321, 191 (17%) reported visiting Bool Lagoon between 1-5 times in the last 10 years while 97 (8%) reported visiting Bool Lagoon over 10 years ago. About 23 people (2%) reported visiting Bool Lagoon between 5-10 times while 10 (1%) reported visiting over 10 times (**Error! Reference source not found.**).

It is worth noting that part of the rationale for using a DCE was its ability to capture non-use values, and the relatively low visitation rate supports the view that the many of the values harnessed in these data are non-use in form.

B.1. Bool lagoon visitation

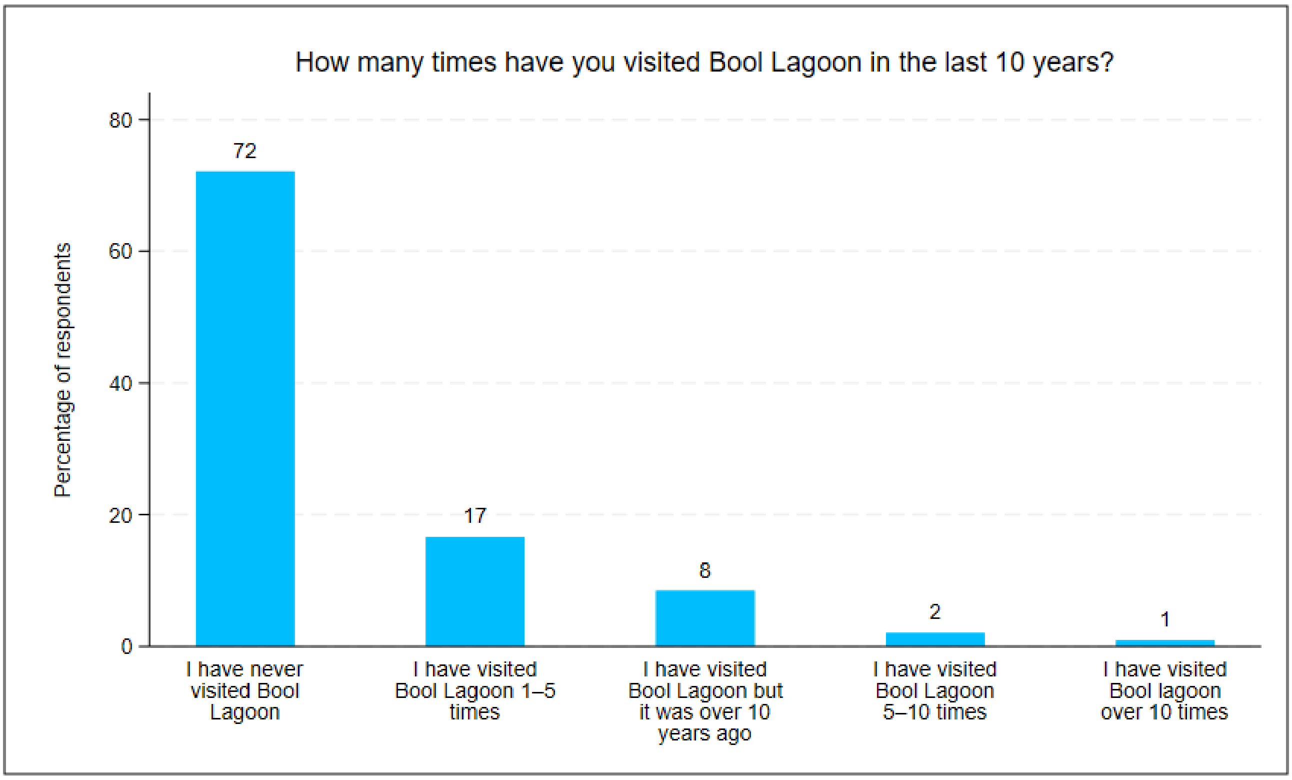

Figure 15. Frequency of visiting Bool Lagoon in the last 10 years.

There were significant differences detected in the frequency of visitation by gender (p=0.001) with a higher percentage of women (76%) reported having never visited Bool Lagoon compared to men (65%). There were also differences in visitation by household income (p <0.001), but no differences by dwelling type (p=0.802) or ownership type (i.e., owned outright, owned with a mortgage or rented/other) (p=0.062).

Although the sample only contained 40 people (3.5%) reporting Aboriginal or Torres Strait Islander origin, Aboriginal/Torres Strait Islander status was found to significantly influence frequency of visitation (p <0.001).

Although most respondents in the sample (94.5%, n=1,089) were not members of any environmental groups (e.g. Friends of Bool and Hacks Lagoons, Friends of Belair National Park Inc.), membership in an environmental group significantly impact visiting frequency (p <0.001) with non-visitation to Bool Lagoon being significantly higher (74%) among non-members than members (38%) (Figure 16).

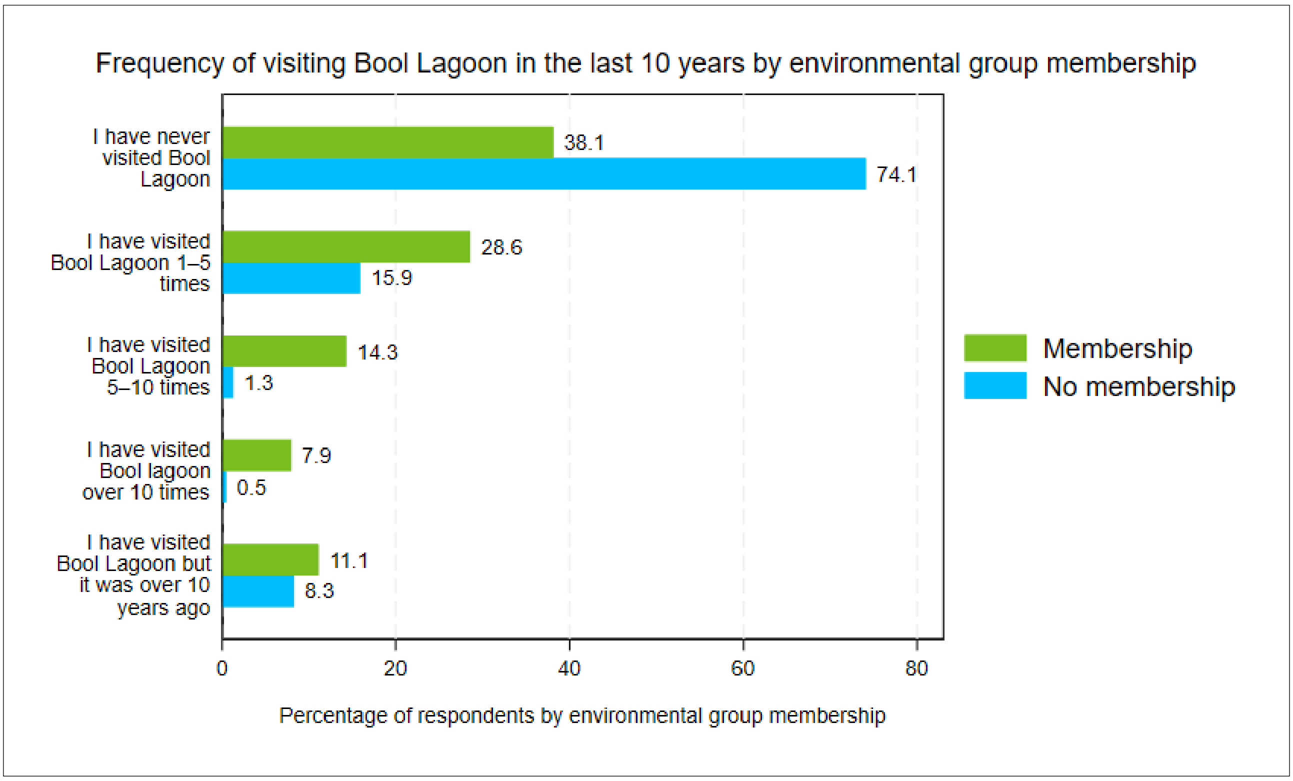

Figure 16. Frequency of visiting Bool Lagoon in the last 10 years by membership in environmental group(s).

B.2. Bool lagoon activities

Bushwalking/hiking was the most common reported activity (28%) followed by nature appreciation (26%) and picnics (19%) (Figure 17). Of those who reported visiting Bool Lagoon 1–5 times (191 respondents), 63%, 58%, 38% respectively did so for these activities. Camping, fishing, and duck hunting were reported by 12%, 7% and 4% of respondents.

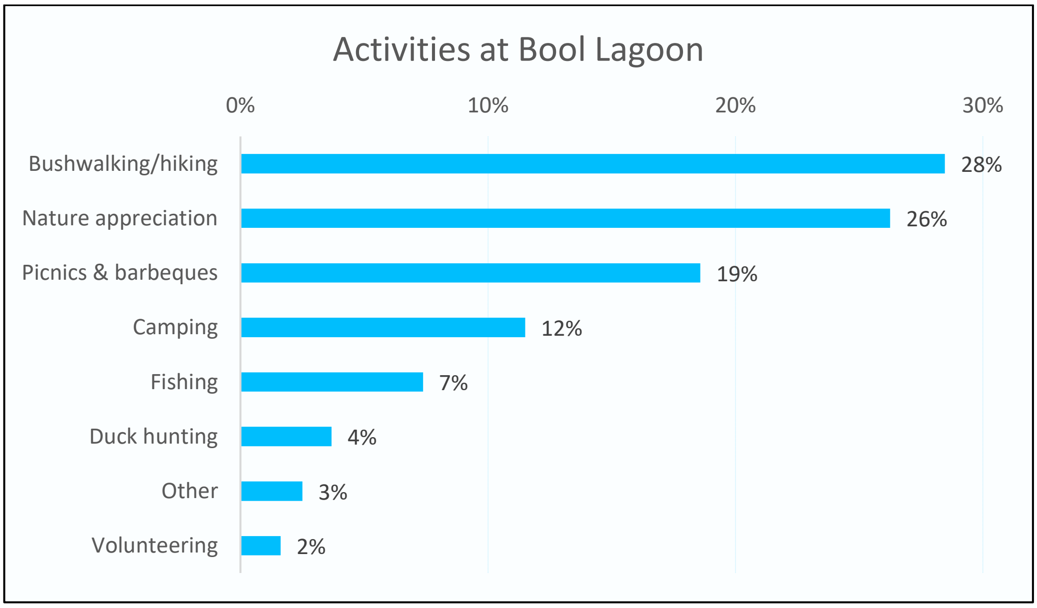

Figure 17. Activities at Bool Lagoon.

B.3. Environmental attitudes

Participants were asked a series of questions about their attitudes to the natural environment. These questions were adapted from the New Environmental Paradigm (Dunlap, 2008), which is one of the most widely used measure of environmental concern. A list of statements was provided, and the level of agreement recorded. From Figure 18, which summarises the participants' responses, it appears that most participants are concerned with the natural environment with substantial agreement with statements about the natural environment. For example, 94% agree or strongly agree with the statement, "*It makes me sad to see natural environments destroyed*" while 92% agree or strongly agree that "*It is important to improve the ecological value of waterways for future generations*" and 61% agree or strongly agree that "*Climate Change will have a negative impact on Bool Lagoon*".

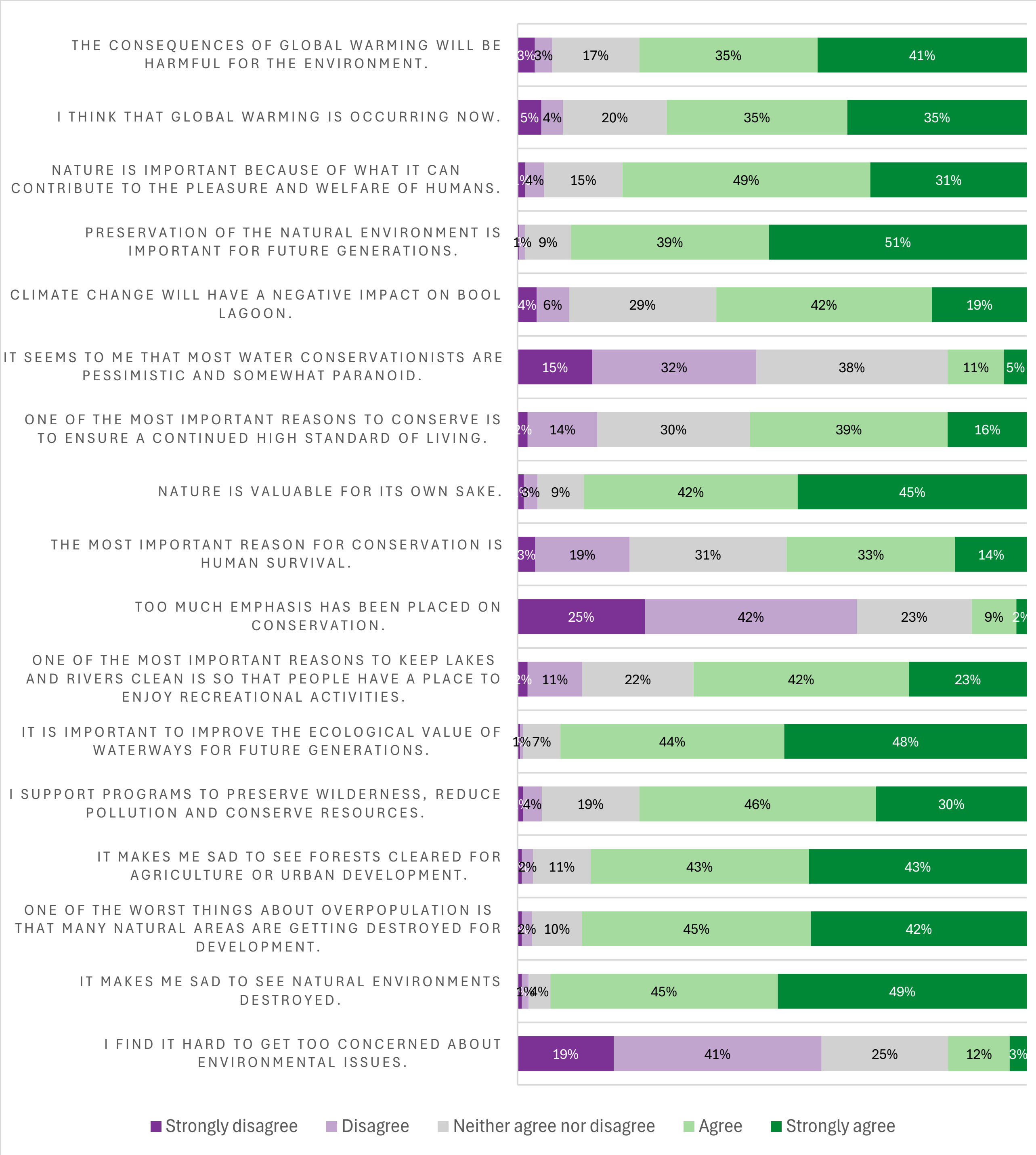

Figure 18. Level of agreement with statements about the natural environment.

B.4. Test questions

Respondents were asked additional questions about the benefits of providing extra water for Bool Lagoon after viewing a short media clip. As noted, this is one way of measuring attentiveness and brining that into the statistical model. After viewing the background information, most participants believed providing water for the environment will result in an increase in native species (1093, 95%). The majority also agreed that Bool Lagoon was getting drier for longer in recent years (1085, 94%). 93% of respondents (1,071) answered at least 2 of the 3 questions correctly.

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