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Community adaptation to worsening droughts and floods in the CLLMM

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The Goyder Institute for Water Research Coorong, Lower Lakes and Murray Mouth (CLLMM) Research Centre, based in Goolwa SA, was established in 2023 through funding by the Australian Government.

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Executive Summary

The Coorong, Lower Lakes, and Murray Mouth (CLLMM) region, a nationally and internationally significant wetland system, faces an unprecedented climate challenge that threatens ecosystem services and regional prosperity. Reflecting the magnitude of values at risk, previous valuation studies indicate that the community's willingness to pay for environmental improvements in the region is substantial, with estimates of approximately \$13 billion, including \$5.8 billion specifically for the Coorong.

Prolonged droughts reduce freshwater inflows, elevate salinity, and drive habitat losses that affect water supply, fisheries, agriculture, and tourism. In the CLLMM, these impacts can be mediated or exacerbated not only by climatic conditions but also by Murray-Darling Basin water governance, including upstream extraction, allocation settings, and environmental water policy. The Millennium Drought highlighted this vulnerability, resulting in widespread and prolonged ecological damage and significant impacts on local communities and businesses. These impacts triggered more than \$810 million in emergency spending, including \$208.6 million for water infrastructure, \$174.8 million to compensate for tourism losses, and \$163.1 million for habitat restoration. With ongoing climate change, rising sea levels threaten to transform the region from a predominantly freshwater system into a more marine-dominated environment, fundamentally altering the ecosystem services it can provide and its economic baseline.

This report describes two parallel and complementary engagements with the community in the CLLMM, exploring perspectives on climate adaptation. One engagement used an economic approach, costing impacts, actions, and outcomes. The other used a creative arts approach, co-developing a community-led short animation that articulated community concerns and aspirations for the CLLMM in the face of the climate crisis. These engagements are reviewed through a climate-readiness lens, with themes reflecting specific climate adaptation imperatives.

The economic analysis drew on ecosystem valuation from previous studies, agricultural opportunity costs derived from entitlement markets and hydro-economic literature, and recent experiences of community adaptation gathered through a new targeted survey. A synthesis of Murray-Darling Basin hydro-economic, econometric, and computable general equilibrium studies indicates that reallocating water to the environment may, in some scenarios and under specific assumptions, deliver aggregate social benefits, grounded in stated community values for ecological improvement, that exceed estimated agricultural opportunity costs. High-security water entitlements provide one indicator of water value and have recently traded in the range of \$7,000–\$9,000 per megalitre, with annualised equivalents of approximately \$550–\$750 per megalitre. These entitlement values are not a universal metric across all sectors or jurisdictions, given differences in entitlement classes, reliance on annual trade, and regional production systems. Basin-scale evidence further suggests that adaptation across the Murray-Darling Basin can buffer impacts on agricultural profit, with modelling indicating that a 35% reduction in water availability may be associated with an estimated 18% decline in regional production value. However, these aggregate results can mask severe localised transitional costs, including lost production, lost income, and adjustment pressures for individual enterprises and communities.

Despite the economic imperative to adapt, local water-dependent enterprises encounter barriers to adjustment and adaptation. Qualitative evidence from open-ended survey responses by active CLLMM businesses indicates that many organisations have adopted flexible booking practices, new water sources, and water-efficiency technologies. However, escalating capital and insurance costs, information gaps, and complex regulatory environments can keep operators in reactive crisis management rather than enabling proactive, strategic adaptation.

The community-led short animation was a key activity and output of the project. It provided a creative process through which participants identified and expressed local priorities, lived experiences of environmental change, and aspirations for climate adaptation. The animation complemented the economic engagement by providing a different form of evidence about what climate change means for the community and how adaptation is understood at a local level.

Together, the economic and creative arts engagements effectively involved community members in exploring current and emerging priorities for building resilience to climate change in the CLLMM. Across both approaches, participants consistently emphasised a shift from reactive emergency mitigation toward more proactive, coordinated, and system-level responses. Key themes raised through the two activities included securing baseline ecological flows to reduce reliance on emergency responses; improving access to clear, plain-English information to support climate-smart decision-making; providing financial assistance, such as small grants and low-interest loans, to accelerate adaptation; and adopting coordinated, cross-sectoral planning approaches that prioritise collective action.

The economic evidence and the engagement activities concluded that many local community members view downstream environmental health as closely linked to regional prosperity, rather than as a competing objective. While there is substantial local-scale activity to respond to climate events, there was a strong and consistent sentiment that the scale of change required to address climate impacts exceeds the capacity of local communities alone, and that large policy and institutional responses are required.

Acknowledgements

We acknowledge the cultural connections to the land and connected waters, as well as the cultural significance of waterbirds that exist between people of the Ngarrindjeri and Boandik Nations across the Coorong, Lower Lakes, and Murray Mouth region. We recognise that First Nations peoples' spiritual, social, cultural, and economic practices come from their lands and waters, and they continue to maintain their cultural heritage, economies, languages, and laws which are of ongoing importance. We are committed to fostering and nurturing ongoing relationships with First Nations community in the CLLMM region, as we continue to work together towards a diverse and thriving waterbird community.

This work would not have been possible without the enthusiastic participation by members of the CLLMM community in the economic survey and the development of the creative piece.

This project was funded by the Goyder Institute for Water Research's CLLMM Research Centre, which is funded by the Australian Government. We thank the CLLMM Research Centre staff for project initiation, support and management. We thank the Goyder Institute's Research Advisory Committee and two independent reviewers for constructive feedback on the report.

1 Introduction

1.1 Background

The Coorong, Lower Lakes, and Murray Mouth (CLLMM) region is recognised both nationally and internationally for its ecological and cultural importance at the end of the Murray-Darling Basin. This Ramsar-listed wetland supports ecosystem services vital to local communities, providing water for agriculture, supporting commercial fisheries, sustaining tourism, and holding deep cultural significance for the Ngarrindjeri and Boandik Nations and other First Nations peoples connected to the region (Colloff et al., 2015; Kingsford et al., 2009).

Over the past century, the CLLMM has faced mounting environmental pressures. Reduced river inflows, water extraction, and extreme events such as the Millennium Drought have driven significant ecological decline, particularly in sensitive areas including the Coorong South Lagoon. While some recovery has occurred since 2010, the system remains vulnerable and many of its natural functions are still at risk (Banerjee et al., 2013; Colloff et al., 2015).

Climate change and variability have exacerbated these challenges, driving more frequent and severe droughts and floods, rising temperatures, and sea-level rise. These changes are threatening the integrity of the wetland systems in the region, jeopardising the ecosystem services that underpin local economies, community wellbeing, and biodiversity. Key risks include reduced freshwater inflows, increased salinity, rising sea levels, habitat loss, declining water quality, and ecological transformation as parts of the system shift toward more saline or estuarine conditions (Rees et al., 2022; Dunlop et al., 2022). In this report, transformation refers to large-scale changes in ecological character, hydrology, management context, and community uses of the CLLMM, rather than incremental adjustment within the existing system.

In response to these challenges, the Australian and South Australian governments initiated the Healthy Coorong, Healthy Basin Action Plan, investing $70 million to restore and protect the region's long-term health through on-ground works, scientific research, and community partnerships. In 2023, the CLLMM Research Centre was established to improve understanding of climate change impacts and responses and to support locally grounded adaptation research (DEW 2024a).

Despite these efforts, important questions remain about how climate change is affecting the region's ecosystem services and the economic wellbeing of water-dependent industries. The effectiveness of past and proposed adaptation strategies in building regional resilience also remains uncertain, particularly in the face of ongoing climatic change and institutional complexity.

Drawing on peer-reviewed research, ecosystem service modelling, economic analysis, community engagement, and creative arts practices, this report has four interrelated objectives: (i) to improve understanding of key ecosystem services and their values in the CLLMM region; (ii) to document how local businesses and community members have adapted, and may continue to adapt, to climate-induced changes to these values; (iii) to work with the CLLMM community to develop a creative product that expresses community concerns and aspirations in the face of ongoing climate change; and (iv) to use themes from prior scenario-based adaptation pathways work to reflect across the economic and creative engagements (Dunlop et al., 2022).

1.2 Project Overview

This research project integrated scientific analysis, community engagement, creative arts, and researcher reflection to explore regional resilience to climate change in the CLLMM.

The research involved three linked components: a bioeconomic analysis, two contrasting approaches to engaging community members, and a reflective synthesis (Figure 1). The bioeconomic analysis explored the costs of, and options for, managing climate change impacts, drawing on ecosystem service valuation from previous studies, water market evidence, agricultural opportunity cost estimates, and information on the impacts of droughts and floods in the region. This analysis was informed by earlier and parallel work on ecosystem service values and water management options in the CLLMM (e.g. Banerjee et al., 2013; Colloff et al., 2015; Bark et al., 2016).

The first community engagement approach used a targeted economic survey to elicit information from water-dependent enterprises about the impacts of droughts and floods and the adaptation strategies they have adopted. The second approach used creative practice, engaging community members in the scoping and co-development of an animation to identify, develop, and express local priorities, concerns, and aspirations related to climate change resilience.

After completion of the economic survey and the creative activity, a reflective synthesis was undertaken using a climate-readiness lens. This synthesis examined how the processes and outputs of these contrasting approaches engaged participants with key factors relevant to building capability to adapt to climate change. The reflection drew on adaptation themes identified in prior scenario-based adaptation pathways analyses for the CLLMM, which also informed the design and interpretation of the engagement activities (Dunlop et al., 2022).

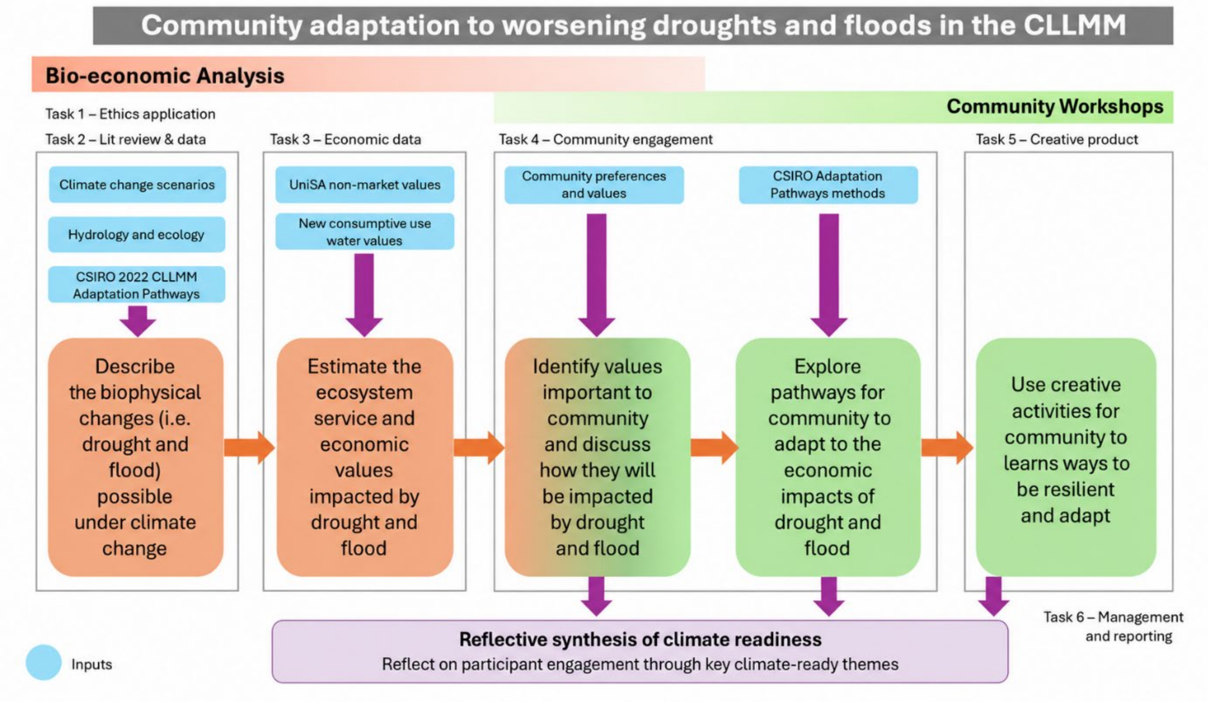

Figure 1. Overview of project methods.

1.3 Summary of the Interim Report ecosystem service values

This report incorporates and builds on the project's unpublished interim report, which provided a review and synthesis of existing knowledge to guide scenario translation, economic analysis, and preparations for collecting new data in community workshops. The interim report focused on three main tasks: reviewing the value of ecosystem services in the CLLMM region, building spatial models of key ecosystem services, and interpreting the CSIRO Adaptation Pathways framework and future scenarios to understand the likely nature and direction of impacts to key ecosystems. It also summarised other economic values in the region that are influenced by climate change and synthesised baseline economic values directly exposed to climate extremes (Banerjee et al., 2013; Colloff et al., 2015).

Specifically, the interim report established a quantitative baseline for downstream ecosystem services and documented the region's sensitivity to climate change. It showed that commercial fisheries contribute approximately $31.5 million annually to the local economy, while nature-based tourism faces potential revenue losses of up to $200 million per year during severe droughts (BDO EconSearch, 2021; Banerjee et al., 2013). The report also highlighted the scale of impacts experienced during the Millennium Drought, which triggered more than $810 million in emergency response and remediation expenditure, including around $208.6 million for water infrastructure, $174.8 million associated with tourism losses, and $163.1 million for habitat restoration (Banerjee et al., 2013; Colloff et al., 2015).

Beyond market impacts, the interim synthesis highlighted substantial non-market values. It reported aggregate community willingness to pay (WTP) for environmental improvements across the Basin of approximately $13 billion, with $5.8 billion specifically attributed to restoring the Coorong and Lower Lakes (Hatton MacDonald et al., 2011; Morrison and Hatton-MacDonald, 2010). These non-market valuation estimates provide important context for understanding the scale of social values associated with ecosystem condition, but they are inherently context-specific and sensitive to assumptions about populations, scenarios, and valuation methods.

By linking these economic baselines to CSIRO hydrological and adaptation pathway scenarios, ranging from extreme drying trajectories to sea-level rise and estuarine transition, the interim report provided a foundation to explore the potential economic trade-offs associated with future water management decisions in the CLLMM (Dunlop et al., 2022; Rees et al., 2022).

1.4 This report

This report advances the foundational findings of the interim report through a mixed-methods design that integrates economic analysis, community engagement, creative practice, and reflective synthesis. It addresses the complex trade-offs between consumptive agricultural production, downstream environmental health, and the lived realities of regional enterprises and communities under escalating climate stress. Moving beyond baseline valuation, the project brings together ecosystem service valuation from previous studies, water entitlement market data, residual value estimates, synthesis of Murray-Darling Basin hydro-economic literature, open-ended survey responses from water-dependent enterprises, and a community-led creative process to explore adaptation options for the CLLMM.

Section 2 details the methodology underpinning the analysis. It first outlines the approach to quantifying downstream ecosystem values under extreme low-flow and sea-level rise scenarios, drawing on existing valuation and modelling studies. It then describes the mechanisms used to estimate agricultural opportunity costs, triangulating permanent entitlement market values, residual farm-budget returns, and a synthesis of Murray-Darling Basin hydro-economic literature. This is followed by the qualitative framework used to capture and examine the lived adaptation strategies of water-dependent industries, based on open-ended responses from a targeted survey of businesses active in the CLLMM. Section 2 also describes the participatory creative practice used to co-develop a community-led animation, which enabled community participants to identify, develop, and express local priorities, concerns, and aspirations in relation to climate change adaptation. Finally, the approach used to reflect across the economic and creative engagements using a climate-readiness lens is outlined. Together, these components bring economic evidence, community experience, and creative engagement into a single analytical frame.

Section 3 presents the core results. It evaluates valuation impacts, water reallocation trade-offs, and behavioural responses to climate stress, reporting both market and non-market values at risk under projected climatic change. It then examines the costs of water reallocation, exploring whether aggregate public willingness-to-pay for environmental flows exceeds foregone agricultural production values under the scenarios and assumptions considered, including recent high-security entitlement prices in the range of \$7,000–\$9,000 ML^{-1}. This section also reports adaptation enablers and barriers identified through the business survey, highlighting how practices such as flexible booking, switching of water sources, and water-efficiency investments coexist with significant constraints. These constraints include rising capital and insurance costs, information gaps, and regulatory complexity, which can limit private-sector resilience and keep some enterprises in reactive crisis management. Climate adaptation in this context is likely to involve business contraction, exit, or redeployment of capital to other industries or regions. This section also presents the workshop process and results for the community co-design short animation. A link is provided for downloading the animation.

Section 4 reconciles the triangulated evidence and discusses implications for water resource management. It interprets the systemic trade-offs inherent in reallocating water to the environment to enhance climate resilience, acknowledging that while reallocation may deliver broad social benefits under some valuation assumptions, transitional costs can be concentrated on resource-dependent local businesses and communities. This section also outlines methodological limitations, explicitly addressing data gaps, uncertainties in climate projections, and the limited representation of intrinsic and First Nations values within the economic analysis.

The report concludes by identifying implications for policy and investment that are grounded in the analysis and the voices of community participants. Across the qualitative adaptation survey and creative arts activity, participants expressed a view that reliance on reactive emergency interventions alone is insufficient for the scale and nature of climate change facing the CLLMM. Reflecting these findings, the report highlights priorities raised through the research, including securing environmental water to support baseline ecological function, improving access to clear and locally relevant information, strengthening coordinated cross-sectoral planning, and providing transitional financial assistance to support adaptation by water-dependent enterprises and communities.

2 Methods

2.1 Economic analysis

This section provides an economic evaluation of values at risk under climate extremes and analyses the trade-offs between upstream water extraction and downstream ecological sustainability. In doing so, it distinguishes between long-term structural reallocation of water to the environment and the mitigation of acute climate impacts experienced across different sectors.

Specifically, this section evaluates:

- the values at risk under worsening drought and sea-level rise,
- the opportunity cost of reallocating water from irrigation to environmental flows, and
- the behavioural, institutional, and financial barriers constraining adaptation at the local enterprise level.

To address these objectives, a data-synthesis approach is employed, drawing on three distinct methodologies using evidence from previous studies and data generated through this project.

1. **Ecosystem service valuation** synthesises existing work to quantify baseline market and non-market values at risk. Scenarios from prior studies compare baseline conditions with extreme dry trajectories, characterised by prolonged drought and elevated salinity, and sea-level rise trajectories resulting in estuarine transition. These valuation estimates are treated as context-specific indicators of values at risk rather than comprehensive or definitive measures of all ecological, cultural, or social values.
2. **Entitlement market valuation and residual value estimation** are used to estimate the cost of reallocating water. Water entitlement prices reflect the capitalised value of reliable irrigation access within specific entitlement classes and jurisdictions, while residual farm-budget analyses isolate net returns per megalitre for different production systems. A synthesis of Murray-Darling Basin hydro-economic literature captures historical profit sensitivities to reduced water availability, explicitly accounting for market-based adaptation mechanisms such as water trading and carryover.
3. **Qualitative evidence from water-dependent enterprises** was generated through targeted surveys of active businesses operating in the CLLMM region. Open-ended responses were analysed using thematic coding to identify operational adjustments, barriers to adjustment and adaptation, and the practical effectiveness of adaptation strategies implemented in response to droughts, floods, and longer-term climate pressures.

Together, this three-part approach brings together ecosystem service valuation evidence, empirical market and farm-budget data, hydro-economic literature, and enterprise-level lived experience. It provides an integrated basis for examining economic trade-offs and adaptation challenges in the CLLMM, linking basin-scale economic insights with the on-the-ground realities faced by water-dependent businesses.

2.1.1 Quantifying ecosystem values

This component of the analysis draws on existing valuation and modelling studies, including the project's unpublished interim ecosystem service values report and the supplementary water management options analysis by Tingey-Holyoak et al. (2026a,b), to establish a baseline of ecosystem service values at risk under climate extremes. No new non-market valuation surveys or hydrological modelling were undertaken for this project. Instead, prior non-market valuation studies, biophysical modelling, and sector-based economic assessments were synthesised to clarify the types, scale, and context of ecosystem services potentially exposed to worsening drought, sea-level rise, and altered water availability.

The ecosystem services considered include commercial fisheries, nature-based recreation and tourism, water supply, water quality regulation, and habitat provision for waterbirds and other biota. These services were selected because they are well documented in the literature and are strongly linked to freshwater inflows, salinity, and hydrological connectivity in the CLLMM.

Monetary estimates from past droughts are used as reference points for the scale of economic exposure and public response costs associated with low-flow conditions, rather than as complete measures of ecosystem damage or as costs that would necessarily be avoided through different water allocation settings. During the Millennium Drought, reported drought-related losses and response expenditures associated with the CLLMM and Lower Murray system exceeded $810 million, including major investments in water infrastructure, unrecovered tourism losses, and emergency habitat restoration expenditure (Banerjee et al., 2013). These figures capture selected market impacts and public response costs only. They do not represent the full cost of ecological degradation, nor do they imply that restoration expenditure equates to avoided damage or that ecological recovery was achieved through intervention rather than subsequent wetter conditions.

Complementary non-market valuation studies indicate substantial social values associated with ecosystem condition. Previous stated-preference studies estimated aggregate community willingness to pay (WTP) for environmental improvements across the Murray-Darling Basin at approximately $13 billion, with $4.3–$5.8 billion attributed specifically to improving the Coorong and Lower Lakes from poor to good ecological status (Morrison and Hatton-MacDonald, 2010; Hatton MacDonald et al., 2011). These estimates reflect the preferences of the populations surveyed under the scenarios and methods used in those studies. They are therefore treated here as context-specific indicators of social value, not as values that can be transferred uncritically across different climate futures, extraction regimes, or adaptation contexts. These valuations primarily reflect preferences for mitigating the impacts of historical extraction and degradation, rather than direct valuation of climate-driven change.

Scenario analysis in this report builds on previously developed work, rather than introducing new scenario modelling. It draws on the environmental flow and water reallocation scenarios described in a companion study funded by the CLLMM Research Centre (Tingey-Holyoak et al., 2026a and Tingey-Holyoak et al., 2026b). The study synthesised water market evidence, residual value estimates, and non-market valuation results to explore trade-offs at the margin between consumptive and non-consumptive water use in the CLLMM. These scenarios consider alternative distributions of available water under differing climate and management assumptions, including conditions broadly characterised by status quo flows and scenarios with approximately 2,000 GL, 4,000 GL, and 6,000 GL of additional average annual flow over the barrages. The additional flows examined in these scenarios are conceptual constructs used to explore economic trade-offs, rather than statements about the physical availability, source, or achievability of such volumes under future climate conditions.

The links between hydrological conditions and ecological outcomes used in this project are drawn from existing environmental water requirement studies and prior adaptation pathways and vulnerability assessments. These studies describe relationships between freshwater inflows, salinity, waterbird breeding frequency, fish recruitment, and broader ecological condition. In line with Tingey-Holyoak et al. (2026a), these relationships are used here to explore how ecosystem service values may change under different climate and allocation trajectories. They do not imply that ecological targets can necessarily be met under low-flow futures, nor that environmental water alone would prevent significant ecological transformation under severe climate change.

A detailed summary of the valuation evidence used in this project is presented in Table A1 of the Appendix.

2.1.2 Estimating the opportunity cost of reallocation

The opportunity cost of reallocating water from irrigation to the environment was estimated using a triangulated evidence framework, rather than a single analytical model. This approach was used to establish a plausible range of opportunity costs and to understand how different methods represent irrigation value under varying assumptions. The three sources of evidence were: (i) water entitlement market values, (ii) residual value estimates from farm-budget analyses, and (iii) a synthesis of Murray-Darling Basin (MDB) hydro-economic, econometric, and computable general equilibrium (CGE) studies.

First, entitlement market valuation drew on observed prices for high-security water entitlements across selected southern MDB trading zones over the period 2014–15 to 2024-25, where selected high-security water entitlements have traded in the range of \$7,000–\$9,000 ML^{-1} (DEW 2024b). High-security entitlements were used because they provide a transparent, traded indicator of the capitalised value of reliable irrigation access under long-run scarcity and policy expectations. They are not a universal metric of irrigation value. Reliability definitions differ substantially across jurisdictions, and many irrigators rely on combinations of lower-security entitlements, temporary allocation trade, and carryover. For this reason, entitlement prices are treated as one indicator of opportunity cost rather than a comprehensive measure of irrigation value (Tingey-Holyoak et al., 2026b).

Entitlement prices were sourced from DEW time-series data (2014–25) and converted to annual equivalents (DEW 2024b). These prices reflect long-run scarcity, expectations about future water availability, and policy settings, rather than short-term drought conditions. Allocation (spot) prices observed during acute drought periods, including the Millennium Drought, were treated as supplementary indicators of short-run scarcity value, but were not used as the primary basis for estimating long-term reallocation costs.

To enable comparison with annual economic measures, entitlement prices were converted to annual equivalent values using a 7 per cent real discount rate and a 30-year investment horizon, yielding indicative annual values of approximately \$550–\$750 ML^{-1}. This conversion is used solely to express capital prices in annual terms; comparisons with annual production returns and non-market valuation estimates are indicative only, given that these metrics are derived from different contexts and valuation methods (Tingey-Holyoak et al., 2026b).

Second, residual value estimation was used to infer the implicit value of water within irrigated production systems. This method draws on farm-budget analyses to calculate the net return per megalitre after accounting for non-water input costs such as labour, capital, fertiliser, and energy. Residual values therefore represent the maximum water price an enterprise could sustain without eroding profitability, rather than the standalone contribution of water to output. Estimates reported in the MDB literature indicate residual values ranging from approximately \$300 ML^{-1} for low-value pasture systems to around \$2,600 ML^{-1} for high-value horticultural crops such as almonds and some fruit (Connor et al., 2014; Kirby et al., 2014; Tingey-Holyoak et al., 2026b). These estimates are highly sensitive to assumptions about crop type, yield, commodity prices, input costs, land, infrastructure, and management, and therefore provide bounds rather than point estimates of irrigation value.

Third, a literature synthesis compiled impact estimates from two decades of MDB hydro-economic, econometric, and CGE studies examining drought, water recovery, and reduced water availability. The synthesis recorded study method, spatial scale, time period, scenario type, and assumptions about adaptation, including water trading, carryover, crop switching, efficiency gains, buyback payments, and structural adjustment (Connor et al., 2014; Grafton and Jiang, 2011; Kirby et al., 2014; Dixon et al., 2011; Wittwer and Griffith, 2011). This synthesis distinguishes between enterprise-level impacts and aggregate basin-scale outcomes, and between short-run drought shocks and longer-term structural reallocation scenarios.

Across this literature, reported production and profit impacts are consistently non-linear with respect to reductions in water availability. Hydro-economic models commonly find that reductions in water availability of 20–35 per cent are associated with aggregate farm profit reductions of approximately 5–17 per cent, reflecting adaptive responses such as changes to crops grown, water trading, farm efficiency improvements, and exit from lower-value uses of water (Kirby et al., 2014; Grafton and Jiang, 2011). Econometric analyses suggest that a 10 per cent reduction in allocation is associated with around a 1 per cent reduction in irrigation revenue at the basin scale (Connor et al., 2014). CGE studies indicate that, under some policy-driven reallocation scenarios, regional GDP impacts may be neutral or positive once buyback payments and infrastructure spending are recycled through local economies (Dixon et al., 2011).

Together, these three lines of evidence delineate a plausible range of irrigation opportunity costs relevant to the CLLMM flow scenarios examined in the supplementary water management options analysis reported in Tingey-Holyoak et al. (2026a). The relevance of historical MDB studies to future CLLMM scenarios is limited by differences in climate trajectories, commodity prices, entitlement structures, spatial exposure, and adaptation capacity. For this reason, the estimates are used to explore potential trade-offs and the distribution of costs, rather than to generate precise predictions for individual enterprises or communities. While aggregate impacts may appear modest relative to water volumes, the literature consistently indicates that adjustment costs can be highly localised and unevenly distributed (DCCEEW, 2026). Detailed data sources and study summaries are provided in Table A2 in the Appendix.

2.1.3 Evaluating lived adaptation strategies

This component of the research provides the lived-experience evidence within the economic analysis. It was designed to understand how water-dependent businesses in the CLLMM experience and respond to past and recent climate extremes, particularly droughts, floods, salinity, and changing water availability, and how they anticipate adapting to future climate change. The survey was not used as a direct input to the valuation calculations described in Sections 2.1.1 and 2.1.2. Instead, it provides complementary qualitative evidence to help interpret why adaptation may be difficult at the enterprise level, even where aggregate economic analyses suggest adjustment is feasible.

Method

A targeted survey was conducted with water-dependent industries, including fishing, tourism, irrigated agriculture, and associated hospitality and service businesses operating in the CLLMM region. The survey combined structured questions on business characteristics (e.g. sector, scale, water dependence) with open-ended questions that elicited respondents' experiences of climate-related impacts, adaptation actions already undertaken, barriers to further adaptation, enabling conditions, and perceptions of Basin-scale water governance. The focus was on adaptation to observed past extremes and recent conditions, with additional reflection on anticipated future climate change.

Ethics

Institutional ethics approval was granted by the Flinders University Human Research Ethics Committee (14/04/2025; project number 8272). All participants received a participant information sheet and provided explicit informed consent prior to participation. The protocol ensured protection of intellectual property, commercial-in-confidence business information, cultural knowledge, and participant anonymity throughout data collection and analysis.

Participant recruitment

To capture the lived realities of commercial enterprises, a targeted recruitment strategy was used, focusing on active business owners, managers, and industry representatives operating in water- and river-flow-dependent sectors in the CLLMM. Eligible participants were required to have a minimum of two years' direct management experience in their industry.

Prospective respondents were identified through regional industry registries, peak body networks, and targeted stakeholder mapping. This initial sampling frame was supplemented by snowball recruitment, whereby existing respondents recommended other eligible participants with substantial local and commercial experience. Invitations were issued via direct email and provided access to a confidential 10-15-minute online survey. An optional follow-up interview was offered; however, the analysis presented here relies exclusively on qualitative data collected through the survey instrument. No respondents took the offer of a follow-up interview. The survey remained open from October to November 2025. A copy of the survey instrument is provided in the Appendix. The recruitment strategy was appropriate for exploratory regional research but was not designed to generate a statistically representative sample of all CLLMM businesses. The findings therefore reflect the experiences and perspectives of participating enterprises rather than the full regional economy.

Data analysis

Open-ended survey responses were analysed using a hybrid inductive-deductive qualitative approach. Initial coding categories were informed by the survey structure and the project's focus on adaptation actions, barriers, enabling conditions, and governance. Additional themes were identified inductively from the data.

The analysis proceeded in several structured stages. First, responses were cleaned to remove blank or unusable entries, standardise formatting, reduce duplication arising from minor spelling or punctuation differences, and remove common filler words. Where possible, meaningful multi-word expressions were retained so they could be analysed as single concepts.

The cleaned text was then analysed in Python using natural-language-processing techniques. Frequency analysis was conducted on single words and on two- and three-word sequences (bigrams and trigrams) to identify commonly recurring issues (e.g., "*regulatory complexity*", "*lack of information*", and "*water market rules*"). Topic modelling and clustering methods were used to group related responses and identify recurring themes and narratives. Outputs from these computational steps were reviewed against the original survey responses to refine interpretation and ensure that identified themes accurately reflected respondents' intended meaning.

The analysis focused on adaptation to past and recent climate-related extremes and current operating conditions, rather than hypothetical optimisation under future scenarios. Issues relating to cultural and Indigenous perspectives were included only where they were raised explicitly by respondents or were directly relevant to governance and local knowledge; the survey was not designed to provide a standalone analysis of First Nations perspectives.

This qualitative evidence complements the economic analysis by clarifying why adaptation that appears efficient at an aggregate scale may be constrained or resisted at the enterprise level when transitional support, information, finance, or institutional arrangements are insufficient. Detailed results from this analysis are presented in Section 3.3, with additional detail provided in Table A3 in the Appendix.

2.2 Community creative artefact - short animation

2.2.1 Research Design

A participatory co-design approach was used to engage community members within the CLLMM region to identify shared and, where present, divergent knowledges, values, and future-oriented practices through collaborative arts-based methods. Participatory co-design is increasingly used in environmental research and practice because it highlights collaboration, shared decision-making, and locally grounded knowledge production, positioning participants as active contributors rather than passive recipients of expert-driven interventions (Norström et al., 2020).

This orientation aligns with sustainability scholarship that emphasises social learning, adaptive governance, and the co-production of knowledge as essential for addressing complex environmental challenges (Reed et al., 2010; Wyborn et al., 2019). Co-design approaches can support context-responsive innovation by enabling participants to articulate lived experience, values, and priorities, while also providing space for differing perspectives to be expressed and explored (Voorberg et al., 2015; Norström et al., 2020).

The co-design process followed an iterative methodology grounded in principles of being context-based, pluralistic, goal-oriented, and interactive (Norström et al., 2020). A series of five workshops was conducted within the CLLMM region and facilitated by members of the research team. Each workshop was structured around a guiding question and incorporated creative engagement techniques, including facilitated discussion, story development, visual and narrative exploration, and collective review of emerging material. Workshops typically ran for several hours, and outputs were recorded through facilitator notes, visual artefacts, draft scripts, and participant feedback, with each workshop informing the design and focus of subsequent sessions.

The workshop series progressed through phases of co-design, co-production, and co-dissemination (Wyborn et al., 2019), culminating in the creation of a collaboratively developed creative artefact: an animated short film. The animation uses a turtle as a narrative device to explore interconnection, change over time, and collective responsibility, and was designed to express participant concerns, priorities, and aspirations regarding climate change and adaptation in the CLLMM region.

The project aimed to engage a diverse cross-section of the community; however, the final co-design group comprised a small cohort of five participants with similar age profiles and a strong interest in environmental conservation. This limited demographic and sectoral diversity represents a constraint on representativeness. The creative process is therefore best understood as an in-depth participatory engagement with a small group of community members, rather than a comprehensive account of all community perspectives in the CLLMM.

2.2.2 Ethics

Institutional ethics approval was granted by the University of South Australia Human Research Ethics Committee [25/11/2024; project number: 206665]. All participants provided informed written consent prior to engagement, ensuring the strict protection of intellectual property, cultural knowledge, and personal data throughout the co-design and survey processes.

2.2.3 Recruitment and participants

The project was advertised throughout the CLLMM region via local community networks, including social media, newsletters, email distribution lists (including community-based conservation groups), and word-of-mouth through professional networks. Key community stakeholders, including community engagement officers within relevant organisations, supported this outreach. A $100 voucher was offered to participants in recognition of their time and contribution.

Recruitment materials sought to attract a diverse cross-section of community members, including individuals connected to industries closely linked to the CLLMM environment, such as fisheries, agriculture, and tourism, as well as those involved in environmental groups and natural resource management.

Recruitment took place during March 2025 and concluded in April 2025. As expressions of interest were received, it became apparent that there was no representation from local industry sectors (fishing, farming, tourism). Targeted recruitment efforts were subsequently undertaken to increase participation from these sectors; however, these efforts did not yield additional volunteers. As a result, the project scope was adjusted to align with the expertise and interests of the participating group. Specifically, rather than focusing on industry-specific adaptation pathways, the creative process emphasised broader ecological values, environmental stewardship, community narratives, and lived experience of regional change. This adjustment represents a methodological limitation, as it constrains the extent to which the creative artefact and associated insights can be interpreted as reflecting the perspectives of local industries or the wider CLLMM community.

A survey was circulated to registered participants to determine availability and preferred workshop location, and the first workshop was scheduled according to the date and location preferred by the majority. Of the fourteen individuals who initially registered interest, five attended the first workshop at the CLLMM Research Centre in May 2025 and formed the initial co-design group. Through word-of-mouth, one additional participant joined from the third workshop onward, resulting in a final group of six participants.

Participants ranged in age from 51 to 74 years, and the group was gender-diverse. They were motivated to participate due to personal and professional interests in environmental conservation and environmental management. Participants held administrative and service roles within conservation organisations, had professional experience in environmental sectors, and reported direct experience of climate-related impacts in the region.

2.2.4 First Nations perspective

None of the participants in the core co-design group identified as First Nations. To ensure cultural integrity, a First Nations consultant was engaged separately to provide cultural guidance and review during the animation's co-production phase. The consultant participated in Workshop 4 to review the animation prototype and provided rigorous feedback on the final draft animation via email, embedding critical cultural perspectives into the final output. The final animation was narrated by a First Nations woman who used both English and Indigenous Language.

2.3 Bringing it all together: Reflective synthesis on climate readiness

The project engaged with the CLLMM community to explore their understanding of vulnerability and capacity to adapt to floods and droughts that are likely to be exacerbated by climate change. Two complementary engagement processes were undertaken, involving different groups of participants. One group participated in the co-design and development of a community-led animation that expressed concerns, priorities, and aspirations related to climate change in the Coorong. The other group completed a targeted survey focused on climate impacts, recent extreme events, and the responses of water-dependent businesses. Together, these approaches generated different forms of evidence about how climate risk, adaptation, and change are understood and experienced within the region.

Previous work on climate adaptation in the CLLMM identified a set of considerations relevant to effective adaptation initiatives, reflecting characteristics that distinguish climate change from climate variability and other regional natural resource challenges (Dunlop et al., 2022). These considerations, together with insights from research on drought in the CLLMM and elsewhere in South Australia, informed the design of both engagement processes. They shaped an explicit focus on transformational climate impacts, understood in this report as large-scale changes in ecological character, hydrology, management context, and community uses of the system, rather than incremental adjustment within existing arrangements (see Section 1.1).

This section describes the method of reflective synthesis of how the animation and the survey engaged participants with these key climate adaptation considerations. The reflective synthesis does not evaluate the effectiveness or quality of the engagement processes themselves. Instead, it observes which adaptation-relevant issues were surfaced through each approach, illustrates the diversity of ways in which people can be introduced to deliberation about climate change and adaptation, and identifies topics that appeared more difficult to raise or explore through community engagement.

2.3.1 Reflective Synthesis Approach

Six themes were developed to support a reflective synthesis of the two community engagement processes. The themes were derived from prior Coorong adaptation work that identified climate-ready principles and priority actions and were informed by insights from research on the social impacts of drought in the region (Dunlop et al., 2021; Dunlop et al., 2022). The themes were used as an organising framework for reflection, rather than as evaluative criteria.

The six themes were:

- Accommodate large/transformational change,
- Work with increasing uncertainty, complexity and ambiguity,
- Attend to multiple values,
- Don't delay,
- Adaptation as a pathway, and
- Create a safe and encouraging environment to deliberate about change.

These themes are described in more detail in Section 3.5 to support interpretation of the reflective synthesis. The reflection focused on three guiding questions:

1. To what extent did each engagement process (animation and business survey) acknowledge or engage with the issues reflected in the six themes?
2. How was this engagement expressed through the processes and outputs?
3. How did participants respond to these issues?

Initial written reflections were prepared by three members of the project team, which were then deliberated on and refined collectively by the full project team. Reflections drew on four primary sources of material:

- the design and facilitation of the animation process, including framing and intentions,
- the animation itself, including script and visual elements,
- observations of participant responses during the animation development, and
- responses to the community survey.

The interpretation of the animation involved coding the animation transcript and associated materials against all six themes. The interpretation of the survey material involved coding a synthesised summary of qualitative survey responses (an expanded version of Table A3) against the first three themes, which were most directly applicable to the enterprise-focused survey data. A three-level interpretive scale was used to characterise how survey responses related to each theme: '*impedes*' (counter to climate readiness), '*neutral*' (no explicit signal of climate readiness, but potentially interpretable in a climate-ready way), or '*supports*' (explicit signal of climate readiness), following the approach outlined in Dunlop et al. (2021).

One member of the project team conducted the initial coding of the survey material, and a second member independently cross-coded the results. Differences in interpretation were resolved through discussion. Initial interpretations from the animation process, the animation content, and the survey analysis were then compared across the project team and refined through collective deliberation to produce the reflective synthesis presented in Section 3.5.

3 Results

3.1 Climate impacts on ecosystem services at risk under increased drought and flood

This section reports results from the synthesis of existing economic valuation evidence and scenario analysis described in Section 2.1.1. It summarises which ecosystem services and associated economic activities are most exposed to increased drought, flooding, and sea-level rise, rather than introducing new analysis.

The synthesis indicates that several downstream ecosystem services and economic activities in the CLLMM remain highly sensitive to climate extremes:

- Commercial fisheries contribute approximately $31.5 million annually to the local economy and are strongly dependent on climate-sensitive freshwater inflows, salinity regimes, recruitment conditions, and habitat availability,
- Nature-based tourism is exposed to severe drought conditions, with potential revenue losses estimated to reach up to $200 million per year during extreme low-flow periods,
- The Millennium Drought illustrated these vulnerabilities, with reported impacts including $174.8 million in tourism losses and $163.1 million in habitat restoration expenditure, alongside other unquantified ecological and community impacts (DEW 2026), and
- Sea-level rise and increased flooding threaten to transform parts of the system from predominantly freshwater to more marine-dominated environments, affecting freshwater-dependent species, activities, and assets.

Beyond sector-specific impacts, the Millennium Drought also triggered substantial public response costs. More than $200 million was spent on emergency water supply and infrastructure measures, including alternative pipelines and channel stabilisation (DEW 2026). These figures are reported here as indicators of economic exposure and response costs, rather than as comprehensive estimates of total ecological, cultural, or social losses.

Non-market valuation evidence further highlights the scale of values at risk. Previous stated-preference studies estimate aggregate household willingness to pay of around $13 billion for environmental improvements across the Murray-Darling Basin, with approximately $4.3–$5.8 billion attributed specifically to improving the ecological condition of the Coorong and Lower Lakes. These estimates are context-specific and depend on the populations, scenarios, and valuation methods used in the original studies.

Taken together, these results demonstrate that climate-driven changes in drought, flooding, and sea level have the potential to affect both market and non-market ecosystem services in the CLLMM. They also indicate that impacts extend beyond immediate production losses to include substantial public expenditure and longer-term risks of ecological transformation, with implications for fisheries, tourism, and water-supply systems. Detailed results and associated references are provided in Table A1 in the Appendix.

3.2 Trade-offs between agricultural production and environmental flows

This section reports results from the application and synthesis of existing evidence described in Section 2.1.2 and the supplementary water management options analysis. It does not present new hydrological, macroeconomic, or water market modelling. The results should therefore be interpreted as indicative estimates of potential trade-offs under the scenarios and assumptions used, rather than as predictions of outcomes.

3.2.1 Indicators of irrigation opportunity cost

Recent market evidence shows that selected high-security water entitlements in parts of the southern Murray-Darling Basin have traded in the range of \$7,000–\$9,000 ML^{-1}, which corresponds to an annualised equivalent value of approximately \$550–\$750 ML^{-1} when expressed using a 7 per cent real discount rate and a 30-year horizon. These prices provide one indicator of the long-run, capitalised cost of reliable irrigation access. They do not represent the value of all irrigation water, as entitlement reliability and usage differ across jurisdictions and many irrigators rely on lower-security entitlements, allocation trade, and carryover.

3.2.2 Residual value evidence

Residual value estimates demonstrate substantial variation in the implicit value of water across agricultural activities. Published farm-budget analyses indicate residual values ranging from around \$300 ML^{-1} for lower-value pasture systems to approximately \$2,600 ML^{-1} for high-value horticultural enterprises such as almonds and some fruit. These values are not returns to water alone; they reflect production systems that depend on land, trees, infrastructure, equipment, labour, management skill, and other enterprise assets. The wide range in residual values highlights that water use is highly place-based and sector-specific, and that differences in value cannot be interpreted as simple market failures or automatic justifications for reallocation.

3.2.3 Evidence on adaptation and aggregate impacts

The synthesis of Murray-Darling Basin hydro-economic, econometric, and CGE studies indicates that aggregate production and profit impacts are often smaller than proportional reductions in water availability, because irrigators adapt through water trading, carryover, crop switching, efficiency gains, changes in irrigation scheduling, and, in some cases, contraction or exit (ABARES, 2024). Across the studies reviewed, a 10 per cent reduction in water availability is commonly associated with around a 1–2 per cent reduction in aggregate irrigation profits, while larger reductions of 20–35 per cent are associated with approximately 5–17 per cent declines in aggregate farm profit or production value. These findings apply primarily at basin or regional scales and mask substantial heterogeneity, including severe impacts for some enterprises and locations.

3.2.4 Indicative application to CLLMM flow scenarios

Applying these established relationships to the supplementary water management scenarios, which explore alternative distributions of available water equivalent to approximately 2,000–6,000 GL of additional average annual flow over the barrages, yields indicative capitalised irrigation opportunity costs on the order of $16-48 billion, assuming water is sourced at current high-security entitlement prices and further adaptation is limited. These figures are intended to illustrate the order of magnitude of potential opportunity costs, not to predict realised costs for specific sectors or enterprises.

The same supplementary analysis also explored non-market environmental values associated with improved ecological condition in the CLLMM. Using previously published basin-wide willingness-to-pay estimates as a reference point, and scaling these values across the illustrative flow volumes, the analysis generated indicative non-market value ranges of approximately $120–360 billion. These estimates reflect a capitalised, basin-wide social value under the assumptions used, rather than a direct measure of benefits attributable to specific flow volumes or locations.

3.2.5 Interpreting the trade off

Taken together, the results indicate that environmental water provision has the potential to generate material social value, while also imposing concentrated and uneven adjustment costs on some irrigators, industries, and communities. Comparisons between stated-preference non-market values and irrigation opportunity costs require caution because the two values are derived from different methods, populations, contexts, and assumptions. The results therefore do not provide a definitive calculation of net social benefit. Instead, they highlight the nature of the trade-off: broadly distributed public values associated with ecosystem health versus more localised and sector-specific costs of adjustment (DCCEEW, 2026). Detailed results, data sources, and references are provided in Table A2 in the Appendix.

3.3 Adaptation enablers and barriers

Despite the difference between the estimated non-market value of ecosystem improvements associated with additional environmental flows and the opportunity cost of that water to agriculture at an aggregate scale, evidence from the industry survey of water-dependent businesses indicates that local adaptation is constrained by significant practical and structural barriers (Table 1). These results reflect the experiences of participating enterprises and illustrate how aggregate economic signals do not automatically translate into feasible or timely adaptation by local businesses.

Many respondents reported successful adaptation actions that increased efficiency, reduced exposure to water variability, or diversified income sources. Examples included investing in centre-pivot irrigation and soil-moisture probes to reduce per-hectare water use while maintaining milk yields; diversifying tourism products away from lake-level-dependent boating into birdwatching and cultural tours; and deliberately under-irrigating lower-value blocks to protect higher-value crops during periods of water scarcity. These actions were perceived by respondents to increase the marginal productivity and effective value of water within individual enterprises, demonstrating adaptive capacity where conditions allow.

However, these successes coexist with pervasive barriers to adjustment and longer-term adaptation. Respondents highlighted rising operating and capital costs, limited access to affordable finance, heavy administrative and compliance burdens, fragmented and complex policy information, and acute labour shortages during critical operational windows. While many of these pressures are common across rural and regional Australia, participants indicated that they are intensified in the CLLMM by high dependence on water availability, exposure to salinity risk, recurrent droughts and floods, and the complexity of Basin- and state-level water governance arrangements.

Information gaps related to local salinity dynamics, climate hazards, and climate projections were reported to inhibit strategic planning and investment. Slow regulatory approvals and complex water-market rules limited timely responses to observed ecological change. Many participants felt that their on-ground knowledge and experience were not adequately recognised in state-level and Basin-wide decision-making, contributing to reduced trust in institutions.

Together, these barriers were associated with a pattern in which some businesses relied on reactive crisis management rather than proactive resilience investment. Examples included short-term operational changes, delayed capital expenditure, emergency water purchases at peak spot prices, temporary changes in water sources, unplanned reductions in production, or tactical adjustments to fishing effort and irrigation scheduling in response to rapidly changing conditions. Respondents noted that such responses often occurred even where longer-term economic signals appeared to favour adaptation, reflecting constraints related to finance, information, regulatory timing, and uncertainty rather than lack of willingness to adapt.

These results indicate that the key challenge for adaptation in the CLLMM is not only the relative magnitude of aggregate environmental and agricultural values, but also the institutional, financial, and informational conditions that shape whether enterprises can act on those signals. Additional detail on adaptation actions, enablers, and barriers identified through the survey is provided in Table A3 in the Appendix.

Table 1. The core adaptation drivers and frictions emerging from the qualitative analysis.

Adaptation enablers	Structural barriers
Investment in efficient irrigation and monitoring technologies	High capital, insurance, and energy costs limiting financial headroom for adaptation
Operational flexibility (booking changes, route shifts, destocking)	Information gaps on salinity, hazards, and climate; fragmented data sources
Diversification into less water-dependent products and services	Regulatory complexity and slow approvals; difficulty navigating multiple agencies and programmes
Strategic use of water markets and carryover (where feasible)	Market uncertainty and contract insecurity discouraging long-term investments
Peer-to-peer learning and demonstration of successful practices	Limited staff capacity and planning bandwidth, especially in small operations
Collaboration with community and research partners	Marginalisation of local and Indigenous knowledge in formal planning and modelling
Investment in efficient irrigation and monitoring technologies	High capital, insurance, and energy costs limiting financial headroom for adaptation
Operational flexibility (booking changes, route shifts, destocking)	Information gaps on salinity, hazards, and climate; fragmented data sources

3.4 *The community creative artefact – short animation*

The participatory co-design process resulted in a community creative artefact in the form of a collaboratively developed animated short film that expresses participant perspectives on climate change, environmental change, and adaptation in the CLLMM region. The animation represents a key project output and provides a complementary form of evidence to the economic analysis and survey results.

Participants selected animation as the preferred medium because it was seen as accessible, engaging for younger audiences, and capable of conveying complex ideas without relying on technical or data-driven messaging. The final narrative uses a long-necked turtle as a central narrative device and elder figure, symbolising continuity, memory, and connection to place. Through this device, the animation explores climate change as a long-term, cumulative process rather than a series of isolated events.

Several core themes are embedded in the animation:

- the interconnection of river flows, ecosystems, and human activity over time, emphasising that “everything is connected”,
- recognition of past ecological and cultural loss alongside concern for future change,
- tension between human-centred economic priorities and more relational, interconnected worldviews, and
- framing adaptation as a collective responsibility, with an emphasis on shared action rather than individual blame or crisis narratives.

As a form of evidence, the animation surfaces relational, normative, and intergenerational dimensions of climate adaptation as articulated by participants, such as values, meanings, and collective responsibility, that are not readily captured through economic valuation or enterprise-focused survey data and therefore complements those results.

The animation was designed for ongoing community use, including multi-site community screenings and unrestricted sharing through local networks, to support continued discussion and reflection about climate adaptation in the CLLMM. The animation does not aim to represent all community perspectives; rather, it reflects the values, concerns, and aspirations of the participating co-design group.

The rest of this section documents the results of the workshop process, facilitation methods, and chronological development of the co-designed animation. It provides methodological detail to support transparency and reproducibility.

3.4.1 Workshop 1: Establishing purpose and connection to place

Facilitators from the research team introduced the project aims and outline. Examples of co-design projects and a diverse range of artefacts were presented to illustrate potential outputs.

Participants engaged in a ‘show and tell’ activity, sharing artefacts (e.g. photos, pamphlets) that they had brought with them representing what the CLLM region means to them (Figure 2). Facilitators introduced a range of potential creative techniques, including redacted text, postcards, and visual mapping and timeline exercises.

Figure 2. Activity in Workshop 1.

3.4.2 Workshop 2: Mapping meaning and identifying a creative direction

Participants undertook a mapping activity (Figure 3), pinning colored tags on an oversized map of the region to identify sites of meaning and significance. Discussion emerged on how place locations evoke temporal memories and situated forms of knowing. Participants reflected on how the project might capture change over time.

A CSIRO film depicting climate adaptation challenges within the CLLMM was screened and discussed. Participants then engaged in a redacted text exercise designed to surface alternative perspectives and contested knowledges.

Through group discussion, the idea emerged to utilise an animal character as narrative device to foster relational engagement. Animation was identified by the group as their preferred medium, appropriate for engaging and impacting the target audience. Participants referenced a prior community project featuring "Murray the Turtle" as a potential creative antecedent that could be referenced and built upon.

The group emphasised the importance of engaging younger generations in terms of the potential for action and change. They also emphasised the theme 'everything is connected' and discussed the narrative potential of the character turtle traveling upstream, alongside a multi-site launch extending beyond the CLLMM region.

Figure 3. Activity in Workshop 2

3.4.3 Workshop 3: Developing narrative and visual style

Participants were guided through a structured process to develop the animation narrative and select a preferred visual style. This included viewing and discussing example films and illustrated characters. Group consensus was reached on a gently unfolding animation style using soft tones and a line-drawing technique that built movement from left to right across the screen, reflecting the movement of the river.

A first-person narration delivered by the turtle was selected as the preferred storytelling device. Participants stressed that the film should not focus solely on environmental problems but should present solutions and a call to collective action. The turtle character was framed as a wise elder figure, comparable to a grandfather, speaking to humans about environmental change across time.

Members of the research team shared perspectives on climate adaptation and on the limitations of economic framings that treat nature primarily as a resource. Scientific input was provided where required to ensure accurate portrayal of species, behaviours, and contexts. This led to further refinement of the narrative concept, with the turtle positioned as an ambassador of nature speaking on behalf of interconnected species and ecosystems. The inclusion of additional regionally significant species was also discussed.

3.4.4 Between workshops 3 and 4: Narrative synthesis

Following Workshop 3, the project team synthesised key themes into a high-level narrative. Themes included:

- The interconnection of river flow and temporal change,
- Memorialisation of the past alongside adaptive futures,
- Tensions between human-centred and interconnected worldviews,
- Framing adaptation with collective action, and
- Positioning the long-neck turtle as a central narrative figure representing a broader ecological community.

A draft narrative and storyboard sketches were circulated to participants via email (19 June 2025). The storyline began with a global perspective before zooming into the CLLMM region, tracing the river's movement through time. The turtle was portrayed as an ambassador of nature attending a parliamentary "nature crisis meeting," challenging prevailing economic paradigms and calling for relational approaches to adaptation. The narrative concluded with the turtle recounting adaptive strategies to younger generations, emphasising collective action and future-oriented change.

Participant feedback informed subsequent revisions, including the selection of species, representation of adaptation strategies, refinements to the voice-over script, and adjustments to character design and visual elements.

3.4.5 Workshop 4: Reviewing animatic and cultural guidance

Professional animators were engaged during the interim period to develop an animatic and initial character drafts (Figure 4). At Workshop 4, participants reviewed these materials and provided feedback on landscape representation (including grasses and barrages), contrasts between ecological health and degradation, sound design, and species inclusion.

The group also discussed the use of First Nations language for creature names with a First Nations cultural consultant.

Figure 4. Activity in Workshop 4

3.4.6 Between workshops 4 and 5

Revised sketches, voice test recordings (including male and female narration and character voices), draft colour scripts, and creature illustrations (Figure 5) were circulated via email. Participants provided written feedback, which informed further refinements to the animation.

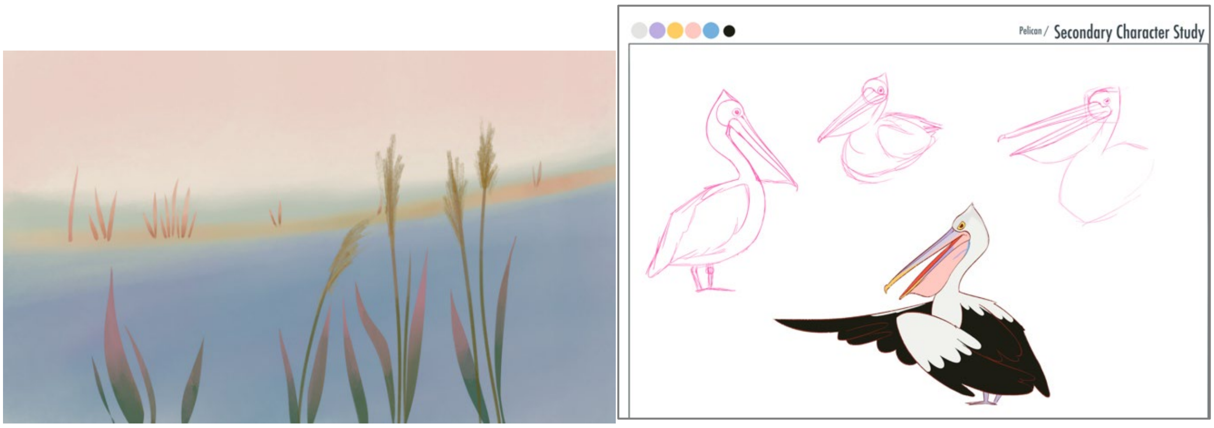

Figure 5. Draft animations

3.4.7 Workshop 5: Final review and dissemination planning

A near-final draft of the animated film was screened for participants, with clarification that only minor revisions could be accommodated at this stage of production. Participants provided feedback on the geographical accuracy of the river's visual representation, ensuring fidelity to key landscape features. The pronunciation of the First Nations word for "turtle" (Figure 6) was identified as requiring confirmation with the cultural consultant. The group also discussed the use of a male voice-over, inclusion of a water treatment plant in the visual sequence, and refinements to the concluding scene to avoid unintended anthropomorphism.

Participants then engaged in a collaborative brainstorming process to generate potential titles for the film, with shortlisted options to be circulated by email for final selection.

A dissemination strategy was also developed, including an official community launch event timed to coincide with "Turtle Day," followed by additional satellite screenings hosted by community groups. It was agreed that participants were to have ongoing, unrestricted access to the film for use within their organisations, networks, and community groups.

As not all participants attended the final workshop, the animation and requests for final feedback were circulated by email.

Figure 1. Turtle images

The final version of the animation can be viewed here, and on the CLLMM Research Centre YouTube site.

3.5 Reflective synthesis on climate adaptation themes

This section presents a reflective synthesis by the project team on a set of climate adaptation themes and summarises how these themes were surfaced through the two engagement processes: the community-led animation workshops and the economic survey of water-dependent businesses. The synthesis does not evaluate community capacity or performance. Instead, it reflects on how different issues associated with climate adaptation were engaged with, expressed, or constrained through each engagement approach.

The themes provide a lens for examining the types of climate adaptation challenges and considerations that emerged from the engagement processes, and for identifying issues that were readily articulated as well as those that appeared more difficult to engage with.

3.5.1 Theme 1: Accommodate large/transformational change

Climate change is expected to drive changes that are substantially more significant than those experienced to date, including more frequent and intense extreme events, reduced recovery time between events, and shifts toward hotter and drier baseline conditions. Parameters that are often treated as stable, such as temperature, rainfall, river flows, coastlines, seasonal events, ecological communities, and species distributions, are likely to change. Preparing for these conditions requires recognising that past and present environmental states may no longer provide suitable benchmarks for future objectives, and that existing aspirations and governance arrangements may not remain effective.

Animation

The animation explicitly acknowledges large-scale and ongoing change in several ways:

- it refers to major changes that have occurred over long timeframes, alongside the expectation that "with climate change, all these things will happen more often",
- it states clearly that "we can't go back to how it was years ago", and
- it notes that even after improvement, "that doesn't mean everything is perfect."

The responses articulated in the animation engage directly with the pervasive nature of change, including calls to "rethink everything" and to adopt "new ways of thinking." Adaptation is portrayed as an ongoing process rather than a one-off intervention, with responsibility extending across generations ("you young ones have to carry on helping, caring, and adapting"). The animation also conveys that action is required at multiple scales, locally, upstream, at state and national levels, and across the Basin, rather than being confined to individual or community action alone.

Economic survey

Survey responses indicate that some businesses are undertaking strategies consistent with structural or transformational adjustment, rather than responding only to short-term variability. This was most evident among respondents with sufficient financial, organisational, and cognitive capacity to diversify into less climate-exposed activities, for example by developing new business lines or expanding beyond water-dependent production. Professional networks and peer-to-peer learning groups also emerged as important mechanisms for identifying and sharing practical responses to large-scale change before crisis conditions are reached.

Respondents identified specific forms of support that would enable transformational adaptation, including targeted financial assistance to support major transitions and investment in adaptive public infrastructure (such as adjustable jetties) designed to accommodate permanent changes in water levels.

At the same time, respondents described adaptation strategies that are effective for managing current and near-term extremes, such as droughts and heatwaves, but which may be insufficient under longer-term transformational change. These measures can function as transitional responses, buying time to prepare for deeper structural shifts. However, without explicit planning for permanent baseline change, reliance on near-term adaptations can increase long-term vulnerability. For example, major investments in irrigation upgrades and water-efficiency technologies may reinforce path dependency and prolong reliance on water-dependent livelihoods unless paired with strategies to transition toward lower-water-reliance activities once ecological or hydrological thresholds are exceeded.

Respondents also highlighted acute constraints on accommodating large-scale change. Pressures to maintain business-as-usual operations during severe heatwaves created staff safety risks and delivered poor economic returns. Capital-intensive technological fixes aimed at preserving historical operating conditions were frequently described as high-risk or poor-value investments. Where enterprises were operating with limited financial reserves, high debt, constrained organisational capacity, or limited time for strategic planning, the ability to undertake transformational change was severely restricted.

These findings highlight an important distinction between individual enterprise survival and regional-scale adjustment. While some businesses may contract, exit, or redeploy capital as climate and water pressures intensify, broader regional adaptation depends on whether policy and institutional settings support both orderly transition for existing enterprises and the emergence of new, climate-appropriate activities. From this perspective, accommodating large-scale change is not solely a matter of individual decision-making, but of creating conditions that enable transformation at the regional system level.

3.5.2 Theme 2: Work with increasing uncertainty, complexity and ambiguity

Climate change is characterised by increasing uncertainty, complexity, and ambiguity. Some of these uncertainties are irreducible and cannot be eliminated through improved modelling or forecasting. Working within this reality requires approaches that accommodate volatility and imperfect information, rather than delaying action until certainty is achieved.

Animation

The animation engaged with uncertainty and complexity primarily through relational framing. Messages such as “everything is connected” and “we cannot do it on our own” conveyed that outcomes emerge from interacting ecological, social, and institutional processes rather than linear cause–effect relationships. The narrative also showed that even collective action does not produce perfect or final outcomes, emphasising that adaptation requires ongoing effort under changing conditions.

While the animation necessarily simplified complex adaptation challenges, it presented uncertainty as something to be lived with and worked through. Complexity was made accessible through metaphor and story rather than through institutional or technical detail, foregrounding cooperation, learning, and continuing responsibility rather than definitive solutions.

Economic survey

Survey respondents described a range of agile operational strategies used to manage short-term uncertainty and complexity. These included flexible booking arrangements, designing tourism products that could operate under variable conditions, adjusting fishing or irrigation effort to match prevailing flows and salinity, and timing maintenance activities to coincide with periods when operations were constrained by low water.

Respondents also identified supports that would assist them in working more effectively with uncertainty. Peer influence, local demonstrations, and shared experience of past extremes were seen as important for reducing perceived risk when adopting new practices. Many respondents emphasised the value of consolidated, plain-English regional information, particularly dashboards integrating climate, salinity, flow, and hazard data, to reduce information asymmetries and support decision-making in complex environments.

At the same time, respondents highlighted clear limits. They cautioned against extrapolating from short-term success, noting that practices effective in one season or set of conditions may fail under different circumstances. As one respondent noted, there is "no silver bullet." Cumulative stress, fatigue, financial pressure, and limited time reduced the capacity of operators to evaluate and implement new options. Business models requiring certainty in market pricing, supply contracts, or environmental conditions were consistently described as highly exposed in volatile estuarine systems.

3.5.3 Theme 3: Attend to multiple values

Climate change affects the CLLMM through multiple, intersecting pathways, influencing a wide range of values held by the community. These include instrumental values (e.g. nature as an input to fisheries or agriculture), relational values (e.g. cultural connections, memory, sense of place), and intrinsic values (e.g. nature's right to exist). Under climate change, some values may persist while others are transformed or lost.

Animation

The animation surfaced multiple values primarily through the voices and experiences of different species, illustrating varied forms of environmental degradation and their consequences. The narrative placed strong emphasis on intrinsic values of nature, repeatedly calling on people to "value and prioritise nature" and to adopt "new ways of thinking."

While the animation acknowledged that prioritising nature does not result in perfect outcomes, it focused less on explicit negotiation between competing human interests or on economic trade-offs associated with water reallocation. Adaptation responses were framed as multi-scale: responding to highly specific local needs (e.g. different biota) while also requiring changes to broader system processes, such as water-sharing arrangements, to support values such as fairness.

Economic survey

Survey responses indicated that attending to multiple values can expand adaptation options. Tourism operators who diversified offerings to appeal to varied consumer values, such as culinary, birdwatching, and cultural experiences, were able to reduce reliance on water-level-dependent activities. Respondents also described non-market values as central to decision-making, including cultural obligations to Country, ecological stewardship, and community wellbeing, even where this involved foregoing short-term financial gain.

Conversely, respondents highlighted how the dominance of market values can constrain adaptation. Contractual standards and premium market requirements for reliability often drove operators to secure expensive water or intensify existing systems, increasing exposure. Rising input costs further reduced the financial headroom required to attend to broader non-market values.

Survey responses also revealed situations where climate impacts forced values into direct conflict. Examples included tensions between labour demand and worker safety during heatwaves, and failed partnerships where external operators prioritised extraction over local culture and environmental limits. Respondents expressed frustration that local practitioner knowledge was often marginalised in high-level decision-making, undermining trust and social licence.

3.5.4 Theme 4: Don't delay

Preparing for transformational change requires long lead times. Where impacts unfold faster than adaptive responses can be implemented, the capacity to prepare erodes. Proactive, anticipatory action can expand future options compared to reactive responses undertaken during crisis conditions.

Animation

Urgency in the animation emerged primarily from existing degradation and past management impacts. The narrative made clear that unacceptable impacts are already occurring, while also foreshadowing more extreme future conditions. Anticipatory action was implied through intergenerational messaging ("you young ones have to carry on helping, caring and adapting"), but urgency was driven more by current damage than by explicit framing of immediate action to prepare for fundamentally different future states.

Economic survey

Survey respondents demonstrated that they are already adapting and do not view climate change as a distant issue. Actions were commonly taken in response to recent shocks such as algal blooms, sudden flow reductions, salinity changes, heatwaves, and flood-related disruption.

However, most adaptations described were reactive or near-term. Respondents reported that financial, time, and labour constraints limited their capacity to undertake anticipatory structural planning. As a result, while adaptation activity is ongoing, immediate pressures frequently crowd out longer-term preparation for transformational change.

3.5.5 Theme 5: Adaptation as a pathway

Adaptation can be understood as a continuous pathway of incremental steps rather than a sequence of isolated responses. Such pathways involve learning, adjustment, and coordination over time, potentially enabling more significant transformation.

Animation

The animation narrative unfolded as a connected sequence of actions: an initial local "Nature Crisis meeting," engagement with national decision-making through parliamentary processes, shifts in values, local actions across multiple regions, improved cooperation between states, and ongoing adaptation. Adaptation was portrayed as iterative and continuous, reinforced by the message that responsibility does not end once conditions improve.

The narrative also highlighted the importance of building human capabilities and governance arrangements, including working together locally and across scales and managing conflicts between values and users through cooperative institutions.

Economic survey

Although the survey was not designed to map formal adaptation pathways, responses indicated that operators often treat adaptation as an iterative learning process. Respondents described testing new practices, observing outcomes, and refining decisions over time, for example, trialling drought-tolerant crops, modifying tour routes, adjusting fishing effort, or changing irrigation scheduling.

These responses suggest experiential learning and incremental adjustment in response to climate events. However, the development of explicit long-term pathways was constrained by capital limitations, uncertainty, time pressure, and the need to maintain day-to-day viability.

3.5.6 Theme 6: Create a safe and encouraging environment to deliberate about change

Climate change challenges established ways of living and working, making it important to create environments where people can deliberate about change without professional, social, or commercial repercussions. Such environments often require external facilitation and structured processes.

Animation

The creative process provided a collective space for deliberation. The use of animation and the framing of animals discussing a crisis created psychological distance from participants' personal circumstances, enabling discussion of difficult issues through metaphor and story.

Within the animation itself, a safe deliberative space was depicted: animals develop a shared position before taking it to a more contested forum, the human parliament. Through the character of Thukabi, the narrative allowed non-human perspectives to articulate responsibility and change. Themes of cooperation and mutual support ("…can help each other") were prominent throughout.

Economic survey

The survey functioned as a confidential space for reflection. Anonymity allowed respondents to describe vulnerabilities, financial and operational pressures, and systemic concerns without fear of reputational or regulatory consequences.

In doing so, the survey generated a shared evidence base that captured both immediate strategies for maintaining business viability and the broader supports respondents saw as necessary for structural adaptation, including accessible finance, clearer information, and more inclusive governance. While the survey did not create interactive deliberation, it enabled candid reflection that would be difficult in more public settings.

4 Discussion

4.1 A unique approach

The application of different disciplinary approaches within a single project yielded complementary perspectives on climate adaptation in the CLLMM. Rather than a fully integrated design in which one method directly shaped the other, the project brought together creative arts and economics through parallel engagement processes, followed by a shared reflective synthesis. This combination remains uncommon in regional climate adaptation research and provides insight into how different forms of evidence can be placed in conversation.

Different participants were drawn to each engagement stream. The creative arts research attracted community members interested in collaboratively developing a creative artefact to communicate perspectives on climate adaptation using emotional, symbolic, and narrative forms. This resulted in the animation, which highlights systemic and societal dimensions of climate change in the CLLMM and appeals to broadly shared values through metaphor and story.

The economics research attracted water-dependent business owners and operators willing to reflect on the impacts of climate change on their livelihoods and on the practical challenges of adaptation. Survey responses focused on day-to-day operational realities, financial and regulatory constraints, and the trade-offs involved in responding to climate extremes.

The two engagement processes were not designed to be mutually influential during implementation. The economic analysis was not presented to participants in the creative workshops, and the animation process did not shape the valuation or survey analysis. Instead, the value of the approach lies in the post-hoc synthesis of two distinct forms of evidence: one that surfaces relational, normative, and intergenerational dimensions of adaptation, and another that documents enterprise-level constraints, incentives, and adjustment strategies.

The use of a climate-readiness lens provided a common framework for interpreting results across both approaches. This enabled the project team to draw out context-specific insights from a single regional case, while also identifying transferable analytical lessons about how different engagement methods illuminate different aspects of climate adaptation.

4.2 Climate readiness of the CLLMM community

4.2.1 Responses of the different facets of the community

The project provides insight into how different parts of the CLLMM community understand climate adaptation, what they find helpful, and the barriers they encounter. These insights are necessarily partial, reflecting the perspectives of participants engaged through the animation workshops and the economic survey rather than the full diversity of the regional community.

Both engagement processes reflected the experiences of people who view climate change as a current and tangible issue, already affecting their lives, livelihoods, and the places they value in the CLLMM. Applying a climate-readiness lens enabled a more detailed reflection on how this awareness is expressed and acted upon by different participants.

Across both groups, there was a shared awareness of the need to adapt to large-scale change, accompanied by a strong sense of urgency. In both cases, however, this urgency was primarily driven by impacts already experienced, rather than by anticipation of future conditions that may be more extreme. The nature of the response to large change differed between the two engagement streams. The animation articulated a call to "rethink everything," focusing on societal values and the underlying drivers of climate impacts, and situating responsibility and action across multiple scales. In contrast, the economic survey emphasised feasible, near-term adaptation actions available to individuals and enterprises, many of which may be effective in buying time but do not necessarily constitute preparation for longer-term transformational change. It remains unclear whether this difference reflects the engagement methods themselves or the characteristics and constraints of the participants drawn to each process.

In relation to uncertainty and complexity, the animation readily embraced the idea that systems are interconnected, outcomes are imperfect, and cooperation is essential. Survey respondents responded to uncertainty by cultivating flexible operating practices, while also identifying systemic constraints, such as market expectations, regulatory complexity, and cumulative pressures, that limit their ability to operate effectively under volatile conditions.

Both engagement approaches highlighted the importance of engaging with multiple values in the CLLMM. The animation highlighted intrinsic values of nature and the need to prioritise ecological integrity, while the economic survey demonstrated that attending to a broader set of values, including cultural, relational, and community values, can expand adaptation options. At the same time, the survey showed how a strong dominance of market values can constrain adaptation and reinforce exposure to climate risk.

A central theme emerging across both methods is the risk of insufficient preparedness. While many local business operators demonstrate considerable agility, this can mask a lack of deeper resilience. Many businesses appear to be operating close to the limits of their financial, organisational, emotional, informational, and coordination capacity, managing compounding climate shocks through reactive crisis responses rather than planned transformational investment. This does not reflect a lack of awareness or capability, but rather the burden of operating under sustained stress and uncertainty.

This dynamic creates a fragile regional equilibrium. The longer adaptation to future climate change is delayed, the harder it becomes for people and businesses to adjust through gradual, managed transitions. Instead, there is an increased risk of abrupt adjustment, including business contraction or exit, loss of equity, stranded assets, erosion of valued places and practices, and reduced opportunities to maintain social and cultural connections. At a regional scale, adaptation may involve some enterprises exiting while new activities emerge, but whether this transition is orderly or disruptive will depend heavily on the policy, institutional, and support settings that shape climate readiness across the CLLMM.

4.2.2 Implications and strategic pathways

Both engagement processes created opportunities for community participants to articulate their perspectives within a highly contested and complex discourse on climate adaptation. The co-produced animation provides an artefact that can be shared beyond the project to support broader discussion and reflection. The economic survey created a structured opportunity for respondents to reflect on their own strategies and constraints, while also generating evidence that allows participants and the wider community to better understand the diversity of responses occurring across the region. This form of reflection and sharing can be understood as an important component of climate adaptation, which is fundamentally a collective learning process.

Taken together, the animation and survey results highlight ways in which broader socio-economic, institutional, and policy settings can either support or constrain effective adaptation. The animation emphasised that while there is local adaptive capacity, the scale of disruption associated with climate variability and change, combined with upstream extraction and other pressures, means that action is also required at broader structural and governance scales. Survey respondents similarly indicated that some policy settings can, in certain circumstances, inadvertently encourage delayed adaptation, for example where expectations of emergency assistance reduce incentives to undertake earlier, more difficult adjustments. These findings suggest that policy settings which provide earlier, targeted support for adaptation, transition, innovation, or diversification are associated with the potential to reduce reliance on reactive emergency responses and support more managed adjustment where activities or sectors become highly exposed.

The qualitative evidence also points to limits in current preparedness. Many enterprises operate on tight margins and manage compounding climate shocks through short-term crisis responses rather than planned long-term investment. In this context, policy options such as structured exit and transition packages, when combined with support for innovation, skills development, and new enterprises, could help manage consolidation in climate-exposed industries while also creating pathways for new, climate-appropriate activities to develop within the region.

The findings also point to important gaps in the current evidence. Much of the economic adaptation and resilience data is based on conditions observed during or immediately after the Millennium Drought. Since that time, structural changes, including increased reliance on capital-intensive permanent plantings and the maturation of water markets, have altered regional risk profiles. Updated research is needed to quantify contemporary market and non-market economic returns, social outcomes, and distributional effects associated with different adaptation pathways under anticipated future climate conditions.

Projected decreases in rainfall, increases in evaporation and water demand, and the longer-term influence of marine processes on the Lower Lakes and the Coorong are likely to further transform how people relate to and value the region. These changes may alter the opportunities available to agriculture, tourism, fisheries, and other industries, as well as the marginal economic value of water for different uses and the dynamics of upstream water availability and demand.

Taken together, the results provide distinct forms of strategic value for different audiences:

- **Policymakers:** The analysis suggests that policy settings which support earlier adaptation, transition, innovation, or exit by water-dependent enterprises could reduce future reliance on emergency funding. It also indicates that increases in environmental flows could, under certain assumptions, reduce drought-related impacts on CLLMM ecosystems and generate substantial non-market social value.
- **Local communities:** The documented adaptation barriers and successes provide evidence to support peer-to-peer learning, collective reflection, and community-led advocacy.
- **Research communities:** The project demonstrates the value of combining quantitative economic analysis, qualitative survey evidence, and creative arts-led co-design to explore the socio-economic dimensions of regionally focussed climate adaptation and resilience.

4.3 Reconciling the triangulated economic evidence

This section reconciles three distinct bodies of evidence examined in this report:

1. existing non-market valuation and ecosystem service studies relevant to environmental improvement in the CLLMM;
2. opportunity-cost evidence derived from entitlement market prices, residual value estimates, and Murray–Darling Basin hydro-economic and macroeconomic literature; and
3. qualitative evidence generated in this project, including the industry survey and insights from the community-led animation process.

Together, these evidence streams highlight a persistent tension between aggregate, system-scale assessments and local, lived realities of climate adaptation. Available estimates suggest that, under some scenarios and assumptions, increasing environmental flows may deliver net social benefits. However, these estimates are derived from different methods, populations, contexts, and time periods, and are not directly comparable or transferable to future climate conditions without qualification.

Evidence from production economics and water-market studies suggests that aggregate production and profit impacts of reduced water availability are often estimated to be proportionally smaller than the reduction in water volumes, reflecting adaptive responses such as water trading, crop switching, efficiency gains, business restructuring or exit, and capital redeployment. These findings are most relevant at basin or regional scales. At the enterprise and district scale, however, both the literature and this project's survey evidence show that changes in water availability can generate substantial stress, including stranded assets, network effects, and abrupt contraction or exit.

The survey evidence demonstrates that many CLLMM businesses are already adapting, but face significant barriers including capital constraints, complex policy settings, fragmented information, regulatory delays, labour shortages, and limited institutional recognition of local knowledge. These constraints help explain why changes that appear advantageous at an aggregate scale may be difficult, costly, or socially contested locally.

The evidence also indicates that environmental water can support ecosystem health and reduce some drought-related impacts depending on availability, timing, allocation rules, and ecological thresholds. Environmental water cannot remove drought risk, and during severe droughts there may be limited water available for delivery to any use. The case for increasing environmental flows therefore depends on the specific scenario considered and the assumptions used.

The quantitative foundations for opportunity-cost estimates summarised in this project rely heavily on models developed during or soon after the Millennium Drought. Since then, the Basin economy has shifted toward more capital-intensive production systems, water markets have matured, and climate projections have become more severe. Older model elasticities may therefore understate contemporary rigidity, transition costs, and the risk of stranded assets. In addition, most models report aggregate indicators rather than fine-grained local outcomes, obscuring who bears costs and where.

Finally, the economic assessment under-represents intrinsic, cultural, and First Nations values. Insights from the animation and qualitative survey highlight the deep connection between healthy Country and healthy communities and the importance of relational values and Traditional Ecological Knowledge. This points to the need for decision-making frameworks that can consider market values, non-market values, cultural perspectives, and local knowledge together, while making areas of uncertainty and contestation explicit.

Taken together, the triangulated evidence supports a cautious dual message. Increasing environmental flows may generate substantial social and ecological value under the assumptions used in existing valuation work, but any reallocation pathway will create uneven local impacts. Policy and governance settings that reduce information barriers, support earlier adaptation, and provide targeted transition, innovation, or exit support could reduce the social and economic fragility of adjustment. Whether these outcomes are realised depends on how such measures are designed, timed, and aligned with local conditions, rather than on aggregate efficiency arguments alone.

4.4 Priority interventions

The findings of this study do not identify a single preferred policy pathway. Instead, they point to a set of priority interventions that emerge from the combined economic analysis, qualitative survey evidence, and creative arts co-design process. The priority interventions reflect the structural conditions identified in the analysis and the needs articulated by community participants, rather than prescriptive recommendations.

- **Environmental water acquisition and flow management:** The valuation synthesis indicates that, under certain assumptions, additional environmental flows could generate substantial non-market social value. Progressing towards CLLMM scenarios in which barrage outflows and ecological targets are more consistently pursued and may therefore support ecosystem health and associated values. The realised benefits depend on how water is sourced, timed, and delivered, particularly under drought conditions when total water availability is constrained.
- **Transitional assistance for affected irrigators and communities**: Survey evidence indicates that capital constraints, debt exposure, and the risk of stranded assets are major barriers to structural adaptation. Policy options such as structured buyback and adjustment packages, support for on-farm efficiency improvements and crop transitions, and measures to avoid stranded delivery infrastructure could facilitate more managed transitions for highly exposed sectors, compared to reliance on reactive emergency assistance.
- **Information and governance reforms:** Both engagement processes highlighted information asymmetries and governance complexity as constraints on adaptation. Practical reforms, such as a single, plain-language regional dashboard integrating water levels, salinity, algal alerts, and access conditions, could reduce uncertainty and support decision-making. Stronger integration of local and First Nations knowledge into Basin and state-level planning processes may also improve trust and ensure that values not captured by standard economic metrics are more fully considered.
- **Support for community-led adaptation and diversification:** Qualitative survey results show that businesses can reduce climate exposure by diversifying products and services, while the creative process highlighted the importance of place-based values and locally grounded solutions. Targeted support for trialling diversified tourism products, adaptive fisheries strategies, and place-based planning could help address the lack of financial headroom reported by operators and enable experimentation with lower-risk adaptation options.
- **Coordinated, cross-sectoral planning for adaptation:** A consistent message across the animation and business survey evidence is that the scale of climate and water-related change exceeds what individual enterprises or community members can manage alone. More coordinated planning across sectors and scales could help align environmental objectives, economic adjustment, and social outcomes, reducing the risk that adaptation efforts in one area inadvertently increase vulnerability elsewhere.

4.5 Role of the creative process in community adaptation

The creative co-design process did not build adaptation capacity in a direct or instrumental sense, nor was it intended to represent the full diversity of community perspectives. Its value lies in providing a safe, accessible space for deliberation on complex and emotionally charged issues, surfacing relational and intrinsic values, and enabling participants to articulate concerns that are difficult to express through economic or survey instruments alone. As such, arts-based engagement is a valuable pathway for supporting collective reflection and dialogue to complement policy, financial, or institutional interventions.

Together, these priority areas highlight that effective climate adaptation in the CLLMM depends not only on the magnitude of environmental or economic benefits identified in aggregate analyses, but also on the design of supportive institutional, informational, and transitional settings that shape whether adaptation pathways are feasible, timely, and socially viable.

5 Conclusion

This report brings together economic analysis, qualitative enterprise evidence, and a community-led creative process to provide a multi-dimensional and multi-disciplinary account of climate adaptation in the CLLMM. By placing these distinct forms of evidence in conversation through a climate-readiness lens, the study reveals both the scale of social and ecological value at stake and the practical constraints that shape how adaptation unfolds at the local level.

The findings highlight a persistent tension between aggregate system-level assessments and the lived realities of water-dependent communities, where transitional costs, uncertainty, and institutional settings strongly influence adaptive capacity. While environmental water provision may generate substantial social value under certain assumptions, the analysis shows that adaptation pathways are only viable when supported by appropriate information, governance, and transition mechanisms.

The project also demonstrates the power of creative, arts-based engagement to help understand relational, cultural, and intergenerational dimensions of adaptation that are not well captured by economic metrics alone. Taken together, the report contributes a context-specific but analytically transferable framework for understanding climate adaptation as a systemic, place-based, and socially contingent process.

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Appendix A. Evidence Base for Ecosystem Service Valuation, Water Reallocation Trade-offs, and Community Adaptation Analysis

Table A1. Key studies informing quantification of ecosystem values in the CLLMM

STUDY	GEOGRAPHIC FOCUS	PRIMARY METHOD	ECOSYSTEM SERVICE(S)/ OUTCOME VALUED	KEY QUANTITATIVE INSIGHTS FOR CLLMM CONTEXT
Banerjee et al. (2013)	CLLMM region	Economic valuation of drought impacts	Multiple services (water supply, tourism, habitat, salinity mitigation)	Estimates approximately AUD 810 million in selected economic losses and emergency expenditures associated with the Millennium Drought. These figures provide a historical indicator of exposure and response costs under extreme low-flow conditions, not a measure of ecosystem damage avoided by environmental flows. Drought impacts and reduced baseline flows are analytically distinct, and environmental water can mitigate impacts only where water is physically available.
Bark et al. (2016)	CLLMM and MDB	Integrated ecological–economic modelling	Ecosystem service improvements from environmental flows	Links ecological response functions (e.g. salinity and flow relationships) with monetary valuation evidence. Resulting estimates are conditional on the ecological changes modelled, valuation assumptions, and beneficiary populations, and do not represent objective or transferable values across different future contexts.
BDO EconSearch (2021)	Lakes and Coorong Fishery	Socioeconomic impact assessment	Commercial fisheries	Estimates approximately AUD 31.5 million in annual economic contribution and ~189 FTE jobs, providing a baseline indicator of fisheries activity exposed to changes in freshwater inflows, salinity, and habitat condition, rather than a valuation of ecosystem services per se.
Brookes et al. (2023)	MDB (CLLMM focus)	Policy and performance review	Basin Plan outcomes; ecological condition	Identifies the Coorong as a sentinel system, linking flow shortfalls and water management outcomes to ecological degradation and potential ecosystem service loss, without quantifying monetary values.
Colloff et al. (2015)	CLLMM and MDB wetlands	Ecosystem service synthesis	Multiple hydrology-	Identifies 26 ecosystem services associated with the CLLMM and highlights their

STUDY	GEOGRAPHIC FOCUS	PRIMARY METHOD	ECOSYSTEM SERVICE(S)/ OUTCOME VALUED	KEY QUANTITATIVE INSIGHTS FOR CLLMM CONTEXT
			dependent services	dependence on freshwater inflows, hydrological connectivity, and ecological condition. The study does not rank services or imply stable priorities under future climate change.
Dunlop et al. (2022)	CLLMM	Adaptation pathways analysis	Ecosystem condition under climate futures	Describes low-flow and sea-level rise pathways as distinct, temporally separated climate contexts, not simultaneous alternatives. These pathways inform thinking about ecological transformation but are not quantified flow scenarios and require fundamentally different baselines, ecosystem services, and valuation frameworks under future conditions.
Gehrig et al. (2020)	SA Murray and CLLMM	Hydro-ecological modelling (EWRs)	Environmental flow requirements	Specifies flow and salinity relationships relevant to ecological condition. These provide biophysical context for interpreting ecosystem responses, but do not define the monetary value of meeting flow targets or of alternative ecological states.
Grigg et al. (2022)	CLLMM	Vulnerability assessment	Climate-sensitive ecosystem services	Identifies assets, services, and system components vulnerable to climate change, emphasising that future baselines and priorities will differ from historical ones and that new, forward-looking processes are required to identify future values and objectives.
Hatton MacDonald et al. (2011)	MDB (CLLMM focus)	Choice modelling (stated preference)	Non-market environmental values	Estimates approximately AUD 13 billion in aggregate willingness to pay for environmental improvements across the Basin, including ~AUD 5.8 billion for the Coorong and Lower Lakes. These values reflect the survey population, scenarios, and methods used and cannot be transferred directly to future climate or water-management contexts without qualification.
La Notte et al. (2021)	Global (conceptually applied to CLLMM)	Conceptual ecosystem service framework	Habitat and species maintenance	Provides a conceptual basis for interpreting biodiversity and waterbird habitat as ecosystem services; does not provide site-specific valuation.

STUDY	GEOGRAPHIC FOCUS	PRIMARY METHOD	ECOSYSTEM SERVICE(S)/ OUTCOME VALUED	KEY QUANTITATIVE INSIGHTS FOR CLLMM CONTEXT
Lester et al. (2011)	CLLMM	Eco-hydrological assessment	Salinity and flow–ecology relationships	Links freshwater inflows to salinity gradients and habitat condition, providing ecological context for interpreting drought, reduced flows, and sea-level rise impacts.
Prowse (2020; 2022)	CLLMM	Ecological assessment	Waterbird habitat	Identifies key species and habitat dependencies, informing interpretation of climate-sensitive ecosystem services without assigning monetary values.
Rees et al. (2022)	CLLMM	Scenario-based ecological modelling	Habitat and species response	Models cascading ecological impacts under reduced inflows and climate stress, supporting understanding of potential ecological transformation rather than valuation of specific states.
SEEA–UN (2021)	Global	Ecosystem accounting framework	Recreation and biodiversity services	Defines classification and accounting structures for ecosystem services, providing a framework for integration rather than values.
Tingey-Holyoak et al. (2026a)	CLLMM and MDB	Discrete choice experiment and best–worst scaling	Non-market values of environmental flows	Estimates willingness to pay for ecological improvements and environmental flows under specified survey scenarios. These marginal values are context-dependent, relying on assumptions about flows, governance, ecological responses, and populations surveyed.
UN (2021) SEEA EA	Global	Statistical framework	Ecosystem accounting	Provides an international standard for integrating biophysical and monetary ecosystem accounts; does not prescribe values.
Department for Environment and Water (2024a; 2025)	SA Murray and CLLMM	Policy/technical reporting	Ecological condition and management targets	Defines current ecological objectives and condition information relevant to management. These baselines provide policy context but may be insufficient for future-focused climate adaptation assessment, where ecological states and values may differ.
Connor et al. (2014)	MDB	Econometric analysis	Irrigation production value	Provides evidence on irrigation revenue responses to reduced water availability under historical conditions. Relevance depends on spatial scale (enterprise vs Basin), time horizon, market adjustment,

STUDY	GEOGRAPHIC FOCUS	PRIMARY METHOD	ECOSYSTEM SERVICE(S)/ OUTCOME VALUED	KEY QUANTITATIVE INSIGHTS FOR CLLMM CONTEXT
				and evolving production systems.
Dixon et al. (2011)	MDB	CGE modelling	Economy-wide impacts of water reallocation	Explores how buyback payments, investment effects, and regional adjustment can influence aggregate GDP outcomes. Aggregate results may mask localised losses and network effects.
Grafton and Jiang (2011)	MDB	Hydro-economic modelling	Agricultural production impacts	Estimates profit impacts under specified water-reduction scenarios and model assumptions. Results are context-specific and not directly transferable to future CLLMM conditions.
Kirby et al. (2014)	MDB	Hydro-economic modelling	Irrigation response to scarcity	Demonstrates non-linear production responses to water reductions and the role of trade and crop choice in shaping opportunity costs.
Hughes et al. (2025)	MDB	Hydro-economic modelling	Climate adaptation and water markets	Identifies limits to adaptation under extreme scarcity and trade constraints, highlighting divergence between historical recovery contexts and future climate conditions.
Zeleke and Luckett (2025)	MDB	Empirical production analysis	Irrigation productivity ($/ML)	Shows structural shifts toward high-value crops and increased returns per ML, indicating that current opportunity costs differ from earlier production mixes.
Zuo et al. (2019)	MDB	Econometric/time-series analysis	Water market dynamics	Shows price volatility and structural adjustment under water recovery, providing context for interpreting entitlement and allocation market evidence.
Wittwer and Griffith (2011)	MDB	CGE modelling	Drought impacts and recovery	Shows temporary employment losses and recovery dynamics under drought, while illustrating that aggregate recovery can obscure distributional impacts.
Young and Loomis (2014)	General	Economic theory/applied methods	Valuation of water	Provides the conceptual basis for residual value estimation and interpretation of water's contribution to production.
Zhao and Ancev (2024)	MDB	Policy/market analysis	Water recovery impacts	Assesses effects of policy-driven water recovery on markets, relevant for interpreting contemporary water-recovery contexts.
Saradifis (2024)	MDB	Econometric analysis	Adjustment dynamics	Examines adjustment dynamics associated with water recovery, including the extent

STUDY	GEOGRAPHIC FOCUS	PRIMARY METHOD	ECOSYSTEM SERVICE(S)/ OUTCOME VALUED	KEY QUANTITATIVE INSIGHTS FOR CLLMM CONTEXT
				to which impacts persist or mean-revert over time.
Banerjee (2015)	MDB	CGE modelling	Policy and investment impacts	Explores how infrastructure investment, buybacks, and broader adjustment influence production and regional outcomes. Buybacks may compensate entitlement holders but do not remove all production, community, or network effects.
Damoah et al. (2024)	Global/Australia	Conceptual/Indigenous valuation	Nature values and Indigenous perspectives	Expands valuation frameworks to include plural, cultural, and Indigenous values that are typically under-represented in standard economic valuation.
Cooper et al. (2023)	Australia	Stated preference	Environmental water values	Estimates household willingness to pay for environmental flows under specific survey contexts, populations, and framing.
Cooper et al. (2024)	Australia	Stated preference	Investment prioritisation	Quantifies public preferences for waterway investments within the decision contexts presented to respondents, not as universal priorities.
Cooper et al. (2025)	South Australia	Applied adaptation study	Climate adaptation and water systems	Integrates valuation with adaptation planning, demonstrating how economic evidence can inform but not determine adaptation decisions.

Table A2. Evidence base for estimating opportunity cost of water reallocation

STUDY	METHOD/MODEL TYPE	SPATIAL AND TEMPORAL SCOPE	WATER REALLOCATION/SCARCITY CONTEXT	KEY QUANTITATIVE INSIGHTS FOR OPPORTUNITY COST RANGES (WITH CONTEXT AND LIMITS)
Ricardo Water Markets Reports (2014–2026)	Descriptive market statistics	Southern MDB trading zones; annual VWAP 2014–15 to 2024–25	Observed entitlement and allocation market outcomes under drought, policy recovery, and structural demand shifts	High-security entitlements in NSW Murray, Vic Murray, NSW Murrumbidgee, and SA Murray increased from approximately AUD 1,500–3,000/ML to AUD 7,000–9,000/ML. These prices reflect a combination of factors: prolonged drought conditions, Basin Plan water recovery, expectations of future scarcity, maturation of water markets, and a shift toward capital-intensive perennial crops. When expressed as annual equivalents, these imply approximately AUD 550–750/ML at a 7% real discount rate over 30 years.
BoM (2026)	Market and hydrological dashboards	MDB water markets; 2000s–2020s	Seasonal scarcity and trading patterns	Provides time series of allocation prices and traded volumes, used to contextualise entitlement values and distinguish short-run drought scarcity from longer-run capitalised entitlement values.
Young and Loomis (2014)	Valuation methods text (residual value, NPV)	Generic; applied to MDB irrigation	General water valuation and project appraisal	Sets out the residual value framework and annuity/NPV methods used to convert per-ML net returns and capital prices into annualised or capitalised opportunity cost metrics. Provides methodological foundations rather than site-specific estimates.
Kandulu et al. (2024)	Applied residual value and project appraisal	Australian irrigation systems	Dam and irrigation project economics	Demonstrates residual value estimation for irrigated agriculture, supporting an indicative range from ~AUD 300/ML (low-value pasture systems) to >AUD 2,600/ML (high-value horticulture). These values reflect whole production systems, not the marginal contribution of water alone, and are sensitive to crop choice, capital intensity, and prices.
Zeleke and Luckett (2025)	Econometric/panel analysis	Southern MDB; multiple irrigation districts	Policy change and rainfall variability driving structural adjustment	Shows dominance of high-value horticulture in some sub-basins (up to ~70% of allocations), linking policy and climate pressures to cropping

STUDY	METHOD/MODEL TYPE	SPATIAL AND TEMPORAL SCOPE	WATER REALLOCATION/SCARCITY CONTEXT	KEY QUANTITATIVE INSIGHTS FOR OPPORTUNITY COST RANGES (WITH CONTEXT AND LIMITS)
				mix. This concentration helps explain higher residual values and increased exposure to water scarcity in perennial systems.
Connor et al. (2014)	Econometric (panel regression)	17 agro-ecological regions, MDB; Millennium Drought	Observed drought-driven scarcity	Finds that a 10% reduction in allocations was associated with approximately 1% reduction in irrigation revenue at the Basin scale. This non-linear response reflects aggregate outcomes shaped by spatial redistribution, water trading, crop switching, and exit. It should not be interpreted as uniform enterprise-level resilience.
Zuo et al. (2019)	Time-series regression	Goulburn–Murray Irrigation District	Government water recovery and market adjustment	Shows that a 1% increase in cumulative recovery reduced temporary trade volumes by ~0.14% and increased price volatility, while broad regional indicators remained relatively stable. Highlights structural but uneven adjustment rather than absence of impact.
Saradifis (2024)	Econometric (turnover dynamics)	MDB irrigation businesses	Post-recovery adjustment	Finds that water recovery triggered a temporary negative turnover shock followed by mean-reverting recovery at the scale analysed, suggesting transitional impacts rather than permanent aggregate decline.
Dixon et al. (2011)	Dynamic CGE (TERM-H2O)	Southern MDB; 10 statistical subdivisions; 10-year simulation	1,500 GL buyback program	Estimates that a 1,500 GL buyback led to real regional GDP approximately 0.1% above baseline by 2018, driven by wealth effects and re-spending of buyback funds. Aggregate results may mask localised losses and network effects.
Wittwer and Griffith (2011)	Dynamic CGE (TERM-H2O)	Southern MDB; 14 statistical subdivisions	Millennium Drought; diversions ~59% of normal	Simulates drought-induced shortfalls causing up to 20% regional GDP declines and ~6,000 job losses, with recovery after drought. Provides an upper-bound estimate of short-run impacts under severe climate stress.
Banerjee (2015)	CGE/policy and cost-effectiveness analysis	MDB; Basin-wide	Environmental water recovery via buybacks vs infrastructure	Shows that buybacks can be more cost-effective than infrastructure subsidies for water recovery. Buyback payments may offset some aggregate economic impacts,

STUDY	METHOD/MODEL TYPE	SPATIAL AND TEMPORAL SCOPE	WATER REALLOCATION/SCARCITY CONTEXT	KEY QUANTITATIVE INSIGHTS FOR OPPORTUNITY COST RANGES (WITH CONTEXT AND LIMITS)
				but do not eliminate production losses, community effects, or irrigation-network impacts.
Grafton and Jiang (2011)	Hydro-economic model	MDB-wide; 19 SDL regions	3,000–4,400 GL reduction scenarios	Finds that a 3,000 GL reduction lowered net irrigated profits by ~10% and 4,000 GL by ~17%, with GVIAP declines of 13–17%. Results are aggregate modelled estimates under specified assumptions.
Grafton et al. (2011)	Stochastic dynamic programming	Murray River system	Optimal environmental vs irrigation allocation	Shows that, within the model structure, optimised reallocation can deliver ecological gains at lower modelled cost than existing policies, with estimated irrigation profit losses of ~3.3%. Results depend on optimisation assumptions and ecological objectives specified.
Grafton and Wheeler (2018)	Policy and empirical review	Basin-wide; Northern and Southern MDB	Basin Plan recovery (2,750 GL)	Synthesises evidence that real production values fell by ~10% despite large reductions in water use, and that buybacks are cheaper per ML than infrastructure. Aggregate trends may obscure sectoral and regional heterogeneity.
Hughes et al. (2025)	Monthly hydro-economic/market model	Southern MDB trading zones; historical and CMIP6 SSP5-8.5 scenarios	Climate-driven inflow reductions (–10% to –40%)	Projects that a 35% reduction in average water availability causes ~18% production loss and ~16% decline in perennial area, with downstream prices exceeding AUD 500/ML under a "Future Dry" scenario. Provides an upper-bound estimate of structural opportunity costs under severe climate change.
Kirby et al. (2014)	Integrated hydro-economic model	MDB; 58 catchments, 17 crop regions; 1895–2009	Climate change and 2,400–3,200 GL reallocation	Finds that a 25% water reduction yields ~10% decline in irrigation revenue, with largest impacts on rice and cotton. Demonstrates that climate change can remove volumes comparable to Basin Plan recovery, but impacts vary by crop and region.
Kirby et al. (2015)	Hydro-economic adaptation analysis	MDB; hydrology–economics framework	Adaptation under 2,750 GL recovery	Shows that aggregate gross income declines are smaller than proportional water cuts once trade, carryover, and adaptation are allowed, with marginal activities exiting first, reinforcing non-linear opportunity cost relationships.

STUDY	METHOD/MODEL TYPE	SPATIAL AND TEMPORAL SCOPE	WATER REALLOCATION/SCARCITY CONTEXT	KEY QUANTITATIVE INSIGHTS FOR OPPORTUNITY COST RANGES (WITH CONTEXT AND LIMITS)
Quiggin et al. (2010)	State-contingent simulation	19 catchment regions plus Adelaide and Coorong	Climate change (2050, 2100); adaptation vs mitigation	Estimates that maintaining current environmental flows under climate change could require 29–32% reduction in irrigation use (~3,500–3,800 GL). Long-run returns fall sharply under "adaptation only" but less so when mitigation is included, highlighting long-run structural risk.
Qureshi et al. (2007)	Stochastic mathematical programming	Southern MDB; 13 regions, 12 activities	500 GL expected recovery; trade vs no trade	Finds net revenue losses of ~AUD 68/ML (targeted) to ~AUD 121/ML (pro-rata) without trade. Free trade can eliminate or reverse net profit losses in the model, underscoring the importance of markets in reducing aggregate opportunity costs.
Zhao and Ancev (2024)	Applied market impact study	Southern MDB	Effects of water recovery on markets	Shows that water recovery has significant but manageable effects on allocation prices and trading patterns where compensation and market adjustment mechanisms are present.
Hughes et al. (2023)	Market performance assessment	Southern MDB	Carryover and structural change	Demonstrates the role of carryover and trade in supporting investment in high-value perennials and increasing returns per ML, consistent with rising entitlement prices and increased exposure to dry-year scarcity.

Table A3. Summary of qualitative survey themes: Lived adaptation strategies, structural barriers, and enabling conditions

THEME	DESCRIPTION AND PRACTICAL APPLICATION	PRIMARY SECTORS	ECONOMIC AND STRUCTURAL IMPLICATIONS
Diversification and flexibility	Shifting revenue streams away from water-dependent assets (e.g., cultural tours, retail) and implementing agile booking policies to absorb hazard shocks.	Tourism, commercial fishing, accommodation	Mitigates stranded asset risk by decoupling income from direct ecosystem health, though often requires sacrificing core operational efficiency.
Technological and agronomic shifts	Upgrading irrigation infrastructure, adopting drought-tolerant varieties, and substituting water sources to manage acute heat and salinity stress.	Irrigated agriculture, viticulture, horticulture	Delivers short-run efficiency gains but risks deepening long-term path dependency if absolute biophysical thresholds are permanently breached.
Flow-responsive operations	Dynamically reallocating fishing effort and marine services in response to real-time salinity gradients and water levels.	Commercial fishing, boating services	Demonstrates high micro-level allocative efficiency, exposing the heavy opportunity cost of maintaining immobile capital in volatile estuarine zones.
Capital and financial frictions	Escalating input, energy, and insurance costs colliding with existing debt structures to eliminate operational headroom.	All water-dependent sectors	Traps operators in reactive crisis management; absolute capital starvation prevents necessary structural transitions despite clear market signals.
Information and regulatory complexity	Fragmented hazard data, rigid compliance frameworks, and slow approval processes inhibiting proactive decision-making.	Small business, marine services, agriculture	Introduces severe information asymmetries and transaction costs, destroying the enterprise agility required to navigate rapid ecological shifts.
Marginalisation of knowledge	Systematic exclusion of Traditional Ecological Knowledge and lived practitioner experience from macroeconomic basin planning.	First Nations enterprises, commercial fishing	Guarantees sub-optimal, top-down policy instruments and erodes the social licence necessary to execute efficient water reallocation.
Labour and bandwidth deficits	Severe workforce shortages compounding the intense cognitive load of daily crisis administration.	Agriculture, horticulture, tourism	Crowds out long-term strategic planning; capital investments yield zero return without the complementary labour required for execution.
Targeted financial support	Deploying small, flexible grants and low-interest loans to bypass bureaucratic friction and address immediate liquidity constraints.	All water-dependent sectors	A highly effective intervention mechanism for converting theoretical adaptation willingness into executed capital deployment.
Information architecture and extension	Providing consolidated, plain-English regional dashboards alongside high-touch, peer-to-peer learning networks.	Tourism, agriculture, community organisations	Substantially reduces search costs for critical hazard data and leverages social proof to accelerate the adoption curve of resilient practices.

Appendix B. Social survey

Water Use and Economic Impact Survey (Coorong Region)

Inclusion Criteria

This survey is intended for business owners or managers operating in flow-dependent primary industry sectors in the Coorong region, including but not limited to agriculture, fisheries, and tourism. Eligible participants should:

1. Have an active business operation in the Coorong or Lower Lakes area
2. Be directly involved in the management or decision-making processes of the business
3. Have at least 2 years of experience in their current industry sector
4. Be able to provide information on their business's water usage, production costs, and revenues
5. Be 18 years of age or older
6. Be willing to share anonymous business data for research purposes

If you meet these criteria, we invite you to participate in this important study. Your insights will be valuable in understanding the economic impacts of climate variability on local industries and informing future water management strategies. **The survey will remain open until 31 November 2025, so we kindly ask you to complete it by then.**

Participant Information and Consent:
Dear Participant,
You are invited to take part in a research study examining the economic implications of climate extremes on flow-dependent primary industries in the Coorong region. Please note that participants must be 18 years of age or older to take part in this survey. This study is being conducted by Flinders University and has been approved by Flinders University's Human Research Ethics Committee (ETHICS APPROVAL No: HEL8272-3).
The survey will take approximately 10-15 minutes to complete. **The survey will remain open until 31 November 2025, so we kindly ask you to complete it by then.** Your participation is voluntary, and your responses will be kept confidential and anonymous. We will not share any information that could identify you. Your responses will be used for research purposes only to inform water management strategies in the region. You can skip any questions that might be distressing or stop the survey at any time.
If you experience feelings of distress as a result of participation in this study, you can contact the following services for support:

- Lifeline: 13 11 14 (24/7 crisis support and suicide prevention)
- Beyond Blue: 1300 22 4636 (mental health support)
- Rural Financial Counselling Service: 1800 686 175 (free financial counselling for farmers and small rural businesses)
- Your local GP or mental health professional

If you have any questions, please contact:
1. Dr. John Kandulu, Flinders University, College of Business, Government and Law
Phone: 0423 395 757
Email: john.kandulu@flinders.edu.au.

2. Professor Neville Crossman, Flinders University, College of Business, Government and Law
Phone: 0439 844 628
Email: neville.crossman@flinders.edu.au.

Queries or concerns regarding the research can be directed to the research team. If you have any complaints or reservations about the ethical conduct of this study, please contact the Flinders University's Research Ethics, Integrity and Compliance Office via telephone (08) 8201 2543 or by emailing human.researchethics@flinders.edu.au.
By proceeding with the survey, you consent to participate in this research.

Are you willing to participate? (Y/N) ___

About Your Business:

1. What is the name of your business or organisation? [Short text]

2. Which main industry sector does your business currently operate in?

(You may tick more than one option if applicable)

□ Broadacre cropping (e.g., cereals, grains, oilseeds)

□ Dairy farming

□ Horticulture (e.g., vegetables, fruit, nuts)

□ Livestock production (e.g., beef, sheep, poultry)

□ Viticulture/Wine Production

□ Fisheries (fin fish, pipi/cockles, multi-species)

□ Commercial Fishing (non-fisheries, including indigenous operations)

□ Tourism (accommodation, caravan park, holiday park, river/boat tours, adventure tours, aquatic club, heritage/charters)

□ Boating/Marine Services (chandlery, jetty building, boat haven, marina)

□ Environmental Conservation/Landcare

□ Local Government/Council

□ Food & Beverage Processing (e.g., winemaking, food processing)

□ Indigenous-owned Business/Cultural Tourism

□ Community Advisory/Industry Representative

□ Other (please specify): _______________

3. Briefly, how would you describe your main business activities or services?
[Short text]

4. Approximately how large is your operation?
Land area/hectares (if relevant): ___
No. of staff (full- or part-time): ___
Output/service volume (e.g., tonnes, visitor numbers, charters): ___

5. How long has your business been operating in the region?

□ Less than 2 years

□ 2–5 years

□ 6–10 years

□ More than 10 years

6. What is your main production system and water source?

(You may tick more than one option if applicable)

a) **Production system:**

□ Irrigated (using supplementary or full irrigation)

□ Dryland/rainfed only

□ Not applicable

b) **Main water source(s) for your business:**

□ Mains water/town supply

□ Murray River (licensed extraction)

□ Groundwater (bore, well)

□ On-farm storage (dam, rainwater tanks)

□ Other (please specify): _______________

Climate Change Adaptation Strategies:

6. Have you noticed impacts from climate variability or climate change affecting your business

(for example: extreme weather, changing seasonal patterns, drought, floods, water access issues, or market disruptions?

□ Yes

□ No

If yes, please briefly describe the impacts you've observed:

[Open-ended]

Please feel free to write as much as you like—there's no word limit

7. What actions or changes has your business considered or made to adapt to these climate challenges?

(for example: diversification, forming business partnerships, adopting new technologies, shifting the timing of activities, switching industry, or exiting certain activities)

[Open-ended]

Please feel free to write as much as you like—there's no word limit

8. Which actions or changes did you decide to put in place, and what influenced those choices?

[Open-ended response]

Please feel free to write as much as you like—there's no word limit

9. Looking back, what approaches worked well, and which were less successful?

[Open-ended response]

Please feel free to write as much as you like—there's no word limit

10. Are there any barriers or challenges that have made adaptation difficult or prevented you from doing more?

(for example: cost, information, regulations, technical difficulties, social or cultural factors, uncertainty, etc)

[Open-ended]

Please feel free to write as much as you like—there's no word limit

11. Can you suggest any practical solutions or supports that would help your business or others overcome these barriers to adaptation?

(for example: policies, funding, information, training, collaboration, infrastructure, market development, community support, etc.

[Open-ended]

Please feel free to write as much as you like—there's no word limit

Final Reflection:

12. Is there anything else you'd like to share about climate adaptation, water management, or business resilience in your region?

[Open-ended]

Please feel free to write as much as you like—there's no word limit

Thank you for your time and valuable input. Your responses will contribute to improving water management and supporting businesses in the Coorong region.

CLLAMM RESEARCH CENTRE

GOYDER INSTITUTE FOR WATER RESEARCH