NCEconomics

FINAL REPORT

Socio-economic outcomes of environmental watering in northern Victoria

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EXECUTIVE SUMMARY

Environmental watering has been a major Government program in Victoria, particularly since the 'Millennium drought'. The focus of this program has been to manage the water flow regime to help improve or maintain the health of rivers, floodplains and wetlands - and associated plants and animals. A large proportion of this program has been directed at the northern regions of Victoria including the Mallee, North Central, and Goulburn Broken catchment management areas.

Healthy rivers, floodplains and wetlands in these catchment areas provide a range of benefits that are important for society and the economic system both within these geographical (catchment management) areas and across the wider Victoria. However, to date, the nature and extent of these socio-economic benefits have not been well understood by many stakeholder groups.

To help improve this understanding, the Victorian Environmental Water Holder (VEWH) in collaboration with the Mallee Catchment Management Authority, North Central Catchment Management Authority (NCCMA), Goulburn-Broken Catchment Management Authority and the Department of Environment Land Water and Planning (DELWP) have engaged Natural Capital Economics (NCE) to describe and value these benefits in economic terms - to the extent possible based on existing data and information. This is intended to contribute to an increased awareness of benefits generated as well as to inform where future research effort is best allocated.

Methodological approach and study focus

The methodological approach developed for this study employed an ecosystem services framework to help establish a sound and shared understanding of the chain of relationships between environmental watering through to socio-economic benefits. This framework was used to assess five ecosystem service flows and related benefit categories in quantitative monetary terms:

- Pollination services to almond production
- Climate regulation services
- Water quality regulation services – avoided salinity management costs
- Water quality regulation services – avoided hypoxic blackwater and blue-green algae risk management costs for livestock production
- Recreation services – contribution of Gunbower Forest to community enjoyment, health and recuperation
- Existence and bequest benefits.

Different valuation techniques were used for each benefit category to suit the nature of benefits being assessed, the availability of secondary data, and the timeframe available to complete the analysis. A key focus was to underpin the economic analysis with best-available scientific information and to transparently account for key uncertainties in data inputs using the monte-carlo simulation process. The analysis assessed benefits generated from environmental watering relative to a scenario without any environmental watering interventions. Benefits were measured in annual terms for the current time period (i.e. 2019/2020) as well as ten years in the future (i.e. 2030) – to account for the dynamic and long response-rates of many ecosystem elements to environmental watering.

Results and suggestions for future research

The values estimated for each of the benefit categories are summarised in Table ES1. Due to data gaps in many input parameters and hence the need to make expert judgements – which are explicitly documented in the body of the report and which exercised a conservative approach - the values presented should be interpreted as a conservative plausible range of likely values. They do not reliably represent a probabilistic confidence range, or a strict upper and lower bound.

Moreover, the results summarised below do not represent the overall benefits generated from environmental watering in northern Victoria. In particular, recreation benefits covered one case-study sites - Gunbower Forest. Also, a number of important benefit categories – for example (i) cultural benefits to Traditional Owner groups, and (ii) erosion control services –have not been valued in economic terms in this assessment. For these reasons the results should be interpreted as providing insight to ***part*** of the contribution of environmental watering to society and the economic system only.

Table ES1. Summary of results (2018$M/year)

Benefit category	2020			2030		
	Low	Mid	High	Low	Mid	High
Pollination services – contribution to almond production	13	25	38	29	51	78
Climate regulation services	1	3	5	4	9	15
Water quality regulation services – avoided salinity management costs	1	2	2	2	3	4
Water quality regulation services – avoided blackwater and blue-green algae risk management costs in Murray River for livestock farmers	1	2	3	2	4	5
Recreation services – contribution of Gunbower Forest to community enjoyment, health and recuperation	1	2	4	3	4	8
Existence and bequest values	13	19	27	28	41	58

Key findings and recommendations

Benefits to agriculture sector

A key insight of the analysis is that environmental watering provides substantial benefits to segments of the agriculture sector. One important benefit stream pertains to the contribution of healthy *Eucalyptus* forests (particularly River Red Gum forests) in supporting commercial pollination services to almond production. These benefits are estimated to be in the range of $13 million to $38 million per year, and largely accrue to the Mallee region where almond production in Victoria is located.

Other benefits to the agriculture sector that have less supporting evidence and analysis relate to the role that environmental watering plays in mitigating blackwater and blue-green algae events and associated impacts on livestock production. Preliminary analysis undertaken for the Murray River indicates these benefits are likely to be material (in the range of $1 million to $3 million per year at 2020, increasing to between $2 million and $5 million per year by 2030) and thus warrant further research.

Recommendation: To provide for a more precise assessment of pollination related benefits it is suggested that further research work be undertaken to better understand the degree to which commercial honeybee populations depend on *Eucalyptus* forests that are supported by environmental watering. This would involve more extensive surveying of apiarists to accurately establish the extent to which they currently utilise *Eucalyptus* forests supported by environmental watering to feed/sustain their European honeybee stocks. It would also involve further investigation of the degree to which substitute forest/feeding options are available to apiarists should access to healthy *Eucalyptus* forests be reduced.

Recommendation: To better understand the risks of blackwater and BGA events (including under a more extreme climate future) and the role of environmental watering in helping to manage these risks, it is recommended that further research work be undertaken to examine these issues. In the first instance, research work should focus on developing a more in-depth understanding of the biophysical effect environmental watering plays in reducing the frequency and intensity of blackwater and BGA events. Once the underpinning biophysical knowledge is better established, a more accurate and reliable assessment of the associated socio-economic benefits can be undertaken - building on the work that has been undertaken as part of this study. Assessment of avoided water treatment costs for water corporations from blackwater and BGA events should also be undertaken at that time.

Water quality regulation services – avoided salinity management costs

Environmental watering dilutes salinity in the Murray River system which in turn reduces the need to invest in public salinity management measures such as salt-interception schemes. The extent of this effect however is not precisely known and is the subject of ongoing research.

Based on the understanding of dilution effects of environmental watering as documented in the *Modelling to support the general review of salinity management in the Basin* (MDBA, 2017), the value of these avoided salinity management costs are estimated to be in the range of $1 million to $2 million per year at 2020, increasing to between $2 and $4 million per year by 2030.

Recommendation: It is suggested the avoided salinity management costs estimated in this study be revisited once work currently underway to refine scientific modelling of river salinity impacts in the southern Murray Darling Basin has been completed. This will provide for a more accurate understanding of the the dilution effects of environmental watering in the northern Victoria region.

Climate regulation services

Healthier ecosystems help to regulate global climate conditions by sequestering greenhouse gases and storing them in above-ground and below-ground biomass (Alcaraz-Sequera et al, 2013). In this way, environmental watering mitigates against climate change which is otherwise expected to result in increasing frequency and intensity of damaging climate-related events such as drought and heatwaves (Climate Council of Australia, 2017).

The results of the analysis show the value of these benefits is in the range of $1 million to $5 million in 2020. This value is expected to further increase to between $4 million and $15 million in 2030 in line with increasing unit values of carbon ($ per tonne of CO_2 equivalent) and as the contribution of environmental watering to the condition of forest and wetlands (relative to a without-environmental watering scenario) increases.

One key knowledge gap identified, and hence a limitation of the analysis, was a lack of published research to establish the carbon sequestration response of wetlands to environmental watering. The Blue Carbon Research Lab at Deakin University is currently undertaking some selected case study work in this area and is thus expected help fill this gap. At the time of writing, a research paper had been submitted to an academic journal (for publishing) and was in the process of being reviewed.

Recommendation: Review the work of the Blue Carbon Research Lab on the carbon sequestration response of wetlands to environmental watering once published with the view to potentially supporting further research, if needed.

Recreation related benefits

The analysis supports the widespread understanding that environmental watering contributes to a range of passive and active nature-based recreation activities - e.g. fishing, swimming, camping, bushwalking, boating and kayaking, and contemplation (VEWH 2018, MDBA 2017). These activities in turn generate important heath, enjoyment and recuperation benefits for local and out-of-catchment communities. They also generate some additional economic activity in the region.

Benefits generated from watering at Gunbower Forest is conservatively estimated to be in the range of $1 million to $4 million per year at 2020, increasing to between $3 million and $8 million per year by 2030. When other ecosystem assets are also taken into account, for example the other Living Murray icon sites, the overall value of recreation related benefits provided by environmental watering is likely to be substantial.

One important limitation of the analysis was that it had to rely on a number of expert judgements and conservative assumptions to approximate site visitation and changes in site visitation that are attributable to environmental watering. This was necessary because of a lack of longitudinal visitation data available for the case study sites and because primary survey work was beyond the scope of this study. Results should thus be interpreted as a conservative indicative range.

Recommendation: It is recommended that strategic collection of visitor data for key recreation assets be undertaken as a priority monitoring activity under the environmental watering program. This should include visitor surveys which are designed with benefit valuation (i.e. travel cost method applications) in mind.

Existence and bequest vales

Socio-economic benefits from environmental water-dependent ecosystems extend beyond benefits generated from the direct use of the ecosystems (e.g. pollination, recreation). Some Victorians derive a benefit from the knowledge that these ecosystems exist in reasonable condition (referred to as 'existence values') and/or are available for future generations to use/enjoy (referred to as 'bequest values'). That is, they value an ecosystem (and its health/condition) even if they never have or never will use it.

The analysis undertaken as part of this study demonstrates that the contribution of environmental watering to existence and bequest benefits in the northern Victoria context are substantial – conservatively estimated to be in the order of $13 to $27 million per year, increasing to between $28 and $58 million per year by 2030.

It should be noted however there were a number of important limitations with this part of the analysis – in large part reflecting the inherent difficulty in quantifying non-use environmental values. In particular, the analysis relied on a number of pre-existing source studies which are now all more than 10 years old. It is very possible that community preferences for environmental improvements valued in these studies have shifted since this time – for example in the knowledge that the planet is now experiencing a sixth mass-extinction event. Also, the source studies did not disaggregate non-use values from other components of value that households derive from ecosystem improvement. This study has attempted to address this by apportioning relative values based on a rapid review of relevant economic literature.

Recommendation: Future research should be undertaken to gain a better understanding of the relative importance of existence and bequest benefits compared to other socio-economic benefits for the northern Victorian environmental watering context. In the first instance, this should involve a more extensive review of the literature expanding to other disciplines such as (social) anthropology.

Concluding remarks

The analytical framework developed as part of this assessment provides a logical and practical methodology for assessing the socio-economic benefits generated from environmental watering in northern Victoria.

This initial desktop application of the framework provides insight into the order-of-magnitude values of key benefit categories and, related to this, identifies priority areas for further data collection and research. Over time, and with additional data inputs, the application of the analytical framework can be progressively refined to generate more accurate results that can be incorporated into the monitoring and evaluation framework for the environmental watering program and used to inform ongoing learning for improvement.

Future applications of the analytical framework may consider expanding the coverage of the analysis to also include other socio-economic benefits that have been identified as potentially significant but not assessed in detail in this report due to time and resource constraints. These benefits include (i) cultural benefits to Traditional Owner groups, and (ii) erosion control services (avoided costs of river remediation works achieved through improved condition of in-stream and bank riparian vegetation and associated riverbank stabilization). A further benefit not investigated in this report but potentially worthy of future exploration relates to the contribution of environmental watering to a 'clean and green' branding of agriculture goods produced in northern Victoria.

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1 INTRODUCTION

Context

Environmental watering has been a major Government program in Victoria, particularly since the 'Millennium drought'. The focus of this program has been to manage the water flow regime to help improve or maintain the health of rivers, floodplains and wetlands – and associated plants and animals. A large proportion of this program has been directed at the northern regions of Victoria including the Mallee, North Central, and Goulburn Broken catchment management areas.

Healthy rivers, floodplains and wetlands in these catchment areas provide a range of benefits that are important for society and the economic system both within these geographical (catchment management) areas and across Victoria. However, to date, the nature and extent of these socio-economic benefits have not been well understood by many stakeholder groups and are not systematically monitored and evaluated as part of the environmental watering program implementation.

To help improve this understanding, the Victorian Environmental Water Holder (VEWH) in collaboration with the Mallee Catchment Management Authority(MCMA), North Central Catchment Management Authority (NCCMA), Goulburn-Broken Catchment Management Authority (GBCMA) and the Department of Environment Land Water and Planning (DELWP) have engaged Natural Capital Economics (NCE) to describe and value the socio-economic benefits attributable to environmental watering in economic terms (to the extent possible). This is intended to contribute to an increased awareness of the relative importance of benefits generated as well as to inform areas where further data collection and research effort could most usefully be allocated.

Objectives

The objective of this study is to assess the nature, extent and distribution of socio-economic benefits generated as a result of environmental watering in the northern Victoria region.

More specifically, the assessment aims to answer a number of key assessment questions that are important for VEWH's and CMAs' program-management needs. These key assessment questions are:

- What are the different types of socio-economic benefits generated through environmental watering in northern Victoria? How – through what ecological mechanisms – are these benefits achieved/provided? [i.e. what is the *nature* of benefits?]

- What is the approximate size or magnitude of each key benefit type? How important are each of these benefit streams? [i.e. what is the *extent* of benefits?]

- Who receives each of these benefit types and over what time scale? [i.e. what is the *distribution* of benefits across different stakeholder groups, regions and time?]

- What is level of accuracy or confidence in our current understanding of each benefit category? What are the key areas of uncertainty/knowledge gaps? What areas should be a focus of further research? [i.e. what are the key areas of *uncertainty*?]

Structure of report

The economic assessment report is organised into four parts:

- **Part A** provides background information on environmental watering in northern Victoria along with a brief explanation of key concepts and terminology used in this assessment. It then provides an overview of the methodology that has been followed to value socio-economic benefits in economic terms.

- **Part B** describes the methodology employed for each of the key benefit categories and reports the results of these assessments.

- **Part C** reports the aggregate results.

- **Part D** provides summary remarks and offers suggestions for next steps.

In addition, the appendices provide some more detailed information on the technical elements of the assessment:

- Appendix 1 outlines the method for assessing ecosystem condition changes attributable to environmental watering;

- Appendix 2 to 7 details the methodology employed for each of the key benefit categories and reports additional results of the uncertainty analysis.

PART A: CONTEXT AND APPROACH

2 ENVIRONMENTAL WATERING IN NORTHERN VICTORIA

Northern Victorian waterways are highly connected and contain a myriad of significant floodplains and wetlands. They are home to, and support, many unique native plants and animals including threatened species and communities listed under the Victorian *Flora and Fauna Guarantee Act 2017* and the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999*.

Many of Victoria's major river systems have been modified to store water to allow for the growth of rural communities and irrigated agriculture and horticulture. As a result, some of these waterways have substantially less water than would have naturally flowed throughout the year. Also, the natural water flow patterns in these regulated rivers has been reversed, with high flows now occurring in summer to service farming and urban demand and lower flows in winter and spring. This change has had a direct impact on habitat, breeding triggers, food sources (for aquatic and water-dependent fauna) and vegetation health.

The environmental water reserve (EWR) was established under the *Water Act 1989* to help manage the health of rivers, wetlands and floodplains in Victoria. The EWR consists of water held in environmental entitlements as well as other water in the system that contributes to environmental outcomes. The Victorian Environmental Water Holder (VEWH) was established in 2011 as an independent authority tasked with holding and managing Victoria's environmental entitlements.

The objectives of the EWR are to improve the environmental values and health of water ecosystems, including their biodiversity, ecological functioning, water quality, and other uses that depend on ecosystem condition. In rivers, this includes delivering some of the small and medium sized flows that play an important role in supporting life cycles of native plants and animals. In wetlands and floodplains, the focus is on replicating more natural wetting and drying cycles.

The river, floodplain and wetland ecosystems that are the target of environmental watering interventions in northern Victoria are the focus of this analysis and are shown in Figure 1. These include five river systems (i.e. Murray, Campaspe, Loddon, Broken, and Goulburn), four floodplain ecosystems (i.e. the Living Murray icon sites at Lindsay, Wallpolla, Mulcra Islands; Hattah Lakes; Gunbower Creek and Forest; and Barmah-Millewa Forest), and many wetlands.

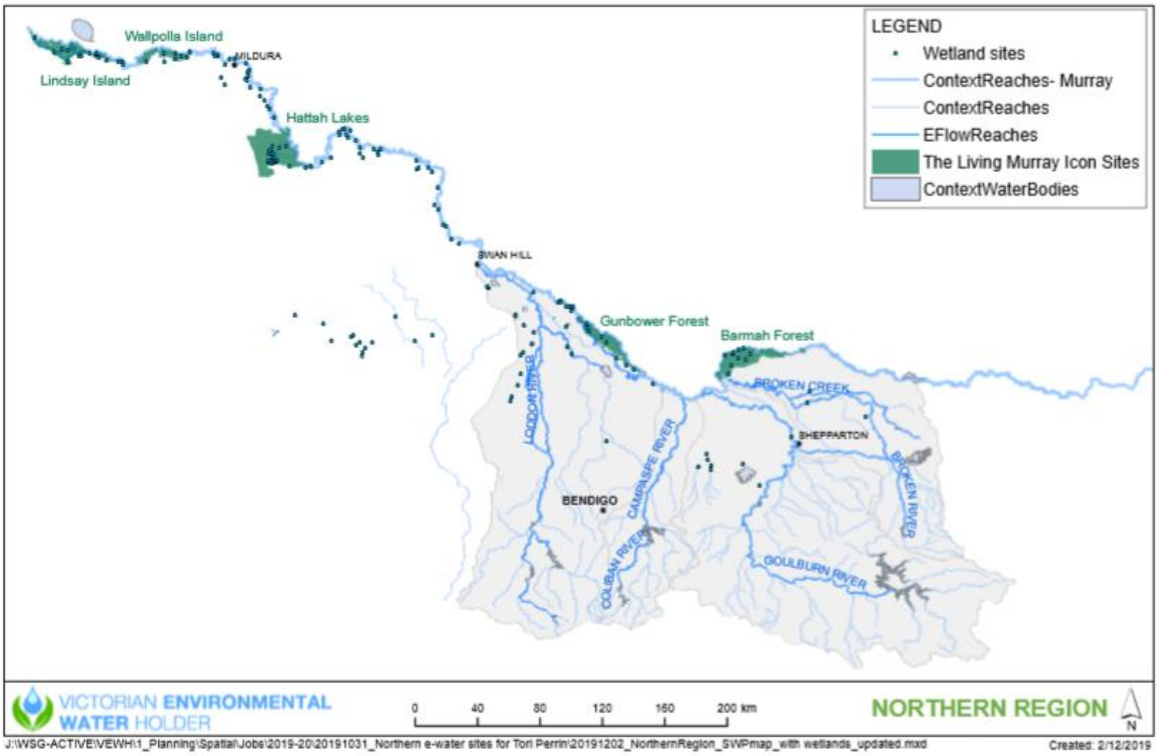

Figure 1. **Study location map**

Source: Victorian Environmental Water Holder (produced 1 November 2019)

Environmental water management framework

The Victorian environmental watering program involves many people and organisations including local communities, Traditional Owners, waterway managers (Catchment Management Authorities and Melbourne Water), storage managers, environmental water holders, land managers and scientists.

CMAs work with local communities and partner agencies to scope potential environmental water activities in their region, drawing on scientific studies (documented in environmental flow studies and environmental water management plans) and monitoring outcomes from previous environmental watering activities. These potential watering actions are documented in Seasonal Watering Proposals, which are submitted to the VEWH for consideration and inclusion in the VEWH's annual Seasonal Watering Plan. The VEWH Seasonal Watering Plan is a state-wide plan that informs environmental watering decisions in Victoria.

The VEWH prioritises how the final environmental water available in any year is used across the state and authorises CMAs to work with storage and land managers to implement actions as outlined in the VEWH Seasonal Watering Plan.

Implementation of environmental watering in Victoria is supported by two statewide monitoring programs - Victorian Environmental Flows and Assessment Program (VEFMAP) and Wetland Monitoring and Assessment Program (WetMAP) - as well as CMA-specific monitoring programs. Outcomes are reported on an annual basis in technical reports, on CMA websites, and in the annual publication of VEWHs Reflections.

3 ECOSYSTEM SERVICES FRAMEWORK

The methodological approach employed in this study applies the **ecosystem services framework** to establish a sound and shared understanding of the chain of relationships linking environmental watering to socio-economic outcomes (i.e. benefits). This provides a clear and logical structure for the analysis.

Key concepts of the ecosystem services framework

Current international best-practice developments in the ecosystem services framework are described in the Common International Classification of Ecosystem Services (CICES). The CICES has been developed by the European Environment Agency to support their contribution to the revision of the System of Environmental-Economic Accounting: Experimental Ecosystem Approach (SEEA:EEA) – which is currently being led by the United Nations Statistical Division (UNSD) and has been endorsed by the Department of Environment, Land, Water and Planning (DELWP) through its strategic plan *Valuing and Accounting for Victoria's Environment.* The CICES follows the tradition of the Millennium Ecosystem Assessment (MA, 2005) and initiatives such as The Economics of Ecosystems and Biodiversity (TEEB) and the Intergovernmental Platform for Biodiversity and Ecosystem Services (IPBES).

The conceptual framework in which CICES is set is based on the cascade model shown in Figure 2. This model shows the chain of cause-effect relationships for how changes to the environment leads to changes in socio-economic outcomes.

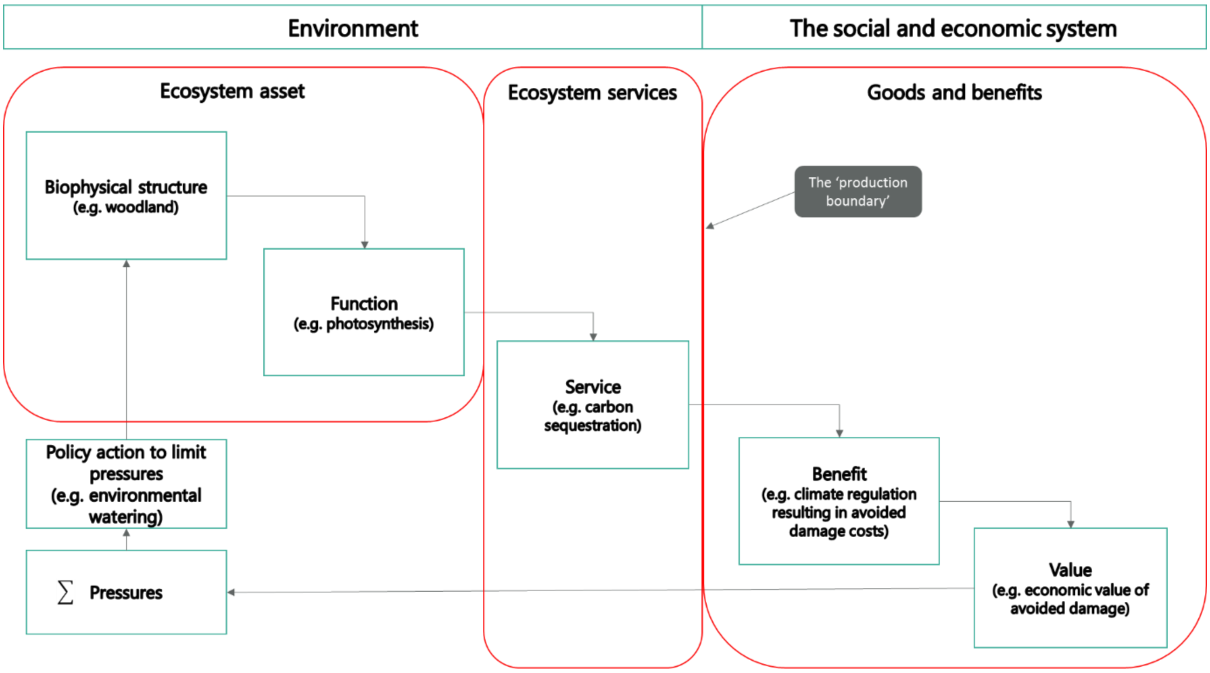

Figure 2. Cascade model of ecosystem services

Source: adapted from Potschin and Haines-Young (2016)

The ecosystem services framework starts with the concept of ecosystem assets – which are defined as spatial areas containing a combination of biotic and abiotic components and other characteristics that function together. An example of an ecosystem asset is a river ecosystem.[1] The extent and condition of these assets are influenced by pressures (e.g. water extractions) and policy interventions aimed at alleviating these pressures (e.g. environmental watering).

[1] Ecosystem assets are characterised in terms of *extent* and *condition*.

The functioning of ecosystem assets generates a range of 'services' that contribute to human well-being.[2] These services, known as ecosystem services, refer specifically to the 'final' outputs from ecosystems that most directly affect the well-being of people (Haines-Young et al 2018). An example of an ecosystem service is climate regulation (carbon sequestration) services.

Services give rise to benefits, as in the case of avoided damages and losses from climate change events when the 'production boundary' is crossed. Benefits are the things that ultimately have value for people.

Under the CICES, ecosystem services are further organised into three broad categories. The first category is *provisioning services* which consist of all the products obtained from ecosystems (e.g. genetic material, wild fish harvest). The second category is *regulating services,* which includes all the ways in which ecosystems control the environment of people such regulation of water quality, air quality, climate, flood and erosion. And the third category is *cultural services* which comprises all non-material ecosystem outputs that have symbolic, cultural or intellectual significance. In other words, these are the intangible ecosystem outputs that enable a range of experiential and intellectual activities such as recreational swimming or kayaking.

Identification of ecosystem services provided by river, floodplain and wetland ecosystems in northern Victoria

There are a wide range of different ecosystem services that are provided by river, floodplain, and wetland ecosystems in the northern Victoria context.

To systematically identify and categorise the main ecosystem services (and related benefits) that are linked to environmental watering a two-stage process was followed.

The first stage was to identify the ecosystem service classes from the CICES (Haines-Young et al 2018) that are considered material for freshwater river, wetland, and floodplain ecosystems in northern Victoria. This identification process followed the guidance on the application of the CICES system (Haines-Young et al 2018).[3]

The second stage was to further develop the ecosystem service description identified from the relevant CICES classes for the northern Victoria environmental watering context – and grouping certain ecosystem services where considered appropriate. This was informed by a rapid review of select literatures documenting the main environmental and socio-economic outcomes related to environmental watering in Victoria (e.g. VEWH 2018, MDBA 2017) as well as workshops by the project team, including the project steering committee (PSC).

The full list of ecosystem services that were identified through this process as resulting from environmental watering are summarised in Table 1.

In addition, a number of disbenefits from environmental watering were also identified as part of the above-outlined process. These are briefly discussed at the end of this chapter.

[2] CICES further defines ecosystem services as the "contributions that ecosystems (i.e. living systems) make to human well-being."

[3] This included a focus on (final) ecosystem services that depend on living systems (i.e. biotic ecosystem services) – as opposed to abiotic ecosystem services.

Table 1. Ecosystem services and related benefits provided by environmental watering in northern Victoria

Title	Description of service provided through environmental watering and related benefit
Provisioning services	
Provision of timber/wood	Environmental watering of forest areas increases the productivity and biomass (wood) produced by these forests. In some areas, this wood can be harvested for direct use or commercial sale. Most commonly, this is *Eucalyptus* species harvested for firewood in line with park management plans and regulations. There are also select examples where timber species are harvested as part of commercial timber operations (e.g. River Red Gum in Gunbower Forest).
Provision of wild plants (e.g. aquarium plants) and seeds	Environmental watering leads to improved condition of vegetation and inter-related animal and plant populations – which increases quantity and quality of wild plants and seeds produced within these ecosystems. Some of these wild plants and seeds can be harvested for commercial sale. An example is river redgum seeds.
Provision of food/sustenance for commercial honeybee stocks (related to pollination services)	Environmental watering leads to improvements in the condition of *Eucalyptus* forest and woodland ecosystems (including River Red Gum forests) and in turn the flowering functions of these ecosystems. Flowering ecology supports honeybee populations through the provision of food/sustenance. Healthier honeybee populations in turn have greater capacity to provide commercial pollination services important for crop production (e.g. almonds) and/or to produce honey for commercial sale.
Provision of genetic material (from plants, algae, fungi or animals)	Environmental watering supports the overall health of river, floodplain, and wetland assets – and its component biodiversity. Biological resources are in turn available for potential use in a range of different applications (e.g. agriculture production, pharmaceuticals). An example is *Dianella Longifolia* (flax lily) which contain chemicals with anti-viral properties (ENRC, 2000).
Regulating services	
Water quality regulation services	Environmental watering helps to regulate the quality of consumptive water that is used for agriculture (irrigation and livestock) and town supply. This occurs through a number of different biotic (e.g. buffering nutrient run-off) and abiotic (e.g. dilution) processes which in turn affects different aspects of water quality (e.g. salinity, dissolved organic carbon). Improved water quality achieved through environmental watering reduces or avoids the impacts of poor quality water that would have otherwise occurred. This includes reduced impacts on livestock production from hypoxic blackwater and blue-green algae events; reduced salinity management costs (e.g. construction and operation of salt interception schemes); and avoided water treatment costs for water corporations.
Erosion control services	Environmental watering, in combination with other interventions , supports improved condition of in-stream and bank riparian vegetation which in turn stabilises riverbanks. To the extent that more stable riverbanks mitigate against erosion, this is expected to reduce remediation works and associated costs that would otherwise be required to maintain water delivery services along northern Victoria rivers.
Climate regulation services	Environmental watering promotes ecosystems' productivity and their ability to sequester and store greenhouse gases (carbon dioxide) from the atmosphere. This occurs through a chemical process known as photosynthesis whereby light energy from the sun is used by plants to convert carbon dioxide and water to glucose sugar and oxygen through a series of reactions.

Title	Description of service provided through environmental watering and related benefit
	In this way, environmental watering helps to mitigate against (global) climate change which is otherwise expected to result in increasing frequency and intensity of climate-related events such as drought and heatwaves - and associated damages and losses.
Pest control (including invasive species) services	Environmental watering supports populations of native pest control agents which can regulate pests and associated damage caused by these pests to agriculture production. An example is the role of ibis in controlling crickets on irrigated pastures - especially in the western part of the Goulburn Murray Irrigation District (pers. comm Garry Smith).
Soil quality regulation services	The processes through which environmental watering and ecosystems contribute to improved soil quality on adjoining agricultural lands is not well understood (CSIRO 2003). One mechanism that is somewhat understood is the role of improved extent and condition of native vegetation on mitigation of soil acidification risk (CSIRO 2003). Environmental watering contributes to soil acidification benefits through improved extent and condition of native vegetation.
Air quality regulation services	Healthy vegetation areas that are supported by environmental watering can help to filter and accumulate dust that is sometimes experienced during dry climate periods. No documented examples were located in the time available for this analysis – though this effect is likely to be material, especially in the future under a hotter and drier climate future.
Flood regulation services	The physical characteristics of healthy floodplain and wetland ecosystems (e.g. presence of more trees, depressed wetland topography) that are supported by environmental watering can store and slow water and mass movement associated with flooding events. This in turn can help to reduce the damages and losses experienced from such flooding events.
Supporting services to other ecosystems	Environmental watering supports nursery and habitat services (including gene pool protection) for plant and animal populations that intersect with other ecosystems (e.g. the marine ecosystem). In this way, environmental watering contributes to benefits that are generated through ecosystem services provided by other ecosystem assets. This reflects the inter-connected nature of ecosystems.
Cultural services	
Recreation-related services	The river, floodplain and wetland ecosystems in northern Victoria support a wide range of active and passive recreation activities and experiences. In river ecosystems, these activities include swimming, fishing, kayaking, waterskiing, birdwatching, hiking, cycling, camping, and picnicking – amongst others. Characteristics or attributes of river ecosystems that are important for these activities include clean water, native fish populations (e.g. Murray cod), native bird populations, and healthy native vegetation. In wetland and floodplain ecosystems, birdwatching, hunting and camping are key recreation activities. Characteristics or attributes that are important for these activities include native bird populations and healthy native vegetation. People value these activities because they derive a level of enjoyment. They also value them – to varying degrees – because they support health and recuperation outcomes as well as social/community interaction. Further, to the extent that recreation activities are associated with consumption of (market) goods and services in the local regional economy (e.g. purchase of fuel, bait and food), they also contribute to the local tourism sector.
Indigenous cultural values	Environmental watering supports health of 'Country' which in turn provides a wide range of benefits important to Traditional Owner and more broadly to Aboriginal people. The nature of these benefits are varied and complex and are being more thoroughly investigated

Title	Description of service provided through environmental watering and related benefit
	through a range of programs, including Victoria's Aboriginal Water Program, as well as by partners in Victoria's environmental watering program.
Non-Indigenous cultural and heritage values	Environmental watering supports the presence and condition of certain ecosystem attributes that are resonant in terms of culture or heritage. These elements contribute to a sense of local identity (well-being) as well as to the local tourism sector. An example is the heritage value of the Murray River in the historical settlement of Echuca.
Existence and bequest values	Socio-economic benefits from water-dependent ecosystems extend beyond benefits generated from the direct use of the ecosystems (as identified above). Some Victorians further derive a benefit simply from the knowledge that these ecosystems exist (referred to as 'existence values') and/or are available for future generations to use/enjoy (i.e. bequest values). That is, they value an ecosystem even if they never have or never will use it. Existence and bequest values can correspond to a particular species or feature of an ecosystem (e.g. Murray hardyhead) and/or to the overall health of an (river, floodplain, wetland) ecosystem.

Ecosystem services that are the focus of this study

Given the time and resources available for this analysis it was necessary to focus the detailed analysis on a subset of ecosystem services and related benefits.

To help inform the selection of this subset of ecosystem services and related benefits, a basic multi-criteria analysis (MCA) was undertaken by the project team and the project steering committee. The criteria used in this analysis were:

i. Whether data is ***likely*** to be available to support meaningful valuation of the ecosystem services and associated benefits that are attributable to environmental watering.[4]
ii. The ***judged*** size (or level of importance) of the ecosystem service flows that are attributable to environmental watering and the corresponding economic value of these ecosystem services to Victoria overall.
iii. Whether the ecosystem service contributes to benefits to local communities (i.e. distribution of benefits).[5]

The subset of ecosystem services and related benefits that were selected as the focus of the study – based on the MCA – are summarised in Table 2.

Table 2. Ecosystem services and related benefits that are the focus of this study

Ecosystem service	Benefit and primary recipient of benefit
Provisioning services	
Pollination-related services	Contribution to commercial pollination service providers Contribution to select crop production
Regulating services	
Water quality regulation services	Reduced / avoided salinity management costs for farmers
	Reduced / avoided productivity impacts for livestock producers
Climate regulation services	Reduced / avoided costs of mitigating climate change, benefiting the broader community
Cultural services	
Characteristics of ecosystems that enable active and passive **recreation** activities and experiences	Well-being (health, recuperation, enjoyment) for general population Contribution to tourism (local and international tourists)
Characteristics or features of living systems that have an **existence** or **bequest** value	Well-being for the broader community

Potential socio-economic dis-benefits from environmental watering

It is important to acknowledge that the delivery of water for the environment can, in some instances, potentially result in socio-economic disbenefits. A brief summary of the type of dis-benefits that can potentially be generated from environmental watering is provided in the table below.

[4] Scoring for this criterion was separated into two component parts – (i) data available for the biophysical analysis (of estimating the effect of environmental watering on ecosystem condition and in turn on flow of ecosystem services) and (ii) data available for economic analysis (for assessing the contribution of ecosystem services to benefits and assigning values to this contribution).

[5] This criterion reflects an objective of the study to help better demonstrate how environmental watering benefits local communities, as opposed to benefits outside the region.

Potential socio-economic dis-benefits from environmental watering are managed through the Victorian Environmental Watering Program Risk Management Framework (RMF) which ensures all risks are appropriately managed prior to delivering any watering actions. The includes (but is not limited to):

- Annual risk assessment workshops to with all environmental watering partners to identify and establish risk management strategies. The outcomes of these workshops are incorporated into the CMA Seasonal Watering proposals and VEWH Seasonal Watering Plan
- Ongoing adaptive management through operation advisory groups established for each system
- Incident reporting and continuous improvement.

Where the risk assessment identifies that dis-benefits are potentially significant, detailed investigation to understand the risk is undertaken and appropriate management strategies are established.

Residual risks and related dis-benefits are therefore considered to be small in magnitude. For this reason, quantification of these residual risks/disbenefits is not a focus of this study.

Table 3. Potential socio-economic disbenefits from environmental watering in northern Victoria

Title	Description of dis-service provided through environmental watering and related dis-benefit
Water quality regulation dis-services	Environmental watering has been associated with increased concentrations of dissolved organic carbon, total nitrogen, and total phosphorous in some locations where environmental flows connect floodplains and channels (Wentworth Group, 2017). This effect however has not been found to result in any hypoxic blackwater events or BGA blooms that are known to cause material dis-benefits for livestock production and/or town water supply.
Erosion control dis-services	Environmental watering, if not carefully designed, can exacerbate bank erosion in vulnerable areas – for example, banks that have been weakened from overgrazing (GBCMA 2019). This bank erosion in turn can require costly remediation works.
Pest control dis-services	Environmental watering may support animal populations that are themselves pests. One example is the *European Carp* (Wentworth Group, 2017). Carp have been reported to cause a range of different economic disbenefits including increased bank erosion[6] (DPI, 2019) which in turn can require costly remediation works.
Flood regulation dis-services	The physical characteristics of healthy floodplain and wetland ecosystems (e.g. presence of more trees, depressed wetland topography) that are supported by environmental watering can store and slow water and mass movement associated with flooding events. Slowing water movement however can extend the duration of a flood event in a given area, potentially leading to some increased damages and losses in those areas.
Recreation-related dis-services	The delivery of water for the environment can have some negative effects on recreational uses of ecosystem assets. For example, floodplain watering can restrict access for camping and the like to some park areas.

[6] Caused by their feeding habits.

4 METHOD OVERVIEW

As mentioned above, the methodological approach employed in this study applies the **ecosystem services framework** to establish a sound and shared understanding of the chain of relationships between environmental watering through to socio-economic outcomes (i.e. benefits).

The application of the ecosystem services framework is underpinned by a range of economic valuation techniques to assess each of the component ecosystem service flows and related benefit categories. The techniques employed for each category have been selected to suit the nature of benefits being assessed, availability of secondary data and the timeframe available to complete the assignment.

The methodology for the northern Victoria environmental watering application can be further described as three specific steps (refer Figure 3) – in line with the cause-effect logic of the ecosystem services conceptual framework/model outlined in Figure 2. These steps are generic and were performed for each key ecosystem service type. A summary of each step is provided below. More detailed information on the approach adopted for each ecosystem service is set out in Part B and in the appendices.

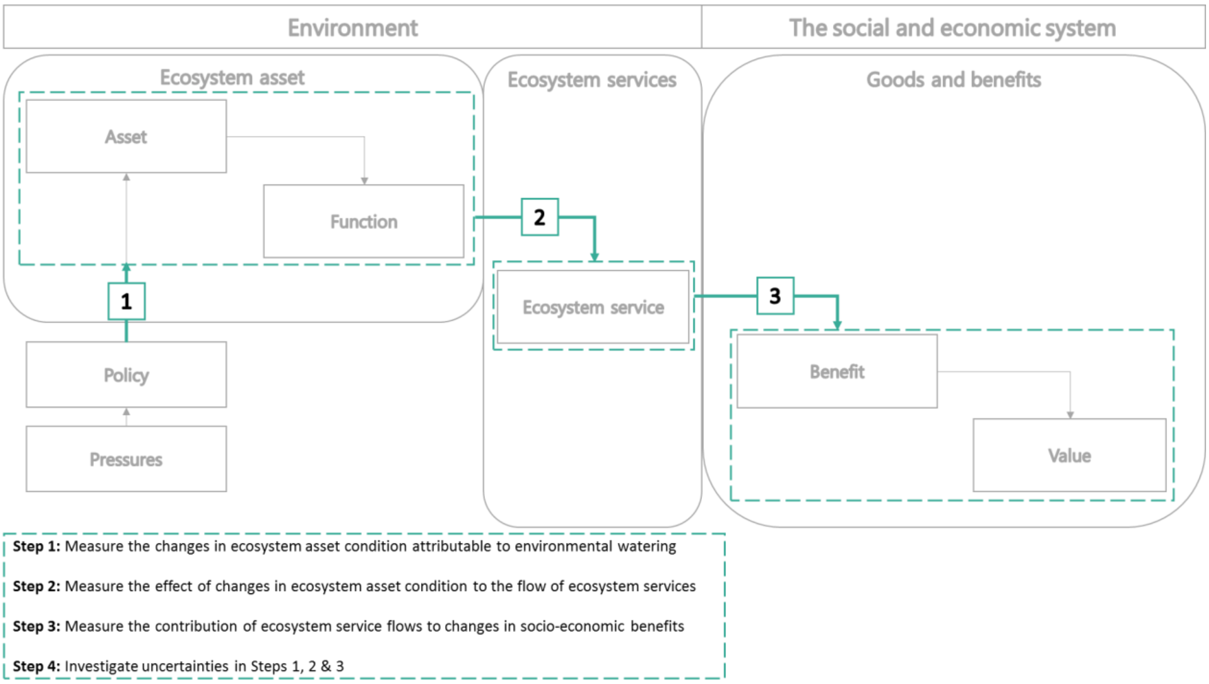

Figure 3. Generic stepwise procedure for valuing socio-economic benefits from environmental watering

Step 1: Measure the changes in ecosystem asset condition attributable to environmental watering

Step 1 of the analytical procedure measured the changes in ecosystem asset condition attributable to environmental watering.

The intention of this step was to identify and measure only the changes in ecosystem condition that are clearly associated with environmental watering, and not include changes that would have occurred anyway.

The methodological approach for doing this was to first assess what would happen to key measures of ecosystem condition for each asset type if the environmental watering program was not implemented ('without environmental watering' scenario), and then compare this to what has happened under the environmental watering program ('with-environmental watering' scenario). The differences between these scenarios are the changes that are attributable to environmental watering.

The 'without-environmental watering' scenario was taken to be 2010 levels of water recovery for the environment – prior to the implementation of large-scale environmental water recovery programs.

The 'with-environmental watering' scenario is the current water resource management regime in the northern Victoria region –managed through the environmental water management framework described in section 2.

Differences between the 'with' and 'without' environmental watering scenarios were determined at two points in time – at 2019/2020 (i.e. now) and 2029/30 (i.e. 10 years in the future) (see Figure 4). The rationale for including a future time period is to account for the dynamic and long response-rates of many ecosystem condition elements to environmental watering interventions. Given the majority of water entitlements under the environmental watering program were only secured around 2010, assessing outcomes only at the current point in time is likely to significantly understate the contribution of the program.

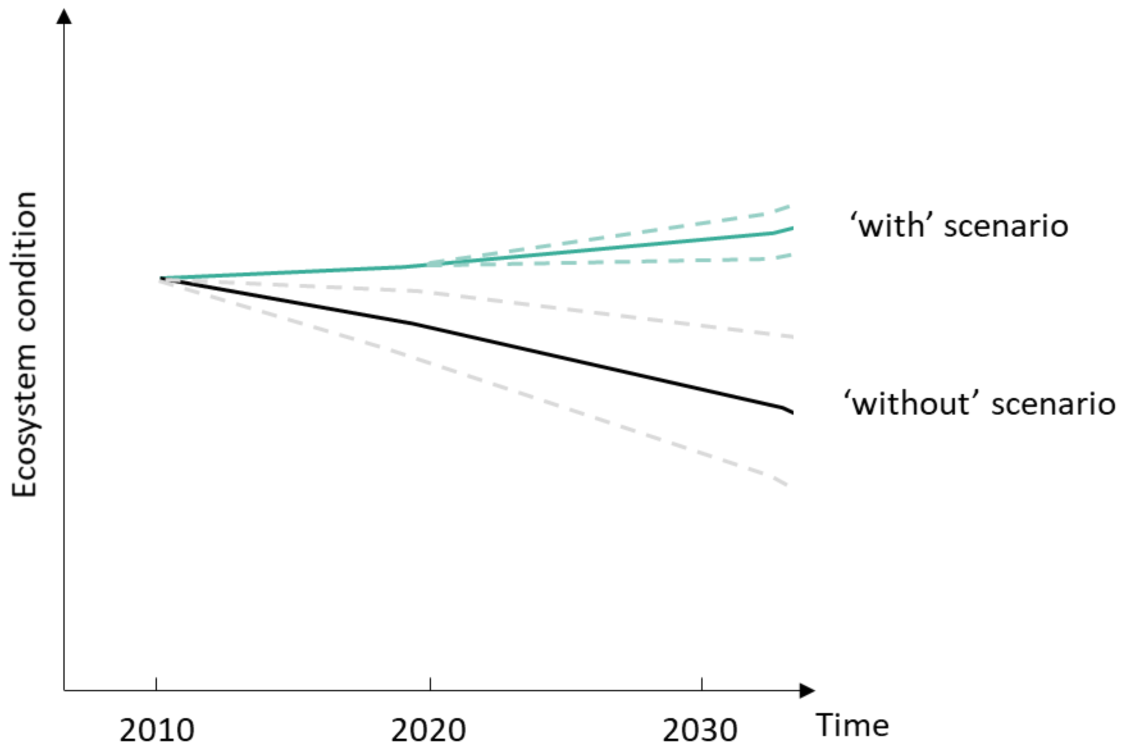

Figure 4. 'With' and 'without' analysis

A summary of the ecosystem asset condition elements that were measured in the 'with' and 'without' analysis along with the corresponding ecosystem services they support and the underlying assumptions for each scenario is outlined in Table 3. Appendix 1 outlines the detail regarding data limitations and rationale for the assumptions used in this analysis.

Table 4. Summary of the biophysical assessment approach

Ecosystem condition element	Associated ecosystem services	Biophysical metric assessed and relevant assets	Data sources	Scenario assumptions	
				'With' environmental water	'Without' environmental water
Native fish abundance	• Recreation • Existence and bequest	Change in large bodied native fish abundance with diverse range of age cohorts over time – Golden Perch and Murray Cod. Assets assessed: • The Living Murray icon sites • Rivers	Victorian Environmental Flows Monitoring and Assessment Program fish monitoring (Rivers). The Living Murray fish condition monitoring program (The Living Murray Icon Sites).	The 'with' scenario applied: • A positive linear regression based on actual catch data for each asset.	The 'without' scenario applied: • An assumed 1% per year linear decline in 2010 catch data for Living Murray Icon Sites. • The maintenance of 2010 abundance levels for rivers.
Vegetation condition	• Recreation • Pollination services • Climate regulation services • Existence and bequest	Change in vegetation condition over time. Assets assessed: • The Living Murray icon sites • Rivers • Wetlands	The Living Murray River Red Gum Forest Stand Condition reports (The Living Murray Icon Sites). Index of Stream Condition streamside zone sub-index (Rivers). Index of Wetland Condition biota sub-index (wetlands).	The 'with' scenario applied: • The maintenance of 2010 vegetation condition.	The 'without' scenario applied: • An assumed 2% per year linear decline in 2010 vegetation condition.
Waterbird abundance	Existence and bequest	Change in waterbird abundance over time. Assets assessed: • The Living Murray icon sites • Wetlands	The Living Murray waterbird condition monitoring program (The Living Murray Icon Sites). CMA waterbird datasets (some Living Murray icon sites and wetlands).	The 'with' scenario applied: • The maintenance of 2010 waterbird abundance.	The 'without' scenario applied: • An assumed 2% per year linear decline in 2010 waterbird abundance.

Ecosystem condition element	Associated ecosystem services	Biophysical metric assessed and relevant assets	Data sources	Scenario assumptions	
				'With' environmental water	'Without' environmental water
Water quality – salinity	Salinity mitigation	Change in the modelled salinity levels at Morgan over time. Assets assessed: • Murray River	MDBA General Review of Salinity Management in the Murray-Darling Basin (2014).	The 'with' scenario applied: • The modelled 95th percentile salinity at Morgan under 2400 GL water recovery scenario[7].	The 'without' scenario applied: • The modelled 95th percentile salinity at Morgan under 2010 management arrangements (Baseline Diversion Limits).
Water quality – hypoxic blackwater	Water quality regulation services	Change in the frequency and duration of hypoxic blackwater events over time. Assets assessed: • Murray River	Published reports – Baldwin and Whitworth (2013) and Symes (2017).	The 'with' scenario applied: • Maintaining the number of hypoxic blackwater days at 2010 levels.	The 'without' scenario applied: • An assumed increase in the number of hypoxic blackwater days by 19% at 2020 and 25% at 2030.
Water quality – Blue-green algae	Water quality regulation services	Change in the frequency and duration of red alert level Blue-green algae blooms over time. Assets assessed: • Murray River	Published reports – Croome et al (2011) and Crooke (2002). Water NSW Murray River BGA database.	The 'with' scenario applied: • Maintaining the number of red alert BGA bloom days at 2010 levels.	The 'without' scenario applied: • An assumed increase in the number of red alert BGA days by 13% at 2020 and 19% at 2030.

[7] The data used to inform the salinity assessment are modelled outputs based on implementation of Basin Plan water recovery targets, not based on the outcomes of actual water delivery.

Step 2: Measure the effect of changes in ecosystem asset condition on the flow of ecosystem services

Step 2 of the procedure was to assess how changes in ecosystem condition have translated to changes in the flow of ecosystem services. This step measured ecosystem flows in biophysical terms (e.g. tonnes of carbon dioxide equivalent abated), drawing on a range of data sets, academic literature and grey literature (specified in relevant appendices).

Step 3: Measure the contribution of ecosystem service flows to changes in socio-economic benefits

Step 3 was to measure how ecosystem service flows contribute to benefits within the social and economic system.

This step firstly measured benefits in biophysical terms (e.g. yield of almonds, visitation rates to ecosystems), drawing on a range of data sets, academic literature and grey literature (specified in relevant appendices).

It then assigned economic values to these benefits streams. A range of different economic valuation techniques were used and these were selected to suit the benefit category in question as well as the availability of secondary data and the timeframe available to complete the study. Details on the specific valuation techniques applied for each benefit category are described in the relevant chapters of Part B and further detailed in the appendices.

Step 4: Investigate uncertainties in steps 1, 2, and 3

Step 4 of the procedure was to investigate uncertainties in steps 1, 2 and 3 of the modelling using a monte-carlo simulation method.

The main element of the monte-carlo method is to define probability distributions for key input parameters in the model (as described in steps 1 to 3), and to run simulations of these parameters to approximate an expected range of possible parameter values. In this application, a triangular probability distribution was defined for most parameters drawing on available information to indicate a most-likely estimate, low estimate (broadly corresponding to the 5^{th} percentile) and high estimate (broadly corresponding to the 95^{th} percentile). Where information available to inform definition of probability distributions was thin and only a most likely estimate (sometimes also referred to as central estimate) was available, expert judgement was employed to define low and high point estimates as either:

i. ±50 per cent of most likely estimate - corresponding to parameter values considered to have 'high' uncertainty;
ii. ±25 per cent of most likely estimate - corresponding to parameter values considered to have 'moderate' uncertainty; or
iii. ±10 per cent of most likely value estimate - corresponding to parameter values considered to have 'low' uncertainty.

The advantage of defining a probability distribution for parameter inputs, instead of a single estimate, is that it helps to create a realistic picture of the expected economic value of benefits – by describing a **plausible range of likely values**. Another advantage is that it provides insight on the cumulative effect of multiple uncertainties and the **relative importance of each component of uncertainty**. This information can be used, amongst other things, to help prioritise where future research and data collection effort should best be allocated.

The first output of the monte-carlo analysis step was a plausible range of likely benefit values – reported as the 'low' estimate, the 'most likely' value, and 'high' estimate.

The second output of the monte-carlo analysis was a 'tornado graph'. This graph shows the relative contribution of uncertainty for each input parameter to the accuracy of the overall benefit value estimation.

Summative step

In addition, following the stepwise procedure for the individual benefit analysis, a final summative step was also undertaken to aggregate results.

The analysis is for current economic conditions and populations. This is considered appropriate given the substantial uncertainties associated with modelling future economic activities and that the intention for this study is to inform short-medium term water resource planning.

PART B: ASSESSMENT OF KEY BENEFIT CATEGORIES

Part B provides a summary of the assessment undertaken for each of the ecosystem services and related benefits that were the focus of the study (refer Table 2).

For each ecosystem service, the assessment is organised into four sections as follows:

1. Nature of ecosystem service and contribution to benefits in northern Victoria context.
2. Description of how environmental watering impacts ecosystem service flows.
3. Valuation methodology.
4. Results and suggestions for further research

More detailed technical explanations of the method and results are also provided at Appendices 2 through to 7.

5 POLLINATION SERVICES

Nature of ecosystem service and contribution to benefits in northern Victoria context

A large proportion of agricultural production in northern Victoria depends on insect pollination. This includes almonds which, in 2017/18, made up some 30 per cent ($322 million) of total agriculture output in the Mallee ($1,803 million). It also includes apples, pears, and stonefruit which are a similarly important for the Goulburn Broken ($366 million) and, to a lesser extent, the North Central ($85 million) regional economies (ABS 2018).

Many different insects can affect pollination of the abovementioned crops. However, the European honeybee has for many reasons become the predominant pollination agent of choice in northern Victoria (and indeed most parts of the world). Producers of these crops have thus come to depend on the services provided by honeybees to achieve economically viable productivity (Keogh et al, 2010).

For almonds, pollination is generally affected by the deliberate introduction of honeybees to the crop at flowering – either by the grower of the crop or by an apiarist as part of a commercial arrangement with the grower. This is achieved by placing hives within the orchard areas. As at 2016, 96 per cent of all commercial managed pollination services in Victoria were provided to almond crops (Van Dijk et al, 2016). Apiarists often transport hives large distances in order to provide these services.

Figure 5. Beehives in orchards of north-west Victoria

Source: ABC Rural

For other crops such as pome and stone fruit only a small proportion of (European honeybee) pollination services to these crops are from commercial managed pollination service providers (Van

Dijk et al 2016). Pollination services to these crops are instead provided 'incidentally' from feral honeybee populations located within[8] those areas (Keogh et al, 2010).

European honeybee populations used for commercial pollination services rely heavily on floral resources (nectar and pollen) provided by healthy native forest assets – especially *Eucalyptus* forests – for their sustenance (Keogh et al, 2010). As at 2017, around 50 per cent of beekeepers in Victoria are understood to depend on River Red Gum forests to sustain their bee stocks (MDBA, 2017). Furthermore, anecdotal evidence suggests that the (carrying) capacity of River Red Gum forests to support commercial beehives, including those used in commercial pollination services, is currently considered to be "about exhausted in Victoria" (Vic Beekeeper MDBA, 2017).[9]

Description of how environmental watering impacts ecosystem service flows

Environmental watering leads to improvements in the condition of *Eucalyptus* forest and woodland ecosystems (including River Red Gum forests) and in turn the flowering functions of these ecosystems.

Flowering ecology supports native and non-native insect pollinator populations – through the provision of food/sustenance. Healthier insect pollinator populations have greater capacity to provide commercial (and non-commercial) pollination services important for crop production.

A graphic showing the cause-effect relationships from environmental watering to pollination services and its contribution to crop production is shown in Figure 6.

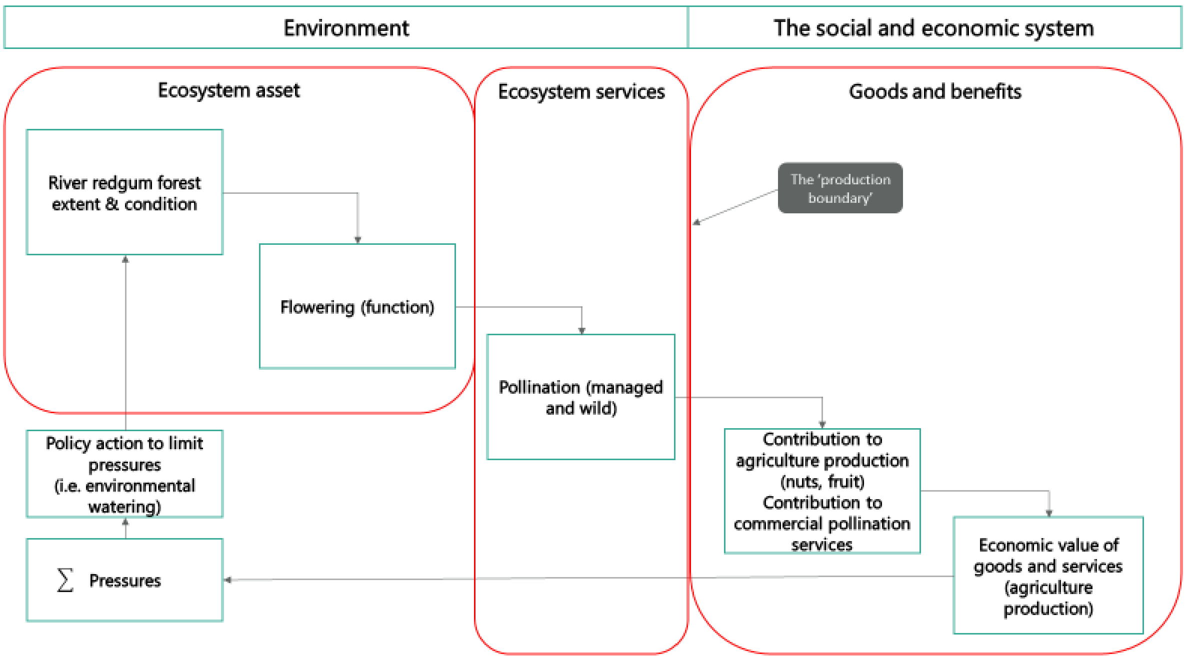

Figure 6. Conceptual model for pollination services

Valuation methodology

The methodology employed to value the contribution of pollination services attributable to environmental watering to the agriculture sector was a basic production-function approach. This approach measures the physical change in output due to environmental changes and then uses market prices or costs to value these changes/impacts in monetary terms (Hanley et al 2009).

[8] Honeybees have a relatively small territorial range – usually travelling between 1 and as much as 6 kilometers to feed (https://beekeepercenter.com/how-far-do-bees-travel/).

[9] The placement of European honeybees in native vegetation is the source of some controversy in various parts of Australia. Those opposed to it have concerns that it has negative impacts on the natural ecology (Keogh et al 2010).

The production-function application for pollination services focused on commercially managed honeybee pollination services to almond production – as this makes up the large majority of benefits provided.

The procedure for applying this method - following the generic stepwise approach outlined in Part 1 – is summarised below.

Table 5. Procedure for valuing the contribution of pollination services to the agriculture sector

Step of generic procedure	Description
Step 1. Measure changes in ecosystem asset condition attributable to environmental watering	The first step of the procedure was to measure the changes in ecosystem condition that are relevant for supporting pollination services. These are *Eucalyptus* forest and woodlands. River Red Gum forest stand condition was taken as the measure of Eucalyptus forest and woodland condition. This index was measured for the Mallee CMA area - where 96% of the commercial pollination services in Victoria are provided. The method for assessing change in River Red Gum stand condition using the 'with' and 'without' (environmental watering) analysis is outlined in Appendix 1. These results were further expressed as a percentage of the with-environmental watering condition. The output of this step was the estimated percentage change in River Red Gum stand condition.
Step 2: Measure the effect of changes in ecosystem asset condition to the flow of ecosystem services	The second step of the procedure was to measure the effect of changes in the condition of Eucalyptus forest and woodlands on the flow of pollination services provided by honeybee populations. The specific relationship between River Red Gum stand condition, flowering ecology, the health of honeybee populations, and the pollination services provided by these populations is not currently well-understood (MDBA, 2017). In the absence of this knowledge, it was conservatively assumed that changes in River Red Gum stand condition result in commensurate percentage changes in managed honeybee stocks and pollination services provided by those stocks. The output of this step was the estimated percentage change in pollination service flows in forest areas that are supported by environmental watering.
Step 3: Measure the contribution of ecosystem service flows to changes in socio-economic benefits	The third step of the procedure was to measure the benefits that pollination services attributable to environmental watering provide to the almond sector. This was calculated using the equation below. **Equation 1. Contribution of pollination services** $Value\ of\ almond\ production\ (2018\$) = (E \times H \times L) \times PDF \times GM$ *Where:* *E* = percentage change in pollination service flows in River Red Gum forest (%, from step 2) *H* = proportion of managed honeybee populations that depend on River Red Gum forests (%) *L* = land area in the Mallee region used for almond production (ha) *PDF* = managed pollination-dependence-factor of almond production (factor)

Step of generic procedure	Description
	GM = average gross margin[10] of almond production ($/ha) The output from this step was the estimated value of benefits to the almond industry in the study area.
Step 4: Investigate uncertainties	Monte-Carlo analysis was used to explore the sensitivity to uncertainties in a number of key input parameters – notably (i) change in River Red Gum forest stand condition attributable to environmental watering, (ii) proportion of commercial pollination services that depend on River Red Gum forests supported by environmental watering (from Step 3), and (iii) gross margin values for almond production.

Results and suggestions for future research

The results of the analysis show the estimated value of the contribution of environmental watering to almond production through pollination-related ecosystem services (see Table 6) is in the range of $13 million to $38 million in 2020 and increasing to between $29 million to $78 million in 2030. These benefits accrue to the Mallee region, where northern Victoria's almond production and commercial pollination service providers are located.

Table 6. Estimated value of the contribution of pollination services provided by environmental watering to the almond sector (2018$M/year)

	2020			2030		
	Low	Mid	High	Low	Mid	High
Estimated change in productivity of almond producers	13	25	38	29	51	78

The large range is mostly explained by uncertainty in the proportion of commercial bee populations that depend on River Red Gum forests supported by environmental watering (Step 3) as well as uncertainty in the modelled River Red Gum stand condition decline under the without-environmental watering scenario (Step 1).

It is therefore suggested that further research be undertaken to better understand the dependence of commercial bee populations on River Red Gum forests supported by environmental watering. This would involve more extensive surveying of apiarists to accurately establish the extent to which they utilise Eucalyptus Forests supported by environmental watering to feed/sustain their European honeybee stocks. It would also involve investigating the degree to which there are substitute forest/feeding options available to them. This will provide greater confidence when reporting pollination benefits to almond producers.

[10] A gross margin refers to the total income derived from an enterprise less the variable costs incurred in the enterprise. Generally, the gross margins for any agricultural crop are determined by deducting variable costs from the gross farm income of a given crop for a given period of time (usually per year or per cropping season). They are not a measure of farm profit as they do not include capital (land, buildings, machinery, irrigation equipment etc.) or fixed costs (building and machinery depreciation, administration, insurance, rates, taxes, etc.).

6 CLIMATE REGULATION SERVICES

Nature of ecosystem service and contribution to benefits in northern Victoria context

Floodplain and wetland ecosystems help to regulate global climate conditions by sequestering greenhouse gases and storing them in above-ground and below-ground biomass (Alcaraz-Sequera et al 2013, Carnell et al 2018). In this way, floodplain and wetland ecosystems in northern Victoria help contribute to mitigation of global climate change which is otherwise expected to result in increasing frequency and intensity of climate-related events such as drought and heatwaves (Climate Council of Australia, 2017).

When climate-events (e.g. drought and heatwaves) occur, they can cause a range of damages and losses to many different sectors of the social and economic system. This includes the health sector as well as the agriculture sector – which are both very important sectors for the northern Victorian regions.

Damages and losses from climate-events can be very substantial, when they occur. For example, a study of the losses incurred by heatwaves in Victoria found for a very extreme heatwave event[11] losses are in the order of $1 billion – representing around 0.31 per cent of Gross State Product (NCE, 2018). This study further showed that the Mallee, Goulburn Broken, and North Central CMA regions were proportionately more affected (as a percentage of Gross Regional Product) compared to Melbourne and the Victorian average – reflecting the high impacts on the agriculture sector.

Description of how environmental watering impacts ecosystem service flows

Environmental watering promotes ecosystems' productivity and their ability to remove greenhouse gases (carbon) from the atmosphere. This occurs through a chemical process known as photosynthesis whereby light energy from the sun is used by plants to convert carbon dioxide and water to glucose sugar and oxygen through a series of reactions.

A graphic illustrating this cause-effect relationship from environmental watering to climate regulation and its contribution to avoiding damages and losses from climate events is shown in Figure 7.

[11] Similar to the 2014 Victorian heatwave event.

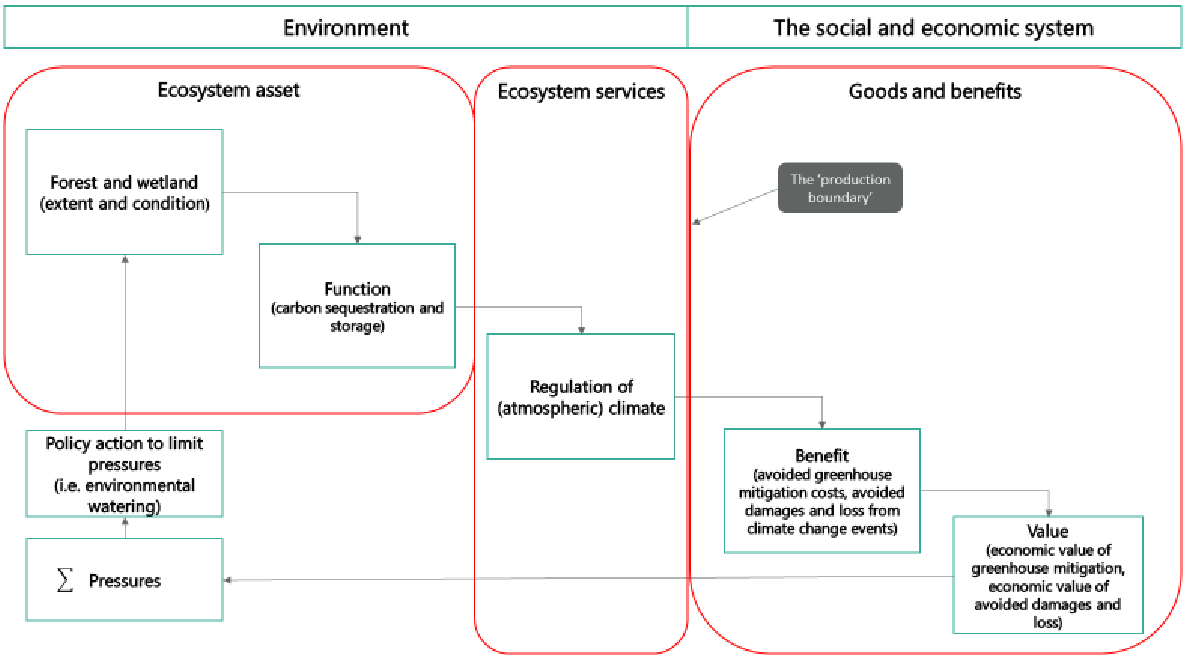

Figure 7. Conceptual model for climate regulation services

Valuation methodology

The methodologies employed to value the contribution of climate regulation services attributable to environmental watering was a benefits-transfer approach. Benefits transfer involves the use of values estimated in an existing study and using these estimates to infer values for a different study application.

The studies identified as being most suitable for this benefits-transfer application were:

- IPCC Fifth Assessment Report (2014).
- World Bank Carbon Pricing Dashboard.

These studies are used by DELWP for valuing greenhouse gas emissions.

The procedure for applying this method – following the generic stepwise approach outlined in Part 1 – is summarised below.

Table 7. Procedure for valuing the contribution of climate regulation services

Step of generic procedure	Description
Step 1. Measure changes in ecosystem asset condition attributable to environmental watering	The first step of the procedure was to measure the changes in ecosystem condition that are relevant for supporting climate regulation services. These are forest and woodland areas in the Living Murray (TLM) icon sites, as well as vegetation in wetland areas. River Red Gum (River Red Gum) forest stand condition was taken as the measure of forest and woodland condition for all forest and woodland types – as monitoring work does not yet provide for measurement of the condition of blackbox-dominated or other forest and woodland types. The index of wetland (IWC) condition biota sub-index was taken as the measure of wetland vegetation condition. The method for assessing change in River Red Gum stand condition and IWC using the 'with' and 'without' (environmental watering) analysis is outlined in Appendix 1. The output of this step was the change in River Red Gum stand condition and IWC.

Step of generic procedure	Description
Step 2: Measure the effect of changes in ecosystem asset condition to the flow of ecosystem services	The second step of the procedure was to measure the effect of changes in the River Red Gum stand condition and IWC biota-sub index on the sequestration and storage of carbon dioxide. For forests and woodlands (within TLM icon sites), the relationship between River Red Gum stand condition and carbon sequestration rates was approximated using a study by Smith et al (2016) – which measured the relationship between crown health and carbon sequestration rates (tonnes of carbon dioxide/ha/year) for River Red Gum forests in Namoi (NSW). For wetlands, there is currently (as at July 2019) no published research which demonstrates the carbon sequestration response to changes in or environmental watering directly (pers comms Katy Limpert, Blue Carbon Research Lab, Deakin University). In the absence of this information, the approach taken was to adjust the functional relationship used for River Red Gum forests (mentioned above) in line with differences in index scoring scale and average annual carbon sequestration rates between the two asset classes. The change in carbon sequestration rates measured for each relevant asset were then multiplied by the total area of that asset to estimate the total carbon dioxide mitigated annually. The output from this step was the estimated change in carbon sequestration associated with environmental watering for forests and wetlands.
Step 3: Measure the contribution of ecosystem service flows to changes in socio-economic benefits	The third step of the procedure was to measure the benefits that carbon sequestration and storage attributable to environmental watering provide to the economic system. The economic value of benefits was approximated using the 2014 IPCC Fifth Assessment Report and the World Bank Carbon Pricing Dashboard – as has been the practice by DELWP for valuing greenhouse gas emissions. These studies measure the unit cost of greenhouse gas abatement based on existing global carbon market values and emission reduction pathways in line with scenarios to limit warming to below 2 degrees Celsius. The total value of carbon sequestration services to the social and economic system was thus estimated by multiplying the quantity of carbon dioxide abated in step 2 by the unit cost of carbon dioxide ($ per tonne of carbon dioxide equivalent). The output from this step was the estimated value of carbon dioxide equivalent sequestered and stored by forests and wetlands associated with environmental watering.
Step 4: Investigate uncertainties	The fourth step was to investigate the effect of uncertainties in key input parameters on the modelled results, and the relative importance of each of these uncertainties. Key input parameters investigated were (i) change in River Red Gum stand condition and IWC attributable to environmental watering, (ii) relationship between River Red Gum stand condition and marginal carbon sequestration rates, and (iii) unit values for the (social) cost of carbon dioxide equivalent.

Results and suggestions for future research

The results of the analysis show the estimated benefits from greenhouse gas mitigation attributable to environmental watering (see Table 8) is in the range of $1 million to $5 million in 2020. This value is expected to further increase to between $4 million and $15 million in 2030 in line with increasing unit values of carbon ($ per tonne of CO_2 equivalent)[12], and as the contribution of environmental watering to the condition of forest and wetlands (relative to a without-environmental watering scenario) increases.

Table 8. Estimate value of the contribution of environmental watering to climate regulation services (2018$M/year)

	2020			2030		
	Low	Mid	High	Low	Mid	High
TLM icon sites						
Mallee	0 – 1	0 – 1	0 – 1	1	2	4
North Central	0 – 1	0 – 1	0 – 1	1	1	2
Goulburn Broken	0 – 1	1	3	2	5	8
Sub-total	*1*	*3*	*4*	*4*	*9*	*14*
Wetland						
Mallee	0	0 – 1	0 – 1	0 – 1	0 – 1	0 – 1
North Central	0	0 – 1	0 – 1	0	0 – 1	0 – 1
Goulburn Broken	0	0 – 1	0 – 1	0	0	0 – 1
Sub-total	*0*	*0 – 1*	*0 – 1*	*0 – 1*	*0 – 1*	*1*
Total estimated benefits	**1**	**3**	**5**	**4**	**9**	**15**

The large variance in these results is mostly explained by uncertainty in the unit value of carbon (Step 3). To a lesser extent it is also explained by the uncertainty in the modelled River Red Gum stand condition decline under the without-environmental watering scenario (Step 1), and the marginal carbon sequestration rates from healthier River Red Gum forests (Step 2).

A key knowledge gap identified as part of the analysis is a lack of published research to establish the carbon sequestration response of wetlands to environmental watering. The Blue Carbon Research Lab at Deakin University is currently undertaking selected case study work in this area and is thus expected to help fill this gap. At the time of writing, a research paper had been submitted to an academic journal (for publishing) and was in the process of being reviewed. Further research may be required to adequately establish this knowledge and understanding.

[12] which, amongst other things, is reflective of the trajectory of (greenhouse gas) emissions reductions – which progressively increase between the years 2020 to 2030. These trajectories are in line with greenhouse gas concentration targets that limit global warming to below 2 degrees.

7 WATER QUALITY REGULATION SERVICES

Environmental watering helps to regulate the quality of consumptive water that is used for agriculture (irrigation and livestock) and town supply. There are a number of distinct dimensions of these services which in turn contribute to a number of different benefit streams in society and the economic system. For this reason, the analysis in this chapter is presented in two parts.

The first part (7.1) examines salinity dimensions of water quality and the benefits generated from environmental watering in terms of avoided salinity management costs.

And the second part (7.2) examines hypoxic blackwater and blue-green algae dimensions of water quality and the benefits generated from environmental watering in terms of avoided impacts on livestock production from these types of events.

7.1 Avoided salinity management costs

Nature of ecosystem service and contribution to benefits in northern Victoria context

Many irrigation districts in the northern Victoria region, particularly the Mallee, are underlain by sandy aquifers containing groundwater as salty as seawater. Because these aquifers are connected in places to the River Murray, irrigation water that is applied to the surface and enters the aquifer from above, squeezes the salty groundwater and mobilises it sideways out of the aquifer. If not intercepted, this salty water enters the river and can degrade water quality (i.e. 'river salinity').

River 'salinity' can cause a range of impacts on users/uses of water resources including crop production, ecosystem health, and urban water treatment costs. If/when these impacts occur they are mostly experienced by third parties downstream of where salinity is generated.[13]

Under the Murray–Darling Basin Agreement and the Basin Plan, partner governments are required to meet a range of salinity management-related obligations. A key element of this is a headline salinity target at Morgan (South Australia).[14]

Each state has its own arrangements for achieving the salinity target at Morgan obligations. In the Victorian Mallee region[15] – where the majority of new irrigation development in Victoria has occurred over the last 10 plus years (Aither, 2016) – a key salinity management strategy has been the construction and operation of off-farm (public) salt-interception schemes. These schemes are large-scale groundwater pumping and drainage projects that serve to reduce the hydraulic gradient that drives saline groundwater towards the Murray River.

Description of how environmental watering leads to changes in socio-economic outcomes

Environmental watering dilutes salinity (measured in terms of Electrical Conductivity, EC) in the Murray River system. This in turn reduces the EC impact from a given irrigation activity and hence the need for additional (public) interventions to manage salinity impacts.

In contrast to most other ecosystem services investigated in this report – which are generated through biotic (i.e. living ecosystem) processes – dilution is an abiotic process. In this way, environmental watering can be thought of as directly providing water quality (salinity) services, rather than via a

[13] This type of environmental problem is characterised in the economics field as a 'unilateral nonpoint externality'.

[14] The BSM2030 outlines a headline salinity target to maintain the average daily salinity at Morgan (South Australia) at a simulated level of less than 800 EC for at least 95 per cent of the time.

[15] Around 59 per cent of new irrigation development (permanent plantings) in the Mallee region over the 2015-2017 period has been nuts (Agriculture Victoria, 2017).

change in the condition and biological functioning of the river ecosystem. This is illustrated in Figure 8.

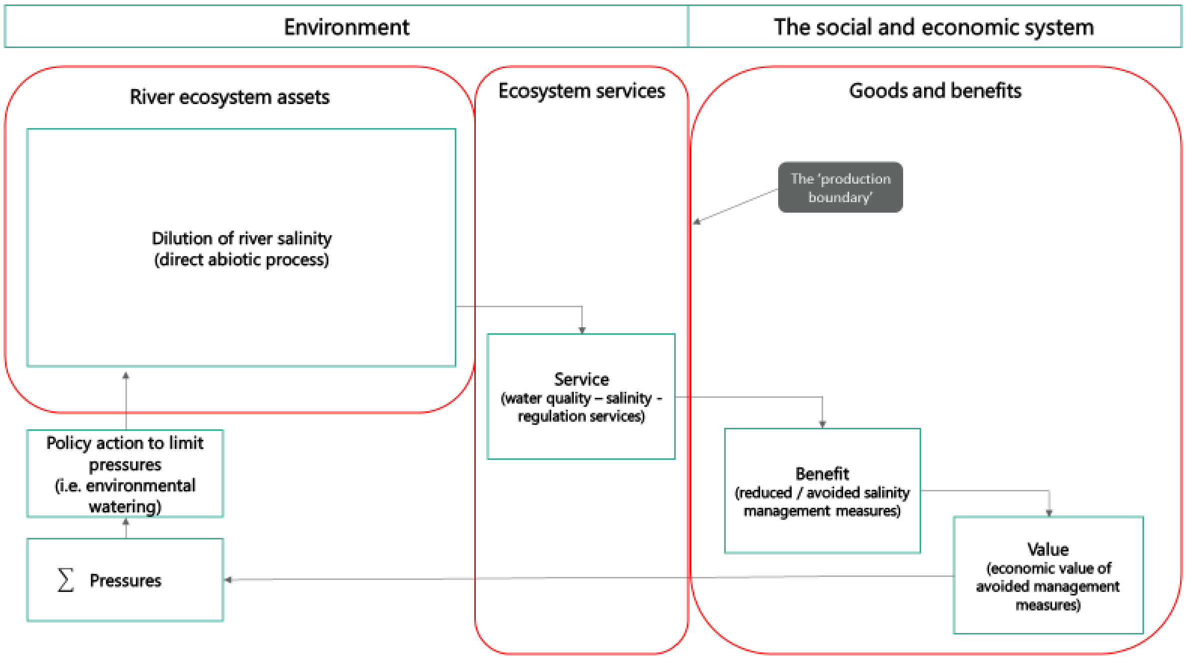

Figure 8. Conceptual model for water quality (salinity) regulation services

Valuation methodology

The methodology employed to value the contribution of environmental watering to avoided salinity management interventions was a cost-based approach. This approach measures the change in off-farm, publicly managed salinity management interventions due to environmental changes, and then used market prices to value this avoided intervention investment.

The procedure for applying this method – following the generic stepwise approach outlined in Part 1 – is summarised below.

Table 9. Procedure for valuing the contribution of salinity mitigation services

Step of generic procedure	Description
Step 1. Measure changes in ecosystem asset condition attributable to environmental watering	As outlined above, river salinity improvements provided by environmental watering are achieved through a direct abiotic dilution process. This is unlike most other ecosystem services considered in this analysis which are generated 'indirectly' through an improvement in the condition and functioning of a living ecosystem asset. As such, this step is not applicable for this service.
Step 2: Measure the effect of changes in ecosystem asset condition to the flow of ecosystem services	The second step of the procedure was to assess the 'direct' dilution effects that environmental watering has on river salinity. The dilution effects utilized in this analysis were based on the Murray Darling Basin Authority modelling in the General Review of Salinity Management in the Murray Darling Basin (2017). The output of this step was the modelled change in EC at Morgan compared to the benchmark period.

Step of generic procedure	Description
Step 3: Measure the contribution of ecosystem service flows to changes in socio-economic benefits	The third step of the procedure was to measure the benefits that reduced river salinity attributable to environmental watering provide in terms of avoided salinity management costs. This was measured as the reduction in the construction and operation of salt-interception schemes and was undertaken as two sub-steps: First, an equivalent annual cost for constructing and operating an average salt-interception scheme ($/EC/year) was estimated. And second, this unit cost was multiplied by the quantity of EC at Morgan associated with new irrigation development that has not required additional salinity management investments – due to dilution effects from environmental watering. The quantity of EC at Morgan associated with new irrigation development are based on rates and location of new irrigation development and corresponding EC generated in the Victorian Mallee for the period 2012/13 to 2017/18 (Mallee CMA). The output was the estimated annual value ($/year) of avoided salt interception scheme costs.
Step 4: Investigate uncertainties	The fourth step was to investigate the effect of uncertainties and variances in key input parameters on the modelled results, and the relative importance of each of these uncertainties. Key input parameters investigated were (i) the capital cost of an salt-intercept scheme and (ii) the expected useful life of a salt-interception scheme.

Results and suggestions for future research

The results of the analysis show the estimated value of avoided salinity management costs from environmental watering (see Table 10) is in the range of $1 million to $2 million in 2020 and up to a range of $2 million to $4 million in 2030.

Table 10. Estimated value of avoided salinity management costs (2018$M/year)

	2020			2030		
	Low	Mid	High	Low	Mid	High
Estimate avoided cost of salt-interception schemes	1	2	2	2	3	4

The differences between low and high result estimates is mostly explained by variance in the capital cost of salt-interception schemes (Step 3).

Further work is currently underway to refine scientific modelling of river salinity impacts in the southern Murray Darling Basin. This will provide a more accurate understanding of the salinity impact from irrigation development in the region as well as the dilution effects of environmental watering.

7.2 Avoided costs of blackwater and blue-green algae events

Nature of ecosystem service and contribution to benefits in northern Victoria context

Hypoxic blackwater[16] events and blue-green algae (BGA) blooms[17] are naturally occurring within the river systems of northern Victoria. However, land and water management practices can exacerbate the frequency and extent of these events. When these events occur, the quality of river water is affected, which in turn impacts on the (consumptive) users/uses of this water (e.g. agriculture, towns). For agricultural water users, the livestock sub-sectors of sheep, dairy and beef are most affected by these events. Livestock are sensitive to water quality, particularly the palatability of water and are likely to drink less or stop drinking altogether when water quality is poor (DPIRD, 2019).[18] Further, BGA can lead to paralysis and respiratory failure if the bloom turns toxic (DPIRD, 2019). Risk management options include destocking the property, carting water and/or finding another water source (e.g. bore water).[19] Each of these options have their own challenges. Destocking the property will likely lead to revenue losses; (anecdotally) there are not enough enterprises that cart water to meet demand of the region; and (where available) bore water might be too saline for consumption by the livestock. Difficulties are amplified for long-lasting events/blooms.[20]

For town water users, BGA presents a major hazard and can be dangerous to the health of humans (CSIRO, 2019). Blackwater events and BGA blooms typically require water corporations to undertake increased (water) chemical treatment activities and monitoring to manage associated health risks. Costs associated with these management activities flow through to consumers in the form of higher water prices.

Description of how environmental watering leads to changes in socio-economic outcomes

Environmental watering can contribute to abatement of hypoxic blackwater and BGA hazard events, and associated impacts, through several different mechanisms.

First, environmental watering can contribute to abatement through direct dilution and mixing effects provided by increased volume of water flow (e.g. dilution of carbon). [21] For example, environmental water was released to provide dilution and refuge during blackwater events in 2012 and 2016 (Baldwin et al 2013; Symes 2017).

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[16] Blackwater is a natural feature of lowland river systems that occurs when organic matter from floodplains is washed into rivers following flooding. The influx of organic matter into the river during warmer times of the year can lead to a sudden reduction in the availability of dissolved oxygen required to sustain aquatic organisms, leading to severe stress and often death - referred to as hypoxic blackwater. It is important to note that carbon inputs from the floodplain are a critical component of riverine food webs. However, when larges sections of riverine systems are affected this can lead to large scale fish and other aquatic animal deaths.

[17] Blue-green algae are types of bacteria known as Cyanobacteria. 'Bloom' is the term used to describe an accumulation of algal cells to a point where they discolour the water, form scums, produce unpleasant tastes and odours, affect fish populations and reduce the water quality. Decomposing algae can also cause depletion of oxygen and induce fish kills.

[18] DPIRD (2019) explains that when "…animals drink less, they will eat less and lose condition", which will lead to a reduction in production.

[19] A portion of water users in northern Victoria secure their supply of fit-for-purpose water through mitigation measures (e.g. off stream storages). It is difficult to estimate the proportion of water users that have this resilience given that in many cases they are not required to hold a licence to access this water. As such, it is also unclear how many days these mitigation measures would last in the event of a poor water quality event.

[20] Farmers are required to meet animal welfare standards, ensuring that their stock do not dehydrate to significant illness or death. In extreme circumstances farmers are expected to euthanize their stock to avoid suffering.

[21] It is noted here however that there is not a sufficient quantity of environmental water to dilute large scale blackwater events as they occur.

Second, environmental water delivery flushes leaf litter and other organic matter build up from riparian zones, floodplains and wetlands; thereby limiting the quantity of organic matter build-up that will be mobilised during natural flooding events (which contributes to hypoxic blackwater events).

And third, environmental watering improves condition of in-stream and riparian vegetation. Healthier vegetation in turn strengthens the buffering functions provided by vegetation in-stream and alongside water courses and thereby remove nutrient run-off (which contributes to BGA).

A simplified graphic illustrating a conceptual model for hypoxic blackwater and BGA regulating services attributable to environmental watering is provided in Figure 9.

It is noted here, there is currently limited information available to reliably establish the contribution of environmental watering to abatement of hypoxic blackwater and BGA hazard events – particularly through flushing and buffering mechanisms. This is in part reflects the complexity of these hazards which involve multiple and inter-related causal factors including – but not limited to – water temperature, amount of sunshine, nutrient levels and the specific algal and microbial species present in the waterway.

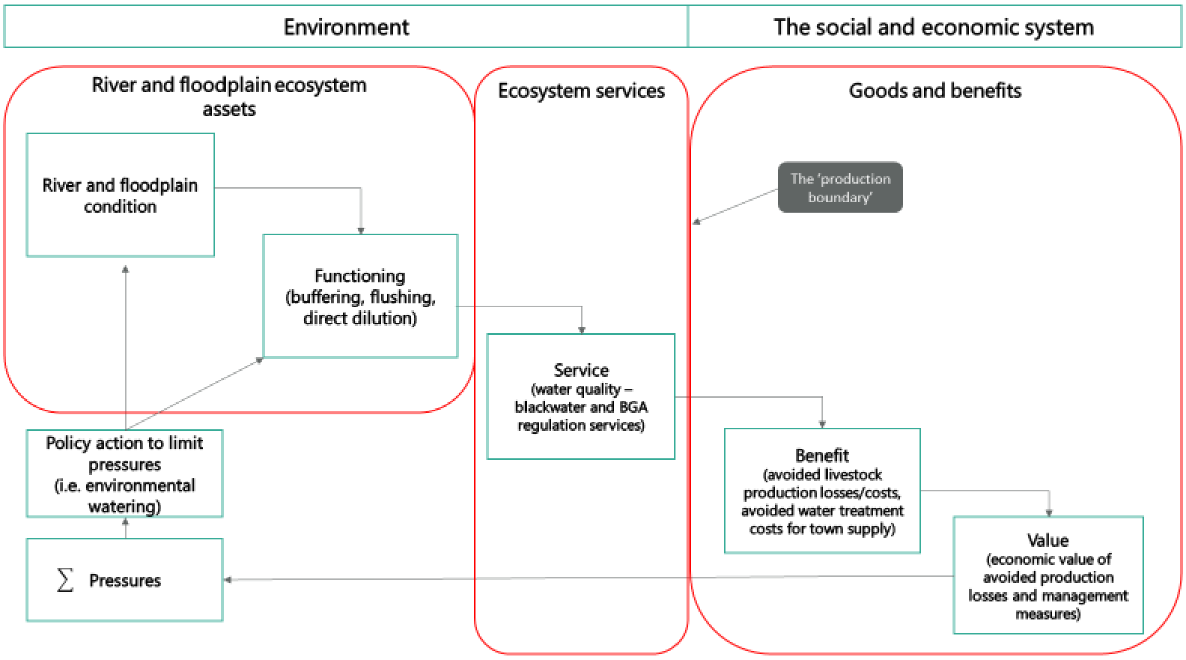

Figure 9. Conceptual model for water quality (blackwater and BGA) regulation services

Valuation methodology

As outlined above, there is currently only limited information available to accurately quantify the effect of environmental watering on abating hypoxic blackwater and BGA hazards. As such, a reliable quantitative assessment of the contribution of water quality regulation services to livestock productivity and town water supplies is not possible at this stage.

However, to help progress understanding in this area a number of hypothetical scenarios were investigated. The objective of this analysis was to help establish whether this is a potentially significant service and thus warrants further research and analysis to better understand.

The Murray River was the sole focus of this part of the analysis because it was the only river in the scope of this study where suitable historical data exists that could be used to plausibly approximate a likely effect of environmental watering on blackwater events and BGA blooms.

Further, the study focused on the potential benefits in terms of livestock (i.e. sheep and lamb, dairy and beef) in the first instance as – given the hypothetical nature of the exercise and the findings of the livestock analysis (discussed below), a further in-depth analysis of water corporations' costs was not considered a priority for research effort at this point in time.

Two methodologies were used to investigate benefits of water quality regulation (blackwater and BGA) services to livestock production, reflecting considerable uncertainty in how blackwater events and BGA blooms impact livestock production.

The first method used a basic production-function approach, determining the physical change in output (i.e. avoided loss of production) due to the reduction in the blackwater and BGA days. This approach then used gross margins to value the avoided loss in production in monetary terms.

The second method used a simplified cost-based approach, to estimate the avoided cost of water carting during blackwater and BGA events.[22]

The procedure for applying each of the methods – following the generic stepwise approach outlined in Part A – is summarised below.

Table 11. Procedure for valuing the contribution of water quality (regulation) services to the livestock sector

Step of generic procedure	Description
Step 1. Measure changes in ecosystem asset condition attributable to environmental watering	As outlined above, blackwater and BGA mitigation services provided by environmental watering are achieved through a combination of biotic and abiotic processes. At this time however, the biotic processes are not well-understood. As such, no ecosystem asset condition elements were explicitly measured or modelled as part of this step.
Step 2: Measure the effect of changes in ecosystem asset condition to the flow of ecosystem services	The second step of the procedure was to measure the changes in the quality of water resources in the Murray River (including consumptive water). These changes were measured in terms of: The change in the expected number of blackwater days per year from environmental watering. The change in the expected number of (Category 2 / High alert) BGA days per year from environmental watering. In the absence of good quality data and studies to support this measurement, a number of conservative scenarios were generated - drawing on the historical frequency and duration of blackwater events and BGA blooms experienced in the Murray River under past climate conditions. Details on these scenarios and their underpinning logic is provided at Appendix 1.
Step 3: Measure the contribution of ecosystem service flows to changes in socio-economic benefits	Method 1: Avoided production losses For method 1, the third step of the procedure was to measure the avoided production losses from reduced blackwater and BGA events. This step firstly quantified the avoided production losses (in terms of kg) associated with reduced blackwater or BGA event duration (from environmental watering) estimated in the step above. This was done by approximating exposure of agricultural land areas to a blackwater or BGA event in the Murray and then using reports prepared by Agriculture Victoria to estimate yields from these areas. Yields were assumed to be zero during days when blackwater and BGA were present. The second part of the step was to assign economic values to avoided production losses using gross margin values (in terms of $/kg) derived from reports published by Agriculture Victoria.
	Method 2: Avoided cost of carting water

[22] Water carting prevents productivity losses but incurs charges primarily for the transportation of water.

Step of generic procedure	Description
	For method 2, the third step of the procedure was to measure the avoided cost of carting water associated with reduced blackwater and BGA events. This step firstly measured the quantity of water carting avoided (in terms of litres) associated with reduced hypoxic blackwater or BGA event duration (from environmental watering) estimated in the step above. Similar to method 1, this involved approximating exposure of agricultural land areas to a blackwater or BGA event in the Murray and then using a combination of academic literature (e.g. McLaren, 1997) and information published online by Agriculture Victoria (2019) to approximate water carting requirements during these events. The second part of this step was to assign economic values to the quantity of water carting avoided (in terms of $/litre) using market prices.
Step 5: Investigate uncertainties	The fourth step was to investigate the effect of uncertainties in key input parameters on the modelled results, and the relative importance of each of these uncertainties. Key input parameters investigated were (i) proportion of land used for livestock production that obtains water from the Murray River in the Goulburn Broken, Mallee and North Central CMA regions, (ii) gross margins for sheep and lamb, dairy and beef, and (iii) market price to cart water ($ per litre).

Results

The results of the analysis indicate the estimated value of avoided costs to livestock producers from both hypoxic blackwater and blue-green algae events are likely to be material.

For hypoxic blackwater events in the Murray River (Table 12), benefits to livestock producers are estimated to be in the range of $1 million to $2 million in 2020, increasing to a range of $1 million to $3 million in 2030.

And for BGA blooms in the Murray River (Table 13), benefits to livestock producers are estimated to be in the range of $1 to $2 million in 2020, increasing to a range of $1 million to $3 million in 2030.

It is noted here the results reported for 2030 are considered conservative as scenarios used in the analysis do not account for more extreme climate events (e.g. heatwaves, drought, or flooding) that may occur in the future under climate change and which are expected to increase hypoxic blackwater and BGA risks

Table 12. Hypothetical benefits to livestock producers of avoiding blackwater events in the Murray River – abiotic and biotic combined & catchments combined (2018$M/year)

Method	Livestock asset	2020			2030		
		Low	Mid	High	Low	Mid	High
Method 1: Avoided loss of production	Sheep and lamb	0 – 1	0 - 1	0 - 1	0 – 1	0 – 1	0 - 1
	Dairy	1	2	2	1	2	3
	Beef	0 – 1	0 - 1	0 - 1	0 – 1	0 – 1	0 - 1
	Total	**1**	**2**	**2**	**2**	**2**	**3**
Method 2: Avoided cost of water carting	Sheep and lamb	0 – 1	0 - 1	0 - 1	0 – 1	0 – 1	0 - 1
	Dairy	0 – 1	1	1	0	1	1
	Beef	0 – 1	0 - 1	0 - 1	0 – 1	0 – 1	0 - 1
	Total	**1**	**1**	**1**	**1**	**1**	**1**

Table 13. Hypothetical benefits to livestock producers of avoiding BGA blooms in the Murray River – abiotic and biotic combined & catchments combined (2018$M/year)

Method	Livestock asset	2020			2030		
		Low	Mid	High	Low	Mid	High
Method 1: Avoided loss of production	Sheep and lamb	0 – 1	0 - 1	0 - 1	0 – 1	0 - 1	0 - 1
	Dairy	1	2	2	1	2	3
	Beef	0 – 1	0 - 1	0 - 1	0 – 1	0 - 1	0 - 1
	Total	**1**	**2**	**2**	**2**	**2**	**3**
Method 2: Avoided cost of water carting	Sheep and lamb	0 – 1	0 - 1	0 - 1	0 – 1	0 - 1	0 - 1
	Dairy	0 – 1	1	1	1	1	1
	Beef	0 – 1	0 - 1	0 - 1	0 – 1	0 - 1	0 - 1
	Total	**1**	**1**	**1**	**1**	**1**	**1**

These results suggest further research work is warranted to better understand the effect of environmental watering in reducing hypoxic blackwater and BGA risks. In the first instance, research work should focus on developing a more in-depth understanding of the biotic and abiotic processes through which environmental watering serves to abate each of these hazards.

Once this underpinning knowledge base is established, a more accurate and reliable assessment of the associated socio-economic benefits should be undertaken – building on the work that has been undertaken as part of this study.[23] At that time, assessment of socio-economic benefits should also be expanded to include the avoided water treatment costs for water corporations.

[23] It is further noted here that, consultation undertaken during this assignment highlighted that staff at the Chief Veterinary Officer Unit and Agriculture Victoria are currently researching BGA risks for the livestock sector.

8 RECREATION

Nature of ecosystem service and contribution to benefits in northern Victoria context

The river, floodplain and wetland ecosystems in northern Victoria support a wide range of active and passive recreation activities and experiences.

In river ecosystems, these activities include swimming, fishing, canoeing, waterskiing, birdwatching, hiking, cycling, camping, and picnicking – amongst others. Characteristics or attributes of river ecosystems that are important for these activities include clean water, native fish populations (e.g. Murray cod), native bird populations, and healthy native vegetation (Bennett et al., 2008). Water quantity is also an important attribute for some activities such as canoeing.

In wetland and floodplain ecosystems, birdwatching, hunting and camping are the key recreation activities. Characteristics or attributes that are important for these activities include native bird populations and healthy native vegetation (Bennett et al., 2008).

Figure 10. Recreation activities at Gunbower National Park

Source: Parks Victoria (2014)

Both local community members and tourists from other parts of Victoria and Australia visit these ecosystems to partake in nature-based recreation related activities. Locals and tourists alike value these activities because they derive a level of enjoyment. They also value them – to varying degrees – because they support health and recuperation outcomes as well as social/community interaction. These are important elements contributing to the livability of rural areas and townships.

Further, to the extent that recreation activities are associated with consumption of (market) goods and services in the local regional economy (e.g. purchase of fuel, bait and food), they also contribute to the local tourism sector.

Description of how environmental watering leads to changes in socio-economic outcomes

Environmental watering contributes to recreation-related benefits through many of the same mechanisms which environmental watering objectives are achieved. [24] This reflects the situation that many environmental watering objectives such as improved River Red Gum health, waterbird populations, and healthy waterways are also the ecosystem features or attributes that people value for recreation.

The cause-effect relationships from environmental watering to recreation services and its contribution to the social and economic system is shown in Figure 11.

[24] As outlined in Part A, environmental watering aims to achieve these environmental objectives by mimicking some of the flows that would have occurred naturally before rivers were modified.

In rivers this generally focus on returning some of the small and medium-sized river flows important in the life cycles of native plants and animals. In wetlands and floodplains, this is more achieved by trying to recreate some of the natural wetting and drying cycles.

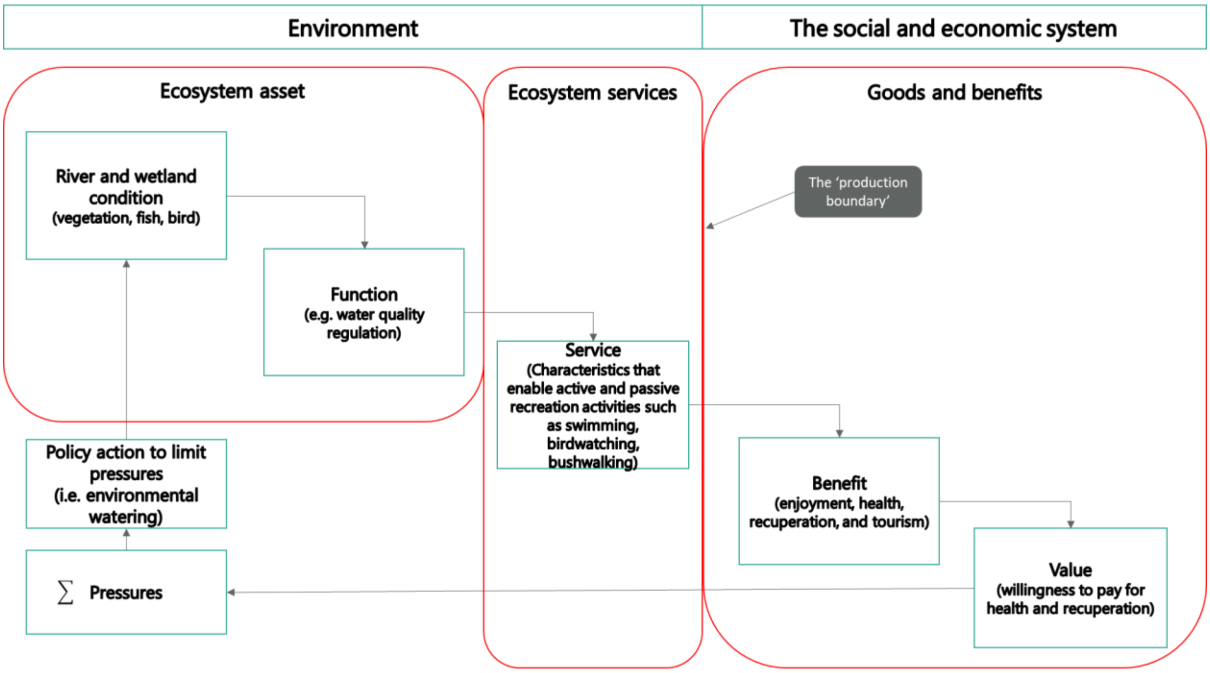

Figure 11. Conceptual model for recreation services

Valuation methodology

The methodology employed to value the contribution of recreation-related services to the social and economic system was a travel cost method. The travel cost method is based on the basic insight that an individual's willingness to pay for recreation at a site – such as camping at a national park – is at least their trip cost of reaching the site (Parsons, 2017). This willingness to pay captures all (or, at least the majority of) of the benefits that people derive from recreation activities – including enjoyment, health and recuperation.

The travel cost method is well suited to modelling the economic benefit of outdoor recreation – and it is widely used for valuing contribution to fishing, hunting, boating, camping and bushwalking activities in particular (Hanley et al. 2009).[25]

In this study, the travel cost method was applied to a case study of Gunbower Forest , where sufficient secondary visitation data was available. The Gunbower Forest in the North Central CMA. This is a 20,000-hectare forest area in the floodplains of the River Murray. The forest area is endowed with various endangered plants and animals and has several Aboriginal and post-settlement cultural heritage sites.

The procedure for applying the travel cost method – following the generic stepwise approach outlined in Part 1 – is summarised below. In reading this procedure, it is important to be aware that only point-in-time visitation data was available to derive benefit estimates and that further surveys were beyond the scope of this study. This constraint has implications for how changes to visitation rates due to environmental watering has been measured (in step 3), and hence what ecosystem attributes are utilised to approximate this effect (in steps 1 and 2).

[25] The travel cost method seeks to place a value on non-market environmental goods (such as nature-based recreation activities in river, floodplain, and wetland areas) by using consumption behaviour in related markets. Specifically, the costs of accessing an ecosystem area – such as a river or a national park forest – are used as a proxy for a market price which does not exist. These consumption costs include costs associated with a round trip travel to the site (Lansdell and Gangadharan 2003).

Table 14. Procedure for valuing recreation services through the travel cost valuation method

Steps	Description
Step 1. Measure changes in ecosystem asset condition attributable to environmental watering	The first step of the procedure was to measure the changes in ecosystem condition that are important for recreation. Selection of these ecosystem condition elements were guided by a choice modelling study of the River Red Gum forests along the Murray river (Bennett et al, 2007). This study identified the health of River Red Gum forests as one of the key attributes that are important for recreation. For this attribute, River Red Gum (River Red Gum) forest stand condition was taken to be the underpinning quantitative metric for this attribute. The method for assessing the change in the level of this condition metric from environmental watering is outlined in Appendix 1. Results were further expressed as a percentage of the 2010 level. The output of this step was the change in River Red Gum stand condition as a percentage of 2010 levels.
Step 2: Measure the effect of changes in ecosystem asset condition to the flow of ecosystem services	As outlined in Part 1, ecosystem services that contribute to recreation are characteristics or attributes that enable passive or active recreation activities. These characteristics are broadly the same thing as ecosystem asset elements – as measured in step 1. Accordingly, no further analysis was undertaken as part of this step.
Step 3: Measure the contribution of ecosystem service flows to changes in socio-economic benefits	The third step of the procedure was to measure the contribution of changes in the quality of ecosystem attributes (indicated by River Red Gum stand condition) to the recreation-related benefits that are derived from these changes. This comprised of two sub-steps – (i) firstly, to approximate the change in park visitation rates due to changes in quality of ecosystem attributes, and (ii) second, to assign economic values to this increased visitation. Change in visitation was assumed to be equal to changes in River Red Gum stand condition index (from step 1) which, as outlined above, is considered a reasonable proxy indicator for the overall health for the ecosystem at the case study site.[26] Economic values of incremental visitors to the case study sites attributable to environmental watering were estimated through a regression model relating travel costs to visitation rates – to approximate a demand curve for the site. From this model, an estimate of the economic value for a typical visitor trip ($/visitor group trip) was derived. Total benefits for each case study site were then calculated by multiplying the incremental number of visitor groups per year attributable to environmental watering by the value for a typical visitor trip.
Step 4: Investigate uncertainties	The fourth step was to investigate the effect of uncertainties in key input parameters on the modelled results, and the relative importance of each of these uncertainties. Key input parameters investigated were (i) visitation response rates, (ii) consumer surplus per visitor group visit, and (ii) total number of visitors per year.

Results and suggestions for future research

[26] It is noted that these visitor response rates are lower than visitor response rates to environmental improvements in Hawkesbury-Nepean River in NSW achieved by environmental watering as estimated in Gillespie et al (2017). In this way, visitor response rates assumed in this study are considered conservative.

The results of the analysis provide insight on the order-of-magnitude value of recreation-related benefits generated by environmental watering. For the Gunbower Forest asset, the value is estimated to be in the range of $1.4 million and $3.9 million, increasing to $2.8 million and $8 million by 2030.

Table 15. Estimated economic benefit of environmental watering (2018$M/year)

Environmental asset	2020			2030		
	Low (p5)	Most likely	High (p95)	Low (p5)	Most likely	High (p95)
Gunbower Forest	1	2	4	3	4	8

An important limitation of the analysis was that it had to rely on a number of expert judgements and conservative assumptions to approximate the changes in site visitation that are attributable to environmental watering. This was necessary because of a lack of (longitudinal) visitation data available for the case study sites and because primary survey work was beyond the scope of this study. Results should thus be interpreted as a conservative indicative range.

Going forward, it is suggested that strategic collection of visitor survey data for key recreation assets be undertaken as a monitoring activity to understand this socio-economic benefit of the environmental watering program. These visitation surveys should be designed with travel cost method applications in mind.[27] They should also be designed to include a forward-looking examination of visitors' likely response rate to changes in key ecosystem attributes. This latter feature would enable a hybrid travel cost and stated preference valuation method that would provide for immediate valuation of incremental recreation benefits provided by environmental watering (i.e. not require full time-series visitation data – though this is preferred).

[27] Including (i) travel method (car/bus/plane etc) for each visitor, (ii) whether the visitor is a single-site or multi-site visitor, (iii) key activities undertaken at the site (swimming, fishing, bushwalking etc), and (iv) expenses other than fuel costs (e.g. accommodation, food, retail).

9 EXISTENCE AND BEQUEST VALUES

Nature of ecosystem service and contribution to benefits in northern Victoria context

Socio-economic benefits from water-dependent ecosystems extend beyond benefits generated from the direct use of the ecosystems (as described in preceding chapters). Some Victorians derive a benefit from the knowledge that these ecosystems exist in a healthy condition (referred to as 'existence values') and/or are available for future generations to use/enjoy (i.e. bequest values). That is, they value an ecosystem even if they never have or never will use it, and they value it more if it is in a healthy state than if it is degraded.

Existence and bequest values can correspond to a particular species or feature of an ecosystem. Examples in the northern Victoria context include the Platypus, Rakali, and Murray Hardyhead.

Existence and bequest values can also correspond to the overall health of an (river, floodplain, wetland) ecosystem. That is, people generate value from the knowledge that the whole system is healthy and functioning well.

Figure 12. Next generation recreating at the Goulburn River, Shepparton

Source: photo and consent provided by Aaron Buncle (NCEconomics Project Manager)

Description of how environmental watering leads to changes in socio-economic outcomes

Environmental watering contributes to existence values through the same mechanisms which environmental watering objectives are achieved. [28] This is because environmental watering objectives such as improved River Red Gum habitats, waterbird populations, and healthy waterways (refer to the Long Term Watering Plan for Northern Victoria) are in line with the ecosystem features or attributes that people value in terms of existence values.

Environmental watering further contributes to a wide range of provisioning, regulating, and cultural ecosystem services that are valued in terms of bequest. An explanation of the mechanisms through which these outcomes are achieved are described in the preceding chapters.

A graphic showing a generalised cause-effect relationship from environmental watering to existence or bequest values is shown in Figure 13.

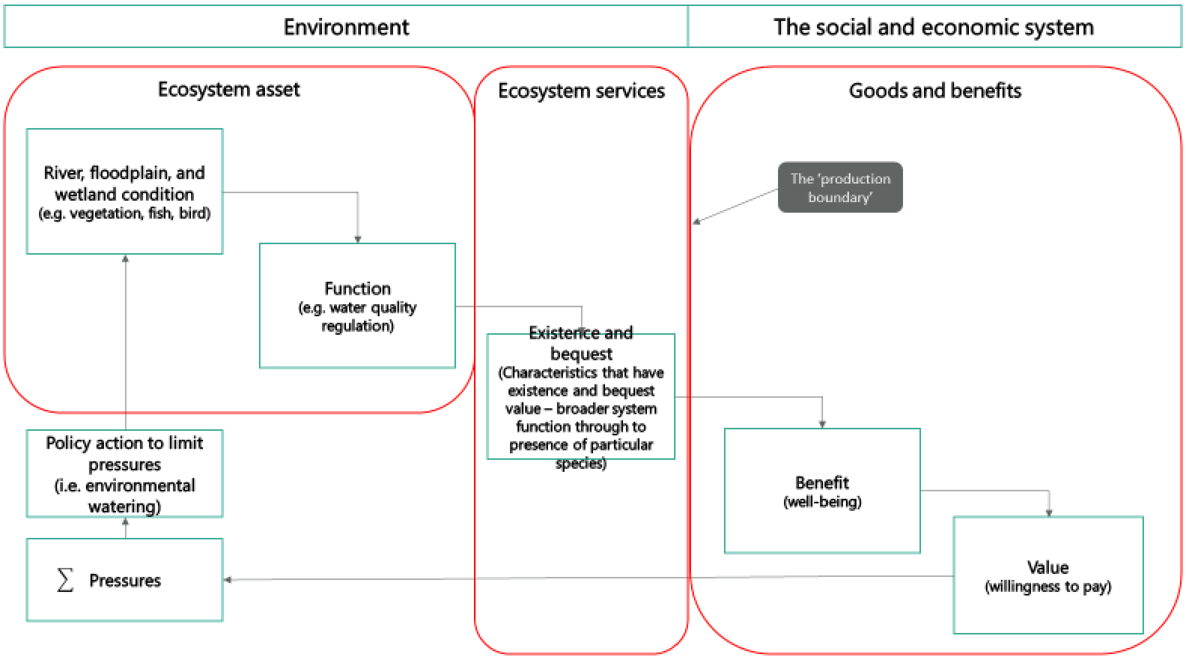

Figure 13. Conceptual model for characteristics that have an existence or bequest value

Valuation methodology

The methodology employed to value the contribution of characteristics or features of living systems that have an existence or bequest value (attributable to environmental watering) was a benefits-transfer approach. Benefits transfer involves the use of values estimated in an existing study and using these estimates to infer values – with adjustments made as appropriate – for the study site.

The studies identified as being most suitable for this benefits-transfer application were:

[28] As outlined in Part A, environmental watering aims to achieve these environmental objectives by mimicking some of the flows that would have occurred naturally before rivers were modified.

In rivers this generally focuses on returning some of the small and medium-sized river flows important in the life cycles of native plants and animals. In wetlands and floodplains, this is achieved by trying to recreate some of the natural wetting and drying cycles.

- *Rivers*: J. Bennett, R. Dumsday, G. Howell, C. Lloyd, N. Sturgess & L. Van Raalte (2008), *The economic value of improved environmental health in Victorian rivers*. This study used choice modelling techniques to estimate values of improving river health in the Goulburn River.[29]

- *Iconic floodplain forests*: Bennett. J.W., Dumsday. R., Lloyd. C., and Kragt. M (2007) *Valuing the Protection of Victorian Forests: Murray River Red Gums, and East Gippsland*. This study used choice modelling techniques to estimate values of improving River Red Gum forest health in the Barmah region.

- *Wetlands*: Bennett. J.W., and Whitten. S.M. (2007), *The Private and Social Values of Wetlands* This study used choice modelling techniques to estimate values of improving wetland health in the Murrumbidgee area (NSW).

The procedure for applying the benefits transfer approach – following the generic stepwise approach outlined in Part A – is summarised below.

Table 16. Procedure for valuing the contribution of characteristics or features of living systems that have an existence or bequest value

Step of generic procedure	Description
Step 1. Measure changes in ecosystem asset condition attributable to environmental watering	The first step of the procedure was to measure the changes in ecosystem condition that are important in terms of existence and bequest. Taking guidance from the type of attributes that were modelled in the source choice modelling studies as well as condition monitoring information that is readily available for the assets, the ecosystem condition elements that were measured for river ecosystems were Index of Stream Condition (ISC) and large bodied native fish abundance. For TLM icon sites, condition elements measured were River Red Gum (River Red Gum) stand condition and large bodied native fish abundance. And for wetlands, condition elements were Index of Wetland Condition biota sub-index (IWC) and Waterbird abundance. The method for assessing change in each of these elements using the 'with' and 'without' (environmental watering) analysis is outlined in Appendix 1.
Step 2: Measure the effect of changes in ecosystem asset condition to the flow of ecosystem services	The second step of the procedure was to convert the metrics measured in Step 1 (which are the metrics commonly recorded as part of environmental watering monitoring programs) into the attribute metrics used in the source studies. This was to convert (i) ISC to % of river length that is "healthy", (ii) fish abundance as a % of the pre-European level, (iii) River Red Gum stand condition to effective forest area that is "healthy", (iv) convert IWC to effective wetland area that is "healthy", and (v) convert waterbird abundance to % of the pre-European level.
Step 3: Measure the contribution of ecosystem service flows to changes in socio-economic benefits	The third step of the procedure was to estimate the benefit derived from changes in ecosystem attributes measured in step 2. This benefit value was measured in terms of 'willingness-to-pay' for change and involved three key sub-steps. The first sub-step was to measure household 'willingness-to-pay' for changes in attributes for each ecosystem. This involved inputting metrics measured in step 2 into the parametric functions from the source choice modelling studies. An example of how these functions were used is illustrated for the river ecosystems below.

[29] And the Moorabool, and Gellibrand systems – though results for these systems were not applied in this benefits-transfer application as they are not representative/similar to the systems that are the focus of this study (i.e. Loddon, Campaspe, Goulburn, Broken).

Step of generic procedure	Description
	$$Household\ value\ (\$\ per\ household) = (\Delta F \times IPF)\ + (\Delta V \times IPV)$$ *Where:* ΔF = change in native fish populations (% of the pre-European level) *IPF* = implicit price for improvement in fish populations ($ per % of pre-European level). Implicit price is defined as the amount, on average, that respondents are willing to pay to enjoy an increase of one unit in this attribute. ΔV = change in percentage of the river's length with healthy native vegetation on both banks (% of river length) *IPV* = implicit price for improvement in health of native vegetation on riverbanks ($ per %) The second sub-step was to extrapolate household values to the population groups across Victoria. The third and final sub-step was to make an adjustment to proportionately disaggregate the total estimated value into the component share that is attributable to existence and bequest values. The adjustment made was in line with analysis of forest protection values for NSW forests which found that the ratio of use (primarily recreation) to non-use values is around 1:3 (Bennett 2000, Bennett and Carter 1993). This adjustment is also consistent with a non-market value study of forests in the Colorado Rocky Mountains by Walsh et al (1990) which found that non-use values are around three times higher than recreation use values.
Step 4: Investigate uncertainties	The fourth step was to investigate the effect of uncertainties in key input parameters on the modelled results, and the relative importance of each of these uncertainties. Key input parameters investigated were (i) change in ecosystem condition attributable to environmental watering (ISC, fish abundance, River Red Gum stand condition, IWC, and waterbird abundance), and (ii) implicit price values.

Results and suggestions for future research

The results of this analysis indicate that existence and bequest values are likely to be in the range of $13 to $27 million per year, increasing to between $28 and $58 million per year by 2030 (see Table 17). These benefits are considered to be conservative estimates as they have not considered some attributes included in the source choice modelling studies that are known to have existence and bequest values – notably threatened parrot populations and "other" animal populations.

Table 17. Estimated contribution to existence and bequest values (2018$M/year)

	2020			2030		
	Low	Mid	High	Low	Mid	High
Rivers						
Loddon	1	1	2	1	2	4
Campaspe	1	1	1	1	2	3
Goulburn	2	3	4	2	4	5
Broken	1	1	2	2	2	3
Sub-total (Rivers)	*4*	*7*	*9*	*6*	*10*	*15*
TLM icon sites						

	2020			2030		
	Low	Mid	High	Low	Mid	High
Chowilla Floodplains & Lindsay-Wallpolla Islands	3	4	5	8	10	13
Hattah Lakes	1	1	1	2	2	3
Gunbower-Koondrook-Perricoota Forest	3	4	5	6	8	11
Barmah-Millewa Forest	1	2	4	4	6	8
Sub-total (TLM icon sites)	*8*	*11*	*15*	*19*	*27*	*35*
Wetlands						
Mallee	0	1	1	1	3	5
North Central	0	1	1	1	1	2
Goulburn Broken	0	0	1	0	1	1
Sub-total (Wetland)	*1*	*2*	*3*	*2*	*5*	*8*
TOTAL (All ecosystem assets)	**13**	**19**	**27**	**28**	**41**	**58**

The large variance in estimates reflects the inherent difficulty in measuring existence and bequest benefits due the non-use nature of these benefits. This characteristic means that valuation methods must rely on (less reliable) hypothetical questionnaires to infer preferences (i.e. implicit prices) rather than use actual behavior or choices. The large variance is also explained by uncertainties in the change in ecosystem condition attributable to environmental watering (Step 1).

It should also be noted there were a number of important limitations with the analysis. Of particular note were that the source studies used in this benefits-transfer application are now all more than 10 years old. It is likely that community preferences for environmental improvements valued in these studies may have shifted since this time – for example in the knowledge that the planet is now experiencing a sixth mass-extinction event (Ceballos et al., 2017). And second, the choice modelling studies used as the source studies do not disaggregate the component parts of households (willingness to pay) values. This study has attempted to address this by apportioning relative values based on studies of forest conservation from NSW – which is a relatively crude approach. For these reasons, the results of this analysis should be treated as preliminary and conservative.

It is suggested that future research be undertaken to gain a better understanding of the relative importance of existence and bequest benefits compared to other socio-economic benefits (e.g. recreation) for the northern Victorian environmental watering context. In the first instance, this should involve a more extensive review of the literature expanding to other disciplines such as (social) anthropology.

PART C: AGGREGATION OF BENEFITS

10 AGGREGATE BENEFITS, WHOLE OF VICTORIA

This chapter aggregates some of the benefit categories estimated in Part B. These include:

- Pollination services – contribution to productivity of almond crops.
- Climate regulation services
- Water quality regulation services – avoided cost of constructing and operating salt-interception-schemes.
- Recreation services – contribution of Gunbower Forest to community enjoyment, health and recuperation.
- Existence and bequest

As blackwater and blue-green algae dimensions of water quality regulation services are based on hypothetical scenarios, the related benefit estimates from this assessment are not included in the aggregated values. Also, it is noted again here that recreation related benefits are only for Gunbower Forest and not for all asset areas that are important for recreation.

For these reasons – and because only a sub-set of ecosystem services provided by environmental watering have been valued in this assessment (refer Table 1) - the aggregate values reported here do not represent an estimate of overall benefits generated from environmental watering in northern Victoria. Rather they should be viewed as **conservatively** telling part of the story for which there is currently a reasonable level of supporting evidence. Table 18 provides a summary of the aggregate results.

Table 18. Summary of estimated aggregate results (2018$M/year)

Benefit category	2020			2030		
	Low	Mid	High	Low	Mid	High
Pollination services – contribution to almond production	13	25	38	29	51	78
Climate regulation services - avoided damages and losses from climate events	1	3	5	4	9	15
Water quality regulation services - avoided salinity management costs	1	2	2	2	3	4
Recreation services – contribution of Gunbower Forest to community enjoyment, health and recuperation.	1	2	4	3	4	8
Existence and bequest values	13	19	27	28	41	58
Estimated aggregate benefits	**29**	**51**	**76**	**66**	**108**	**163**

A key insight from the summary results is that the overall effect of environmental watering on the social and economic system is major. Even without key benefits included (notably, recreation-related benefits generated by other TLM icon sites; the Loddon, Campaspe, Goulburn, and Broken rivers; and the multitude of wetlands) and applying a conservative methodological approach throughout, environmental watering is estimated to make a contribution in the range of $30 million to $76 million per year in 2020, increasing to between $66 million and $164 million in 2030.

Another key insight is that benefits accruing to segments of the agriculture sector are substantial. Much of these benefits flow to the Mallee region - where the majority of almond production and new irrigation developments in Victoria are located.

Furthermore, the analysis shows that the magnitude of estimated aggregate benefits is expected to substantially increase in the future as the health of ecosystems relative to a 'without' environmental watering program scenario becomes more evident. This underscores the long-term nature of environmental watering program (environmental) outcomes and the need to consistently implement these interventions over time.

PART D: SUMMARY OF KEY FINDINGS AND SUGGESTIONS FOR NEXT STEPS

11 CONCLUDING REMARKS AND NEXT STEPS

The analytical framework developed as part of this assessment provides a logical and practical methodology for assessing the socio-economic benefits generated from environmental watering in northern Victoria.

This initial desktop application of the framework provides insight into the order-of-magnitude values of key benefit categories and, related to this, identifies priority areas for further data collection and research. Over time, and with additional data inputs, the application of the analytical framework can be progressively refined to generate more accurate results which can be incorporated into the monitoring and evaluation framework for the environmental watering program and used to inform ongoing learning for improvement.

A summary of key findings and suggestions for next steps is set out below.

Key findings and recommendations

Benefits to agriculture sector

A key insight of the analysis is that environmental watering provides substantial benefits to segments of the agriculture sector. One important benefit stream pertains to the contribution of healthy *Eucalyptus* forests (particularly River Red Gum forests) in supporting commercial pollination services to almond production. These benefits are estimated to be in the range of $13 million to $38 million per year, and largely accrue to the Mallee region where almond production in Victoria is located.

Other benefits to the agriculture sector that have less supporting evidence and analysis relate to the role that environmental watering plays in mitigating blackwater and blue-green algae events and associated impacts on livestock production. Preliminary analysis undertaken for the Murray River indicates these benefits are likely to be material (in the range of $1 million to $3 million per year at 2020, increasing to between $2 million and $5 million per year by 2030) and thus warrant further research.

Recommendation: To provide for a more precise assessment of pollination related benefits it is suggested that further research work be undertaken to better understand the degree to which commercial honeybee populations depend on *Eucalyptus* forests that are supported by environmental watering. This would involve more extensive surveying of apiarists to accurately establish the extent to which they currently utilise *Eucalyptus* forests supported by environmental watering to feed/sustain their European honeybee stocks. It would also involve further investigation of the degree to which substitute forest/feeding options are available to apiarists should access to healthy *Eucalyptus* forests be reduced.

Recommendation: To better understand the risks of blackwater and BGA events (including under a more extreme climate future) and the role of environmental watering in helping to manage these risks, it is recommended that further research work be undertaken to examine these issues. Noting that, consultation undertaken during this assignment highlighted that staff at the Chief Veterinary Officer Unit and Agriculture Victoria are presently researching on the topic of BGA and livestock. In the first instance, research work should focus on developing a more in-depth understanding of the biophysical effect environmental watering plays in reducing the frequency and intensity of blackwater and BGA events. Once the underpinning biophysical knowledge is better established, a more accurate and reliable assessment of the associated socio-economic benefits can be undertaken, building on the work that has been undertaken as part of this study. Assessment of avoided water treatment costs for water corporations from blackwater and BGA events should also be undertaken at that time.

Water quality regulation services – avoided salinity management costs

Environmental watering dilutes salinity in the Murray River system which in turn reduces the need to invest in public salinity management measures such as salt-interception schemes. The extent of this effect however is not precisely known and is the subject of ongoing research.

Based on the understanding of dilution effects of environmental watering, as documented in the *Modelling to support the general review of salinity management in the Basin* (MDBA, 2017), the value of these avoided salinity management costs are estimated to be in the range of $1 million to $2 million per year at 2020, increasing to between $2 and $4 million per year by 2030.

Recommendation: It is suggested the avoided salinity management costs estimated in this study be revisited once work currently underway to refine scientific modelling of river salinity impacts in the southern Murray Darling Basin has been completed. This will provide for a more accurate understanding of the the dilution effects of environmental watering as well as the salinity impact from irrigation development in the northern Victoria region.

Climate regulation services

Healthier ecosystems help to regulate global climate conditions by sequestering greenhouse gases and storing them in above-ground and below-ground biomass (Alcaraz-Sequera et al, 2013). In this way, environmental watering mitigates against climate change which is otherwise expected to result in increasing frequency and intensity of damaging climate-related events such as drought and heatwaves (Climate Council of Australia, 2017).

The results of the analysis show the value of these benefits is in the range of $1 million to $5 million in 2020. This value is expected to further increase to between $4 million and $15 million in 2030 in line with increasing unit values of carbon ($ per tonne of CO_2 equivalent) and as the contribution of environmental watering to the condition of forest and wetlands (relative to a without-environmental watering scenario) increases.

One key knowledge gap identified, and hence a limitation of the analysis, was a lack of published research to establish the carbon sequestration response of wetlands to environmental watering. The Blue Carbon Research Lab at Deakin University is currently undertaking some selected case study work in this area and is thus expected help fill this gap. At the time of writing, a major research paper had been submitted to an academic journal (for publishing) and was in the process of being reviewed.

Recommendation: Review the work of the Blue Carbon Research Lab once complete with the view to potentially supporting further research, if needed.

Recreation related benefits

The analysis supports the widespread understanding that environmental watering contributes to a range of passive and active nature-based recreation activities - e.g. fishing, swimming, camping, bushwalking, boating and kayaking, and contemplation (VEWH 2018, MDBA 2017)). These activities in turn generate important heath, enjoyment and recuperation benefits for local and out-of-catchment communities. They also generate some additional economic activity in the region.

Benefits generated from watering at Gunbower Forest is conservatively estimated to be in the range of $1 million to $4 million per year at 2020, increasing to between $3 million and $8 million per year by 2030. When other ecosystem assets are also taken into account, for example the other Living Murray icon sites, the overall value of recreation related benefits provided by environmental watering is likely to be substantial.

One important limitation of the analysis was that it had to rely on a number of expert judgements and conservative assumptions to approximate the changes in site visitation that are attributable to environmental watering. This was necessary because of a lack of (longitudinal) visitation data available for the case study sites and because primary survey work was beyond the scope of this study. Results should thus be interpreted as a conservative indicative range.

Recommendation: It is recommended that strategic collection of visitor data for key recreation assets be undertaken as a priority monitoring activity under the environmental watering program. This should include visitor surveys which are designed with benefit valuation (i.e. travel cost method applications) in mind.

Existence and bequest vales

Socio-economic benefits from environmental water-dependent ecosystems extend beyond benefits generated from the direct use of the ecosystems (e.g. pollination, recreation). Some Victorians derive a benefit from the knowledge that these ecosystems exist in reasonable condition (referred to as 'existence values') and/or are available for future generations to use/enjoy (referred to as 'bequest values'). That is, they value an ecosystem (and its health/condition) even if they never have or never will use it.

The analysis undertaken as part of this study demonstrates that the contribution of environmental watering to existence and bequest benefits in the northern Victoria context are substantial – conservatively estimated to be in the order of $13 to $27 million per year, increasing to between $28 and $58 million per year by 2030.

It should be noted however there were a number of important limitations with this part of the analysis – in large part reflecting the inherent difficulty in quantifying non-use environmental values. In particular, the analysis relied on a number of pre-existing source studies which are now all more than 10 years old. It is very possible that community preferences for environmental improvements valued in these studies have shifted since this time – for example in the knowledge that the planet is now experiencing a sixth mass-extinction event. Also, the source studies did not disaggregate non-use values from other components of value that households derive from ecosystem improvement. This study has attempted to address this by apportioning relative values based on a rapid review of relevant economic literature.

Recommendation: Future research should be undertaken to gain a better understanding of the relative importance of existence and bequest benefits compared to other socio-economic benefits for the northern Victorian environmental watering context. In the first instance, this should involve a more extensive review of the literature expanding to other disciplines such as (social) anthropology.

Concluding remarks

The analytical framework developed as part of this assessment provides a logical and practical methodology for assessing the socio-economic benefits generated from environmental watering in northern Victoria.

This initial desktop application of the framework provides insight into the order-of-magnitude values of key benefit categories and, related to this, identifies priority areas for further data collection and research. Over time, and with additional data inputs, the application of the analytical framework can be progressively refined to generate more accurate results that can be incorporated into the monitoring and evaluation framework for the environmental watering program and used to inform ongoing learning for improvement.

Future applications of the analytical framework may consider expanding the coverage of the analysis to also include other socio-economic benefits that have been identified as potentially significant but not assessed in detail in this report due to time and resource constraints. These benefits include (i) cultural benefits to Traditional Owner groups, and (ii) erosion control services (avoided costs of river remediation works achieved through improved condition of in-stream and bank riparian vegetation and associated riverbank stabilization). A further benefit not investigated in this report but potentially worthy of future exploration relates to the contribution of environmental watering to a 'clean and green' branding of agriculture goods produced in northern Victoria.

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APPENDIX 1. METHOD FOR ASSESSING ECOSYSTEM CONDITION CHANGES ATTRIBUTABLE TO ENVIRONMENTAL WATERING

Victoria's environmental watering program aims to preserve and improve the environmental values and health of water ecosystems across the state. Environmental watering aims to achieve outcomes across a multitude of ecosystem attributes including fish and bird populations, vegetation health and water quality.

The biophysical assessment determines how the intervention of environmental watering within priority river, wetland, and floodplain ecosystems throughout northern Victoria has contributed to changes in water quality parameters, and fish, bird and vegetation population condition, extent and/or function.

The assessment was based on analysis of available datasets and through the establishment of case studies. Where appropriate, the outcomes of these case studies have been extrapolated to broader assets across northern Victoria.

The following sections outline the overarching methodology to biophysical assessment and how the methodology has been applied for each ecosystem attribute – fish and bird populations, vegetation condition and water quality.

Ecosystem assets

The northern Victorian region contains a diverse range of high-value river, wetland and floodplain assets that can receive water for the environment. This report focuses assets within the Goulburn-Broken, North Central and Mallee Catchment Management Authority regions.

The key tributaries in the region include the Broken, Goulburn, Campaspe and Loddon Rivers and Broken Creek, all of which flow into the Murray River system. The Murray system supports a number of large, iconic floodplain sites, which include Barmah Forest, Gunbower Forest, Hattah Lakes, Lindsay-Mulcra and Wallpolla Island, as well as being the supply source for a number of off-channel wetlands. The Loddon, Goulburn and Broken systems also support a myriad of wetland systems that are supplied predominantly through irrigation infrastructure.

These assets support a broad diversity of vegetation communities, water-dependent fauna, and provide a range of important ecosystem functions.

Overview of the methodology for assessing how environmental water contributes to improvements in ecosystem extent, condition and/or function

The biophysical assessment analyses the changes in ecosystem extent, condition and/or function and quantifies the contribution environmental water played in the identified change.

Environmental watering began being implemented in Victoria in the 1990s. Significant water recovery programs commenced in mid-2000s with the establishment of The Living Murray (TLM) Program and the expansion of environmental water entitlements in Victorian river and wetland systems following water resource assessment projects across the state. A range of comprehensive condition and intervention monitoring programs also commenced in the mid-2000s, to capture outcomes from environmental watering actions.

The following analysis was undertaken with reference to an observed condition at a time prior to the commencement of large-scale environmental watering activities in the northern Victoria. Despite environmental watering occurring in some parts of northern Victoria prior to this time, there is generally an absence of detailed monitoring data prior to mid-2000. The data available from the period from 2003 to 2010 has been used to inform the 'without' environmental water scenario. This ‘without’ environmental water scenario was used to compare to the outcomes achieved following the large-scale implementation of Victoria’s environmental watering program (the ‘with’ environmental water scenario) – from 2010 to 2019 (present year). The differences between these scenarios are the changes (i.e. environmental and socio-economic outcomes) that are attributable to environmental watering, as outlined in Figure 14.

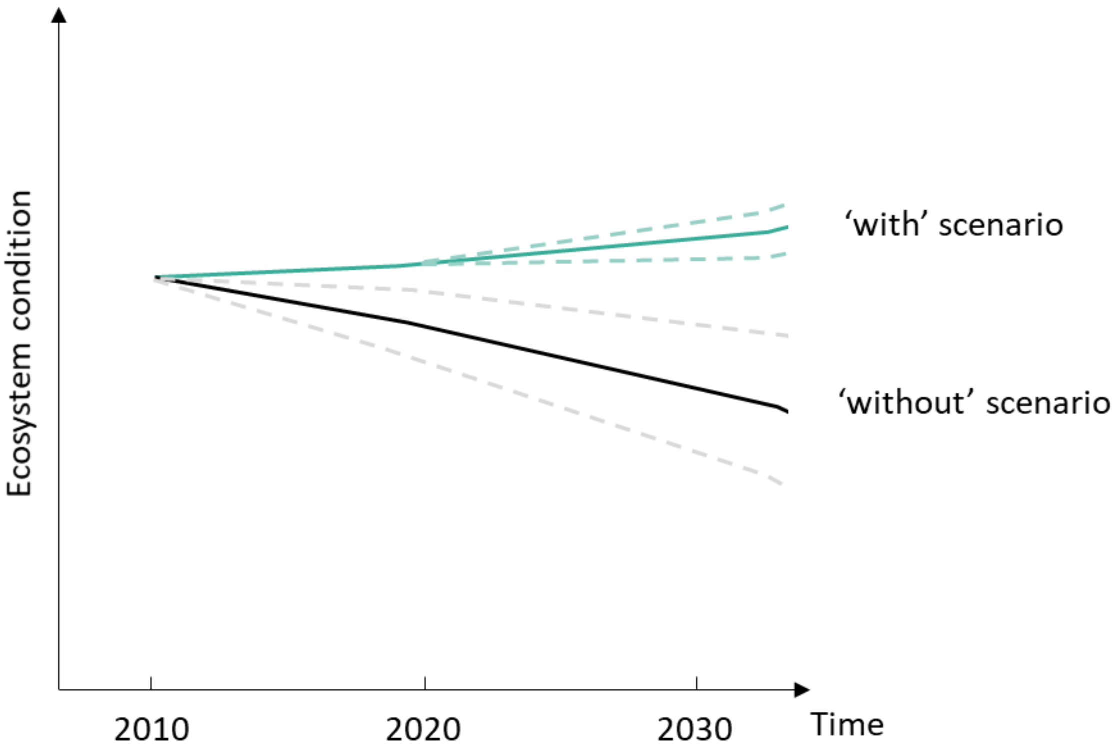

Figure 14. Conceptual ‘with’ and ‘without’ environmental water scenarios

The point-in-time for assessment established for the ‘without’ scenario for each attribute has been determined based on the availability of monitoring data. As a result, the timeframe differs for each attribute, however, all data falls within the period between 2003 and 2010. Insufficient reliable data on ecosystem condition is available prior to this time.

Given the typically long-time frames (e.g. >15 years) under which changes in ecosystem condition are likely to be observed, the ‘with’ scenario included an assessment of the expected trajectory of ecosystem change at 2030. This was determined by extrapolating the benefits provided by the environmental watering program to date, using the targets established in the Long-term Environmental Watering Plan for Northern Victoria (DELWP, 2015) and expert opinion. This process was designed to ensure the environmental and socio-economic benefits identified through the project are not limited to assessment of the outcomes for the program to date, which are likely to significantly underestimate future benefit.

Uncertainty in the scenario analysis was accounted for by also incorporating ‘low’ and ‘high’ range estimates – in addition to the ‘most-likely’ central estimate of the annual rate of change described in the paragraphs above. For the ‘without’ scenario, low and high range scenarios were conservatively assumed to be ±50 per cent of the ‘most-likely’ estimate of annual rate of change - reflecting the limited research and practical experience available to reliably establish this situation. For the ‘with’ scenario, low and high range scenarios were conservatively assumed to be ±25 per cent of the ‘most-likely’ estimate of annual rate of change - reflecting the relatively greater amount of research and practical experience available to reliably establish this future state. Further detail on how uncertainty was incorporated into the assessment using the monte-carlo simulation process can be found in Section 4 of this report.

Assessing the relative contribution of environmental water to ecosystem change

A multitude of complex environmental factors influence the condition of ecosystem assets, including both natural events and processes, and those attributable to human intervention. Environmental water is one of many management interventions that can be implemented to influence change in ecosystem condition. In many cases a combination of interventions will be necessary to drive improvement.

As such, an assessment was made to determine the relative contribution of environmental water in influencing any identified ecosystem change, where this isn't already considered in the monitoring program design. Established research and/or expert opinion was used to determine the relative contribution, as per Table 19 below. This corresponded to a reduction factor (for both the relative contribution and uncertainty assessments) that was applied to scale the ecosystem condition outputs.

Table 19. Relative contribution of environmental water to ecosystem change

Very low (0)	Low (0.25)	Moderate (0.5)	High (0.75)	Very high (1)
Environmental water management has little to no direct influence on ecosystem change	Environmental water management has a low degree of influence on ecosystem change	Environmental water management has some degree of influence on ecosystem change	Environmental water management has a significant influence on ecosystem change	Environmental water management is the predominant driver of ecosystem change

The level of uncertainty in the assessment of the relative contribution of environmental watering to the ecosystem change was categorised according to Table 20. Further detail on how uncertainty was incorporated into the assessment using the monte-carlo simulation process can be found in Section 4 of this report.

Table 20. Uncertainty in the assessment of the relative contribution of environmental water to ecosystem change

Low (0.1)	Moderate (0.25)	High (0.5)
There is a high degree of confidence in the assessment of the relative contribution of environmental water to ecosystem change through established research and practical experience	There some degree of confidence in the assessment of the relative contribution of environmental water to ecosystem change through practical experience	There is a low degree of confidence in the assessment of the relative contribution of environmental water to ecosystem change due to an absence of established research and practical experience

The following sections outline the methodology used to determine how environmental water has influenced change for each ecosystem attribute (fish, waterbirds, vegetation and water quality).

Assessing change in native fish populations

Environmental watering aims to achieve a variety of outcomes for native fish, supporting healthy and diverse populations in Victoria in rivers, wetlands and floodplains.

Native fish populations are affected by a broad range of waterway and catchment health attributes, as outlined in Figure 15 (DELWP, 2017). Many of these important population processes, such as fish spawning and dispersal, are flow-driven. Environmental flows play a key role in supporting these processes, particularly in highly regulated river systems.

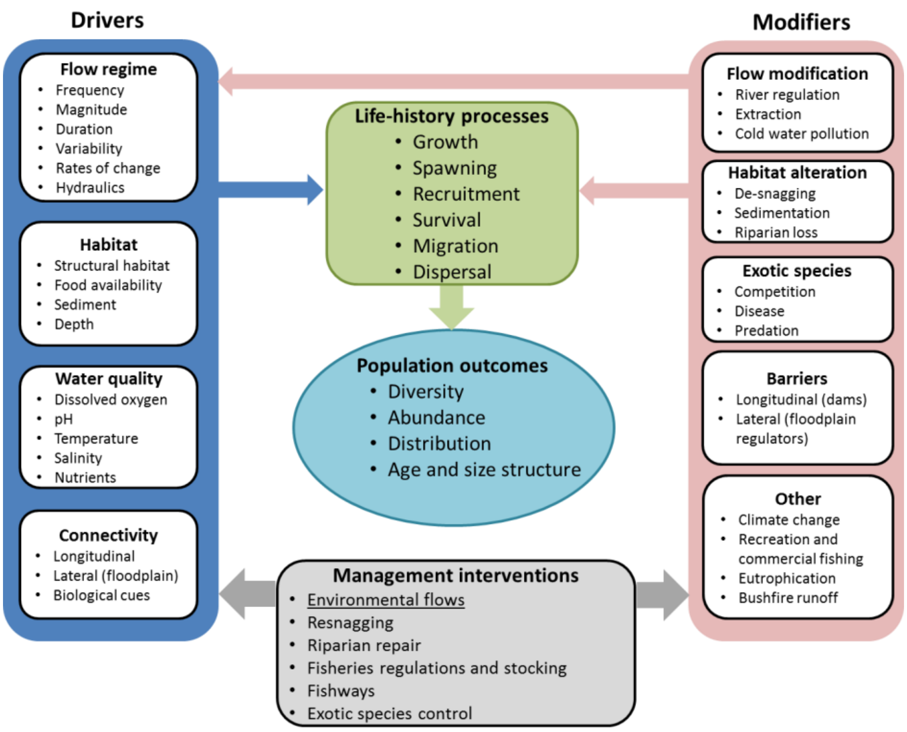

Figure 15. Overarching conceptual model underpinning the key drivers (dark blue) and modifiers (pink) of fish life-history processes (green) and subsequent population outcomes. Example of management interventions (including environmental flows) influencing these drivers and modifiers also included. Important attributes of each driver, modifier, life-history process, population outcome and interventions provided as bullet points.

Long-term monitoring of fish populations has been undertaken through the Victorian Environmental Flow and Assessment Program (VEFMAP) since the late-2000's in the Campaspe, Loddon, Goulburn and Broken river systems. Similarly, fish condition monitoring has been undertaken as part of the Living Murray Program in Gunbower and Barmah forests, Hattah Lakes and Lindsay and Wallpolla islands. These programs generally capture annual data on species abundance, diversity and size classes.

These long-term programs have been supplemented by intervention-based monitoring in recent years, to improve confidence in the link between environmental water management and fish population outcomes.

The analysis of changes in fish population outcomes focuses on flow-dependent, large-bodied native fish, specifically Golden perch and Murray cod. These fish are a focus of environmental watering in most northern Victorian rivers and some Living Murray Icon Sites and are recognized as important recreational fishing species.

The assessment focuses on the patterns of relative abundance over time. The assessment is limited to this element of fish life-history and population processes due to data availability constraints.

The underlying assumptions for the 'with' and 'without' environmental water scenarios are detailed in Table 21, with the conceptual trajectories applied for this assessment illustrated in Figure 16. Outputs for each individual asset are presented in Table 22.

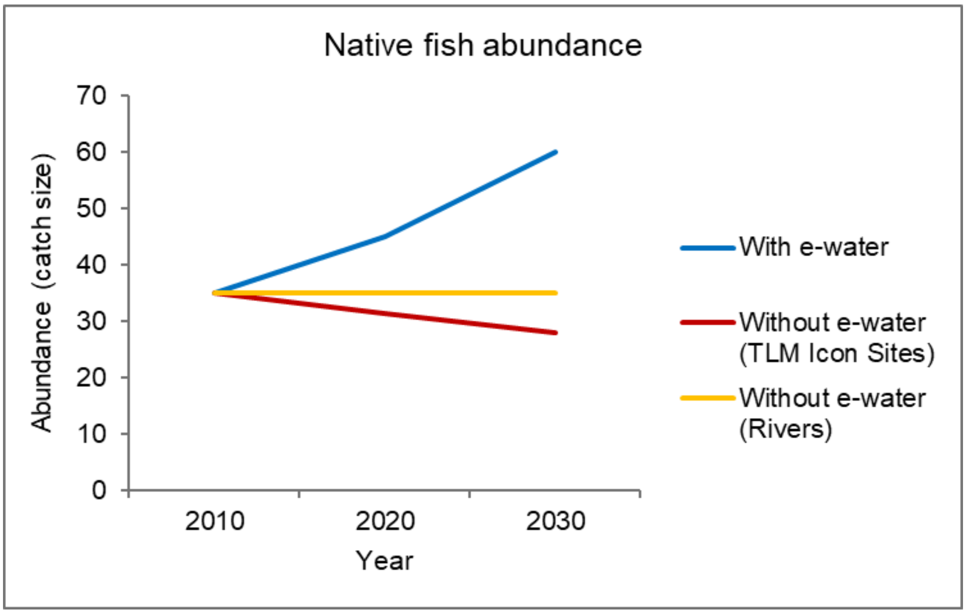

Figure 16. Conceptual native fish abundance 'with' and 'without' scenario trajectories

Table 21. Summary of data sources and key assumptions in fish condition assessment

Data sources and key assumptions	
Metric assessed	Large bodied native fish abundance (Golden perch and Murray cod catch data)
Data sources	*Rivers:* VEFMAP fish sampling *The Living Murray icon sites:* The Living Murray fish condition monitoring program
'With' environmental water trajectory assumptions	A positive linear trajectory informed by actual catch data for each system (2007-2018). Variance: ± 25% (based on expert opinion)
'Without' environmental water trajectory assumptions	*The Living Murray icon sites:* 1% reduction in abundance per year based on data from the Native Fish Strategy for the Murray-Darling Basin 2003-2013 (MDBC, 2003), which identifies that 'native fish populations are currently estimated to be about 10 per cent of their pre-European settlement levels. Without any intervention this is likely to fall to 5 per cent over the next 40 to 50 years' (50% decline over 50 years = 1% decline/year). *Rivers:* maintenance of 2010 abundance (due to the small catch sizes in VEFMAP sampling). Variance: ± 50% (based on expert opinion)
Attribution and uncertainty assessment approach	Expert opinion – Mark Stacey, Amanda Shipp and Tori Perrin, with review from CMA environmental water managers.
Limitations and data gaps	- The assessment focused on Golden perch and Murray cod due to the availability of long-term data, and on the basis that they are popular recreational fishing species (providing clear links to the 'recreational services' assessment). Despite long-term data being collected on these species, low catch numbers of large-bodied native fish through the VEFMAP program limit the ability to infer more meaningful outcomes for life-history and population processes including age and size structure, recruitment and survivorship.

Data sources and key assumptions	
	- No wetland sites have been selected for the assessment of outcomes for fish, as watering objectives in wetlands are predominately related to small-bodied native fish, vegetation, waterbird, frog and turtle outcomes. The known exception to this is wetlands managed to support populations of Murray Hardyhead. Despite the fish outcomes at these wetlands being derived almost solely as a result of environmental water management, the outcomes cannot be extrapolated to other wetland sites across northern Victoria and therefore are not proposed to be included in the assessment.

Table 22. Fish abundance outputs

CMA	Asset class	Asset name	Area (ha) or length (km – river asset)[30]	Golden perch and Murray cod abundance (number of individuals)[31]					Attribution factor (vl, l, m, h, vh)	Uncertainty (h, m, l)	Comments
				2010	2020	2030	2020 without e-water	2030 without e-water			
NCCMA	The Living Murray icon site	Gunbower Creek & Forest	19,450 ha	34	101	169	31	27	Moderate	Moderate	Environmental water provides a substantial contribution to support targeted flows in the system, however consumptive water deliveries through Gunbower Creek are significant.
MCMA		Lindsay, Wallpolla, Mulcra Islands	26154	201	238	317	181	161	High	Low	Influence of environmental water is significant in delivering outcomes for fish, as without active management, only small parts of the system receive consumptive water en route to support fish populations.
GBCMA		Barmah-Millewa Forest	28500	105	110	140	95	84	Moderate	Moderate	There is some active management of environmental water to improve outcomes for fish, however it isn't clear how influential this is, particularly given the delivery of consumptive water en route results in water into these sites. Note: analysis includes permanently flowing sites only.

[30] Source: individual site-based Environmental Water Management Plans or Mapshare Victoria website

[31] Refer to Table 21 for data sources

CMA	Asset class	Asset name	Area (ha) or length (km – river asset)[30]	Golden perch and Murray cod abundance (number of individuals)[31]					Attribution factor (vl, l, m, h, vh)	Uncertainty (h, m, l)	Comments
				2010	2020	2030	2020 without e-water	2030 without e-water			
MCMA		Hattah Lakes	13000	78	63	87	70	62	V High	Low	Influence of environmental water is significant in delivering outcomes for fish. Without active management, only small parts of the system would receive inundation during flood events.
NCCMA	River	Campaspe River	232	10	46	85	10	10	High	Moderate	A significant proportion of targeted flow regime is provided by environmental water, though consumptive deliveries are increasingly being delivered en route, predominantly over the summer period.
GBCMA		Goulburn River	570	18	270	270	18	18	Moderate	Moderate	Environmental water provides a substantial contribution to flow in the system. Consumptive water deliveries are also significant however often at times that are not optimal for fish outcomes.
NCCMA		Loddon River	392	7	50	78	7	7	V High	Low	A significant proportion of the targeted flow regime is provided through the delivery of environmental water.
GBCMA		Broken River	174	21	176	327	21	21	Low	Moderate	The proportion of flow regime that is provided through environmental water is very small.

Assessing change in vegetation communities

Riparian, floodplain and wetland vegetation communities underpin a variety of ecological functions. They provide refuge, breeding habitat and food sources for a wide variety of organisms (including fish and waterbirds) and play a role in reducing erosion, cycling nutrients and carbon and improving water quality.

The provision of appropriate wetting and drying regimes is critical in supporting the long-term health of vegetation communities and the important ecosystem functions they provide. Due to the highly regulated nature of northern Victorian waterways, environmental water plays an important role in supporting the hydrological needs of wetland, riparian and floodplain vegetation communities.

This occurs directly through the inundation of vegetation and wetting of soil that in turn contributes to vegetation growth and health, reproduction and dispersal. Figure 17 outlines the conceptual understanding of the relationships between inundation regime and tree health, as well as the other characteristics and stressors that influence vegetation outcomes.

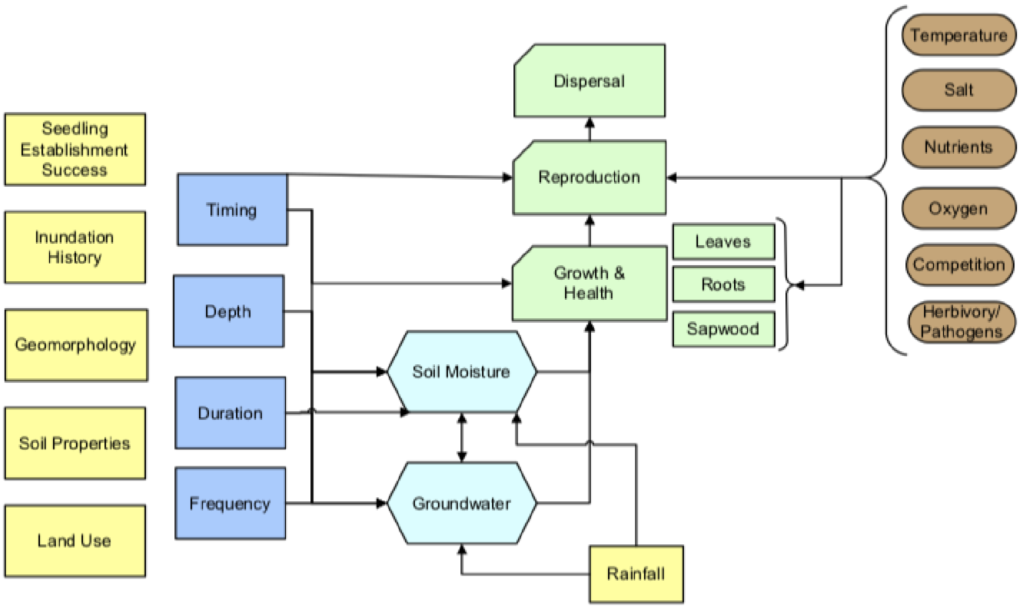

Figure 17. Conceptual model summarising the main relationships between inundation regime characteristics and tree growth and health.

Yellow boxes are modifying factors, blue boxes indicate flooding regime characteristics, light blue hexagons are primary controls, green boxes are response components and brown ovals are potential stressors (MBDA, 2009).

The underlying assumptions for the 'with' and 'without' environmental water scenarios are detailed in Table 23, with the conceptual trajectories applied for this assessment illustrated in Figure 18. Outputs for each individual asset are presented in Table 24.

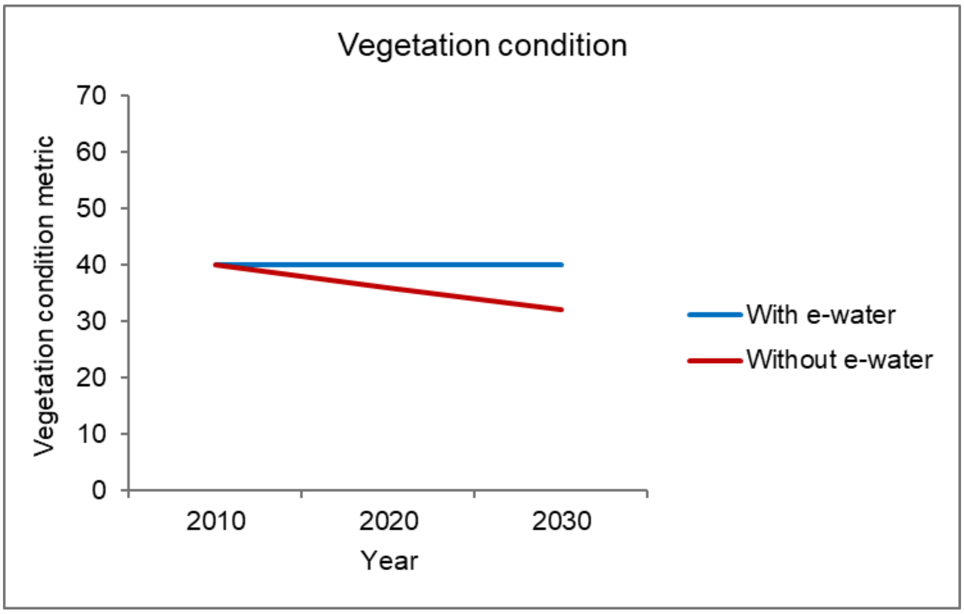

Figure 18. Conceptual vegetation condition 'with' and 'without' scenario trajectories

Table 23. Summary of data sources and key assumptions in vegetation condition assessment

Data sources and key assumptions	
Metric assessed	*The Living Murray Icon Sites:* The Living Murray 'River Red Gum forest' stand condition – percentage of forest in good or moderate condition. *Rivers:* ISC streamside zone sub-index score *Wetlands:* Index of Wetland Condition (IWC) biota sub-index score
Data sources	*The Living Murray Icon Sites:* Icon site Stand Condition Assessments of forests and woodlands - 2015 (MDBA, 2016) *Rivers:* ISC streamside zone sub-index score (DSE 2005, DEPI 2013) *Wetlands:* Index of Wetland Condition (IWC) biota sub-index score (DSE, 2012)
'With' environmental water trajectory assumptions	Condition will be maintained at 2010 levels, consistent with objectives set in Northern Victorian LTEWP (DELWP, 2015). Variance: ± 25% (based on expert opinion)
'Without' environmental water trajectory assumptions	2% decline in condition per year based on MDBA stand condition modeling (Cunningham et al, 2009) that predicted the net decline in the percentage area of Murray River floodplain in 'good condition' from 2003-2009 was 12.5% (equating to an approximate 2% reduction per year). In the absence of information on condition trajectories for riparian and wetland vegetation, the same 2% predicted annual decline in condition has been applied to river and wetland assets. Variance: ± 50% (based on expert opinion)
Attribution and uncertainty assessment approach	Expert opinion – Mark Stacey, Amanda Shipp and Tori Perrin, with review from CMA environmental water managers.
Limitations and data gaps	- River Red Gum forest stand condition was selected as the most applicable metric to assess change across Living Murray Icon Sites, given environmental water management has yet to achieve regular and significant inundation of higher elevation vegetation communities.

Data sources and key assumptions	
	- The monitoring period used to determine the 'without' environmental water trajectory (based on the decline in condition of River Red Gum forest during 2003-2009) occurred during the Millenium drought. This may result in the assessment overestimating the decline in condition expected under the 'without' trajectory. A high variance (± 50%) has been included in the assessment to account for some of this uncertainty. - The methodologies applied to determine the streamside zone vegetation sub-index in the Index of Stream Condition (2010) did vary from the 2004 assessment, with remote sensing technology used as the primary data source. This resulted in understory metrics (species identity and diversity) no longer informing the assessment. Despite environmental watering actions generally targeting these vegetation communities more so than overstorey species, the ISC remains the best available long-term condition snapshot on streamside vegetation condition for Victorian rivers. - For sites in the North Central CMA region where no assessment was completed, IWC assessments undertaken in 2012 and 2014 were adopted as the condition at 2010. Only 9 wetlands in the Mallee CMA region had IWC assessments completed in 2010. The average score of these 9 wetlands (10.1) was adopted as the 2010 condition for all remaining Mallee wetlands.

Table 24. Vegetation condition assessment outputs

CMA	Asset class	Asset name	Area (ha) or length (km – river assets)[32]	Vegetation condition: • The Living Murray sites –Percentage of River Red Gum forest in good or moderate condition • Rivers – ISC streamside zone sub-index score • Wetlands – IWC biota sub-index score					Attribution factor (vl, l, m, h, vh)	Uncertainty (h, m, l)	Comments
				2010	2020	2030	2020 without e-water	2030 without e-water			
NCCMA	Living Murray icon site	Gunbower Creek & Forest	19,450	83.2	83.2	83.2	66.56	49.92	High	Low	High flows in the Murray system results in some parts of Gunbower's River Red Gum forest areas receiving water in the absence of environmental water. However, the use of environmental water has substantially contributed to maintaining the health of the forest.
MCMA	Living Murray icon site	Lindsay, Wallpolla, Mulcra Islands	26,156	90.2	90.2	90.2	72.16	54.12	V High	Low	Influence of environmental water is significant in delivering outcomes for River Red Gum forest condition, as without active management the majority of the forest would not receive flow except during flood events.
GBCMA	Living Murray icon site	Barmah-Millewa Forest	28,500	95.8	95.8	95.8	76.64	57.48	Moderate	Low	The delivery of high flows in the Murray system (and the delivery of consumptive water en route?) results in water in some parts of River Red Gum forest receiving

[32] Source: individual site-based Environmental Water Management Plans or Mapshare Victoria website

CMA	Asset class	Asset name	Area (ha) or length (km – river assets) [32]	Vegetation condition: • The Living Murray sites –Percentage of River Red Gum forest in good or moderate condition • Rivers – ISC streamside zone sub-index score • Wetlands – IWC biota sub-index score					Attribution factor (vl, l, m, h, vh)	Uncertainty (h, m, l)	Comments
				2010	2020	2030	2020 without e-water	2030 without e-water			
											water in the absence of environmental water. However, the use of environmental water has substantially contributed to maintaining the health of the forest.
MCMA	Living Murray icon site	Hattah Lakes	13,000	74.7	74.7	74.7	59.76	44.82	V High	Low	Influence of environmental water is significant in delivering outcomes for River Red Gum forest condition, as without active management the majority of the forest would not receive flow except during flood events.
NCCMA	River	Campaspe River	232	6.33	6.33	6.33	5.07	3.80	Low	High	The apparent change in streamside zone condition between 2004 and 2010 is unlikely to be due to actual on-ground change, but rather a reflection of the change in methodology used in the assessment. Given very little environmental water was delivered in these systems prior to 2010, the influence of environmental water in contributing to condition
GBCMA	River	Goulburn River	570	7.36	7.36	7.36	5.89	4.41	Low	High	
NCCMA	River	Loddon River	392	6.44	6.44	6.44	5.16	3.87	Low	High	
GBCMA	River	Broken Creek	184	6.67	6.67	6.67	5.33	4.00	Low	High	
GBCMA	River	Broken River	174	7.50	7.50	7.50	6.00	4.50	Low	High	

CMA	Asset class	Asset name	Area (ha) or length (km – river assets) [32]	Vegetation condition: • The Living Murray sites –Percentage of River Red Gum forest in good or moderate condition • Rivers – ISC streamside zone sub-index score • Wetlands – IWC biota sub-index score					Attribution factor (vl, l, m, h, vh)	Uncertainty (h, m, l)	Comments
				2010	2020	2030	2020 without e-water	2030 without e-water			
											change in this time is considered low.
GBCMA	Wetland	Black Swamp	27	10.6	10.6	10.6	8.4	6.3	High	Moderate	Environmental water delivery has a significant influence on wetland vegetation condition. In the absence of environmental watering, many of these wetlands will only receive water during floods or periods of significant rainfall.
GBCMA	Wetland	Doctors Swamp	225	18.1	18.1	18.1	14.5	10.9	High	Moderate	
GBCMA	Wetland	Gaynor Swamp	300	4.0	4.0	4.0	3.2	2.4	High	Moderate	
GBCMA	Wetland	Kinnairds Wetland	97	14.0	14.0	14.0	11.2	8.4	High	Moderate	
GBCMA	Wetland	Moodie Swamp	180	17.6	17.6	17.6	14.1	10.6	High	Moderate	
GBCMA	Wetland	Reedy Swamp	130	15.4	15.4	15.4	12.3	9.2	High	Moderate	
NCCMA	Wetland	Hirds Swamp	344	7.3	7.3	7.3	5.8	4.4	High	Moderate	
NCCMA	Wetland	Johnson Swamp	399	5.4	5.4	5.4	4.3	3.2	High	Moderate	
NCCMA	Wetland	Lake Cullen	629	17.0	17.0	17.0	13.6	10.2	High	Moderate	
NCCMA	Wetland	Lake Elizabeth	94	15.8	15.8	15.8	12.6	9.5	High	Moderate	
NCCMA	Wetland	Lake Meran	172	12.5	12.5	12.5	10.0	7.5	High	Moderate	

CMA	Asset class	Asset name	Area (ha) or length (km – river assets) [32]	Vegetation condition: • The Living Murray sites –Percentage of River Red Gum forest in good or moderate condition • Rivers – ISC streamside zone sub-index score • Wetlands – IWC biota sub-index score					Attribution factor (vl, l, m, h, vh)	Uncertainty (h, m, l)	Comments
				2010	2020	2030	2020 without e-water	2030 without e-water			
NCCMA	Wetland	Lake Murphy	172	5.9	5.9	5.9	4.7	3.5	High	Moderate	
NCCMA	Wetland	Lake Yando	78	11.1	11.1	11.1	8.9	6.6	High	Moderate	
NCCMA	Wetland	McDonalds Swamp	164	5.9	5.9	5.9	4.7	3.5	High	Moderate	
NCCMA	Wetland	Richardsons Lagoon	120	16.0	16.0	16.0	12.8	9.6	High	Moderate	
NCCMA	Wetland	Round Lake	40	16.1	16.1	16.1	12.9	9.7	High	Moderate	
NCCMA	Wetland	Wirra-Lo wetland complex	67	8.9	8.9	8.9	7.1	5.4	High	Moderate	
MCMA	Wetland	Brickworks Billabong	15	10.1	10.1	10.1	8.1	6.0	High	Moderate	
MCMA	Wetland	Bridge Creek**	26	10.1	10.1	10.1	8.1	6.0	High	Moderate	
MCMA	Wetland	Bullock Swamp**	428	10.1	10.1	10.1	8.1	6.0	High	Moderate	
MCMA	Wetland	Burra Creek North	3,642	9.0	9.0	9.0	7.2	5.4	High	Moderate	
MCMA	Wetland	Burra Creek South		9.0	9.0	9.0	7.2	5.4	High	Moderate	

CMA	Asset class	Asset name	Area (ha) or length (km – river assets) [32]	Vegetation condition: • The Living Murray sites –Percentage of River Red Gum forest in good or moderate condition • Rivers – ISC streamside zone sub-index score • Wetlands – IWC biota sub-index score					Attribution factor (vl, l, m, h, vh)	Uncertainty (h, m, l)	Comments
				2010	2020	2030	2020 without e-water	2030 without e-water			
MCMA	Wetland	Burra Creek South Proper		9.0	9.0	9.0	7.2	5.4	High	Moderate	
MCMA	Wetland	Butlers	116	10.1	7.6	7.6	8.1	6.0	High	Moderate	
MCMA	Wetland	Cardross Lake	81	6.0	4.5	4.5	4.8	3.6	High	Moderate	
MCMA	Wetland	Carina Bend	136	10.1	7.6	7.6	8.1	6.0	High	Moderate	
MCMA	Wetland	Cowanna Billabong	12	10.1	7.6	7.6	8.1	6.0	High	Moderate	
MCMA	Wetland	Heywoods Lake	163	14.4	10.8	10.8	11.5	8.6	High	Moderate	
MCMA	Wetland	J1 Creek (Yungera Wetland)	11	10.1	7.6	7.6	8.1	6.0	High	Moderate	
MCMA	Wetland	Lake Carpul	62	16.5	12.4	12.4	13.2	9.9	High	Moderate	
MCMA	Wetland	Lake Hawthorn	148	10.1	7.6	7.6	8.1	6.0	High	Moderate	
MCMA	Wetland	Lake Koorlong	12	10.1	7.6	7.6	8.1	6.0	High	Moderate	
MCMA	Wetland	Lake Powell	128	8.9	6.7	6.7	7.1	5.3	High	Moderate	

CMA	Asset class	Asset name	Area (ha) or length (km – river assets) [32]	Vegetation condition: • The Living Murray sites –Percentage of River Red Gum forest in good or moderate condition • Rivers – ISC streamside zone sub-index score • Wetlands – IWC biota sub-index score					Attribution factor (vl, l, m, h, vh)	Uncertainty (h, m, l)	Comments
				2010	2020	2030	2020 without e-water	2030 without e-water			
MCMA	Wetland	Liparoo East	253	10.1	7.6	7.6	8.1	6.0	High	Moderate	
MCMA	Wetland	Liparoo West		10.1	7.6	7.6	8.1	6.0	High	Moderate	
MCMA	Wetland	Little Heywood Lake	25	10.1	7.6	7.6	8.1	6.0	High	Moderate	
MCMA	Wetland	Lock 15 wetlands	100	10.1	7.6	7.6	8.1	6.0	High	Moderate	
MCMA	Wetland	Margooya Lagoon	44	8.5	6.4	6.4	6.8	5.1	High	Moderate	
MCMA	Wetland	Merbein Common	139	10.1	7.6	7.6	8.1	6.0	High	Moderate	
MCMA	Wetland	Neds Corner East and Central	100	10.1	7.6	7.6	8.1	6.0	High	Moderate	
MCMA	Wetland	Nyah Floodplain	500	9.9	7.4	7.4	7.9	5.9	High	Moderate	
MCMA	Wetland	Outlet Creek (Karadoc Swamp)	1,360	10.1	7.6	7.6	8.1	6.0	High	Moderate	

CMA	Asset class	Asset name	Area (ha) or length (km – river assets) [32]	Vegetation condition: • The Living Murray sites –Percentage of River Red Gum forest in good or moderate condition • Rivers – ISC streamside zone sub-index score • Wetlands – IWC biota sub-index score					Attribution factor (vl, l, m, h, vh)	Uncertainty (h, m, l)	Comments
				2010	2020	2030	2020 without e-water	2030 without e-water			
MCMA	Wetland	Parnee Malloo Creek	100	10.1	7.6	7.6	8.1	6.0	High	Moderate	
MCMA	Wetland	Psyche Bend Lagoon**	53	10.1	7.6	7.6	8.1	6.0	High	Moderate	
MCMA	Wetland	Robertsons wetland	100	10.1	7.6	7.6	8.1	6.0	High	Moderate	
MCMA	Wetland	Sandilong Ck	9	10.1	7.6	7.6	8.1	6.0	High	Moderate	
MCMA	Wetland	Vinifera Floodplain	350	9.9	7.4	7.4	7.9	5.9	High	Moderate	
MCMA	Wetland	Woorlong Wetland	153	7.6	5.7	5.7	6.1	4.5	High	Moderate	
MCMA	Wetland	Yungera	11	10.1	7.6	7.6	8.1	6.0	High	Moderate	

Assessing changes in waterbird populations

Waterbirds rely on healthy floodplain and wetland ecosystems for the provision of food and shelter and to support roosting, nesting and breeding. Many birds move significant distances to find suitable habitats, both seasonally and in response to natural events (such as heavy rainfall and floods).

Different waterbirds require different habitats for feeding, roosting and breeding – and most move between habitats to meet these needs. Maintaining a mosaic of habitats across the landscape is important in supporting waterbird distribution and abundance.

Environmental water management aims to support healthy and productive ecosystems, which in turn support abundant and diverse waterbird assemblages. Environmental water has also been used to extend the duration of natural flooding to support waterbird breeding activity.

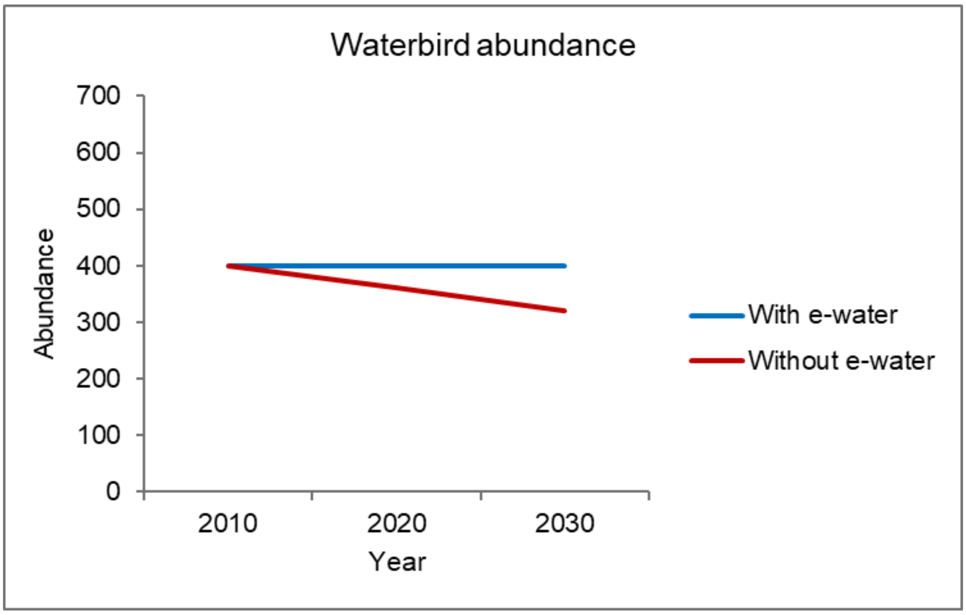

Figure 19. Conceptual waterbird abundance ‘with’ and ‘without’ scenario trajectories

The underlying assumptions for the ‘with’ and ‘without’ environmental water scenarios are detailed in Table 25, with the conceptual trajectories applied for this assessment illustrated in Figure 19. Outputs for each individual asset are presented in Table 26.

Table 25. Summary of data sources and key assumptions in waterbird assessment

Data sources/key assumptions	
Metric assessed	Waterbird abundance
Data sources	CMA records and Living Murray waterbird condition monitoring program
‘With’ environmental water trajectory assumptions	Abundance will be maintained at 2010 levels, which is broadly consistent with trends in CMA data and observations made in MDBA's Basin Plan Evaluation (2017), which notes that 'while populations have continued to decline over the past few decades, the rate of population decline has progressively decreased and populations may now be in the process of stabilising.' Variance: ± 25% (based on expert opinion)

Data sources/key assumptions	
‘Without’ environmental water trajectory assumptions	2% reduction in abundance per year, based on conclusions by Kingsford et al (2013) that waterbird abundance across the Murray Darling Basin has reduced by at least 70% since the early 1980's (an approximate 70% reduction over 40 years). Variance: ± 50% (based on expert opinion)
Attribution and uncertainty assessment approach	Expert opinion – Mark Stacey, Amanda Shipp and Tori Perrin, with review from CMA environmental water managers.
Limitations and data gaps	- No waterbird data was available for wetlands in the Mallee CMA region. Average waterbird abundance at Goulburn Broken and North Central CMA wetlands with similar IWC condition scores were adopted to as 2010 abundance at Mallee sites. - The sampling frequency and methods used to capture waterbird abundance varied between CMA regions, making the results somewhat difficult to compare (e.g. some sampling occurred at a set frequency, some occurred only during watering events, flooding hampered the ability to sample some sites but not others). Where a series of sampling events occurred in one year, the average of all sampling events in that year was used to inform the observed abundance.

Table 26. Waterbird abundance outputs

CMA	Asset class	Asset name	Area (ha)[33]	Waterbird abundance (number of individuals)					Attribution factor (vl, l, m, h, vh)	Uncertainty (h, m, l)	Comments
				2010	2020	2030	2020 without e-water	2030 without e-water			
NCCMA	Living Murray icon site	Gunbower Creek & Forest	19,450	164	164	164	131	98	High	Moderate	Environmental water is the primary source of water in many of these floodplain and wetland systems. Without the environmental watering program, there would not be sufficient inflows to these systems to support waterbird populations.
MCMA	Living Murray icon site	Lindsay, Wallpolla, Mulcra Islands	26,156	163	163	163	130	98	High	Moderate	
GBCMA	Living Murray icon site	Barmah-Millewa Forest	28,500	1381	1381	1381	1105	829	High	Moderate	
MCMA	Living Murray icon site	Hattah Lakes	13,000	310	310	310	248	186	High	Moderate	
GBCMA	Wetland	Black Swamp	27	153	153	153	122	92	High	Moderate	
GBCMA	Wetland	Doctors Swamp	225	31	31	31	25	19	High	Moderate	
GBCMA	Wetland	Gaynor Swamp	300	1890	1890	1890	1512	1134	High	Moderate	
GBCMA	Wetland	Kinnairds Wetland	97	112	112	112	90	67	High	Moderate	
GBCMA	Wetland	Moodie Swamp	180	133	133	133	106	80	High	Moderate	
GBCMA	Wetland	Reedy Swamp	130	3039	3039	3039	2431	1823	High	Moderate	
NCCMA	Wetland	Hirds Swamp	344	1209	1209	1209	967	726	High	Moderate	
NCCMA	Wetland	Johnson Swamp	399	1369	1369	1369	1096	822	High	Moderate	
NCCMA	Wetland	Lake Cullen	629	2161	2161	2161	1729	1297	High	Moderate	
NCCMA	Wetland	Lake Elizabeth	94	1609	1609	1609	1287	965	High	Moderate	

[33] Source: individual site-based Environmental Water Management Plans or Mapshare Victoria website

CMA	Asset class	Asset name	Area (ha)[33]	Waterbird abundance (number of individuals)					Attribution factor (vl, l, m, h, vh)	Uncertainty (h, m, l)	Comments
				2010	2020	2030	2020 without e-water	2030 without e-water			
NCCMA	Wetland	Lake Meran	172	150	150	150	120	90	High	Moderate	
NCCMA	Wetland	Lake Murphy	172	2318	2318	2318	1854	1391	High	Moderate	
NCCMA	Wetland	Lake Yando	78	426	426	426	341	256	High	Moderate	
NCCMA	Wetland	McDonalds Swamp	164	208	208	208	166	125	High	Moderate	
NCCMA	Wetland	Richardsons Lagoon	120	316	316	316	253	190	High	Moderate	
NCCMA	Wetland	Round Lake	40	1783	1783	1783	1427	1070	High	Moderate	
NCCMA	Wetland	Wirra-Lo wetland complex	67	544	544	544	435	327	High	Moderate	
MCMA	Wetland	Brickworks Billabong	15	721	721	721	577	433	High	Moderate	
MCMA	Wetland	Bridge Creek**	26	721	721	721	577	433	High	Moderate	
MCMA	Wetland	Bullock Swamp**	428	721	721	721	577	433	High	Moderate	
MCMA	Wetland	Burra Creek North	3,642	721	721	721	577	433	High	Moderate	
MCMA	Wetland	Burra Creek South		721	721	721	577	433	High	Moderate	
MCMA	Wetland	Burra Creek South Proper		721	721	721	577	433	High	Moderate	
MCMA	Wetland	Butlers	116	721	721	721	577	433	High	Moderate	
MCMA	Wetland	Cardross Lake	81	721	721	721	577	433	High	Moderate	
MCMA	Wetland	Carina Bend	136	721	721	721	577	433	High	Moderate	
MCMA	Wetland	Cowanna Billabong	12	721	721	721	577	433	High	Moderate	
MCMA	Wetland	Heywoods Lake	163	721	721	721	577	433	High	Moderate	
MCMA	Wetland	J1 Creek (Yungera Wetland)	11	721	721	721	577	433	High	Moderate	
MCMA	Wetland	Lake Carpul	62	1296	1296	1296	1037	778	High	Moderate	
MCMA	Wetland	Lake Hawthorn	148	721	721	721	577	433	High	Moderate	

CMA	Asset class	Asset name	Area (ha)[33]	Waterbird abundance (number of individuals)					Attribution factor (vl, l, m, h, vh)	Uncertainty (h, m, l)	Comments
				2010	2020	2030	2020 without e-water	2030 without e-water			
MCMA	Wetland	Lake Koorlong	12	721	721	721	577	433	High	Moderate	
MCMA	Wetland	Lake Powell	128	721	721	721	577	433	High	Moderate	
MCMA	Wetland	Liparoo East	253	721	721	721	577	433	High	Moderate	
MCMA	Wetland	Liparoo West		721	721	721	577	433	High	Moderate	
MCMA	Wetland	Little Heywood Lake	25	721	721	721	577	433	High	Moderate	
MCMA	Wetland	Lock 15 wetlands	100	721	721	721	577	433	High	Moderate	
MCMA	Wetland	Margooya Lagoon	44	721	721	721	577	433	High	Moderate	
MCMA	Wetland	Merbein Common	139	721	721	721	577	433	High	Moderate	
MCMA	Wetland	Neds Corner East and Central	100	721	721	721	577	433	High	Moderate	
MCMA	Wetland	Nyah Floodplain	500	721	721	721	577	433	High	Moderate	
MCMA	Wetland	Outlet Creek (Karadoc Swamp)	1,360	721	721	721	577	433	High	Moderate	
MCMA	Wetland	Parnee Malloo Creek	100	721	721	721	577	433	High	Moderate	
MCMA	Wetland	Psyche Bend Lagoon**	53	721	721	721	577	433	High	Moderate	
MCMA	Wetland	Robertsons wetland	100	721	721	721	577	433	High	Moderate	
MCMA	Wetland	Sandilong Ck	9	721	721	721	577	433	High	Moderate	
MCMA	Wetland	Vinifera Floodplain	350	721	721	721	577	433	High	Moderate	
MCMA	Wetland	Woorlong Wetland	153	721	721	721	577	433	High	Moderate	
MCMA	Wetland	Yungera	11	721	721	721	577	433	High	Moderate	

Assessing changes in water quality

Environmental watering contributes to improvements in water quality, which in turn benefit consumptive water users.

Water quality related benefits are achieved through the following two broad mechanisms:

- Regulation services provided by functioning of living systems (biotic service), including buffering functions provided by living vegetation (in-stream and alongside water courses) to remove nutrients in run-off. Environmental watering contributes to these functions through improvements to the condition of (in-stream and riparian) vegetation.
- Abiotic (non-living) processes directly associated with environmental watering. An example of this service is dilution and mixing effects provided by increased volume of water flow (e.g. dilution of salinity).

The water quality analysis focusses on assessing changes in salinity, and the frequency and duration of hypoxic blackwater and blue-green algae events – all of which have implications for the environment and consumptive water users.

The study explored data on these water quality parameters in northern Victorian rivers. However, outputs have only been derived for the Murray River due to the scale and incidence of the events being unlikely to have a meaningful influence on the socio-economic modelling.

Salinity levels at Morgan

It is expected that environmental water provides improved salinity outcomes, increasing water flow and the dilution of salt across the Murray-Darling Basin (MDBA, 2014).

The assessment of the benefits of environmental watering on salinity has been derived from modelling undertaken in MDBA's General Review of Salinity Management in the Murray-Darling Basin, completed in 2014. The report models the salinity levels at Morgan (in South Australia) under 2010 management arrangements and under Basin Plan water recovery targets, to forecast the benefit derived through increased flow associated with environmental water recovery.

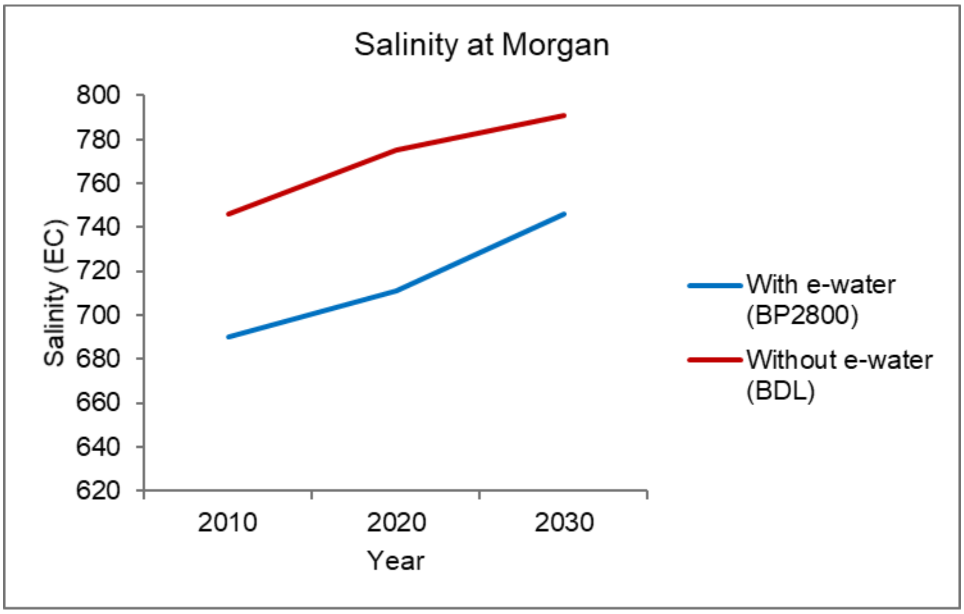

Figure 20. 'With' and 'without' environmental water outputs for salinity at Morgan

The underlying assumptions for the 'with' and 'without' environmental water scenarios are detailed in Table 27, with the conceptual trajectories applied for this assessment illustrated in Figure 20. Outputs for each individual asset are presented in Table 28.

Table 27. Summary of the data source used in salinity assessment

Data sources and key assumptions	
Metric assessed	Modeled 95th percentile salinity (electrical conductivity) at Morgan
Data Source	MDBA General Review of Salinity Management in the Murray-Darling Basin (2014)
'With' environmental water trajectory assumptions	Modeled 95th percentile salinity at Morgan under a 2800 GL Basin Plan water recovery scenario at 2010, 2020 and 2030, with the following reduction factors applied: - a 39% reduction factor to reflect Victoria's contribution to the 2800 GL water recovery target (which includes CEWH held water in Victoria) - an additional reduction factor of 13% to reflect the lower benefit derived under a reduced Basin Plan water recovery scenario (2400 GL). This is based on the reported reduction in the modeled average salinity benefit at Morgan from 58 to 50 EC (13%) when the water recovery is reduced from 2800 GL to 2400 GL.
'Without' environmental water trajectory assumptions	Modeled 95th percentile salinity at Morgan under the Baseline Diversion Limit at 2010, 2020 and 2030, reflecting management arrangements that were in place in June 2010.
Attribution and uncertainty assessment approach	As the modelling derives the salinity benefit directly associated with environmental watering, no further attribution or uncertainty assessment was considered necessary.
Limitations and data gaps	- Depending on the realized Basin Plan water recovery, the salinity benefit is likely to differ from the figures used above. No alternate water recovery options were modelled in this report.

Table 28. Salinity assessment outputs

Asset class	Asset name	Area (ha) or length (km)	Modelled 95th percentile salinity at Morgan					
			2010	2020	2030	2010 without e-water	2020 without e-water	2030 without e-water
River	Murray River	2200	690	711	727	746	775	791

Blackwater

Blackwater is a natural feature of lowland river systems that occurs when organic matter from floodplains is washed into rivers following flooding. The influx of organic matter into the river during warmer times of the year can lead to a sudden reduction in the availability of dissolved oxygen required to sustain aquatic organisms, leading to severe stress and often death (referred to as hypoxic blackwater).

Less frequent natural inundation of floodplain ecosystems results in the accumulation of large amounts of organic matter, which increases the risk of blackwater events when floods do occur.

Environmental water can sometimes be used to provide dilution flow and create critical refuges during hypoxic blackwater events (abiotic service). In addition, regular floodplain watering can assist in reducing the build-up of organic matter in these floodplain systems that can contribute to a reduction in the severity of flood-induced backwater events in the longer-term (biotic service).

Environmental water was released to provide dilution and refuge during blackwater events in 2012 and 2016 (Baldwin and Whitworth, 2013; Symes 2017). However, there is currently limited information available on the relative contribution of this more regular inundation in reducing litter loads and consequently the frequency and severity of blackwater events following large-scale natural flood events.

Given the lack of data available to inform this assessment, a hypothetical assessment has been completed based on the best available information. The dilution benefit has been determined based on observations by Baldwin and Whitworth (2013). For illustrative purposes, the benefit provided by environmental water in reducing litter accumulation on floodplains has been determined as providing half the relative quantum of the dilution benefit at 2030.

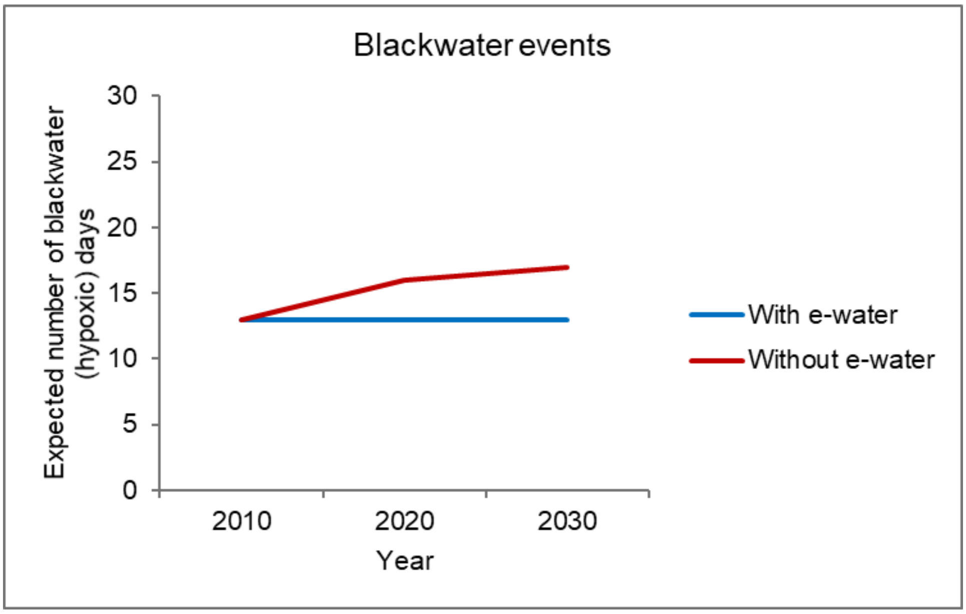

Figure 21. 'With' and 'without' environmental water outputs for blackwater

The underlying assumptions for the 'with' and 'without' environmental water scenarios are detailed in Table 29, with the conceptual trajectories applied for this assessment illustrated in Figure 21. Outputs for each individual asset are presented in Table 30.

Table 29. Summary of data sources and key assumptions in the blackwater assessment

Data sources and key assumptions	
Metric assessed	Average number of hypoxic blackwater days per year
Data sources	Baldwin and Whitworth (2013) and Symes (2017).
'With' environmental water trajectory assumptions	In the period from 2010 to 2019, 3 large hypoxic blackwater events occurred in the Murray system (in 2010, 2012 and 2016). There is limited quantitative evidence of the benefit of environmental watering in diluting hypoxic blackwater, however one study by Baldwin and Whitworth (2013) modelled the contribution of environmental water in providing dilution flow/refuge during a large-scale hypoxic blackwater event in the Murray system in 2012.

Data sources and key assumptions	
	The modelled duration of the hypoxic blackwater event (when dissolved oxygen was <4mg/L) was approximately 45 days. Environmental water released by the CEWH successfully reduced the duration of the hypoxic event to approximately 40 days. The 2010 baseline has been calculated as an average of 13 hypoxic blackwater days (based on a 40-day hypoxic blackwater event occurring at a frequency of 3 in 9 years). The 'with' environmental water scenario assumes the maintenance of the number of blackwater days at 2010 levels (13 days).
'Without' environmental water trajectory assumptions	The dilution benefit associated with environmental water has been determined based on observations and modelling by Baldwin and Whitworth (2013). The benefit provided by environmental water in reducing litter accumulation on floodplains has been assumed to provide half the relative quantum of the dilution benefit at 2030. This results in an increase in the number of blackwater days from 2010 levels by 19% at 2020 (reflecting the reduced dilution benefit) and 25% at 2030 (reflecting the reduced dilution benefit and longer-term reduction in floodplain littler loads).
Attribution and uncertainty assessment approach	N/A. No attribution ratings have been made as the data is based on the assumed direct impact of environmental water in contributing to the change.
Limitations and data gaps	- Data on the management of environmental water to mitigate blackwater events is limited, with the outputs from this assessment based on one event in 2012. The use of environmental water to mitigate hypoxic blackwater events will be highly dependent on a range of factors, including the location of the event, environmental water availability, capacity to deliver water and the timeliness of delivery. Given this assessment relies on data from one event, it is unlikely to be representative of the broad range of potential scenarios.

Table 30. Blackwater assessment outputs

Asset class	Asset name	Area (ha) or length (km)	Average number of hypoxic blackwater days per year					
			2010	2020	2030	2010 without e-water	2020 without e-water	2030 without e-water
River	Murray River	2200	13.33	13.33	13.33	13.33	15.83	16.67

Blue-green algae

Blue-green algae are a type of bacteria (cyanobacteria) that are naturally present in freshwater ecosystems. When the right conditions occur, they can rapidly reproduce and produce 'blooms' that can impact on river ecosystems and users and in some cases can be toxic. Factors that influence the occurrence of blue-green algae blooms include still or slow-flowing water, warm temperatures, abundant sunlight, and nutrients levels in the water.

Stress can occur to aquatic life as blooms subside, when decaying algae deplete oxygen levels in the water creating a hypoxic blackwater event.

An analysis of long-term phytoplankton (algae and cyanobacteria) data for the Murray River found that phytoplankton concentrations have been increasing over the last 30 years, however the frequency of BGA events had remained relatively stable, with one event occurring on average every four years (Croome et al, 2011).

There are limited management actions that can be implemented to stop a bloom once it has started (CEWO, 2018). Providing flushing flows or adjusting river flows may not be practical or possible due to water availability or the type of blue-green algae present. Environmental water has not been used to mitigate blue-green algae blooms. However, if sufficient volumes of water were available, environmental water could possibly be used to provide refuge if a blackwater event was to occur once the bloom had subsided.

Maintaining sufficient low flows to prevent stratification of the water column and reducing nutrient inputs to waterways through improved land management practices are approaches that have been identified to assist in the long-term management of blue-green algae (MDBA 1994, Croke 2002).

Environmental water is used to support the maintenance of low flows in Victorian river systems. It also supports the health and functioning of riparian vegetation, which plays an important role in buffering nutrient inputs to waterways (Hansen et al, 2010). However, there is an absence of quantitative evidence identifying the relative contribution environmental water plays in supporting these functions.

Given the lack of data available to inform this assessment, a hypothetical scenario has been developed to illustrate the potential socio-economic benefit that environmental watering may provide. For illustrative purposes, the benefit provided by environmental water in reducing blue-green algae events has been determined based on half the relative quantum of the dilution (abiotic) benefit identified for blackwater (in supporting the maintenance of low flows/prevention of stratification) and the same biotic benefit as the blackwater case study (supporting riparian vegetation health and functioning to buffer nutrient inputs).

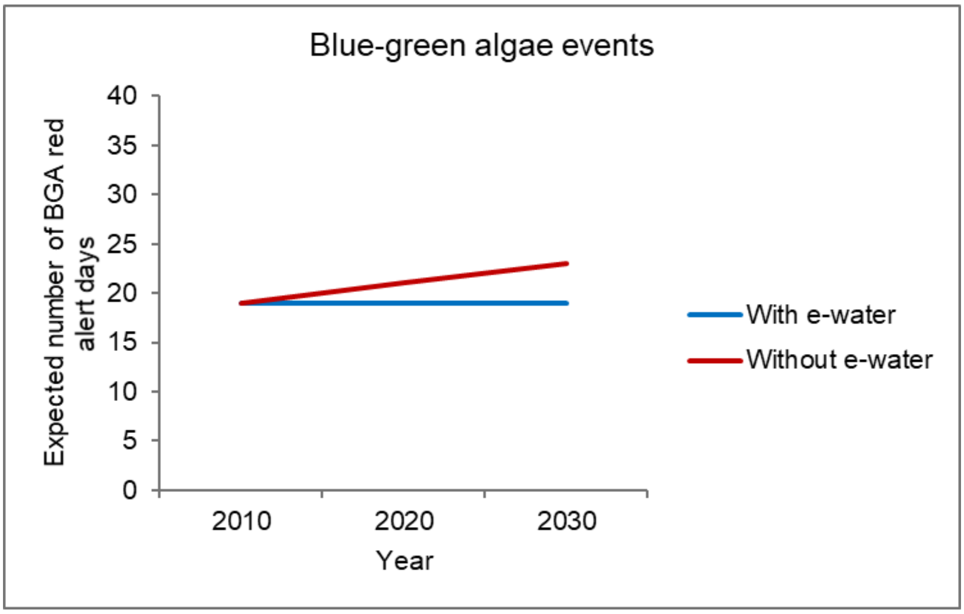

Figure 22. 'With' and 'without' environmental water outputs for blue-green algae

The underlying assumption for the 'with' and 'without' environmental water scenarios are detailed in Table 31 – with the conceptual trajectories applied for this assessment illustrated in Figure 22. Outputs for each individual asset are presented in Table 32.

Table 31. Summary of data sources and key assumptions in blue-green algae assessment

Data sources and key assumptions	
Metric assessed	Average number of red alert BGA days per year
Data sources	Croome et al (2011) and Crooke (2002). Water NSW Murray River BGA database.
Background	The frequency of BGA events in the Murray system has remained relatively stable over the last 30 years, with one event occurring on average every four years (Croome et al, 2011). Since 2010, two events have been recorded on the Murray system at red alert level (where the total toxic algal biovolume is >4mm3/L), in 2010 and 2016, with an average duration of 76 days (NSW Murray River BGA database). For illustrative purposes, a hypothetical scenario has been developed to inform the socio-economic assessment, based on the limited available data and expert opinion. The benefit provided by environmental water in reducing blue-green algae events has been assumed to be: - half the relative quantum of the dilution (abiotic) benefit identified for blackwater, reflecting the lower degree of confidence in the contribution of environmental water in reducing stratification during times of high BGA risk. - the same biotic benefit as the blackwater case study, with environmental water supporting riparian vegetation health and functioning, which in turn provides some degree of buffering of nutrient inputs.
'With' environmental water trajectory assumptions	Maintaining the number of blue-green algae red alert days at 2010 levels.
'Without' environmental water trajectory assumptions	An increase in the number of blue-green algae red alert days by 13% at 2020 (reflecting the low flow/mixing benefit) and 19% at 2030 (reflecting the low flow/mixing benefit and contribution to the maintenance riparian vegetation health).
Attribution and uncertainty assessment approach	N/A. No attribution ratings have been made as the data is based on the assumed direct impact of environmental water in contributing to the change.
Limitations and data gaps	- There is an absence of quantitative evidence identifying the relative contribution environmental water plays in supporting the health and functioning of riparian vegetation, which in turn plays a role in buffering nutrient inputs to waterways. Given the lack of data available to inform this assessment, a hypothetical scenario has been developed to illustrate the potential socio-economic benefit that environmental watering may provide. Further monitoring and research of these important ecosystem functions would strengthen the confidence in future assessments.

Table 32. Blue-green algae assessment outputs

Asset class	Asset name	Area (ha) or length (km)	Average number of red alerts BGA days per year					
			2010	2020	2030	2010 without e-water	2020 without e-water	2030 without e-water
River	Murray River	2200	19	19	19	19	21.38	22.56

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APPENDIX 2. POLLINATION SERVICES

The methodology employed to value the contribution of pollination services attributable to environmental watering to the agriculture sector was a basic production-function approach. This approach measures the physical change in output due to environmental changes and then uses market prices or costs to value these changes/impacts in monetary terms (Hanley et al 2009).

The production-function application for pollination services focused on commercially managed honeybee pollination services to almond production - as this makes up the large majority of benefits provided.

The procedure for applying this method - following the generic stepwise approach outlined in Part 1 – is summarised below.

Step 1. Measure changes in ecosystem asset condition attributable to environmental watering

The first step of the procedure was to measure the changes in ecosystem condition that are relevant for supporting pollination services. These are *Eucalyptus* forest and woodlands.

River Red Gum (River Red Gum) forest stand condition was taken as the measure of *Eucalyptus* forest and woodland condition. This index was measured for the Mallee CMA area - where 96% of the commercial pollination services in Victoria are provided.

The method for assessing change in River Red Gum stand condition using the 'with' and 'without' (environmental watering) analysis is outlined in Appendix 1. These results were further expressed as a percentage of the with-environmental watering condition.

The output of this step was the percentage change in River Red Gum stand condition. The central estimate for this was 20 per cent in 2020 and 41 per cent in 2030.

Step 2. Measure the effect of changes in ecosystem asset condition to the flow of ecosystem services

The second step of the procedure was to measure the effect of changes in the condition *Eucalyptus* forest and woodlands on the flow of pollination services provided by honeybee populations.

The specific relationship between River Red Gum stand condition, flowering ecology, the health of honeybee populations, and the pollination services provided by these populations is currently not well-understood (MDBA, 2017). In the absence of this knowledge, a linear relationship was assumed to approximate the effect that changes in River Red Gum stand condition measured in step 1 have on the stock/health of managed honeybee populations, and pollination services provided by these populations.[34] That is, the changes in River Red Gum stand condition result in commensurate percentage changes in managed honeybee stocks and pollination services provided by those stocks.

This step further assumes that River Red Gum forests are currently at their maximum honeybee carrying capacity - in line with anecdotal evidence reported in MDBA (2017). The implication of this assumption is that any change in River Red Gum health fully translates to changes in pollination service flows.

The output of this step was the percentage change in pollination service flows that are supported by environmental watering (E).

[34] A linear relationship was assumed as a conservative approach in the absence of more detailed information. 'S-functions' – whilst they generally better represent the functional form of ecosystem service flows - have a high(er) risk of generating misleading results where the relationship is not well-understood and correctly specified.

Step 3. Measure the contribution of ecosystem service flows to changes in socio-economic benefits

The third step of the procedure was to measure the benefits that pollination services (attributable to environmental watering) provide to the almond sector.

This was calculated using the equation below.

Equation 2. Contribution of pollination services

$$Value\ of\ almond\ production\ (2018\$) = (E\ \times H \times L) \times PDF \times GM$$

Where:

E = percentage change in pollination service flows in River Red Gum forest (%, from step 2)

H = proportion of managed honeybee populations that depend on River Red Gum forests (%)

L = land area in the Mallee region used for almond production (ha)

PDF = managed pollination-dependence-factor of almond production (factor)

GM = average gross margin[35] of almond production ($/ha)

Data and data sources used in these calculations are summarized in Table 33 below.

Table 33. Data sources for pollination services

Variable	Data	Data source
H	A most likely point estimate of 50% was applied, in line with anecdotal evidence reported in MDBA (2017). A lower bound point estimate of 25% and upper bound of 75% was also modelled (±50% of point estimate, reflecting high uncertainty in this parameter).	MDBA (2017), *Social and Economic Benefits from Environmental Watering: 2017 Basin Plan Evaluation*, https://www.mdba.gov.au/sites/default/files/pubs/social-economic-benefits-e-watering.pdf
L_a	Land areas in the Mallee used for almond production was approximated at 16,493 ha (ABS, 2019). This was derived by dividing the total number of almond trees in the Mallee (5.4 million) by the average planting density for almond crops - 330 trees per ha (Wikifarmer, 2019).	ABS (2019): 71210DO002_201718 Agricultural Commodities, Australia–2017-18. Accessed at <https://www.abs.gov.au/AUSSTATS/abs@.nsf/DetailsPage/7121.02017-18?OpenDocument> on 19/07/2019 https://wikifarmer.com/planting-almond-trees/ [viewed on 19/07/2019]
PDF_a	A factor of 0.9 was applied, with a lower bound point estimate of 0.81 and upper bound of 0.99 was also modelled (±10% of point estimate, reflecting low uncertainty in this parameter). This data input is based on a combination of (i) Keogh et al (2010) which reported that pollination dependence of almond and apple crops are the same/very similar, and (ii) the	Keogh, R., Robinson, A., & Mullins, J. (2010), *Pollination Aware: The Real Value of Pollination in Australia*, Rural Industries Research and Development Corporation (RIRDC), ISBN 978-1-74254-052-8 Allsopp et al (2008), Valuing Insect Pollination Services, https://doi.org/10.1371/journal.pone.0003128

[35] A gross margin refers to the total income derived from an enterprise less the variable costs incurred in the enterprise. Generally, the gross margins for any agricultural crop are determined by deducting variable costs from the gross farm income of a given crop for a given period of time (usually per year or per cropping season). They are not a measure of farm profit as they do not include capital (land, buildings, machinery, irrigation equipment etc.) or fixed costs (building and machinery depreciation, administration, insurance, rates, taxes, etc.).

Variable	Data	Data source
	pollination dependence factor for apples reported in Allsopp et al (2008).	
GM_a	Average gross margin values used were 2018$16,556 per ha with a lower and upper bound value of 2018$12,633 and 2018$20,479 respectively as calculated in Pocock (2007).	Pocock, D. (2007), Economics of Almond Production in South Australia, Rural Solutions SA https://rba.gov.au/calculator/annualDecimal.html

Step 4. Investigate uncertainties in steps 1, 2, and 3

The fourth step was to investigate the effect of uncertainties in key input parameters on the modelled results, and the relative importance of each of these uncertainties. Key input parameters investigated were (i) change in River Red Gum forest stand condition attributable to environmental watering, (ii) proportion of commercial pollination services that depend on River Red Gum forests, and (iii) gross margin values for almond production.

For each parameter, a triangular probability distribution was defined utilizing parameter values outlined in steps 1, 2, and 3 above. A sensitivity analysis was then undertaken using a monte-carlo simulation process.

The first output of this sensitivity analysis was a plausible range for the true benefit value.

The second output was a 'tornado graph' which shows the relative effect of (uncertainty in) each input parameter on the mean benefit estimate.

Results and suggestions for future research

The results of the analysis show the value of the contribution of environmental watering to almond production through pollination-related ecosystem services (see Table 34) is in the range of $13 million to $38 million in 2020 and increasing to between $29 million to $78 million in 2030. These benefits accrue to the Mallee region, where northern Victoria's almond production and commercial pollination service providers are located.

Table 34. Value of the contribution of pollination services provided by environmental watering to the agriculture sector (2018$M/year)

	2020			2030		
	Low	Mid	High	Low	Mid	High
Change in productivity of almond producers	13	25	38	29	51	78

The large variance in these results are explained by uncertainty in the proportion of commercial bee populations that depend on River Red Gum forests (*H*, Step 3) as well as uncertainty in the modelled River Red Gum stand condition decline under the without-environmental watering scenario (Step 1). Figure 23 shows the effect of each of these parameter uncertainties on estimated benefit mean.

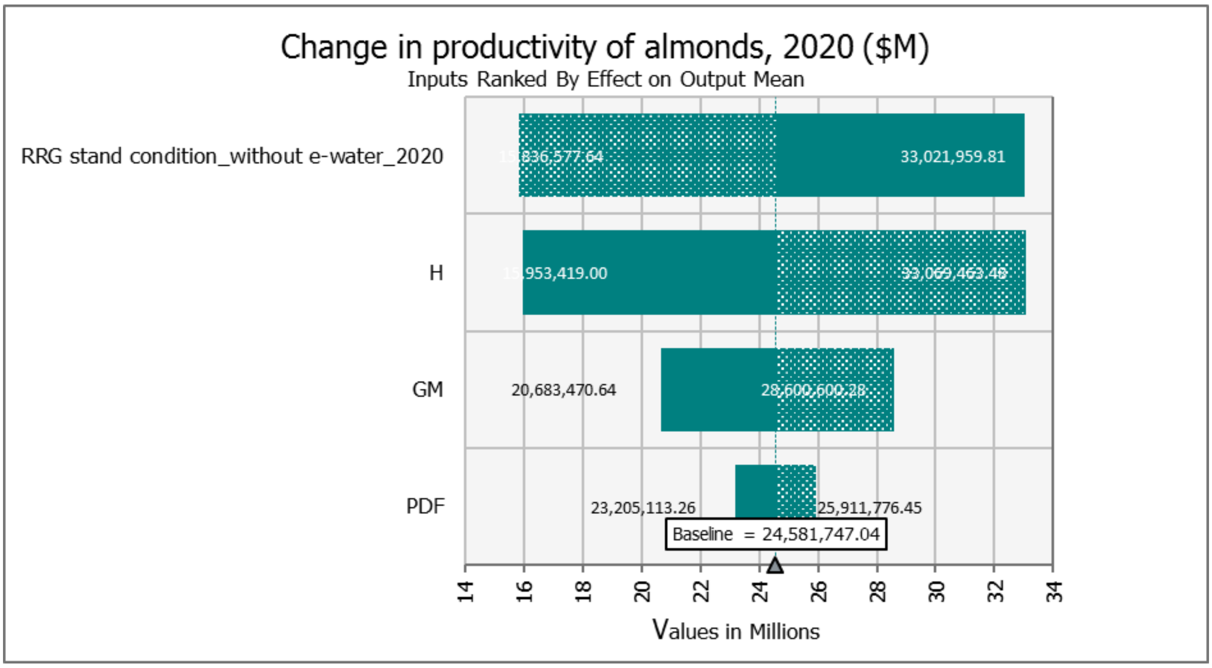

Figure 23. Inputs ranked by their effect on mean estimate of benefits

Given the sensitivity of results to parameter *H (*dependence of commercial honeybee stock populations on *Eucalyptus* forest and woodland areas supported by environmental watering), it is suggested that some further research be undertaken to better understand this relationship. This would provide greater confidence when reporting results to agriculture sector stakeholders.

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APPENDIX 3. CLIMATE REGULATION SERVICES

The methodologies employed to value the contribution of climate regulation services attributable to environmental watering was a benefits-transfer approach. Benefits transfer involves the use of values estimated in an existing study and using these estimates to infer values for a different study application.

The studies identified as being most suitable for this benefits-transfer application were:

- IPCC Fifth Assessment Report (2014).
- World Bank Carbon Pricing Dashboard.

These studies are used by DELWP for valuing greenhouse gas emissions.

The procedure for applying this method - following the generic stepwise approach outlined in Part 1 – is summarised below.

Step 1. Measure changes in ecosystem asset condition attributable to environmental watering

The first step of the procedure was to measure the changes in ecosystem condition that are relevant for supporting climate regulation services. These are forest and woodland areas in the TLM icon sites, as well as vegetation in wetland areas.

River Red Gum (River Red Gum) forest stand condition was taken as the measure of forest and woodland condition for all forest and woodland types – as monitoring work does not yet provide for measurement of condition blackbox dominated or other forest and woodland types. The index of wetland condition biota sub-index (IWC) was taken as the measure of wetland vegetation condition.

The method for assessing change in River Red Gum stand condition and IWC using the 'with' and 'without' (environmental watering) analysis is outlined in Appendix 1.

The output of this step was the change in River Red Gum stand condition and IWC.

Step 2. Measure the effect of changes in ecosystem asset condition to the flow of ecosystem services

The second step of the procedure was to measure the effect of changes in the River Red Gum stand condition and IWC biota-sub index on the sequestration and storage of carbon dioxide.

For forests and woodlands (within TLM icon sites), the relationship between River Red Gum stand condition and carbon sequestration rates was approximated using a study by Smith et al (2016) – which measured the relationship between crown health and carbon sequestration rates (carbon dioxide equivalent /ha/year) for River Red Gum forests in Namoi (NSW). This study found that a change in the classification of crown die back (defined as "healthy", intermediate, or severe") affects carbon sequestration rates by 3.5 tonnes of carbon dioxide equivalent per hectare per year ± 0.81. A further step was required here to convert River Red Gum forest condition index (scores between 0 and 100) to classifications of crown die back as described in Smith et al 2016 (0 = health, 1 = intermediate, 2 = severe). This was done by applying a conversion factor of 0.02 - calculated as 2/100 (i.e. the maximum score for crown die back divided by the maximum score for River Red Gum forest stand condition). The calculation is represented in Equation 3 below.

Equation 3. Change in carbon sequestration rates for forests and woodlands

$$Change\ in\ carbon\ sequestration\ rate\ (CO2e\ per\ ha\ per\ year) = (RRG\ stand\ condition \times CF_{RRG:D}) \times D$$

Where:

River Red Gum stand condition = River Red Gum stand condition index (from step 1)

$CF_{River\ Red\ Gum:D}$ = River Red Gum stand condition to crown die back conversion factor (factor)

D = marginal carbon sequestration rate for change in crown dieback (carbon dioxide equivalent per ha per year)

For wetlands, there is currently (as at July 2019) no published research which demonstrates the carbon sequestration response to changes in IWC scores or environmental watering directly (pers comms Katy Limpert, Blue Carbon Research Lab, Deakin University). In the absence of this information, the approach taken was to proportionately adjust the functional relationship used for River Red Gum forests (mentioned above) in line with the differences in index scoring scale and average annual carbon sequestration rates between the two asset classes. Here, a conversion factor of 0.1 was applied - calculated as 2/20 (i.e. the maximum score for crown die back divided by the maximum score for IWC biota sub-index). Note, this is a somewhat crude approach and has been undertaken to provide an order-of-magnitude estimate only. The calculation is represented in Equation 4 below.

Equation 4. Change in carbon sequestration rates for wetlands

$$Change\ in\ carbon\ sequestraion\ rate\ (CO2e\ per\ ha\ per\ year) = (IWC \times CF_{IWC:D}) \times (D \times AF_{RRG:W})$$

Where:

IWC = Index of wetland condition biota sub-index (from step 1)

$CF_{IWC:D}$ = IWC biota sub-index to crown die back conversion factor (factor)

D = marginal carbon sequestration rate for change in crown dieback (carbon dioxide equivalent per ha per year)

$AF_{River\ Red\ Gum:W}$ = Adjustment factor to account for differences in average carbon sequestration rates between River Red Gum forests and wetland (factor). $AF_{River\ Red\ Gum:W}$ was calculated by dividing the average carbon sequestration rate for freshwater wetlands from Carnell et al (2017) by the average carbon sequestration rate for River Red Gum forests reported in Smith et al from Carnell et al (2017).

The change in carbon sequestration rates measured for each relevant asset was then multiplied by the total area of that asset to estimate the total carbon dioxide equivalent mitigated annually.[36] Area data are outlined in Appendix 1 and are summarised again in Table 35 below.[37]

[36] The impact of this greenhouse gas abatement on the global climate was not explicitly measured as part of this analysis. The analysis instead relied on global climate modelling undertaken and/or used as part of the source-studies of this benefits transfer application.

[37] For forests and woodlands, areas were taken from the TLM icon sites only (and not riparian veg).

Table 35. Forest, woodland and wetland areas

Variable	Data	Data source
Forest and woodland areas (ha) in TLM icon sites		
Mallee	15,597	MDBA (2015), Stand condition assessment of forests and woodlands of Chowilla Floodplain — 2015 https://www.mdba.gov.au/sites/default/files/pubs/TLM-stand-condition-%20Chowilla.pdf MDFRC (2016), The Living Murray Condition Monitoring at Hattah Lakes 2015–16 Part A – Main Report https://www.mdba.gov.au/sites/default/files/pubs/hattah-condition-monitoring.pdf
North Central	14,761	MDBA (2005), The Living Murray Foundation Report on the significant ecological assets targeted in the First Step Decision, https://www.mdba.gov.au/sites/default/files/archived/mdbc-tlm-reports/539_TLM_Foundation_Report_2005.pdf
Goulburn Broken	55,714	MDBA (2005), The Living Murray Foundation Report on the significant ecological assets targeted in the First Step Decision, https://www.mdba.gov.au/sites/default/files/archived/mdbc-tlm-reports/539_TLM_Foundation_Report_2005.pdf
Wetland areas		
Mallee	11,479	Based Environmental Water Management Plans and Mapshare Victoria website
North Central	2,279	Based Environmental Water Management Plans and Mapshare Victoria website
Goulburn Broken	959	Based Environmental Water Management Plans and Mapshare Victoria website

Step 3. Measure the contribution of ecosystem service flows to changes in socio-economic benefits

The third step of the procedure was to measure the benefits that carbon sequestration and storage attributable to environmental watering provide to the social and economic system.

The economic value of benefits was approximated using the 2014 IPCC Fifth Assessment Report and the World Bank Carbon Pricing Dashboard – as has been the practice by DELWP for valuing greenhouse gas emissions. These studies measure the unit cost of greenhouse gas abatement based on existing global carbon market values and emission reduction pathways in line with scenarios to limit warming to below 2 degrees Celsius.[38]

For 2020, unit cost of carbon dioxide equivalent used in the analysis were $15 (low), $29 (most likely), $68 (high). For 2030, unit cost of carbon dioxide equivalent used were $29 (low), $69 (most likely), $108 (high).

The total value of carbon sequestration services to the global social and economic system was thus estimated by multiplying the quantity of carbon dioxide equivalent abated in step 2 by the unit cost of carbon dioxide equivalent ($ per tonne of carbon dioxide equivalent).

[38] Note, an alternative to using the cost of mitigation would be to utilise the social cost of carbon – which measures the damages and losses (impacts) caused by climate change. The cost of mitigation has been selected here to be consistent with the approach typically used by DELWP.

Step 4. Investigate uncertainties in steps 1, 2, and 3

The fourth step was to investigate the effect of uncertainties in key input parameters on the modelled results, and the relative importance of each of these uncertainties. Key input parameters investigated were (i) change in River Red Gum stand condition and IWC attributable to environmental watering, (ii) relationship between River Red Gum stand condition and marginal carbon sequestration rates, and (iii) unit costs values for abating carbon dioxide equivalent.

For each parameter, a triangular probability distribution was defined utilizing parameter values outlined in steps 1, 2, and 3 above. A sensitivity analysis was then undertaken using a monte-carlo simulation process.

The first output of this sensitivity analysis was a plausible range for the true benefit value

The second output was a 'tornado graph' which shows the relative effect of (uncertainty in) each input parameter on the mean benefit estimate.

Results and suggestions for future research

The results of the analysis show the value of the contribution of environmental watering to avoiding climate change impacts (see Table 36) is in the range of $1 million to $5 million in 2020. This value is expected to further increase to between $4 million and $15 million in 2030 in line with increasing unit values of carbon ($ per tonne of CO2 equivalent)[39] and as the contribution of environmental watering to the condition of forest and wetlands (relative to a without-environmental watering scenario) increases.

Table 36. Value of the contribution of climate regulation services (2018$M/year)

	2020			2030		
	Low	Mid	High	Low	Mid	High
TLM icon sites						
Mallee	0 – 1	1	1	1	2	4
North Central	0 – 1	1	1	1	1	2
Goulburn Broken	1	1	3	2	5	8
Sub-total	*1*	*3*	*4*	*4*	*9*	*14*
Wetland						
Mallee	0	0 – 1	0 – 1	0 – 1	0 – 1	0 – 1
North Central	0	0 – 1	0 – 1	0	0 – 1	0 – 1
Goulburn Broken	0	0 – 1	0 – 1	0	0	0 - 1
Sub-total	*0*	*0 – 1*	*0 – 1*	*0 – 1*	*0 – 1*	*0 – 1*
Avoided impacts of climate change	**1**	**3**	**5**	**4**	**9**	**15**

The large variance in these results is mostly explained by uncertainty in the unit value of carbon (Step 3), the modelled River Red Gum stand condition decline under the without-environmental watering scenario (Step 1), and the marginal carbon sequestration rates from healthier River Red Gum forests

[39] which, amongst other things, is reflective of the trajectory of (greenhouse gas) emissions reductions – which progressively increase between the years 2020 to 2030 – required to achieve (greenhouse gas concentration) stabilization targets that limit global warming to below 2 degrees.

(*D*, Step 2). Figure 24 shows the effect of each of these parameter uncertainties on estimated benefit mean.

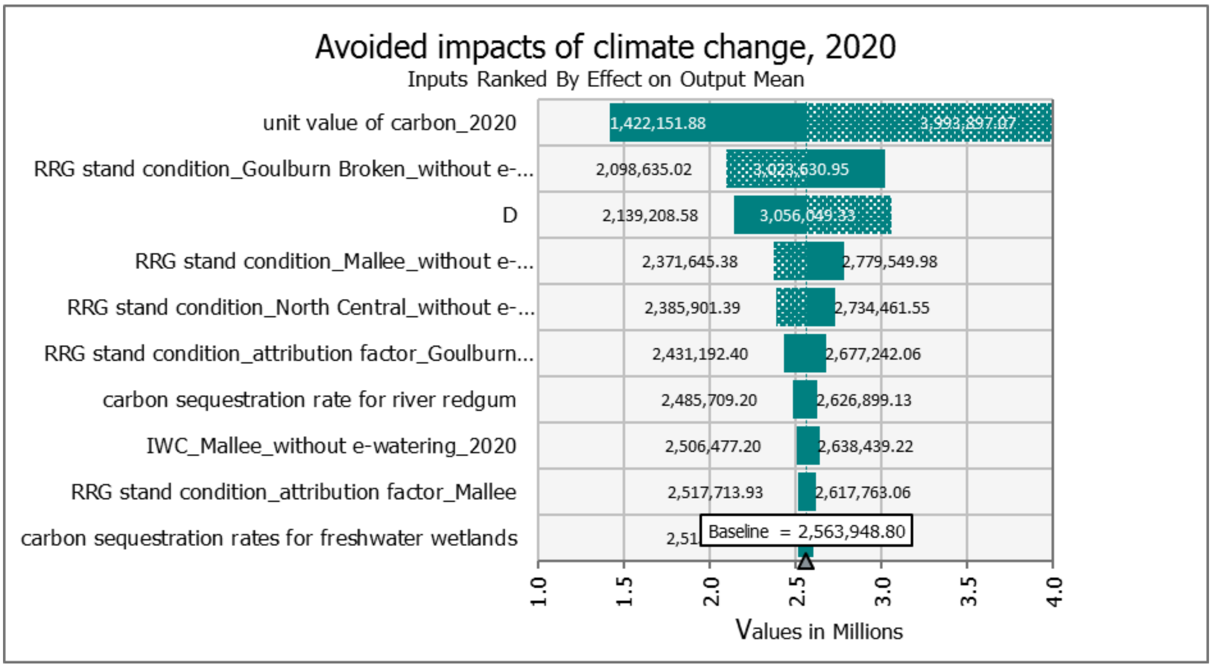

Figure 24. Inputs ranked by their effect on mean estimate of climate change mitigation benefits

One key knowledge gap identified as part of the analysis – and hence limitation of this quantitative analysis - is a lack of published research to establish the carbon sequestration response of wetlands to environmental watering. The Blue Carbon Research Lab at Deakin University is currently undertaking some selected case study work in this area and is thus expected help fill this gap. Some further grant assistance may be required to adequately establish this knowledge and understanding.

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World Bank, Carbon Pricing Dashborad, http://carbonpricingdashboard.worldbank.org

APPENDIX 4. AVOIDED SALINITY MANAGEMENT COSTS

The methodology employed to value the contribution of environmental watering to avoided salinity management interventions was a cost-based approach. This approach measures the change in (off-farm, publicly managed) salinity management interventions due to environmental changes, and then uses market prices to value this avoided intervention investment.

The procedure for applying this method - following the generic stepwise approach outlined in Part 1 – is summarised below.

Step 1. Measure changes in ecosystem asset condition attributable to environmental watering

As outlined above, river salinity improvements provided by environmental watering are achieved through a direct abiotic dilution process. This is unlike most other ecosystem services considered in this analysis which are generated 'indirectly' through an improvement in the condition and functioning of a living ecosystem asset. As such, this step is not applicable for this service.

Step 2. Measure the effect of changes in ecosystem asset condition to the flow of ecosystem services

The direct dilution effects of environmental watering on river salinity is a complex scientific area and is the subject of ongoing research.

The dilution effects utilized in this analysis are taken from the Murray Darling Basin Authority modelling in the General Review of Salinity Management in the Murray Darling Basin (2017). This modelling measures the effects of the river salinity corresponding to the total water recovery in the southern Murray Darling Basin under the Murray Darling Basin Plan – which is 2,750 GL. River salinity in the MDBA modelling is measured in terms of EC at Morgan. Results of this modelling are summarized in Table 37.

Table 37. Key outputs from MDBA (2017) modelling for General Review of Salinity Management in the Murray Darling Basin

	EC at Morgan		
	2010	2020	2030
With environmental watering	690	711	727
Without environmental watering	746	775	791
EC reduction ('without' minus 'with')	*56*	*64*	*64*

Source: MDBA (2017)

The salinity dilution effects that are attributable to the Victorian environmental watering program were approximated as simple pro-rata share of total water recovery. This was an adjustment of 39 per cent – which is Victoria's target contribution (1,075 GL) to the total 2,750 GL total water recovery target.[40]

The outputs of this step are change in EC at Morgan (24.96 EC).[41]

Step 3. Measure the contribution of ecosystem service flows to changes in socio-economic benefits

The third step of the procedure was to measure the benefits that reduced river salinity (attributable to environmental watering) provide in terms of avoided salinity management costs.

[40] $Adjustment = (1{,}075 \div 2{,}750) \times 100 = 39\%$

[41] = 64EC x 39%

This was measured as the reduction in the construction and operation of salt-interception schemes and was undertaken as two sub-steps:

First, an equivalent annual cost for constructing and operating an average salt-interception scheme ($/EC/year) was estimated using the below equation.

Equation 5. Equivalent annual cost of salt-interception schemes ($/EC/year)

$$Equivalent\ annual\ cost\ (\$\ per\ EC\ per\ year) = C\ + \left(\frac{r}{1-(1+r)^{-t}}\right) + O\&M$$

Where:

C = average capital cost of constructing or replacing a SIS ($/EC)

r = discount rate (%)

t = expected useful life of a typical SIS (number of years)

O&M = average operation and maintenance cost for a SIS ($/EC/year)

Data and data sources used in these calculations are summarized in Table 38 below.

The mean equivalent annual cost estimated in this sub-step was $272,000/EC/year.

Table 38. Data sources for calculating equivalent annual cost of salt-interception schemes (2018$/EC/year)

Variable	Data	Data source
C	$2,956,534 per EC (average) The SIS's considered here were Walkerie, Loxton, Bookpurnong, Murtho, Mallee Cliffs, Pyramid Creek, and Upper Darling.	MDBA 2018 Infrastructure Asset Register MDBA 2018 Salinity Register
R	7 per cent. This is the Department of Treasury and Finance (2013) recommended rate for Category 2 type investments.	Department of Treasury and Finance (DTF) (2013), Economic Evaluation for Business Cases: Technical Guidelines. Online: https://www.dtf.vic.gov.au/investment-lifecycle-and-high-value-high-risk-guidelines/technical-guides
T	A mid-point value of 60 years was applied with a lower and upper range value of 50 years and 70 years respectively.	Pers comms Karl Mathers (Wedge Group)
O&M	$87,000 per EC per year. Based on the MDBA budget for operations and maintenance costs of the abovementioned SIS's in 2016-17 (adjusted for reduced operations due to budget constraints) and the four financial years prior, inflated by CPI.	MDBA budget for operations and maintenance costs in 2016-17

And second, the equivalent annual cost of an SIS calculated above was then multiplied by the quantity of EC at Morgan associated with new irrigation development that has not required (does not require) additional salinity management investments (in the form of SISs) – due to dilution effects from environmental watering.

The quantity of EC at Morgan associated with new irrigation development are based on rates and location of new irrigation development and corresponding EC generated in the Vic Mallee for the period 2012/13 to 2017/18 (Mallee CMA) - and utilising the 2018 hoxley coefficients. This translates to an increase in 0.56 EC per year. Based on these calculations, the full quantum of EC generated from new irrigation development (11.19 EC by 2030) does not necessitate new SIS investment due to the countervailing dilution effects of the Victorian environmental watering program (24.96 EC).

The output was the annual value ($/year) of avoided salt interception scheme costs.

Step 4. Investigate uncertainties in steps 1, 2, and 3

The fourth step was to investigate the effect of uncertainties in the capital cost of an SIS (*C*) and the expected useful life of a SIS (*t*) on the benefit results.

Triangular probability distributions were defined for these parameters utilizing values based on different SISs mentioned above. A sensitivity analysis was then undertaken using a monte-carlo simulation process.

The first output of this sensitivity analysis was a plausible range for the true benefit value.

The second output was a 'tornado graph' which shows the relative effect of (variance and uncertainty in) each input parameter on the mean benefit estimate.

Results and suggestions for future research

The results of the analysis show the value of avoided salinity management costs from environmental watering (see Table 39) is in the range of $1 million to $2 million in 2020 and up to a range of $2 million to $4 million in 2030.

Table 39. Value of avoided salinity management costs (2018$M/year)

Avoided cost	2020			2030		
	Low	Mid	High	Low	Mid	High
Avoided cost of constructing and operating a SIS	1	2	2	2	3	4

The moderate variance in these results is mostly explained by uncertainty in the average capital cost of SISs (*C*, Step 3). Figure 25 shows the effect of each of these parameter uncertainties on estimated benefit mean.

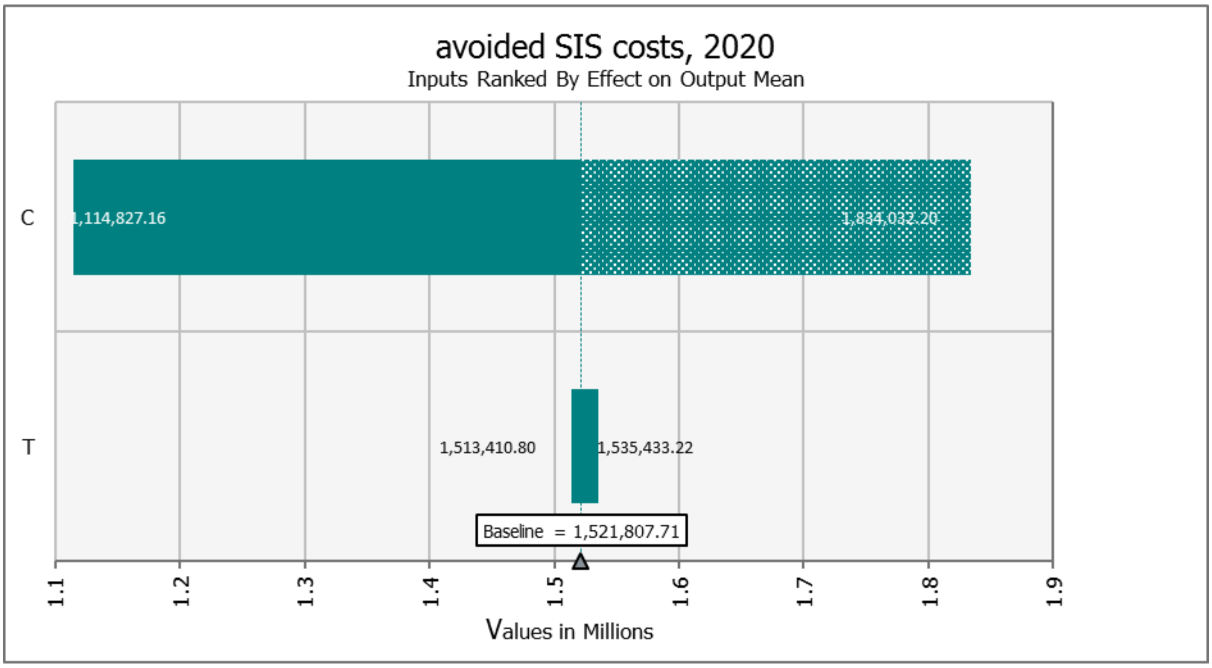

Figure 25. Inputs ranked by their effect on mean estimate of avoided SIS costs

It is further noted that work is currently underway to refine scientific modelling of river salinity impacts in the southern Murray Darling Basin. This will provide for a more accurate understanding of the salinity impact from irrigation development in the region as well as the dilution effects of environmental watering.

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APPENDIX 5. WATER QUALITY (BLACKWATER AND BLUE-GREEN-ALGAE) REGULATION SERVICES

Due to the complexity of hypoxic blackwater and BGA bloom risk and measures to manage them, the effect of environmental watering on (the frequency and duration of) blackwater events and BGA blooms is currently not well-understood. As such, a reliable analysis of the contribution of water quality regulation services to livestock productivity and town water supplies is not possible at this stage.

However, to help progress understanding in this area, several hypothetical scenarios were investigated. The primary objective of this analysis was to establish whether this is a significant benefit category (or potential to be significant) and whether it warrants further research and policy effort to better understand.

The Murray River was the sole focus of this part of the analysis because it was the only river in the scope of this study where suitable historical data exists that could be used to plausibly approximate an effect of environmental watering on blackwater events and BGA blooms.

The procedure for undertaking the analysis follows the generic stepwise approach outlined in Part 1 and is applied below.

Step 1. Measure changes in ecosystem asset condition attributable to environmental watering

Blackwater and BGA mitigation services provided by environmental watering are achieved through a combination of biotic and abiotic processes.

At this time however, the biotic processes are not well-understood. As such, no ecosystem asset condition elements were explicitly measured or modelled as part of this step.

Step 2. Measure the effect of changes in ecosystem asset condition to the flow of ecosystem services

The second step of the procedure was to measure the changes in the quality of water resources in the Murray River (including consumptive water). These changes were measured in terms of:

- The change in the expected number of blackwater days per year from environmental watering.
- The change in the expected number of (Category 2 / High alert) BGA days per year from environmental watering.

In the absence of good quality data and studies to support this measurement, a number of hypothetical scenarios were generated - drawing on the historical frequency and duration of blackwater events and BGA blooms experienced in the Murray River under past climate conditions. Details on these scenarios and their underpinning logic is provided in Appendix 1.

Step 3. Measure the contribution of ecosystem service flows to changes in socio-economic benefits

The third step of the procedure was to measure the benefits of improved water quality services (attributable to environmental watering) provided to the livestock (i.e. sheep/lamb, dairy and beef) sector.

Two methodologies were used to investigate benefits of water quality regulation services to livestock production, reflecting considerable uncertainty in how blackwater events and BGA blooms impact livestock production.

Consistent across both methodologies an approximate of (risk) exposure to a blackwater event or BGA bloom was performed. This was completed by using the VLUIS spatial dataset[42] to estimate land areas exposed and then using reports prepared by Agriculture Victoria (2017; 2018a; 2018b) to estimate yields from these areas.

Method 1: Avoided production losses

The first method used a basic production-function approach, determining the physical change in output (i.e. avoided loss of production) due to the reduction in the duration (days) of blackwater events and BGA blooms. Specifically, during this step we estimated the avoided production losses (in terms of kg) associated with reduced blackwater or BGA event duration (from environmental watering) estimated in the step above. Yields were assumed to be zero during days when blackwater and BGA were present. This reflects the logic that animal weight gain and milk production is inhibited when palatable and safe drinking water is not available. This is based on research by DPIRD (2019) which report that livestock are sensitive to water quality, particularly the palatability of water and are likely to drink less or stop drinking altogether when water quality is poor. Moreover, DPIRD (2019) report that when "…animals drink less, they will eat less and lose condition", which will lead to a reduction in production.

This approach then used gross margins to value the avoided loss in production in monetary terms.

This process was repeated for each catchment and for all three classes of livestock.

Equation 6. Contribution of water quality services to livestock production [avoided production losses]

$$Avoided\ livestock\ production\ losses\ (2018\$) = [(D_{WO} * Y * L) - (D_W * Y * L)] * GM$$

Where:

D_{WO} = Duration of blackwater event or BGA bloom without environmental water (days, Step 1)

D_W = Duration of blackwater event or BGA bloom with environmental water (days, Step 1)

Y = Yield (kg/ha) of livestock

L = Land area in each catchment used for livestock production (ha)

GM = average gross margin[43] of livestock production ($/kg) for sheep, dairy and beef

Data and the associated sources used in these calculations are summarised in Table 40.

Table 40. Data sources for water quality (livestock production) services [avoided production losses]

Variable	Data	Data source
D_{WO}	2020: 15.83 average number of hypoxic *blackwater* days per year 2030: 16.67 average number of hypoxic *blackwater* days per year 2020: 21.38 average number of red alert *BGA* days per year	Determined as indicated in Appendix 1. Combined abiotic and biotic analysis for 2020 and 2030.

[42] Determining which properties rely on water from the Murray River was challenging. The VLUIS spatial dataset helped to identify the location of sheep and lamb, dairy and beef land but did not indicate where the water was obtained for stock on that land. This task was further complicated because of the contribution of other river systems to livestock production in northern Victoria (e.g. Goulburn, Broken, Loddon, Campaspe), the fact that a licence is not needed (under certain conditions) for the extraction of water for stock and domestic use, the existence of the Victorian Water Grid and the presence of stock and domestic bores. With this in mind, a simplifying assumption was made that land areas draw water from the closest river system and sensitivity analysis was performed to estimate the area of properties that rely on water from the Murray River.

[43] A gross margin refers to the total income derived from an enterprise less the variable costs incurred by the enterprise.

Variable	Data	Data source
	2030: 22.56 average number of red alert *BGA* days per year	
D_W	2020: 13.33 average number of hypoxic *blackwater* days per year 2030: 13.33 average number of hypoxic *blackwater* days per year 2020: 19.0 average number of red alert *BGA* days per year 2030: 19.0 average number of red alert *BGA* days per year	Determined as indicated in Appendix 1. Combined abiotic and biotic analysis for 2020 and 2030.
Y	The yield for each class of livestock: Sheep (kg/ha): 91 Dairy (kg Milk Solids/ha): 827 Beef (kg/ha): 251	Agriculture Victoria (2018b) – Livestock Farm Monitor Project: Victoria 2017-2018. Dairy: Agriculture Victoria (2017) – Dairy Farm Monitor Project: Victoria 2016-2017.
L	See Table 41 (below) for an estimated breakdown of land use areas (ha) that are supplied by the River Murray per product type. These areas were derived by estimating the land areas that use Murray River water for livestock production. Given that these values are only estimates a range (lower, more likely and upper) of areas were used in calculation. These were approximated for each region based on VLUIS data and then enhanced by performing sensitivity analysis (discussed in Step 4).	Victorian Resources Online (2019). Victorian Land Use Information System [VLUIS]. Accessed at <http://vro.agriculture.vic.gov.au/dpi/vro/vrosite.nsf/pages/landuse-home>
GM	The gross margins for each class of livestock: Sheep ($/kg): 3.33 Dairy ($/kg MS): 2.79 Beef ($/kg): 1.11 Conversions needed to be undertaken (for sheep and beef) to change from $/DSE to $/kg.	Agriculture Victoria (2018b) – Livestock Farm Monitor Project: Victoria 2017-2018. Dairy: Agriculture Victoria (2018) – Dairy Farm Monitor Project: Victoria 2017-2018.

Table 41. Estimated land use areas (ha) that are supplied by the River Murray per product type

Catchment	Sheep and lamb	Dairy	Beef
Goulburn Broken	13,114	50,968	15,943
Mallee	2,808	172	17,451
North Central	26,925	48,570	10,956

Method 2: Avoided cost of carting water

The second method used a simplified cost-based approach, estimating the avoided cost of water carting (from environmental watering) during blackwater events and BGA blooms.[44]

Using the same estimates from Method 1, this approach involved approximating (risk) exposure to a blackwater or BGA event in the Murray River by using the VLUIS spatial dataset to estimate land areas. The amount of water carting required per day per affected land area was estimated using a combination of academic literature (e.g. McLaren, 1997) and information published online by Agriculture Victoria (2019) – where the water demands of the different classes of livestock are recorded.

Once the water demands were estimated the market price for carting water (in terms of $/litre) was multiplied through to determine cost.[45] For our analysis an estimate of 17,000L capacity truck/tank at a cost of approximately $180 was used (once a range of estimates were considered).[46]

Equation 7. Contribution of water quality services to livestock production [avoided cost of carting water]

$$\begin{aligned} &Avoided\ cost\ of\ carting\ water\ for\ livestock\ (2018\$) \\ &= [(1/DSEa) * AWD * CCW * DSEha] * L * (D_{WO} - D_W) \end{aligned}$$

Where:

CCW = Cost of carting water ($ per Litre)

AWD = Water demand per animal type (Litre)

$DSEa$ = Dry Sheep Equivalent per animal type (DSE per animal)

$DSEha$ = Dry Sheep Equivalent per animal type per ha (DSE per animal per ha)

L = Land area in each catchment used for livestock production (ha)

D_{WO} = Duration of blackwater event or BGA bloom without environmental water (days, Step 1)

D_W = Duration of blackwater event or BGA bloom with environmental water (days, Step 1)

Data and the associated sources used in these calculations are summarised in Table 42.

Table 42. Data sources for water quality (livestock production) services [avoided cost of carting water]

Variable	Data	Data source
CCW	17,000L capacity truck/tank at a cost of approximately $180 (delivered) [or $0.011 per litre]	Cost of carting water determined through consultation with five northern Victorian water carting enterprises.
AWD	Sheep (Litres/day): 10 Dairy (Litres/day): 120 Beef (Litres/day): 100	http://agriculture.vic.gov.au/__data/assets/pdf_file/0006/439134/Water-supply-for-sheep-and-beef-cattle-in-stock-containment-areas.pdf
DSEa	Sheep (DSE/animal): 0.22 – 2.13 Dairy (DSE/animal): 14 – 17 Beef (DSE/animal): 10 – 12	McLaren (1997). Range provided by author.

[44] Water carting prevents productivity losses but incurs charges primarily for the transportation of water.

[45] Market price was estimated by contacting five water carting suppliers in northern Victoria.

[46] It is noted that Victoria has a network of emergency water supply points that can be used to access water generally for free for domestic and stock uses (DELWP, 2019). We were unable to make contact with Water Authorities who we expect would be able to shed further light on the costs to treat the water prior to cartage. Therefore, this will likely underestimate the avoided cost due to water carting.

Variable	Data	Data source
DSEha	Sheep (DSE/ha): 10.3 Dairy (DSE/ha): 26.4 Beef (DSE/ha): 11.5	Agriculture Victoria (2018b) – Livestock Farm Monitor Project: Victoria 2017-2018. Dairy: Agriculture Victoria (2017) – Dairy Farm Monitor Project: Victoria 2016-2017.
L	Per Table 40.	Per Table 40.
D_{WO}	Per Table 40.	Per Table 40.
D_W	Per Table 40.	Per Table 40.

Step 4. Investigate uncertainties in steps 1, 2, and 3

The fourth step was to investigate the effect of uncertainties in key input parameters on the modelled results, and the relative importance of each of these uncertainties. Key input parameters investigated were (i) proportion of land used for livestock production that obtains water from the Murray River in the Goulburn Broken, Mallee and North Central catchments (ii) gross margin values for sheep and lamb, dairy and beef, and (iii) charge per load ($ per litre) to cart water.

For each parameter, a triangular probability distribution was defined utilising parameter values outlined in the tables above. A sensitivity analysis was then undertaken using a Monte-Carlo simulation process.

The first output of this sensitivity analysis was a plausible range for the true benefit value.

The second output was a 'tornado graph' which shows the relative effect of (variance and uncertainty in) each input parameter on the mean benefit estimate.

Results and suggestions for future research

The results of the analysis indicate the value of avoided costs to livestock producers from both blackwater and blue-green algae events are likely to be significant.

For blackwater in the Murray River (Table 43), benefits to livestock producers are estimated to be in the range of $1 million to $2 million in 2020 increasing up to a range of $1 million to $3 million in 2030.

And for BGA blooms in the Murray River (Table 44), benefits to livestock producers are estimated to be in the range of $1 to $2 million in 2020 increasing up to a range of $1 million to $3 million in 2030.

It is noted here the results reported for 2030 are considered conservative as scenarios used in the analysis do not account for more extreme heatwaves, drought, or flooding events that may occur in the future under climate change.

Table 43. Hypothetical benefits to livestock producers of avoiding blackwater events in the Murray River – abiotic and biotic combined & catchments combined (2018$M/year)

Method	Livestock asset	2020			2030		
		Low	Mid	High	Low	Mid	High
Method 1: Avoided loss of production	Sheep and lamb	0 – 1	0 - 1	0 - 1	0 - 1	0 - 1	0 - 1
	Dairy	1	2	2	1	2	3
	Beef	0 – 1	0 - 1	0 - 1	0 - 1	0 - 1	0 - 1
	Total	1	2	2	2	2	3
Method 2: Avoided	Sheep and lamb	0 – 1	0 - 1	0 - 1	0 - 1	0 - 1	0 - 1

Method	Livestock asset	2020			2030		
		Low	Mid	High	Low	Mid	High
cost of water carting	Dairy	0 – 1	1	1	0	1	1
	Beef	0 – 1	0 - 1	0 - 1	0 - 1	0 - 1	0 - 1
	Total	1	1	1	1	1	1

Table 44. Hypothetical benefits to livestock producers of avoiding BGA blooms in the Murray River – abiotic and biotic combined & catchments combined (2018$M/year)

Method	Livestock asset	2020			2030		
		Low	Mid	High	Low	Mid	High
Method 1: Avoided loss of production	Sheep and lamb	0 – 1	0 - 1	0 - 1	0 - 1	0 - 1	0 - 1
	Dairy	1	2	2	1	2	3
	Beef	0 – 1	0 - 1	0 - 1	0 - 1	0 - 1	0 - 1
	Total	**1**	**2**	**2**	**2**	**2**	**3**
Method 2: Avoided cost of water carting	Sheep and lamb	0 – 1	0 - 1	0 - 1	0 - 1	0 - 1	0 - 1
	Dairy	0 – 1	1	1	1	1	1
	Beef	0 – 1	0 - 1	0 - 1	0 - 1	0 - 1	0 - 1
	Total	**1**	**1**	**1**	**1**	**1**	**1**

Across both methods the variance in the results can be explained by three key uncertainties:

- The proportion of land in the focus catchments that are supported by water sourced from the River Murray
- The gross margin values that are used for estimation in method 1 (only)
- The volume and cost of carting water used for estimation in method 2 (only)

Figure 26 to Figure 29 shows the effect of uncertainty for each parameter on estimated benefit.

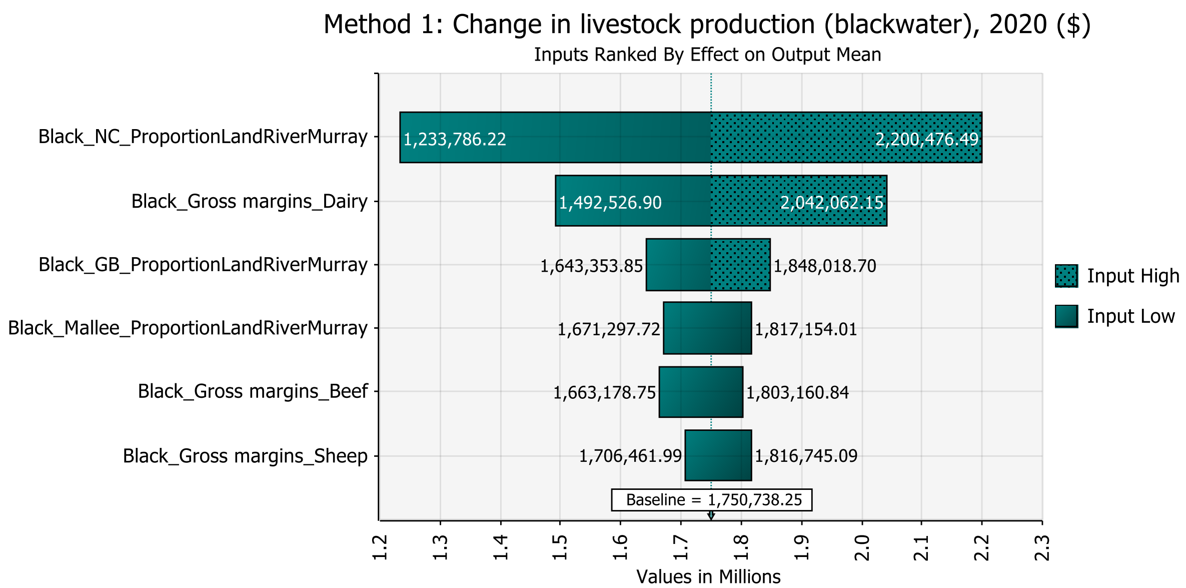

Figure 26. Inputs ranked by their effect on mean estimate of benefits (blackwater 2020 – method 1)

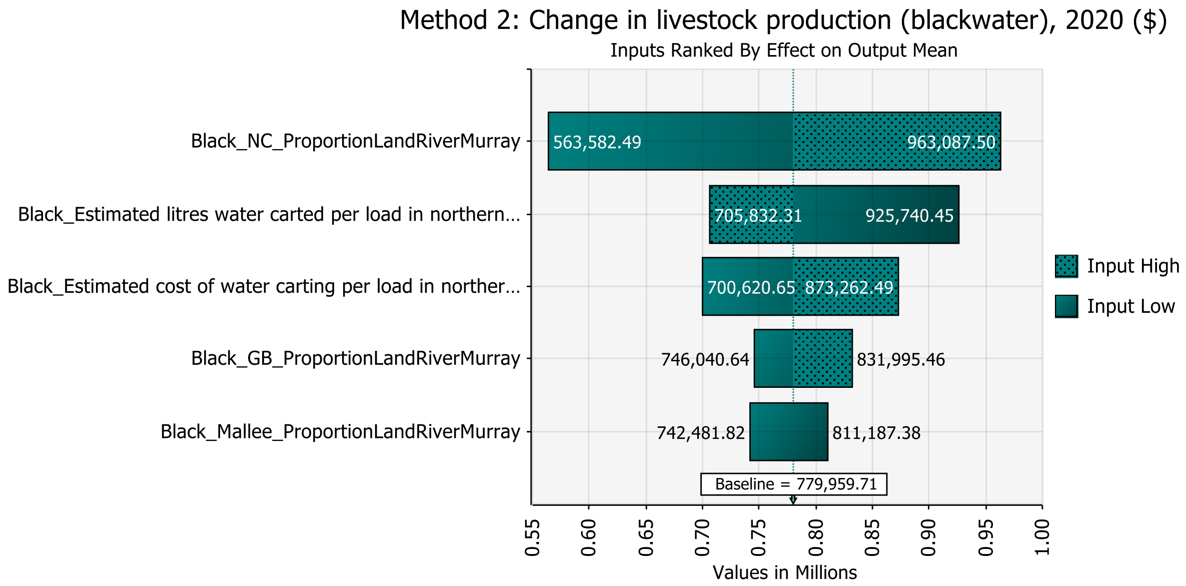

Figure 27. Inputs ranked by their effect on mean estimate of benefits (blackwater 2020 – method 2)

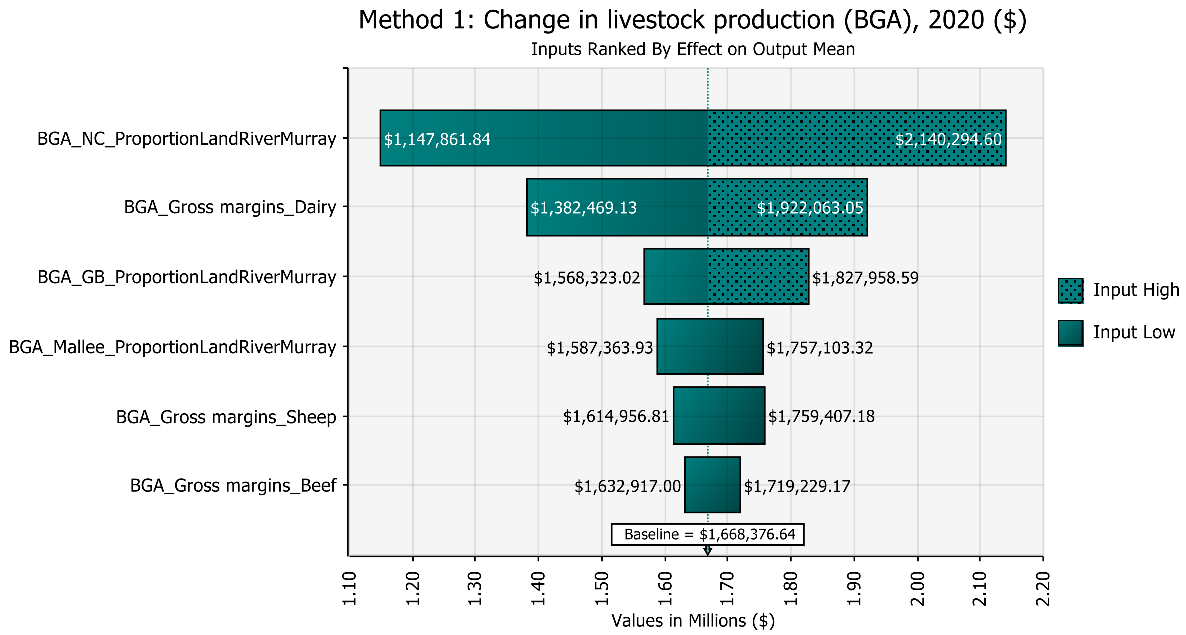

Figure 28. Inputs ranked by their effect on mean estimate of benefits (BGA 2020 – method 1)

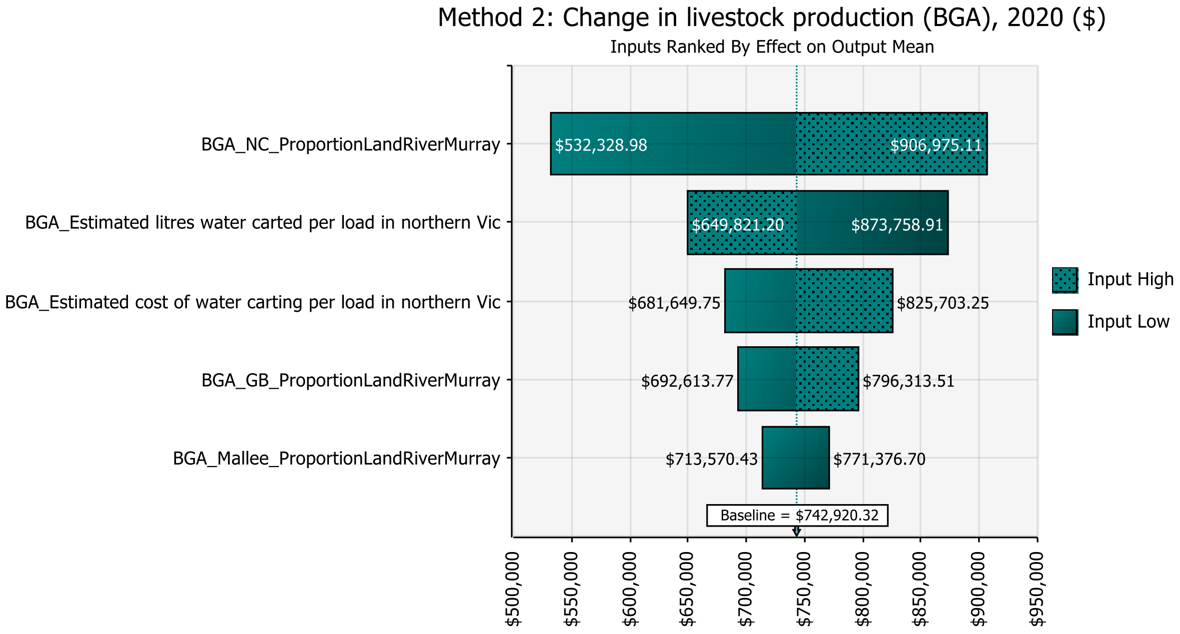

Figure 29. Inputs ranked by their effect on mean estimate of benefits (BGA 2020 – method 2)

These results suggest further research work is warranted to better understand the biophysical effect of environmental watering in reducing hypoxic blackwater events and BGA risks In the first instance, research work should focus on developing a more in-depth understanding of the biotic and abiotic processes through which environmental watering serves to abate each of these hazards.[47]

Once this underpinning knowledge base is established, a more accurate and reliable assessment of the associated socio-economic benefits should be undertaken – building on the work that has been undertaken as part of this study. At that time, assessment of socio-economic benefits should also be expanded to include the avoided water treatment costs for water corporations.

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APPENDIX 6. RECREATION

The methodology employed to value the contribution of recreation-related services to the social and economic system was a travel cost method. The travel cost method is based on the basic insight that an individual's willingness to pay for recreation at a site - such as camping at a national park - is at least their trip cost of reaching the site (Parsons, 2017). This willingness to pay captures all (or, at least the majority of) of the benefits that people derive from recreation activities – including enjoyment, health and recuperation.

The travel cost method is well suited to modelling the economic benefit of outdoor recreation – and it is widely used for valuing contribution to fishing, hunting, boating, camping and bushwalking activities in particular (Hanley et al. 2009).[48]

In this study, the travel cost method was applied to a case study of Gunbower Forest, where secondary visitation data was available.

The Gunbower Forest in the North Central CMA. This is a 20,000-hectare forest area in the floodplains of the River Murray. The forest area is endowed with various endangered plants and animals and has several aboriginal and post-settlement cultural heritage sites.[49]

The procedure for applying the travel cost method - following the generic stepwise approach outlined in Part 1 – is summarised below. In reading this procedure, it is important to be aware that only point-in-time visitation data was available to derive benefit estimates and that further surveys were beyond the scope of this study. This constraint has implications for how changes to visitation rates due to environmental watering has been measured (in step 3), and hence what ecosystem attributes are utilised to approximate this effect (in steps 1 and 2).

Step 1. Measure changes in ecosystem asset condition attributable to environmental watering

The first step of the procedure was to measure the changes in ecosystem condition that are important for recreation.

Selection of these ecosystem condition elements were guided by a choice modelling study of the River Red Gum forests along the Murray River (Bennett et al, 2007). This study identified the health of River Red Gum forests as one of the key attributes that are important for recreation.

For this attribute, River Red Gum (River Red Gum) forest stand condition was taken to be the underpinning quantitative metric for this attribute respectively.

The method for assessing the change in the level of this condition metric from environmental watering is outlined in Appendix 1. Results were further expressed as a percentage of the 2010 condition level.

The output of this step was the percentage change in River Red Gum stand condition relative to 2010 levels.

Step 2. Measure the effect of changes in ecosystem asset condition to the flow of ecosystem services

[48] The travel cost method seeks to place a value on non-market environmental goods (such as nature-based recreation activities in river, floodplain, and wetland areas) by using consumption behaviour in related markets. Specifically, the costs of accessing an ecosystem area – such as a river or a national park forest – are used as a proxy for a market price which does not exist. These consumption costs include costs associated with a round trip travel to the site (Lansdell and Gangadharan 2003).

[49] Survey data for the Gunbower Forest was supplied by North Central CMA and is based on data collected over various dates between January and June 2019 at Gunbower Forest area. There were 46 respondents who had travelled on average 293km to the forest area. On average the respondents visited the site 2.8 times a year.

As outlined in Part 1, ecosystem services that contribute to recreation are characteristics or attributes that enable passive or active recreation activities. These characteristics are broadly the same thing as ecosystem asset elements – as measured in step 1.

Accordingly, no further analysis was undertaken as part of this step.

Step 3. Measure the contribution of ecosystem service flows to changes in socio-economic benefits

The third step of the procedure was to measure the contribution of changes in the quality of ecosystem attributes (indicated by River Red Gum stand condition) to the recreation-related benefits that are derived from these changes. This comprised of two sub-steps – (i) firstly, to approximate the change in park visitation due to changes in quality of ecosystem attributes, and (ii) second, to assign economic values to this increased visitation.

Change in park visitation

As outlined above, time series visitation data was not available for the case study sites – only point in time data. In the absence of this information – and because further surveys[50] are beyond the scope of this study - it was necessary to approximate a plausible range of parameter values for change in visitation rates. This was done based on expert judgement by the project team. The visitation response rates assumed are outlined Table 45 below. The range estimates are equi-proportionate to changes in River Red Gum stand condition index (from step 1)[51] - which is considered a reasonable proxy indicator for the overall health for the ecosystem at the case study site. The estimate visitor response rates are conservative compared those estimated for environmental improvements in Hawkesbury-Nepean River in NSW achieved by environmental watering (Gillespie et al, 2017). This study employed contingent behaviour survey techniques to derive an estimate of 42 per cent visitation rate increase due to improved ecosystem attributes (water quality suitable for swimming, fish abundance, waterweeds) from increased environmental watering.

Table 45. Visitation response rates (% change) to ecosystem health improvements attributable to environmental watering

Location	2020			2030		
	Low	Most likely	High	Low	Most likely	High
Gunbower	10%	15%	20%	20%	30%	41%

To estimate the incremental number of visits per year attributable to environmental watering, the values from Table 45 were multiplied by total observed visitation data for the forest. Annual visitors are approximated to be around 150,000 (pers. comm. Roger Griffiths [Gannawarra Shire Council]).[52] Average visitor group size is 2.9 persons.

The outputs of this sub-step are summarised in Table 46.

Table 46. Incremental visitation attributable to environmental watering (number of visitor group trips/year)

Location	2020			2030		
	Low	Most likely	High	Low	Most likely	High
Gunbower	5,172	7,759	10,345	10,345	15,517	21,207

[50] to better investigate the relationship between ecosystem condition and visitation rates at the case study sites

[51] That is, the visitation rate changes are equal to the percentage change in River Red Gum stand condition relative to 2010 levels.

[52] Given the uncertainty around the number of visits, a +/-20% uncertainty range was applied to the estimated Gunbower Forest annual visits.

Assign economic values to increased visitation

The second sub-step was to assign economic values to the increased visitation.

The central part of this analysis was to estimate a regression model which relates travel costs to visitation rates, and from this model estimate a consumer surplus for a typical visitor trip ($/visitor group trip).

A poisson regression model was used to relate travel costs to visitation rates from five different geographical zones. Zones were defined as (i) Zone 1: 0-50km, (ii) Zone 2: 51-150km, (iii) Zone 3: 151-300km, (iv) Zone 4: 301-450km, and (v) Zone 5: 451km and greater – in line with common categorisations used for recreation assets located outside of metropolitan areas.[53]

Travel costs were estimated using Equation 8 below.

Equation 8. Travel cost ($/trip/group)

$$Travel\ cost\ (\$\ per\ trip\ per\ group) = 2 \times (D \times C)$$

Where:

D = estimated distance between site and suburb of origin (km)

C = average vehicle cost per km ($/km)

Distances were estimated based on information reported in visitor surveys. Average trip distances were 293km for Gunbower.

Vehicle costs were based on the standard Australian Taxation Office (2018) rates – which are $0.68 per km.

It was assumed the opportunity cost of travel time is zero – in line with the approach applied in Pascoe et al (2014), Rolfe & Dyack (2011) and Rolfe & Prayaga (2007), and to remain conservative in our estimates.

The regression model results are provided in Table 47.

Table 47. Zonal travel cost regression results

Variable	Coefficient	95% confidence interval	
Gunbower	-0.0041***	-0.0063	-0.0018

***significant at 1% level

From the regression model results, the consumer surplus per visit was calculated as the inverse of the travel cost coefficient (Prayaga et al., 2010; Adamowicz et al., 1989). These outputs are summarized in Table 48.

Table 48. Consumer surplus estimates ($ per visitor group trip)

Location	Consumer surplus per visitor group trip ($/visitor group trip)		
	Low	Most likely	High
Gunbower	159	246	548

[53] A Poisson regression model is used when the outcome is count data rather than continuous data. A count data model uses a semi-log or log-linear functional form. This allows for a simple and convenient estimation of the consumer surplus per visit as the inverse of the travel cost coefficient (Prayaga et al., 2010; Adamowicz, Fletcher, and Graham-Tomasi 1989). Further statistical tests were undertaken for the suitable of the Poisson regression, where the Poisson regression was not suitable a negative binomial regression model was undertaken.

To estimate the incremental value of recreation use with environmental flows, the consumer surplus per visitor group trips from Table 48 was multiplied by the additional number of trips attributable to environmental watering (refer Table 46).

Step 4. Investigate uncertainties in steps 1, 2, and 3

The fourth step was to investigate the effect of uncertainties in key input parameters on the modelled results, and the relative importance of each of these uncertainties. Key input parameters investigated were (i) visitation response rates, (ii) consumer surplus per visitor group visit, and (ii) total number of visitors per year.

For each parameter, a triangular probability distribution was defined. A sensitivity analysis was then undertaken using a monte-carlo simulation process.

The first output of this sensitivity analysis was a plausible range for the true benefit value.

The second output was a 'tornado graph' which shows the relative effect of (uncertainty in) each key input parameter on the mean benefit estimate.

Results and suggestions for future research

The results of the analysis provide insight on the order-of-magnitude value of recreation-related benefits generated by environmental watering. For the Gunbower Forest asset, the value is estimated to be in the range of $1.4 million and $3.9 million, increasing to $2.8 million and $8 million by 2030.

Table 49. Estimated economic benefit of environmental watering (2018$M/year)

Environmental asset	2020			2030		
	Low (p5)	Most likely	High (p95)	Low (p5)	Most likely	High (p95)
Gunbower Forest	1	2	4	3	4	8

The large variance is explained by the consumer surplus per visitor group trip, as well as uncertainty in visitation response rates and total visitor numbers (Figure 30).

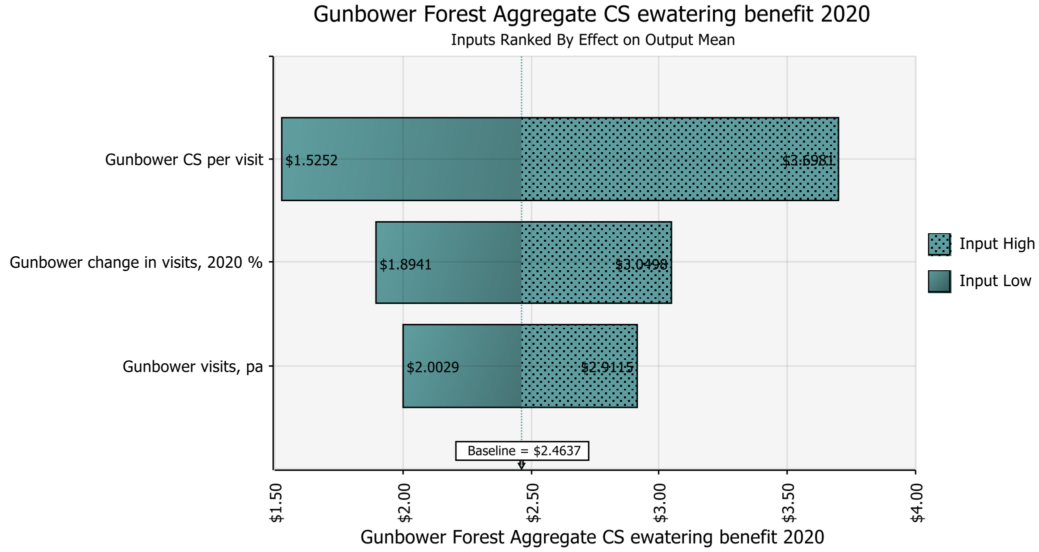

Figure 30. Inputs ranked by their effect on mean estimate of benefits

Going forward, it is suggested that strategic collection of visitor survey data for key recreation assets be undertaken as a monitoring activity to understand this socio-economic benefit of the environmental watering program. These visitation surveys should be designed with travel cost method applications in mind.[54] They may also be designed to include a forward-looking examination of visitor's likely response rate to changes in key ecosystem attributes. This latter feature would enable a hybrid travel cost and stated preference valuation method that would provide for immediate valuation of incremental recreation benefits provided by environmental watering (i.e. not require full time-series visitation data – though this is preferred).

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[54] Including (i) travel method (car/bus/plane etc) for each visitor, (ii) whether the visitor is a single-site or multi-site visitor, (iii) key activities undertaken at the site (swimming, fishing, bushwalking etc), and (iv) expenses other than fuel costs (e.g. accommodation, food, retail).

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APPENDIX 7. EXISTENCE AND BEQUEST VALUES

The methodology employed to value the contribution of characteristics or features of living systems that have an existence or bequest value (attributable to environmental watering) was a benefits-transfer approach. Benefits transfer involves the use of values estimated in an existing study and using these estimates to infer values – with adjustments made as appropriate – for the study site.

The studies identified as being most suitable for this benefits-transfer application were:

- *Rivers*: J. Bennett, R. Dumsday, G. Howell, C. Lloyd, N. Sturgess & L. Van Raalte (2008), *The economic value of improved environmental health in Victorian rivers*. This study used choice modelling techniques to estimate values of improving river health in the Goulburn River.[55]

- *Iconic floodplain forests*: Bennett. J.W., Dumsday. R., Lloyd. C., and Kragt. M (2007) *Valuing the Protection of Victorian Forests: Murray River Red Gums, and East Gippsland.* This study used choice modelling techniques to estimate values of improving River Red Gum forest health in the Barmah region.

- *Wetlands*: Bennett. J.W., and Whitten. S.M. (2007), *The Private and Social Values of Wetlands* This study used choice modelling techniques to estimate values of improving wetland health in the Murrumbidgee area (NSW).

Each of these studies were found to meet most of the criteria required for a valid benefits-transfer application for most of the ecosystem assets in scope for this study (refer Rolfe and Bennett, 2006). The key exceptions were that the Goulburn River does not adequately represent the Murray River. For this reason, the valuation of the Murray River was limited to segments within the TLM icon sites only. Also, the Barmah forest does not closely represent the Chowilla Floodplains & Lindsay-Wallpolla Islands TLM icon site or the Hattah Lakes TLM icon site. The implications of this is further discussed in the findings section below.

In addition, it should be noted that:

- Each of the source studies do not separate out[56] non-use values (e.g. existence and bequest) from other use dimensions of value (e.g. recreation).[57] This matter is discussed further below (see results and suggestions for further research).

- The source studies are now quite dated (i.e. more than a decade old), and thus populations willingness to pay for equivalent environmental changes may have shifted since this time (e.g. in the knowledge that the planet is now experiencing a sixth mass-extinction event[58]).

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[55] And the Moorabool, and Gellibrand systems – though results for these systems were not applied in this benefits-transfer application as they are not representative/similar to the systems that are the focus of this study (i.e. Loddon, Campaspe, Goulburn, Broken).

[56] Or enable separation out

[57] For example, Bennett et al (2008) study of environmental health in Victorian rivers used choice modelling techniques to assess Victorians willingness to pay for changes in four key attributes – native fish, healthy vegetation, native bird species, and water quality. All of these attributes contribute to both use (e.g. recreation) and non-use values - and no additional analytical procedure was undertaken to further understand the relative contribution to willingness to pay responses for different ecosystem service values (e.g. further questioning to understand why respondents value each attribute and the relative import of reasons). Thus, including the full willingness to pay (WTP) results from this study would - without making further adjustments - overstate existence and bequest values.

[58] Worldwide, the natural environment is currently experiencing a sixth mass (species) extinction 'event' – caused by overpopulation and overconsumption by humans (Cerbellos et al 2017). In Australia, some 60 per cent of mammals have lost more than 80 per cent of their range since 1880 (Cerbellos et al 2017). This degree of species decline is major and has been described as "every bit as profound and far reaching as that which wiped out the dinosaurs" (David Attenborough, 2019).

The procedure for applying the benefits transfer approach - following the generic stepwise approach outlined in Part 1 – is summarised below.

Step 1. Measure changes in ecosystem asset condition attributable to environmental watering

The first step of the procedure was to measure the changes in ecosystem condition that are important in terms of existence and bequest.

Taking guidance from the type of attributes that were modelled in the source choice modelling studies as well as condition monitoring information that is readily available for the assets, the ecosystem condition elements that were measured for each ecosystem asset type in this study were:

- *River ecosystems*: Index of Stream Condition (ISC), Large bodied native fish abundance
- *TLM icon sites*: River Red Gum (River Red Gum) stand condition, Large bodied native fish abundance
- *Wetlands*: Index of Wetland Condition biota sub-index (IWC), Waterbird abundance.

The method for assessing change in each of these elements using the 'with' and 'without' (environmental watering) analysis is outlined in Appendix 1.

It is noted here that data for some attributes used in the source studies could not be accessed in the time available for this analysis. This information pertains to the number of breeding pairs of threatened parrot species in River Red Gum habitats, and number of animal species with sustainable populations.

Step 2. Measure the effect of changes in ecosystem asset condition to the flow of ecosystem services

The second step of the procedure was to convert the metrics measured in Step 1 (which are the metrics commonly recorded as part of environmental watering monitoring programs) to the attribute metrics used in the source studies used in the benefits transfer application. The approach employed for converting each of the condition metrics is summarised in Table 50.

Table 50. Approach for converting ecosystem condition metrics to attribute metrics utilised in source studies

Condition metric	Source study metric	Conversion approach
River ecosystems		
Index of stream condition (ISC)	% of river length with "healthy" native vegetation on both sides	Here, "healthy" was taken to be at least "good" as rated in the Third Index of Stream Condition (ISC) reports - https://www.water.vic.gov.au/water-reporting/third-index-of-stream-condition-report. A conversion factor was derived by plotting % of river that is rated as at least "good" in the 2010 ISC reports against overall ISC scores for each river in that year. The conversion factor (CF_{ISC}) derived was 7.35.
Large bodied fish abundance (LBFA)	Native fish species and populations as a % of the pre-European level	Large bodied native fish abundance was converted to native fish species and populations as a % of pre-European levels using the below equation $CF_F = \left(\frac{P_{2010}}{A_{2010}}\right)$ *Where:* P_{2010} = Fish populations at 2010as a % of pre-European levels A_{2010} = Average large bodied fish abundance for TLM segments of Murray River

Condition metric	Source study metric	Conversion approach
		Data on P_{2010} was based on the MDBC Native Fish Strategy 2003-2013 (2003), which noted that as at 2003 'native fish populations are roughly estimated to be around 10 per cent of their pre-European settlement levels. It was assumed – for the purposes of this conversion exercise – which fish populations at 2010 are at this level.
Floodplain ecosystems		
River Red Gum stand condition	Area of River Red Gum forests that are "healthy" (ha)	Here, "healthy" was taken to be at least "good" as rated in the MDBA (2009) TLM Stand Condition Reports, https://www.mdba.gov.au/sites/default/files/pubs/stand-condition-report-2009.pdf A conversion factor was derived by plotting % of River Red Gum forest area that is rated as at least "good" in the 2009 MDBA TLM stand condition reports against overall River Red Gum stand condition scores for each TLM site in 2010. The conversion factor ($CF_{River\ Red\ Gum}$) derived was 0.0095.
Large bodied native fish abundance	cod abundance as a % of pre-European levels	See above (for rivers).
Wetland areas		
Index of Wetland Condition biota sub-index (IWC)	Area of wetland that is "healthy" (ha)	Here "healthy" was taken to be an IWC biota sub-index score of at least 12 - in line with the 2009/10 IWC Statewide rating criteria[59]. A conversion factor was derived by plotting % of wetland area that is rated as at least "good" against overall (weighted average) IWC condition scores for wetlands in a CMA. The conversion factor (CF_{IWC}) derived was 0.20.
Waterbird abundance	Native waterbird populations as a % of the pre-European level	Waterbird abundance was converted to native bird species and populations as a % of pre-European levels using the below equation $$CF_B = \left(\frac{P_{2010}}{A_{2010}}\right)$$ *Where:* P_{2010} = Waterbird populations as a % of pre-European levels at 2010 A_{2010} = Average waterbird abundance for CMA wetland areas at 2010 Data on P_{2010} was approximated based on a combination of: (i) Kingsford et al (2013), who concluded that waterbird abundance across the Murray Darling Basin have reduced by at least 70% since the early 1980's; and (ii) MDBC Native Fish Strategy 2003-2013 (2003), which noted that 'native fish populations are currently estimated to be about 10 per cent of their pre-European settlement levels. Taking guidance from these reports it was assumed – for the purposes of this conversion exercise – that waterbird populations at 2010 is about 12.5% of pre-European levels

[59] https://iwc.vic.gov.au/docs/IWC_Statewide_assessment_condition_of_wetlands_online.pdf

Condition metric	Source study metric	Conversion approach
		with a lower and upper range value of 8% and 20% respectively.

Step 3. Measure the contribution of ecosystem service flows to changes in socio-economic benefits

The third step of the procedure was to estimate the benefit derived from changes in ecosystem attributes measured in step 2. This benefit value was measured in terms of 'willingness-to-pay' for change and involved three key sub-steps.

The first sub-step was to measure household 'willingness-to-pay' for changes in attributes for each ecosystem. This was done for three different population sub-groups (defined as in-catchment, Melbourne, and rural out-of-catchment) and involved inputting metrics measured in step 2 into the parametric functions from the source choice modelling studies.

Parametric functions specify the household marginal willingness to pay (or implicit prices) for a unit increases in ecosystem (health) attributes. An example of how these functions were used to calculate a representative household's value is illustrated for the river ecosystems below.

Equation 9. Household willingness to pay for change in river ecosystem health attributes

$$Household\ value\ (\$\ per\ household) = \Delta F \times IPF\ + \Delta V \times IPV$$

Where:

ΔF = change in native fish populations (% of the pre-European level)

IPF = implicit price for improvement in fish populations ($ per % of pre-European level). Implicit price is defined as the amount, on average, that respondents are willing to pay to enjoy an increase of one unit in this attribute.

ΔV = change in percentage of the river's length with healthy native vegetation on both banks (% of river length)

IPV = implicit price for improvement in health of native vegetation on riverbanks ($ per %)

Household values were further calculated as annual values. Where necessary, this involved converting (once-off) implicit price vales utilising a 4 per cent discount rate and assuming environmental change is for a 20-year period (as per the source study survey). Values were further adjusted to account for inflation for the period since the source studies were undertaken.

The second sub-step was to extrapolate household values to the wider population sub-groups as per Equation 10 below. Extrapolated values were then summed to provide an overall value for each ecosystem asset type.

Equation 10. Extrapolated value

$$Extrapolated\ value\ = population\ \times sample\ response\ rate \times household\ value$$

Where:

$population$ = number of households in a given sub-population group

Sample response rate = the survey response rate in the original choice modelling study (%)[60]

The third and final sub-step was to make an adjustment to proportionately disaggregate the total estimated value into the component share that is attributable to existence and bequest values. This was done by using the below equation.

[60] Where survey response rates were less than 30 per cent, a higher bound estimate was also modelled in line with findings of a study by Morrison (2000) which found that at least 30 per cent of non-respondents are likely to have similar preferences to the survey sample.

Equation 11. Proportionate disaggregation

$$Existence\ and\ bequest\ value\ = extrapolated\ value\ \times P$$

Where:

P = proportion of extrapolated value that is non-use

The value used for *P* was 0.75. This is in line with analysis of forest protection values of NSW forests which found that the ratio of use (primarily recreation) to non-use values is around 1:3 (Bennett 2000, Bennett and Carter 1993). It is also consistent with a non-market value study of forests in the Colorado Rocky Mountains by Walsh et al (1990) which found that non-use values are around three times higher than recreation use values.

Step 4. Investigate uncertainties in steps 1, 2, and 3

The fourth step was to investigate the effect of uncertainties in key input parameters on the modelled results, and the relative importance of each of these uncertainties. Key input parameters investigated were (i) change in ecosystem condition attributable to environmental watering (ISC, fish abundance, River Red Gum stand condition, IWC, and waterbird abundance), and (ii) implicit price values.

For each parameter, a triangular probability distribution was defined. For implicit price values, low and high range estimates were taken from the 95 per cent confidence intervals reported in the source study. And for *P,* a low estimate of 56 per cent and a high estimate of 94 per cent (i.e. ± 25%) reflecting the moderate uncertainty in this parameter. A sensitivity analysis was then undertaken using a Monte-carlo simulation process.

The first output of this sensitivity analysis was a plausible range for the true benefit value.

The second output was a 'tornado graph' which shows the relative effect of (uncertainty in) each key input parameter on the mean benefit estimate.

Results and suggestions for future research

The results (see Table 51) of this analysis indicate that existence and bequest values are likely to be in the range of $13 to $27 million per year, increasing to between $28 and $58 million per year by 2030. These benefits are considered to be conservative estimates as they have not considered some attributes included in the source choice modelling studies that are known to have existence and bequest values - notably threatened parrot populations and "other" animal populations.

Table 51. Contribution to existence and bequest values (2018$M/year)

Location	2020			2030		
	Low	Mid	High	Low	Mid	High
Rivers						
Loddon	1	1	2	1	2	4
Campaspe	1	1	1	1	2	3
Goulburn	2	3	4	2	4	5
Broken	1	1	2	2	2	3
Sub-total (Rivers)	*4*	*7*	*9*	*6*	*10*	*15*
TLM icon sites						
Chowilla Floodplains & Lindsay-Wallpolla Islands	3	4	5	8	10	13
Hattah Lakes	1	1	1	2	2	3
Gunbower-Koondrook-Perricoota Forest	3	4	5	6	8	11
Barmah-Millewa Forest	1	2	4	4	6	8

Location	2020			2030		
	Low	Mid	High	Low	Mid	High
Sub-total (TLM icon sites)	*8*	*11*	*15*	*19*	*27*	*35*
Wetlands						
Mallee	0	1	1	1	3	5
North Central	0	1	1	1	1	2
Goulburn Broken	0	0	1	0	1	1
Sub-total (Wetland)	*1*	*2*	*3*	*2*	*5*	*8*
TOTAL (All ecosystem assets)	**13**	**19**	**27**	**28**	**41**	**58**

The large variance in estimates reflects the inherent difficulty in measuring existence and bequest benefits due the non-use nature of these benefits. This characteristic means that valuation methods must rely on (less reliable) hypothetical questionnaires to infer preferences (i.e. implicit prices) rather than use actual behavior or choices.

The large variance is also explained by uncertainties in the change in ecosystem condition attributable to environmental watering (Step 1), and the proportion of the population that share similar preferences to those surveyed in the source study (*S*, Step 3). Figure 31 illustrates this for the case of the Goulburn River.

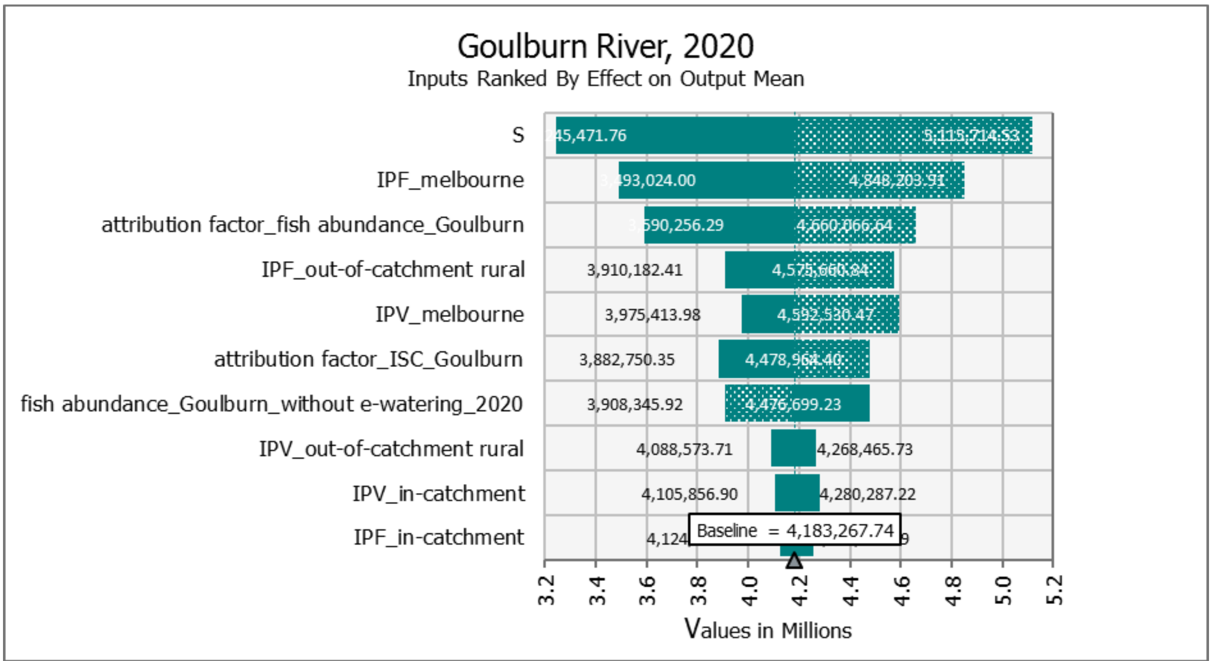

Figure 31. Inputs ranked by their effect on mean estimate of benefits (existence and bequest)

There were a number of limitations with the analysis. Of particular note was that the source studies used in this benefits-transfer application are now all quite dated (more than 10 years old). It is very possible that community preferences for environmental improvements may have shifted since this time – for example in the knowledge that the planet is now experiencing a sixth mass-extinction event. And second, the choice modelling studies used as the source studies do not disaggregate the component parts of households (willingness to pay) values. This study has attempted to address this by apportioning relative values based on studies of forest conservation from NSW which are now very dated. For these reasons, the results of this analysis should be treated as preliminary.

Future research could be undertaken to gain a better understanding of the relative importance of existence and bequest benefits compared to other socio-economic benefits for the northern Victorian environmental watering context. In the first instance, this should involve a more extensive review of the literature expanding to other technical disciplines such as (social) anthropology.

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