Moorabool Maribyrnong Water Resources Project

Southern Rural Water Cover Note

April 2026

This project forms part of the implementation of the Central and Gippsland Region Sustainable Water Strategy, and is specifically related to Action 4 -13 'Review of water resource risks in small, dry, peri-urban catchments'.

This study has examined the impact of small catchment dams on river flows and the associated cultural, environmental, social and economic values in the upper Moorabool and upper Maribyrnong catchments. The project has confirmed that the cumulative impact of small catchment dams on river flows and the associated values is significant in these two catchments, particularly in dry years. The study has also recorded that the number of small catchment dams has continued to grow in the Moorabool and Maribyrnong catchments.

It is important to note that there are other underlying risks to water resources in these catchments beyond the impact of small catchment dams that have not been assessed as part of this study. These risks may include land use change, the potential impact of existing large storage reservoirs, river and groundwater diversions and the impact of a changing climate.

The study has focused on understanding the cumulative risk posed by small catchment dams in these two small, peri-urban, and highly flow stressed catchments. Due to the focus on risks, the study and this report do not highlight the social and economic value of small dams in the Moorabool and Maribyrnong catchments.

Small catchment dams provide important stock and domestic water supplies, water for fire prevention or suppression, lifestyle and recreational values, and local environmental values. These important values will need to be further explored and considered.

A Stakeholder Reference Group of 20 people was established to improve our shared understanding of the water resource challenges facing the area and to inform the content and outcomes of the project. This group included a diverse range of individuals and organisations including local landowners, community members, industry groups, Traditional Owners, government agencies and water corporations.

The group met six times to highlight the values, issues and opportunities in the Moorabool and Maribyrnong catchments in relation to small catchment dams. Having such a diverse range of stakeholders was crucial to the success of the project and we would like to thank all those who took part and contributed.

The report captures the full suite of ideas and opportunities identified by the Stakeholder Reference Group that could help to reduce the future impacts of small catchment dams in the upper Maribyrnong and upper Moorabool. The project did not attempt to prioritise the ideas or seek agreement from the different stakeholders on whether they supported the ideas raised by others in the group.

Over 60 different ideas and opportunities were identified. These include educational opportunities aimed to support the community's understanding of farm dam licence requirements, on farm water efficiency opportunities, operational improvements to support the licensing and compliance functions of agencies, and potential state policy and legislative reform. The ideas and opportunities identified by members of the Stakeholder Reference Group in this report do not necessarily reflect the views of Southern Rural Water.

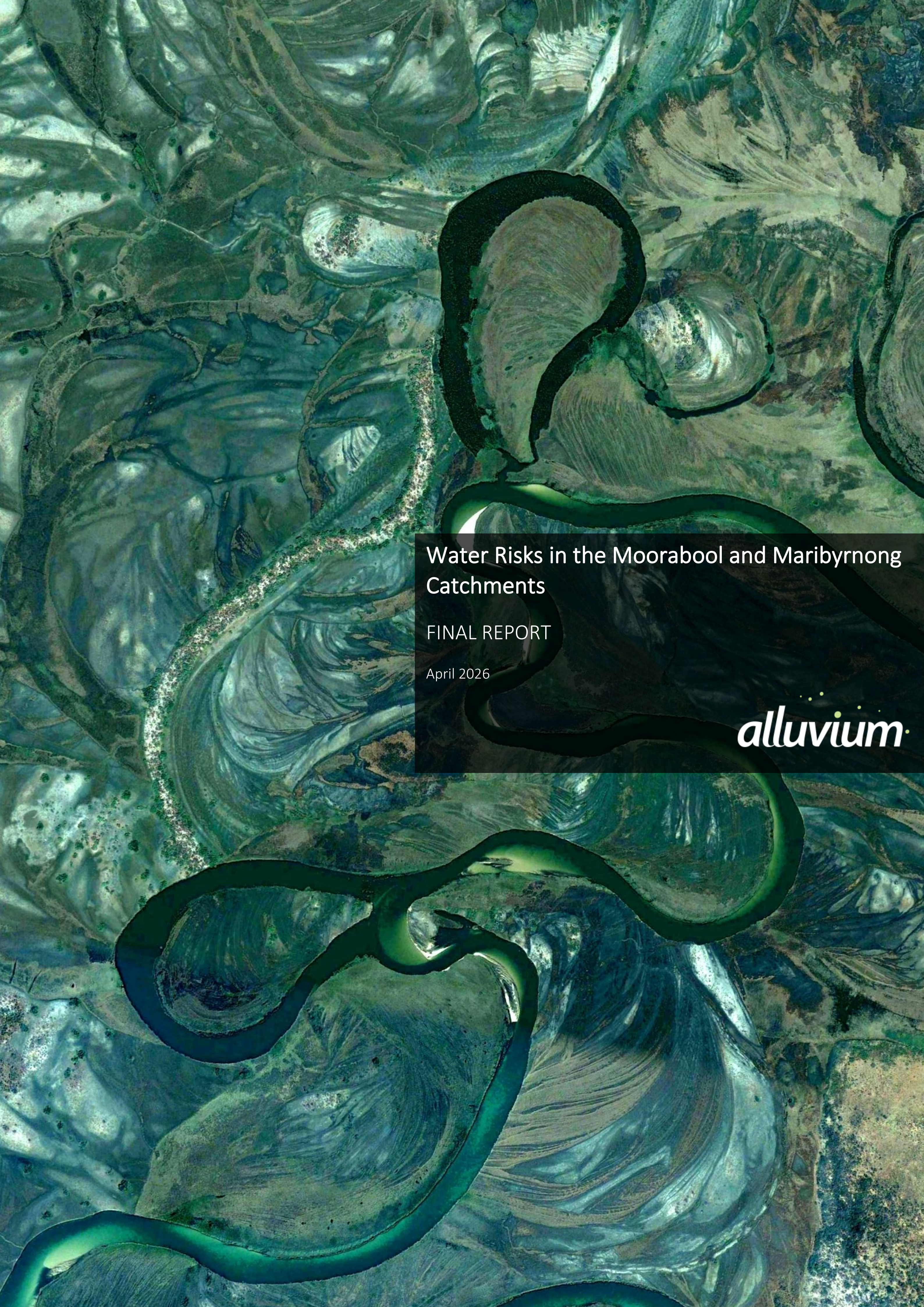
While ongoing management of small catchment dam continues – including community engagement, monitoring, reporting and compliance activities - further analysis of the ideas and opportunities raised by the stakeholder group is needed prior to taking action.

The next step is for the report findings, alongside the ideas and opportunities identified by the Stakeholder Reference Group to be considered by the government and its agencies.

This project aligns with our role as a regulator of surface and groundwater use in the Moorabool and Maribyrnong catchments and our continuing investment in compliance to ensure everyone follows the rules.

We have bolstered our zero-tolerance approach to non-compliance by providing dedicated enforcement staff, including compliance training for operational team members and implementing successful targeted investigation programs.

Southern Rural Water has completed an investigation into potentially non-compliant dams within the Moorabool Catchment and has commenced investigations within the Maribyrnong, Mornington Peninsula and Hopkins Basin Catchments. There are currently several enforcement actions underway.



Water Risks in the Moorabool and Maribyrnong Catchments

FINAL REPORT

April 2026

alluvium

Alluvium recognises and acknowledges the unique relationship and deep connection to Country shared by Aboriginal and Torres Strait Islander people, as First Peoples and Traditional Owners of Australia. We pay our respects to their Cultures, Country and Elders past and present.

Artwork by Melissa Barton. This piece was commissioned by Alluvium and tells our story of caring for Country, through different forms of waterbodies, from creeklines to coastlines. The artwork depicts people linked by journey lines, sharing stories, understanding and learning to care for Country and the waterways within.

This report has been prepared by Alluvium Consulting Australia Pty Ltd for Southern Rural Water under the contract titled 'Water Risks in the Upper Moorabool and Upper Maribyrnong Catchments'.

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Executive Summary

This study is focussed on understanding and responding to the impact of small catchment dams on river flows and the broad range of values that depend on these river systems. Small catchment dams include farm dams, ornamental dams, and other associated small dams.

The Moorabool catchment (upstream of Batesford gauge) and the Maribyrnong catchment (upstream of Keilor gauge) were chosen for this study because these catchments are known hotspots due to the large number of small catchment dams present, potential continued growth in dams and the flow stressed nature of these catchments.

The Moorabool and Maribyrnong catchments are widely recognised as two of the most flow stressed in Victoria. These catchments have been modified and impacted by a range of factors including water extraction and diversion activities including small catchment dams, land use change, and a changing climate. The flow stressed nature of these catchments has been recognised since the early 2000's, and new surface water entitlements have been capped as a result, however small catchment dams (many of which do not require licences) have continued to increase (as both new and enlarged dams).

The project *Water Risks in the Upper Moorabool and Upper Maribyrnong Catchments* was funded by DEECA and led by Southern Rural Water. This work delivers on Action 4-13 of the Central and Gippsland Region Sustainable Water Strategy (CGSWS).

The study has assessed the impact of small catchment dams on the Moorabool and Maribyrnong catchments, and it has enabled a shared understanding with a stakeholder reference group of the:

- Cultural, environmental, social, and economic values in these catchments.
- Water resource risks to these values, including from small catchment dams.
- Potential management opportunities that could help to reduce these risks in future.

Stakeholder reference group

A Stakeholder Reference Group (SRG) was formed to provide guidance and input, local knowledge, and ideas for potential management opportunities, meeting six times at key milestones to guide and inform the process.

The SRG meetings enabled local knowledge and a range of community and stakeholder views to inform the process. This has enabled a robust approach and created a common understanding on the potential risks to water dependant values in each catchment. The SRG were recruited through an expression of interest and included representatives from:

- water authorities,
- community groups,
- farmers,
- Catchment Management Authorities,
- Council representatives,
- Victorian Farmer Federation,
- State government agencies
- Traditional Owners, and
- landholders.

A major outcome of the project was the identification of water management opportunities during SRG Meeting 5. The SRG's feedback shaped all stages of the project, and the opportunities presented in Section 8 were developed collaboratively by this group.

Catchment values

The assessment focused on the peri-urban, mid and upper reaches of the Moorabool and Maribyrnong catchments, where the development of small catchment dams has been ongoing. The aim was to identify water-dependent values, link them to flow targets where possible, and assess risks from changes in hydrological regimes.

These rivers provide vital support to a broad range of environmental, social and cultural values, and they support regionally important public water supplies and the agriculture sector. The concept of the Moorabool and the Maribyrnong rivers as single living entities was identified by community feedback during this project, and it has been widely adopted by community advocacy groups and is central to Traditional Owner perspectives. Local communities in both catchments have a strong values-based commitment to see the rivers survive and improve, and there is a strong local community feeling of stewardship and intergenerational responsibility grounded in lived experience of declining river flows.

The study was focussed on assessing the impact of small catchment dams; however, it is important to recognise the value of small dams to the farming industry and wider economy, and their importance for farm resilience and long-term farm viability, which was outside of the scope of this study.

Maribyrnong catchment

The Maribyrnong River catchment supports a wide range of values that depend on healthy flows. Environmentally, it sustains 80 threatened flora species, 80 listed fauna species—including fish, amphibians, reptiles, mammals, and birds—alongside endangered ecological vegetation communities across three bioregions. Key species such as platypus and diverse macroinvertebrates rely on the flow in this river system.

Economically, the river provides water for urban and agricultural extraction, and a healthy river supports tourism. Social values include recreation, amenity, and wellbeing benefits, influenced by vegetation quality, biodiversity, and water conditions.

Culturally, the river and its tributaries hold deep significance for the Wurundjeri Woi-wurrung people, with numerous heritage sites and a strong connection between healthy water and cultural identity.

Risks to values identified were assessed through quantitative and qualitative approaches, considering flow-dependent relationships and cultural objectives.

Moorabool catchment

The Moorabool River catchment supports a diverse range of values that depend on healthy flows and water quality. Environmentally, it provides habitat for native fish species such as Australian Grayling and River Blackfish, macroinvertebrates that indicate stream health, and iconic species like platypus and water rats.

Remnant vegetation communities, including Stream Bank Shrubland and Riparian Woodland, rely on specific flow regimes, while geomorphic processes shape floodplains and maintain habitat complexity. Water quality factors such as pH, turbidity, salinity, and nutrient levels are critical for ecosystem resilience.

Economically, the catchment underpins water extraction for urban supply (by Barwon Water and Central Highlands Water), and agriculture and it supports tourism linked to a healthy riparian environment. Social values include amenity and recreation. Culturally, the catchment holds deep significance for the Wadawurrung people, with sites such as Lal Lal Falls central to spiritual identity. Goals in the Wadawurrung Country Plan include achieving clean waterways by 2030 and ensuring cultural flows and connectivity by 2025 to sustain culturally important species and healthy ecosystems.

Catchment modelling approach

The catchment modelling assessed changes in flow regimes for the Maribyrnong and Moorabool catchments under historical, current, and future climate scenarios using Source and STEDI models. These models simulate inflows, licensed water use, environmental flows, water supply system operating rules, and small catchment dam impacts.

Four scenarios were tested:

- Unimpacted by small catchment dams,
- 2009/2010 development level,
- 2025 development level, and
- 2025 development with 2065 climate projections (RCP 4.5, medium climate change).

All other elements of the modelling were maintained at the 2025 calibrated representation of the catchments.

Projected climate change for the state indicates reductions in rainfall (≈3%) and streamflow (7–10%) relative to mid-point of post-1975 period conditions (DELWP, 2020). STEDI modelling estimates components of the small catchment dam water balance, including inflows, demands and evaporation. The models used in this study were updated to improve spatial representation of the small catchment dams in the catchments. Modelling limitations include uncertainties in dam identification, inflow estimation, demand, seepage, storage volumes, assumed connectivity from the dam to the river network, and climate projections.

Catchment modelling results

Small catchment dam development has increased in both catchments over recent decades, impacting water availability and flow regimes. The results below show the total changes between the two current climate scenarios that contain the small catchment dam representations of the given years:

- Maribyrnong Catchment (2009–2025)
  - Number of dams: ↑ 2% (6,889 → 7,048)
  - Storage volume: ↑ 6% (13,238 ML → 14,088 ML)
  - Mean annual impact of dam capture: ↑ 5% (6,559 ML/year → 6,907 ML/year)
  - Share of inflows captured by dams: ↑ from 7.6% to 8.0%
  - Share of inflows captured by dams under 2065 climate scenario: impact rises to 7,407 ML/year (9.5% of inflows).
  - Mean impact on summer and autumn (December to May) flows: ↑ from 15.2% to 15.8%
  - Mean impact on winter and spring (June to November) flows: ↑ from 8% to 8.6%

- Moorabool Catchment (2010–2025)
  - Number of dams: ↑ 4% (6,043 → 6,294)
  - Storage volume: ↑ 20% (17,057 ML → 20,517 ML)
  - Mean annual impact of farm dam capture: ↑ 9% (7,287 ML/year → 7,939 ML/year)
  - Share of inflows captured by dams: ↑ from 8.8% to 9.6%
  - Share of inflows captured by dams under 2065 climate scenario: impact slightly decreases to 7,678 ML/year, but proportion of inflow rises to 10.6% due to reduced inflows.
  - Mean impact on summer and autumn (December to May) flows: ↑ from 15.7% to 16.9%
  - Mean impact on winter and spring (June to November) flows: ↑ from 5.6% to 6.3%

Overall, small catchment dams reduce streamflow, especially under drier climate conditions, significantly increasing stress on water-dependent values. The modelling confirms this logic for the Maribyrnong and Moorabool catchments, indicating that growth in small catchment dams since 2009/10 has increased mean annual impacts by 5-9%, with greater impacts in dry years and in summer months. Mean impacts in summer and autumn are estimated to be 16.9%, but in particular dry years the impact was over 30%.

Risk assessment approach

The initial risk assessment for the Moorabool and Maribyrnong catchments evaluated potential negative impacts on environmental, economic, social, and cultural values under different modelled scenarios. Risks were determined using a standard likelihood–consequence matrix, combining the probability of an event with its severity.

Environmental risks were assessed through compliance with flow targets from the most recent FLOWS studies and expert judgment, while economic risks focused on the reliability of water access for irrigation and domestic and stock use. Social risks were evaluated using service level metrics for urban and rural water supply, and cultural risks were assessed qualitatively through engagement with Traditional Owners. Where quantitative thresholds were unavailable, such as for social and cultural values, qualitative discussions informed risk ratings to ensure a comprehensive understanding of potential impacts.

Compliance with environmental flow targets was assessed using eFlow Predictor, alongside custom analysis of cease-to-flow periods, peak flows, and seasonal flow conditions. Economic and social impacts were evaluated through water access reliability for licences, domestic and stock use, and urban supply performance against level-of-service targets.

Risk assessment results

Interrogation of the quantitative risk assessment was challenging because all scenarios—including the unimpacted case—returned uniformly high-risk ratings, masking the incremental effect of small catchment dams. This indicates significant "background risk" from other factors influencing flows. An incremental assessment was conducted to isolate the influence of small catchment dams specifically, comparing compliance with flow targets between undeveloped and developed scenarios. These results revealed that small catchment dams do create meaningful risks, particularly for environmental values, with increased stress on low flows and freshes. Under future climate scenarios, these risks intensify. While some improvements in low-flow performance were observed, they likely occur at the expense of fresh and high-flow events, highlighting complex trade-offs in the flow regime.

The qualitative assessment highlights key risks across all value themes. Key risks include;

- Environmental: Increased risk of loss of river flow connectivity, greater barriers to fish migration and further expansion of terrestrial vegetation. Bird populations are likely to be at increased risk due to reduced vegetation and invertebrate habitat. Lower flows limit the river's ability to flush pollutants, increasing risks of algal blooms and poor water quality, and low flows may limit the effectiveness of environmental releases
- Economic: Reductions in flow will increase the risk to urban and agricultural water supplies. Tourism could be negatively affected as river health deteriorates, reducing the appeal of natural areas. Poor water quality would impact on agriculture production and viability.
- Social: Human wellbeing is likely to suffer because of vegetation quality, biodiversity, and water quality—critical for mental and physical health—are at significant risk.
- Cultural: Traditional Owner values tied to healthy waterways face threats, though the assessment does not capture the full breadth of cultural significance. Specific risks to cultural values cannot be determined without Traditional Owners undertaking dedicated cultural values assessments, which would require access to land along the waterways.

Overall, changes in flow regimes create cascading impacts on ecosystems, community wellbeing, and cultural identity and small catchment dam proliferation pushes more values into higher risk categories.

Management opportunities

The SRG led the process to identify possible opportunities to improve the management of water resource risks related to small catchment dams in the Maribyrnong and Moorabool catchments. The process to identify management opportunities considered the modelling and risk assessment outcomes. Opportunities aimed to address gaps in legislation, compliance, and data, and included structural, governance, and educational measures. Themes discussed by the SRG covered:

- Policy and legislation
- Operations
- Information and education
- Research and innovation
- Other measures

The SRG emphasised that small catchment dams pose increasing risks to water-dependent values, particularly under climate change, and that solutions should combine regulatory, structural, and community engagement approaches.

A large range of potential management opportunities were identified by the SRG, including but not limited to:

- Identifying hot spot catchments and mandating small catchment dam registration
- Capping small catchment dam development in hot spot catchments with tighter controls on new dams and dam expansion, including potential cap and trade measures
- Revision of legislation and guidelines, clarifying "reasonable use", improving waterway definitions and providing a single consistent digital waterway spatial layer for use across all agencies
- Strengthening compliance, including consideration of a new compliance authority
- Promoting farm water planning and water efficiency incentivising dam decommissioning and introducing low-flow bypasses.
- Updating the water register, improve streamflow monitoring, and educating landholders on water rights and risks.
- Development of a public spatial dataset of small catchment dams, leverage technologies like AI for monitoring, and reporting.
- Exploring alternative water sources, protecting low flows, and improved funding mechanisms.

Key messages and outcomes

Overall, the assessment confirms that small catchment dams pose significant risks to environmental, economic, social, and cultural values, with the greatest impacts occurring during low-flow periods. These impacts are most evident in low-flow and fresh flow components, which are highly vulnerable and critical to the health of the entire river system. Climate change will further exacerbate these risks, increasing stress on low, fresh, and high flows.

The report highlights that growth in small catchment dams, including enlargement is likely to have had a significant impact on flows, and that further growth at these rates is also likely to have a significant impact.

The SRG has identified an unconstrained list of potential opportunities for improving water management relating to small catchment dams, at local, regional, and state levels. These opportunities have not been assessed or prioritised, and further work is required by the responsible agencies to assess potential costs, benefits, and risks associated with implementation.

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1 Introduction

The project *Water Risks in the Upper Moorabool and Upper Maribyrnong Catchments* was funded by DEECA and led by Southern Rural Water. This work delivers on Action 4-13 of the Central and Gippsland Region Sustainable Water Strategy (CGSWS)

The Moorabool catchment (upstream of Batesford gauge) and the Maribyrnong catchment (upstream of Keilor gauge) were chosen for this study because these catchments are known hotspots due to the large number of small catchment dams present, the continued growth in dams and the flow stressed nature of these catchments.

The Moorabool and Maribyrnong catchments are widely recognised as two of the most flow stressed in Victoria. These catchments have been modified and impacted by a range of factors including water extraction and diversion activities including small catchment dams, land use change, and a changing climate. The flow stressed nature of these catchments has been recognised since the early 2000's, and new surface water entitlements have been capped as a result, however small catchment dams (many of which do not require licences) have continued to increase (both new and enlarged dams).

This study focused on water resource risks in small, dry, peri urban catchments, sharing evidence and reporting to build a common understanding with communities on the risks, consequences and mitigation opportunities to address the increasing effect of small catchment dams. This study of small catchment dams includes farm dams, ornamental dams, quarries, and any other purpose-built structures across the landscapes of the Upper Maribyrnong and Upper Moorabool catchments.

The project aimed to build a shared understanding with local communities on the:

- Cultural, environmental, social, and economic values in these catchments.
- Water resource risks to these values, including from small catchment dams.
- Potential management opportunities that could help to reduce these risks in future.

1.1 Project Context

The project focused on reviewing the risks, consequences, and mitigation opportunities to understand and manage the cumulative effects of the interception of water by small catchment dams in the Upper Moorabool and Upper Maribyrnong catchments.

For the Moorabool, the study area was defined as the catchment area upstream of the streamflow gauge on the Moorabool River at Batesford (232202). For the Maribyrnong, the catchment area was defined as upstream of Keilor (230105). This intent of this project was to build a shared understanding of issues and solutions through working with key stakeholders and communities.

A Stakeholder Reference Group (SRG) was formed to provide guidance and input, local knowledge, and potential management improvements, meeting seven times at key milestones to guide and inform the process.

The SRG formation was the first task in the project following inception phase and met at key stages to contribute to the subsequent project tasks, as shown in the project plan diagram in Figure 1.

The Moorabool and Maribyrnong Rivers are widely recognised as two of the most flow stressed rivers in Victoria, these catchments are being modified and impacted by a range of factors including; water extraction and diversion activities including small catchment dams, land use change, a changing climate, including a shift in the rainfall-runoff response that occurred during the millennium drought which continues to persist (DELWP, 2022a).

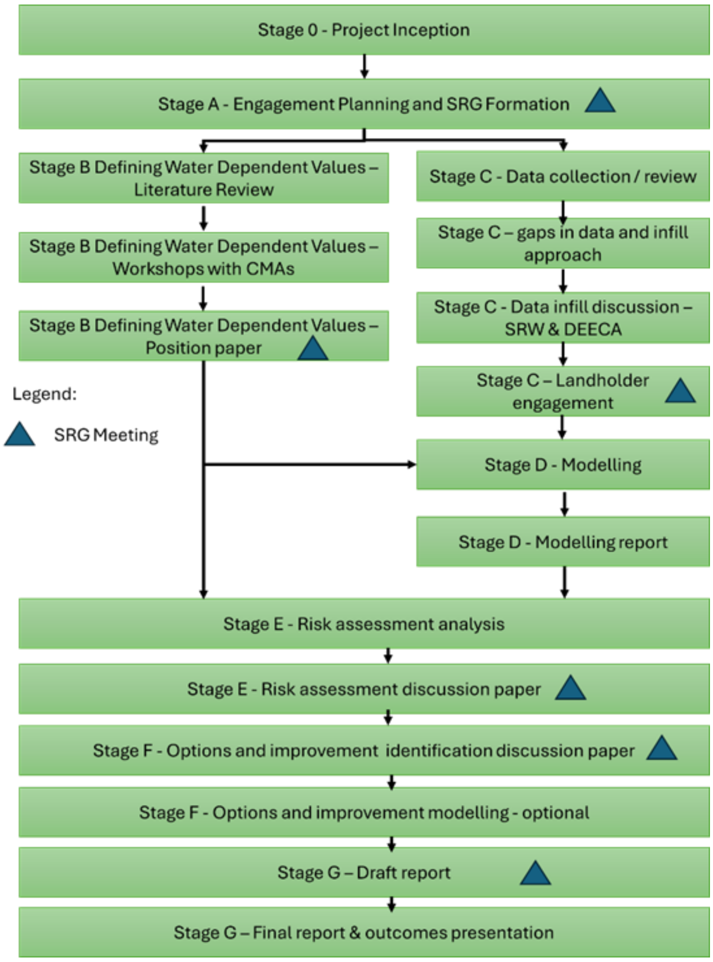

Figure 1 *Project schedule showing key stages and timing of Stakeholder Reference Group meetings*

The analysis consisted of two streams, the identification of water dependent values (Stage B) and the modelling assessment of water resources in the catchment (Stage C and D), to quantify likelihood and consequence of possible future outcomes in a risk assessment (Stage E). This provided the basis to identify opportunities to improve the management of waterways and resources to better support the dependent values in the catchment (Stage F).

1.2 Purpose of this study

The Central and Gippsland Region Sustainable Water Strategy (CGRSWS) was developed with the intent to secure the region's long-term water supplies to protect jobs, farms, ecosystems, communities and the cultural values of the Traditional Owners in the region.

The CGRSWS identified that water resources within peri-urban catchments are facing increasing pressure from small-scale agriculture and changing land use, with increasing urban and semi-rural development. The CGRSWS identified the Upper Maribyrnong and Upper Moorabool catchments as hotspots where land uses are transitioning from agriculture to increased urbanisation, which brings an increased risk to water dependent catchment values.

This study, funded by DEECA and led by Southern Rural Water, focused on the Upper Maribyrnong catchment, upstream of Keilor, and the Upper Moorabool catchment (including tributaries) upstream of Batesford Quarry.

2 Context

2.1 The Maribyrnong System

The Maribyrnong catchment lies on western Victorian volcanic plains, extending from the southern slopes of the Great Dividing Range near Mount Macedon, down to the confluence with the Yarra River in Fisherman's Bend in Melbourne CBD. Much of the catchment is characterised by agricultural and urbanised areas, with only a small portion of the catchment retaining natural vegetation. Waterway and storage management within the Maribyrnong catchment are led by Melbourne Water and Southern Rural Water.

Driven by expansion of urban growth areas and land use change, the Maribyrnong catchment area and runoff behaviours are changing. The study focuses on the catchment area upstream of Keilor gauge, to isolate the impacts on the region that is primarily influenced by river flows (rather than the more estuarine region downstream). The health of the upper catchment directly influences factors such as downstream water quality and ecological integrity and includes key tributaries such as Jacksons Creek and Deep Creek. Rosslynne Reservoir is the only major storage, with limited release capacity (20 ML/day), constraining environmental flow outcomes. There is no permanent environmental water entitlement, and Melbourne Water and the Victorian Environmental Water Holder rely on temporary trades to deliver environmental flows to the system.

Values currently supported by the waterways and catchment include social, cultural, ecological and economic values. Future ability to support the values depend on the health and sustainable management of water resources. The Maribyrnong FLOWS study (Alluvium, 2025) assesses the volumes, timing and frequency of water flows required to sustain ecological and water-dependent values of river systems across the state and has informed the determination of several water dependent values within the Upper Maribyrnong catchment for assessment within this study.

The catchment supports ecological values such as intact streamside vegetation, native fish habitats, macroinvertebrates, birds and platypus. The system includes groundwater-dependent ecosystems, notably Jacksons Creek, which supports aquatic life even during dry periods. Much of the cultural, social, and economic values are closely tied to the health of its waterways, and supporting ecological catchment values in turn supports other value types, such as social values including local identity and recreation, on water activities (like kayaking, fishing), or engagement with waterway environment (picnicking, birdwatching, camping). Economic values include irrigation for agriculture, town water supply and tourism, which are interconnected with other catchment values.

The Maribyrnong catchment lies on the unceded lands of the Wurundjeri Woi-wurrung and Bunurong peoples of the Kulin Nation, and the continual custodianship and connection to the lands and waters of the catchment play a key role in ongoing sustainable management and preservation of values. The Healthy Waterways Strategy is a leading planning strategy that supports Wurundjeri Woi-wurrung Cultural Heritage Aboriginal Corporation (WWCHAC) and Melbourne Water to establish partnership relationships and has guided the identification and incorporation of cultural values into waterway management planning. Cultural values assessments are preferably led by Traditional Owners to ensure technical assessment of impacts to flows appropriately consider cultural factors, and that proposed management interventions are designed with this in mind.

The Upper Maribyrnong River Catchment has seen several sources of stress on inflows to the river system. The expansion of urban fringe in Greater Melbourne has driven a proliferation of urban development and land use change, leading to increased urban runoff, decreased infiltration, pollution and habitat fragmentation. There has been an increase in the number of small catchment dams which capture runoff and exacerbate water scarcity and environmental stress caused by constrained water resources. Water availability is expected to decrease under future predicated climate changes, which is expected to drive increases in climatic extremes and cause a reduction in low flows and extended dry spells.

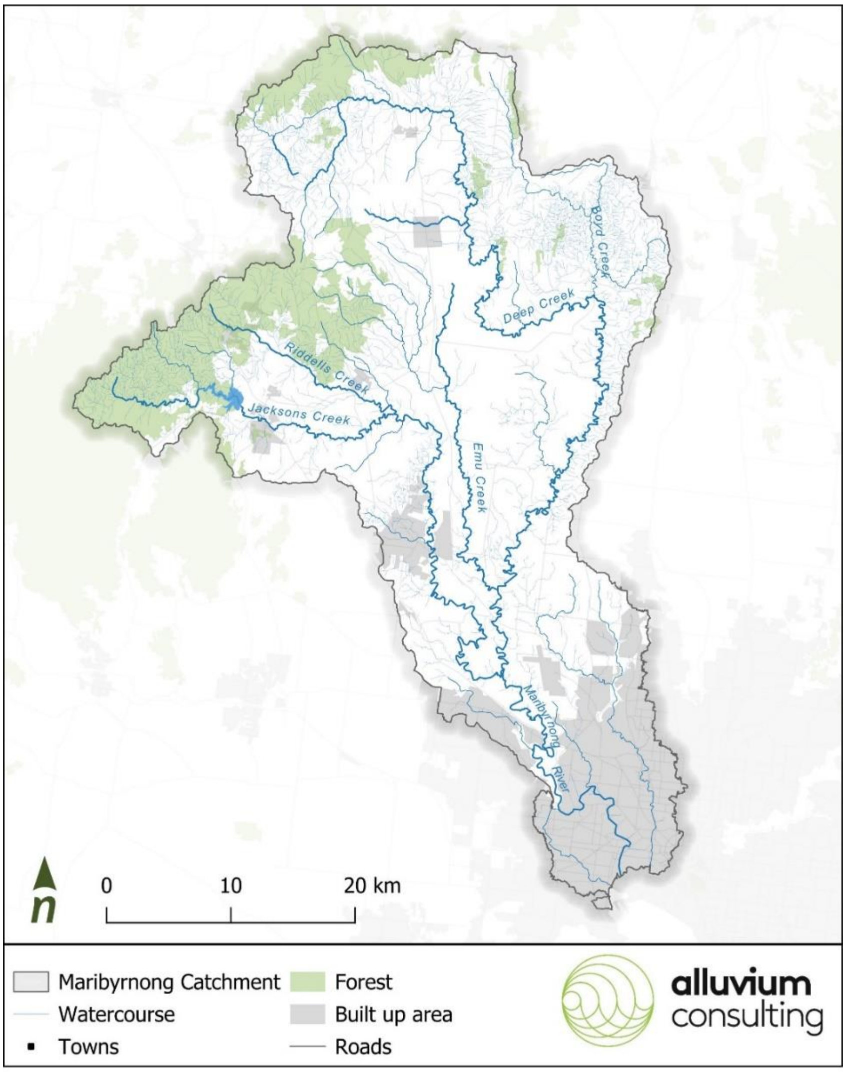

Figure 2 *Map of the Maribyrnong River Catchment showing major river reaches*

2.2 The Moorabool System

The Moorabool system spans around 2000km^2, stretching from the Great Dividing Range near Ballarat to the Barwon River near Geelong. Its east and west branches originate in the Wombat State Forest and flow through confined valleys before merging near Meredith. From there, the river continues through a narrow valley that occasionally widens and narrows again before joining the Barwon River at Fyansford. The Moorabool system plays a critical role in supporting the hydrology and ecology of the lower Barwon basin, supplying water for both environmental and urban uses downstream.

The lands and waters of the Moorabool catchment are within the traditional lands of the Wadawurrung people of the Kulin nation. Their ongoing connection to land, waters, and sky country and custodianship are core to their identity as Traditional Owners of Wadawurrung country. Cultural values and management objectives of the Wadawurrung Traditional Owner Corporation (WTOAC) are detailed in the Paleert Tjaara Dja (Wadawurrung Country Plan), and ongoing works support the management planning and protection of cultural heritage values and caring for Country principles.

The geomorphology of the Moorabool catchment is shaped by ancient volcanic plains, with upstream reaches of the catchment forming in the Wombat State Forest, on the southern slopes of the lower Great Dividing Range. The upper catchment has steep gradients and incised channels, while the mid to lower reaches feature alluvial valleys and sediment deposition zones.

Downstream of Batesford, the Moorabool River flows into the Barwon River system, which supports key ecological features such as the Lower Barwon wetlands, a site of international ecological significance recognised under the Ramsar convention (DEECA, 2025). This connectivity depends on the environmental flows and water quality generated in the upstream Moorabool catchment. The Moorabool River supports a rich ecosystem, including native fish like Australian grayling, river blackfish, and southern pygmy perch. It also features vegetation communities such as streambank shrubland and streamside woodland. Wildlife like platypus, rakali (water rats), swamp wallaby, koalas, echidnas, possums, birds, , snakes, lizards, crayfish, and various water invertebrates inhabit the area (Corangamite CMA, 2025).

The Moorabool system faces challenges with the expansion of urban and peri-urban areas in the lower reaches, and increased catchment activity in the proliferation and expansion of small catchment dams. The increase in number and volume of water storage over the past decade has occurred with both licenced and unlicenced dams and poses risks to the healthy and sustainable management of waterways and water dependent systems within the catchment. Additional to the cultural values identified in the Paleert Tjaara Dja, other waterway dependent values have been identified in the Moorabool River FLOWS study (CCMA, 2015).

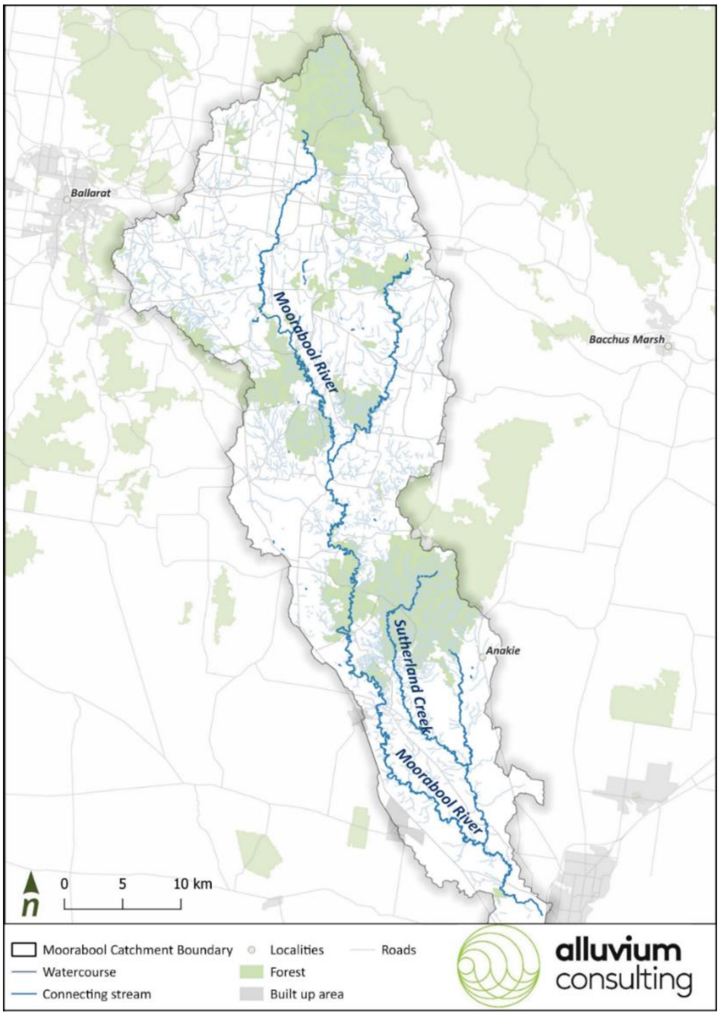

Figure 3 *Map of the Moorabool Catchment showing major river reaches*

Previous investigations into the Moorabool River have shown the challenges being faced by the system. The Water Resource Assessment conducted by SKM in 2003 identified that the Moorabool River was "one of the most heavily committed and therefore flow stressed rivers in Victora" (SKM, 2003). The evidence included in that report stated that median flow below the gauge at Batesford (the downstream end of the study area of this investigation) had dropped from 90 ML/d to 10 ML/d, and the 80th percentile flow from 24 ML/d to 2 ML/d.

2.3 Additional water risks

River flows in both the Moorabool and Maribyrnong Rivers are subject to a range of compounding influences that drive water risks in the catchments. Over allocation of water is a primary risk, with the cumulative demands of urban water supply, licensed surface water diversions, private rights, and environmental needs exceeding the sustainable yield of the system, particularly during dry periods in the Moorabool (SKM, 2003).

In the Moorabool River catchment, groundwater extraction presents another risk, where strong groundwater–surface water connectivity means that pumping can reduce river baseflows. Flow regulation by major storages and weirs further modifies the natural flow regime by reducing flow variability, altering seasonal patterns, and, in some reaches, creating artificially high summer flows and suppressed winter flows, which disrupt ecological processes. These pressures are intensified by climate change, which is projected to reduce average rainfall, increase evaporation rates, and raise water demands, resulting in lower inflows, reduced storage reliability, and more frequent and longer lasting low flow spells (SKM, 2003).

Flows in the Maribyrnong are similarly shown to face pressures from surface water and groundwater extraction, particularly in the upper catchment. Flow releases from Rosslyne Reservoir in the upper Maribyrnong are currently limited by the reservoir release capacity, reducing flow variability and the ability to deliver ecologically important freshes. Urbanisation intensifies hydrological risk by increasing impervious surfaces and stormwater runoff, resulting in flashier flows, reduced infiltration, and degraded water quality. Water resources are placed under further risk due to current and future climate variability and changemaking planning, forecasting and mitigation of risks in an already stressed and sensitive system much more critical (Alluvium, 2025).

Small catchment dams have been shown to be a significant compounding influence on water risks, and form the focus of this investigation, however it is important to note that these are only part of the story. We note that these additional stresses on the systems informed the approach taken to the risk assessment in Section 7.

2.4 The role of agriculture

Although not within the scope of this study, agriculture remains a significant land use and economic contributor within the Maribyrnong and Moorabool River catchments. Farming systems in both catchments are dominated by dryland grazing, mixed cropping, horticulture, viticulture, and intensive enterprises, supporting regional employment, local supply chains, and food production close to metropolitan Melbourne.

Although irrigated agriculture occupies a relatively small proportion of the catchment, it supports high value and water-reliant production, making reliable access to surface water and groundwater critically important for farm viability. Agricultural activities provide direct economic value through farm income and employment, as well as indirect benefits by supporting local processing industries, transport services, and regional towns. Beyond its economic contribution, agriculture also shapes the cultural landscape of the catchment, sustaining long established farming communities and contributing to the region's identity and social fabric (SKM,2003; Alluvium, 2025). Water supply for agriculture is therefore an important value within the catchment, and many of the secondary benefits of productive agriculture depend on reliable supply of high quality water for irrigation and stock watering.

3 Regulatory and legislative context

Private rights to take water for domestic and stock purposes are defined in Section 8 of the *Water Act 1989* (the Act). Section 8 of the Act enables the take of water from a groundwater bore, a waterway, from surface water flowing across a property, and rainwater harvested from a roof. These private rights sit outside the State's entitlement framework (a licence is not required for domestic and stock water use), and there are no volumetric limits on take under these rights, only the limitation that the water is used only for domestic purposes or stock watering (and for fire prevention).

While the volume is not limited, a works licence is required in certain circumstances under State policies for the construction of groundwater bores and dams, the diversion and extraction from rivers and creeks, and the construction of small catchment dams. The following requirements relate to domestic and stock works:

- Groundwater bores greater than 3m depth require a bore construction licence under Section 67 of the Act
- Construction of a dam on a waterway (including a stock and domestic dam) requires a works licence (to construct) under Section 67 of the Act
- Works on a waterway may require a licence under section 67 of the Act.
- The take of water from a waterway where the land adjacent to the waterway is owned by the crown requires a Section 51 take and use licence

Section 3 of the Act defines what stock and domestic water can be used for and the size of gardens that can be irrigated (Attachment 1 contains more details).

Contemporary policy on water accessed for domestic and stock use has evolved through the development and publication by DEECA of various Sustainable Water Strategies (SWS) since 2006, including the Central Region SWS (2006), Northern Region SWS (NRSWS), published in 2009, the Western Region SWS (2011), and Central and Gippsland Region SWS (CGRSWS) in 2022, as well as broader state water policy documents such as Water for Victoria (2016).

Action 4-13 in the CGRSWS relates to the current Water Risks in the Upper Moorabool and Maribyrnong Project, focused on reviewing resource risks from domestic and stock uses and identifying management improvements. The current project will also inform delivery of CGRSWS Action 4-17, to track and improve our understanding of interception activities including small catchment dams.

It is important to note that this report is focussed on unlicensed take, however both catchments are capped for extraction licences, and new licences have to be traded.

Various ministerial policies provide guidance on aspects of stock and domestic activities (further detail is included in Attachment 1).

A key feature of the ministerial policies for managing works licences (2016) is that construction of a dam on a waterway (including domestic and stock dams) should only be allowed if no other options/locations are possible, where an environmental impact assessment has demonstrated a low risk that the dam will impact on the downstream catchment, and that suitable by-pass mechanisms and minimum passing flow rates are enabled.

Fundamental to the consideration of whether a dam is on a waterway or not are the 'Waterway Identification Guidelines', the most recent version signed by the Minister for Water in February 2022. SRW is the delegated licencing authority for determining if works are on a waterway for the Moorabool and Maribyrnong catchments, except for the Maribyrnong downstream of the confluence of Deep Creek and Jacksons Creek (responsibility in these downstream reaches is delegated to Melbourne Water). Further details on how SRW currently implements stock and domestic policy and licensing guidelines are included in Attachment 1.

4 Stakeholder Reference Group

An important element of this project was the guidance, perspectives, and information acquired from key stakeholders within the catchment. Communication and engagement activities involved active participation from members of various stakeholder groups throughout the duration of the project to inform and guide the project. This formally took place via a Stakeholder Reference Group (SRG), who met seven times at key milestone stages throughout the duration of the project. This process helped to build a common understanding of the issues in the catchments with the community.

The SRG meetings were aimed to include local knowledge into the process to ensure a robust approach and create a common understanding on the potential risks to water dependant values in each catchment. The SRG were recruited through an expression of interest and included representatives from:

- water authorities,
- community groups,

- farmers,
- Catchment Management Authorities (CMAs),
- Victorian Farmers Federation,
- Council representatives,
- State government agencies
- Traditional Owners, and
- landholders.

Following the first SRG meeting, it was identified that there was a low representation of farmer water user groups. To ensure a more balanced representation, additional membership was requested to diversify the range of input and values within the group.

One of the key outcomes of the SRG was to allow an informed cross section of the community and stakeholder organisations to develop a series of co-designed response options, which took place in SRG Meeting 5. The outcomes of this meeting can be found in Section 8.

Early SRG meetings gained general acceptance of the approach and scope of the project and confirmed the need for a deeper understanding of the mechanisms of shifts that are being observed within the catchment, and of the magnitude of impact of land use changes on runoff behaviour.

Table 1 *SRG project Meeting Schedule*

Engagement	Title	Date	Purpose
SRG meeting 1	Project introduction and SRG formation TOR	10 December 2024	Introduction of members of the SRG, introduction to the project and session to talk through details of the Terms of Reference and allow for feedback.
SRG meeting 2	Legislative Update and Values	18 March 2025	Overview from SRW about legislative context as an outcome of SRG meeting 1. Water dependent values presentation of outcomes from desktop review and initial assessment and opportunity for feedback.
Briefing to SRG 3 (Online)	Introduction to modelling	20 June 2025	Online briefing to share detail that allows a basic understand of the modelling approach. This session is run before the SRG meeting 3 to allow time for members to process the presentation and ask questions to allow the results session to be more targeted.
SRG meeting 4	Risk Assessment	9 September 2025	Discussion on the modelling outputs and the risk assessment of the potential impact on values
SRG meeting 5	Water management opportunities	1 October 2025	Co-design session of management opportunities
SRG meeting 6	Reporting	17 December 2025	Review and feedback of the Draft version of the report.

The views and input from the SRG were incorporated into all stages and findings of the project. The opportunities identified in Section 8 are SRG developed.

5 Catchment Values

Across southern Victoria, waterway uses and values are known to include environmental, cultural, social and economic values.

Environmental values are significant for underpinning all other waterway values, and include birds, fish, frogs, macroinvertebrates, platypus and vegetation, as well as other water animals (turtles, skinks, water rats, crayfish). These values are described in the respective Healthy Waterways strategies, which also include a description of cultural, social and economic values.

This project aimed to classify what water dependent values there are in the upper catchments, and what hydrological regime they are vulnerable to. This formed the basis of a hydrological impact and risk assessment. Values that have been listed are those that may be at risk from changes in the hydrological regime within the sub-catchments.

Other waterway values were determined by connection to waterway health and condition, recognising the rivers as a living entity. Cultural values are based on physical and spiritual connections to land, waters and sky. Traditional Owners from both catchments hold this connection, which is underpinned by the health of environmental values of land, water, vegetation and wildlife.

Economic values are supported by the quality and condition of waterways, as economic benefits such as urban water supply and storage, industry (commercial, primary production, tourism, power generation and mines), and connection to services (domestic and stock use, sewerage, water treatment, stormwater management, firefighting and essential services) are dependent on waterway condition. Declining waterway conditions can lead to direct economic costs when these services are threatened.

Social values include amenity, entertainment and recreational connection to waterways and their attributes. The environmental values of waterways provide opportunities for community connection to nature, and for entertainment and activities such as swimming, boating, and fishing. The natural greenspace surrounding waterways also contributes to amenity through urban cooling.

This assessment focused on water dependent values in the upper catchments of both the Moorabool and Maribyrnong rivers, to isolate the regions that are considered 'peri-urban' and are experiencing changes to runoff due to the observed expansion of water take activities in the upper catchments. The aim was to determine the impacts of such activities on the hydrological flow regime, and the risks they pose to water dependent values. Wherever possible, values identification focussed on representing water dependant values within the catchment that could be linked to flow targets. Creating links to a quantifiable target allows the targets to be tested against modelled results and develop a clear assessment of any impacts to values.

5.1 Maribyrnong catchment

Environmental

Flow dependant environmental values in the Maribyrnong River are relatively well known, informed by the current update to the FLOWS study completed by Alluvium in 2025. The river flows are known to support the following values:

- *Biodiversity* - within the whole Maribyrnong catchment, 80 threatened flora species and 80 listed fauna species were identified through a NatureKit search. The 80 listed fauna species include seven fish species, two amphibian species, six reptile species, five invertebrate species, 11 mammal species and 49 bird species.

- *Vegetation* - there are three bioregions, within which there are;
  - Three Endangered Ecological Vegetation Communities (EVCs) and four Vulnerable EVCs in the Central Victorian Uplands bioregion
  - Four Endangered EVCs and one categorised as Vulnerable in the Gippsland Plains bioregion

    - Ten Endangered EVCs and two Vulnerable EVCs in the Victorian Volcanic Plain bioregion.

- *Fish* - There are three fish species that are found in the Maribyrnong system that are listed as vulnerable or endangered under the *Flora and Fauna Guarantee Act 1998* (FFG Act) and *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act).

- *Frogs* - Three frog species recorded in the Maribyrnong catchment are listed as endangered or vulnerable, however in the Healthy Waterways Strategy mid-term review (Melbourne Water, 2024b) it was noted that several Maribyrnong sub-catchments that historically supported listed frogs no longer have positive records for Growling Grass Frogs (Deep Creek Upper and Boyd Creek), and for Brown Toadlets (Taylors Creek, Maribyrnong River, Emu Creek, Deep Creek Lower, Deep Creek Upper, Jacksons Creek, Boyd Creek).

- *Platypus* - Platypus populations are now largely restricted to the lower and middle reaches of Jacksons Creek, lower Deep Creek and the upper Maribyrnong River.

- *Invertebrates and aquatic macroinvertebrates* - A survey of macroinvertebrate species in the Maribyrnong system identified 70 families across 17 sites.

- *Birds* - Of the 49 bird species listed on NatureKit, a number of them are classified as vulnerable to critically endangered under the FFG Act and the EPBC Act.

Economic
The flow dependant economic values of the Maribyrnong River are through the availability of water for extraction and use (including urban supplies and water treatment, domestic and stock, and irrigation extraction) and the broader economic benefits that come with supporting a tourism industry. The achievement of water dependant economic values for extraction and use is through the availability of water for use in line with the rules and regulations linked to each of the access requirements. The capacity for the Maribyrnong River to support these values are linked to the operating arrangements in the catchment, as enforced by Southern Rural Water and Melbourne Water.

The economic benefits are also expected to be supported through the availability of a healthy riparian environment, a sustained economy for a community, and resources for the tourism industry. As a result, tourism benefits were assessed through the achievement of environmental and extraction-based flow metrics.

It is noted that the Maribyrnong catchment provides important urban water supplies from numerous reservoirs across the catchment (notably Roslynn Reservoir), and Greater Western Water (GWW) also utilises several local sources within the Maribyrnong catchment to supply the Macedon Ranges towns. The western region supply network is complex, relying on a combination of local, regional, and Melbourne Water sources. Romsey and Lancefield rely primarily on local supplies, with top-ups from Melbourne Water when network conditions allow. GWW is investigating the return of Bulk Entitlements to the Maribyrnong in the short–medium term.

Both Southern Rural Water and Melbourne Water also hold small bulk entitlements in Rosslyn Reservoir, which can be used to support environmental flows and downstream irrigation.

Reductions in catchments flows can reduce water availability for public supply and irrigation and it can impact on the cost of water for users. These values and risks are recognised in this report but with the qualitative economic aspects focussed on impacts on river diversions.

Social
Social values in the Maribyrnong River system are linked to values across the environmental, economic and cultural values. Access to a healthy, flowing river is vital for local communities. Uses range from on river social and recreational activities, as well as general enjoyment of the surrounding riparian area and the physical and mental health outcomes that they provide. Sustaining strong communities is also dependant on maintaining the economic conditions that the community depend on, which a flowing, healthy river should be expected to help protect. Social values are also considered to be supported by the continued supply to urban communities and the capacity for that supply to be maintained at a top level of service.

The concept of the Maribyrnong (and the Moorabool) rivers as a single living entity has been widely adopted by community advocacy groups and is central to Traditional Owner perspectives. Local communities in both catchments have a strong values-based commitment to see the rivers survive and improve, and there is a strong local community feeling of stewardship and intergenerational responsibility grounded in lived experience of declining river flows.

A review conducted in 2024 for Melbourne Water by Mosaic Insights investigated the relationship between the flow dependant values of a catchment and the human wellbeing outcomes they support. The findings included (Mosaic Insights, 2024):

For vegetation

- Trees are the most important factors of aesthetic quality
- People prefer species complexity, diversity, and naturalness
- Clear sightlines of waterways are important for perceived safety but also visually appealing
- High coverage of vegetation can improve the perceptions of amenity and benefit the landscape's restorative effect compared to purely visual landscape
- Tree canopy height has varying levels of importance

Biodiversity

- Sounds of wind, leaves, bird and insect are beneficial for wellbeing
- Human wildlife interactions are important drivers of sense of place and connection to areas
- Some interactions can be negative (certain vegetation, perceptions of snakes)
- More biodiversity may not be universally preferred in urbanized areas, but more biodiversity is generally preferred, enhances wellbeing and health

Water quality/regime

- Devaluation of dry rivers or stagnant water due to aesthetic, recreational and biological reasons
- Cleanliness is tied to positive perception and strong mental restoration potential
- Water motion /water acoustics is important depending on preferences and context

Based on the information described, the social values were viewed through the quantitative approach of the environmental and economic values, and a qualitative impact assessment on the social values described in the Mosaic Insights reporting.

Cultural

The upper Maribyrnong catchment lies on the traditional lands of the Wurundjeri Woi-wurrung people. The Maribyrnong (Mirrangbamurn) River is culturally significant to Traditional Owners. The entire watercourse (mainstem and named tributaries) is recognised as a site of cultural heritage sensitivity (ACHRIS, 2024), as are the thousands of individual cultural heritage sites, including scar trees and artefacts, that demonstrate occupation and interaction with the river and its floodplains by hundreds of generations of Aboriginal people.

The Wurundjeri Woi-wurrung Nation Statement on Water articulates the principle that healthy water means healthy Country and healthy people, and the desire to see healthy and cleaner Country, through well managed and adequately protected hydrological systems. For the Wurundjeri, the natural world is the cultural world, with the natural landscapes holding cultural importances that are essential to the identity and well-being of the people. The risks to cultural values in the Maribyrnong are in the form of a qualitative assessment of the impact of changes in flows on the values identified and the objectives of the Wurundjeri Woi-wurrung people (WWCHAC, 2025)

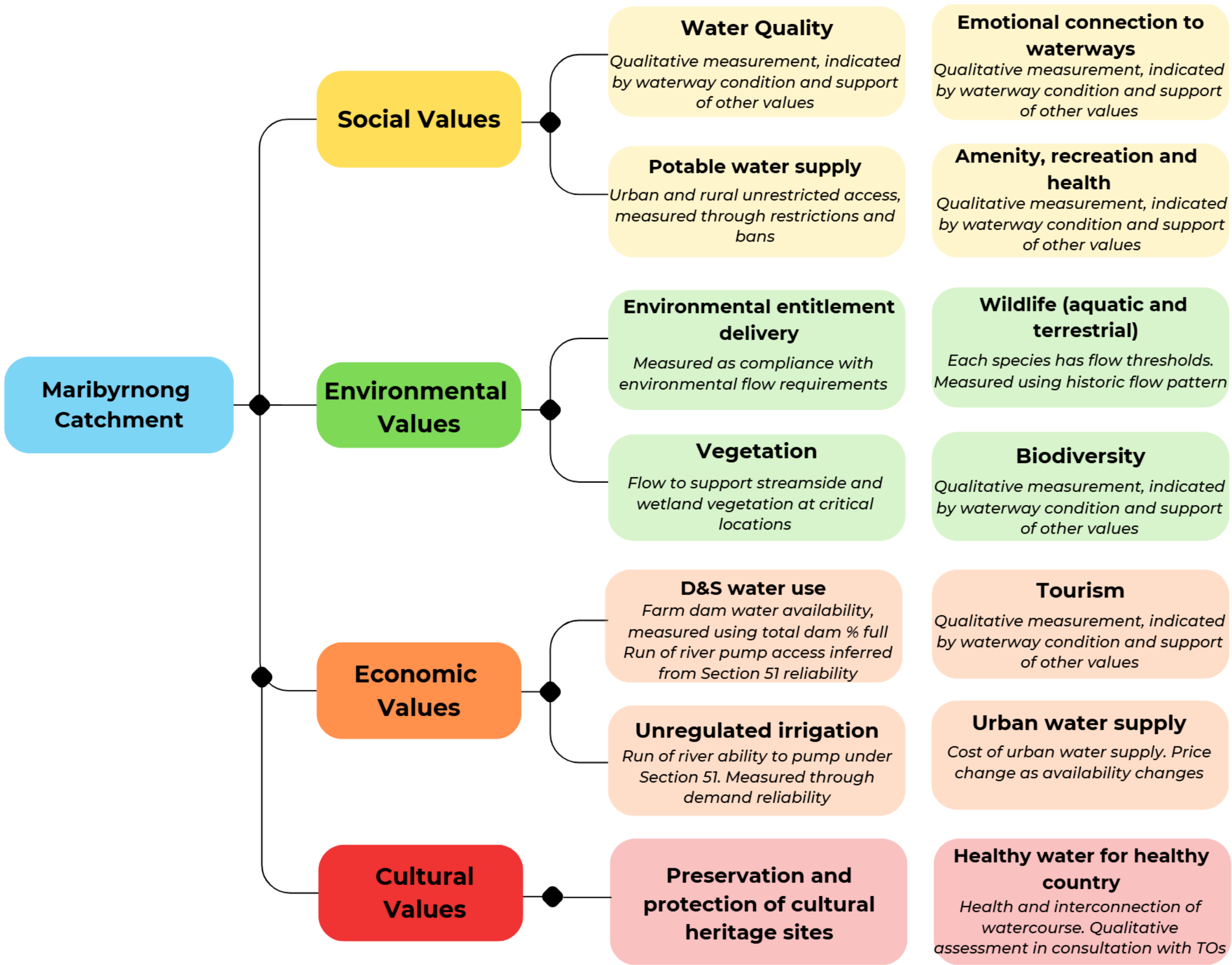

Figure 4 *Maribyrnong catchment values*

5.2 Moorabool Catchment

Environmental

The environmental values of the Moorabool catchment are also reasonably well documented and informed by the FLOWS study completed in 2015. The environmental values within the system include:

- *Fish* - The Moorabool River system supports a number of native freshwater fish species, including Shortfinned Eel, River Blackfish, Common Galaxias, Mountain Galaxias, Spotted Galaxias, Southern Pygmy Perch, Yarra Pygmy Perch, Short Headed Lamprey, Flat-headed Gudgeon, Australian Grayling, Australian Smelt and Tupong.

- *Macroinvertabrates* - Macroinvertebrates have been recorded in the Moorabool and are a general indicator for determining stream condition, due to their sensitivity to changes in catchment use, water quality and habitat availability.

- *Platypus and water rats* - Platypus were recorded in the Moorabool River catchment in 2004 and 2006 in the lower reaches, and anecdotal evidence from nearby landholders suggests relatively regular sightings of platypus from 1950s to present day. Water rats have been recorded throughout the catchment, and it is estimated that the Moorabool River supported a reasonably sizeable population in the mid-2000s, particularly in the lower reaches (between Sharps Road, She Oaks and the confluence of the Barwon River). SRG feedback is that wildlife like platypus, rakali (water rats), and various water invertebrates inhabit the catchment as well as swamp wallaby and koala populations.

- *Vegetation* – The Moorabool River supports various landscapes and bioregions, including volcanic uplands and plains, within which there is diversity in the vegetation profile in different zones. Remnant native vegetation falls under Stream Bank Shrubland, Riparian Woodland and Grassy Woodland EVCs. This includes instream, channel bank and floodplain vegetation, which have different supporting flow requirements depending on position relative to water level and inundation requirements.

- *Habitat processes and floodplains* – habitat values within the Moorabool River system are formed and maintained by physical geomorphic processes that form and shape the channel and floodplains. In the upper parts, the west and east branch are variable, alternating between sections that are narrow gorges and more open with broader floodplains. Downstream of the confluence of the west and east branch, the river valley opens more and there is greater development of alluvial benches and floodplain.

- *Water quality* – Water quality values include pH, turbidity, salinity and volume of dissolved nutrients that are important for the maintenance of stream health for dependent species, human health and to avoid the proliferation of algae.

Economic

The main flow dependant economic values of the Moorabool River are through the availability of water for extraction and use (for public water supply and water treatment, domestic and stock use, and irrigation), and the broader economic benefits that come with supporting a tourism industry. The achievement of water dependant economic values for extraction and use is through the availability of water for use in line with the rules and regulations linked to each of the access requirements. The bulk entitlements for urban water storage and supply are regulated by DEECA. Southern Rural Water is responsible for take and use licences, with surface water licences administering via the Moorabool River Basin Local Management Plan, which includes the percent of maximum daily extraction available for trigger flow volumes at Batesford gauging station. This assessment of economic impacts has focussed on irrigation licences and the impact of reduced river flows on the reliability of water availability, with the Batesford gauge acting as the trigger point.

The economic benefits are also expected to be supported through the availability of a healthy riparian environment, and a sustained economy that can provide a community and resources for the tourism industry.

As a result, potential tourism benefits were assessed through the achievement of environmental and extraction-based flow etrics.

Feedback from the SRG between the draft and final report has highlighted the importance of the river for urban water supply and water treatment, and that reduced flows can impact on water security, operational and treatment costs, and water pricing. These values and risks are recognised in this report but they have not been qualitatively assessed.

Social

The concept of the Moorabool (and the Maribyrnong) rivers as a single living entity has been widely adopted by community advocacy groups and is central to Traditional Owner perspectives. Local communities in both catchments have a strong values-based commitment to see the rivers survive and improve, and there is a strong local community feeling of stewardship and intergenerational responsibility grounded in lived experience of declining river flows.

As was described in the section on the Maribyrnong Catchment, social values are generally associated with the elements that support the local economies, and by providing amenity outcomes for the communities. Social values are also considered to be supported by the continued supply to urban communities and the capacity for that supply to be maintained at a top level of service.

As with the Maribyrnong catchment, the social values were viewed through the quantitative approach of the environmental and economic values, and a qualitative impact assessment on the social values described in the Mosaic Insights reporting.

Cultural

It is recognised that the Moorabool River catchment is on the traditional lands of the Wadawurrung people. The Wadawurrung people hold a deep connection to the lands and waters of the Moorabool (Corangamite CMA, 2024a). Caring for Country, land, sky, and waters, and continual cultural practices are core to the identity of the Wadawurrung people as the Traditional Owners of Wadawurrung Country (WTOAC 2019). The catchment includes Lal Lal Falls, believed to be the earthly home of Bunjil, the Creator to many Victorian Aboriginal tribes. The name Lal Lal is thought to be Aboriginal for "dashing of waters" (Corangamite CMA 2024b).

The cultural values for Traditional Owners identified in the Moorabool System have been drawn from the existing goals identified by the Wadawurrung Traditional Owners Aboriginal Corporation, as detailed below.

Paleert Tjaara Dja (Wadawurrung Country Plan) goals:

- By 2030, the water in the waterways of the Barree Warree Yulluk is clean enough to drink.
- By 2025, the waterways of the Barree Warree Yulluk will have sufficient cultural flows and connectivity to support culturally important species.

Objectives from the Wadawurrung Nation Statement on Water:

- Wadawurrung [Yulluks] and waterway ecosystems flowing freely and are healthy.

The risks to cultural values in the Moorabool Catchment were in the form of a qualitative assessment of the impact of changes in flows on the values identified and the objectives of the Wadawurrung people.

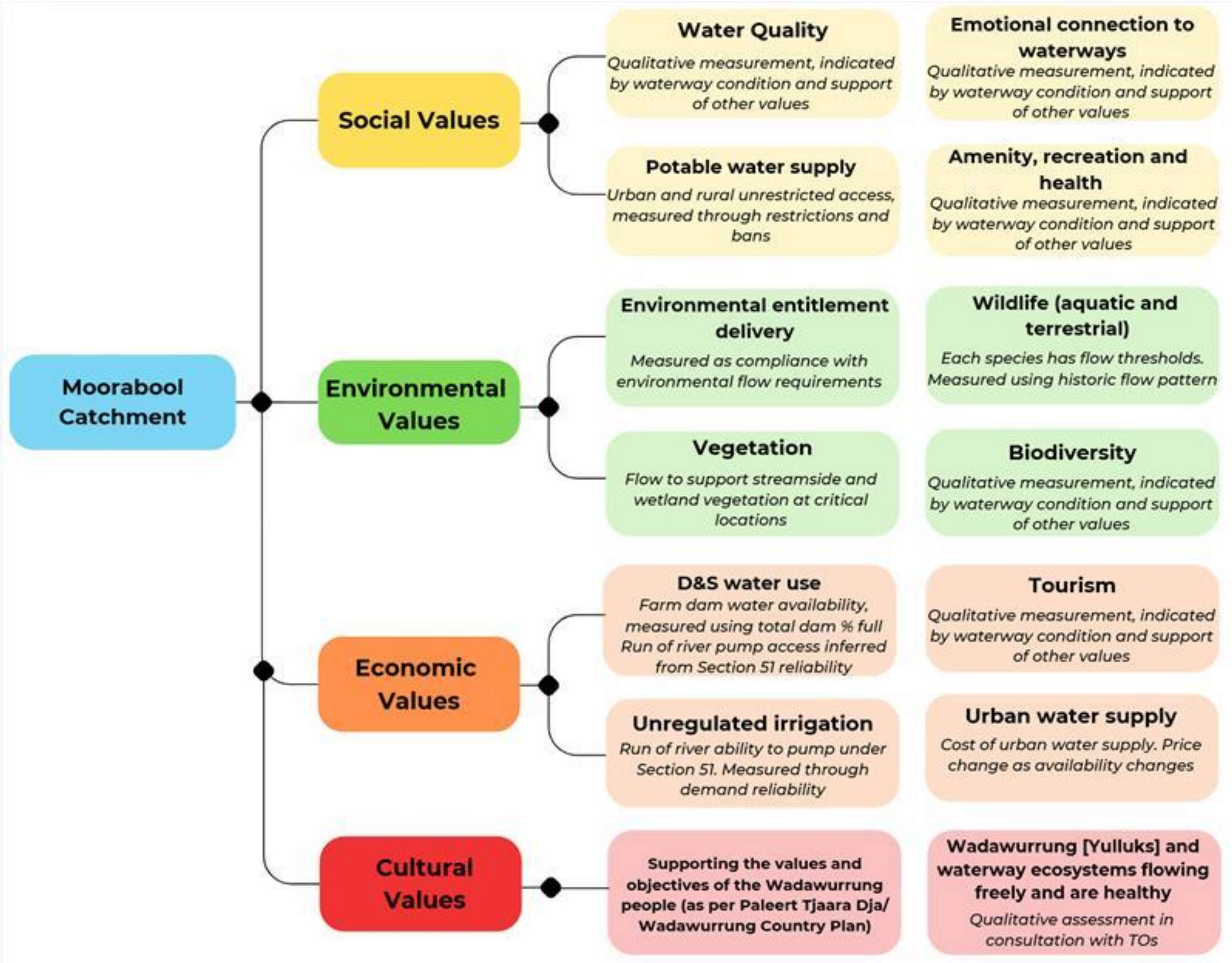

Figure 5 *Moorabool catchment values*

6 Catchment modelling

6.1 Purpose of the modelling

Water resources systems models enable the representation of features such as catchment inflows, supply to licensed users and bulk entitlements, supply to meet environmental and cultural water needs, the operation of large dams and reservoirs, other demands including domestic and stock use, and rules representing transfer of water to simulate a water resource system.

DEECA have developed water resources planning models for the Barwon-Moorabool and Maribyrnong basins using the eWater Source modelling package, developed and supported by eWater. Source is the industry standard software for modelling hydrology and water resources across Australia. These models are used by DEECA, in consultation with stakeholders, to:

- Inform planning and development of water resources allocation policies
- Assess volumes, reliability and pattern of delivery of environmental flows
- Assess yields to bulk entitlement holders (such as Barwon Water and Melbourne Water) and the reliability of those yields
- Assess the impacts on water availability of larger scale Integrated Water Management projects in urban areas
- Assess the impacts of climate change and climate variability on these factors

The Source models for the Barwon-Moorabool and Maribyrnong systems incorporate, either explicitly or implicitly, water that is taken and used by licensed and domestic and stock (D&S) users in these systems. Water take from farm dams in each of the major subcatchments of these systems are explicitly modelled using the Spatial Tool for Estimation of Dam Impacts (STEDI) model (SKM, 2011).

The purpose of the modelling undertaken for this project was to assess changes in flow regimes in the stream reaches of the Maribyrnong and Moorabool catchments that are represented in the Source models, under previous, current and future climate change projection scenarios. The models were also used to assess the changes in the impact of farm dams for each scenario, changes in water available to licensed water users in each system and changes in compliance with environmental flow metrics to inform the risk assessment.

6.2 Hydrologic modelling overview

A map of the subcatchments represented in the Maribyrnong Source model is shown in Figure 6. The Keilor streamflow gauge (230200) is at the downstream boundary of subcatchment F19. Subcatchment F20 is not included in the scope of the current project, even though it is within the extent of the water resources planning model (Source – see below) for the Maribyrnong system, as it is downstream of the scope boundary of this project.

A map of the Moorabool portion of the Barwon-Moorabool Source model is shown in Figure 7. The Source model for the Barwon-Moorabool system includes catchments in the Barwon part of the system that are outside of the Moorabool catchment, and therefore not shown on Figure 7. Within the Barwon part of the system, part of the model and inputs were developed as part of the Ballarat Source model (for Central Highlands Water, CHW) and are labelled site 1 to 19. They are shown in orange on Figure 7. Inputs for some Moorabool subcatchments, labelled F12 to F20 and shown in blue on Figure 7, were developed as part of a separate project. Inflows for CHW sites 14 to 19 are included in the Barwon Moorabool Source model but are outside of the Moorabool basin. Similarly, subcatchment F12 for inflows to Stony Creek reservoir is also outside of the Moorabool basin.

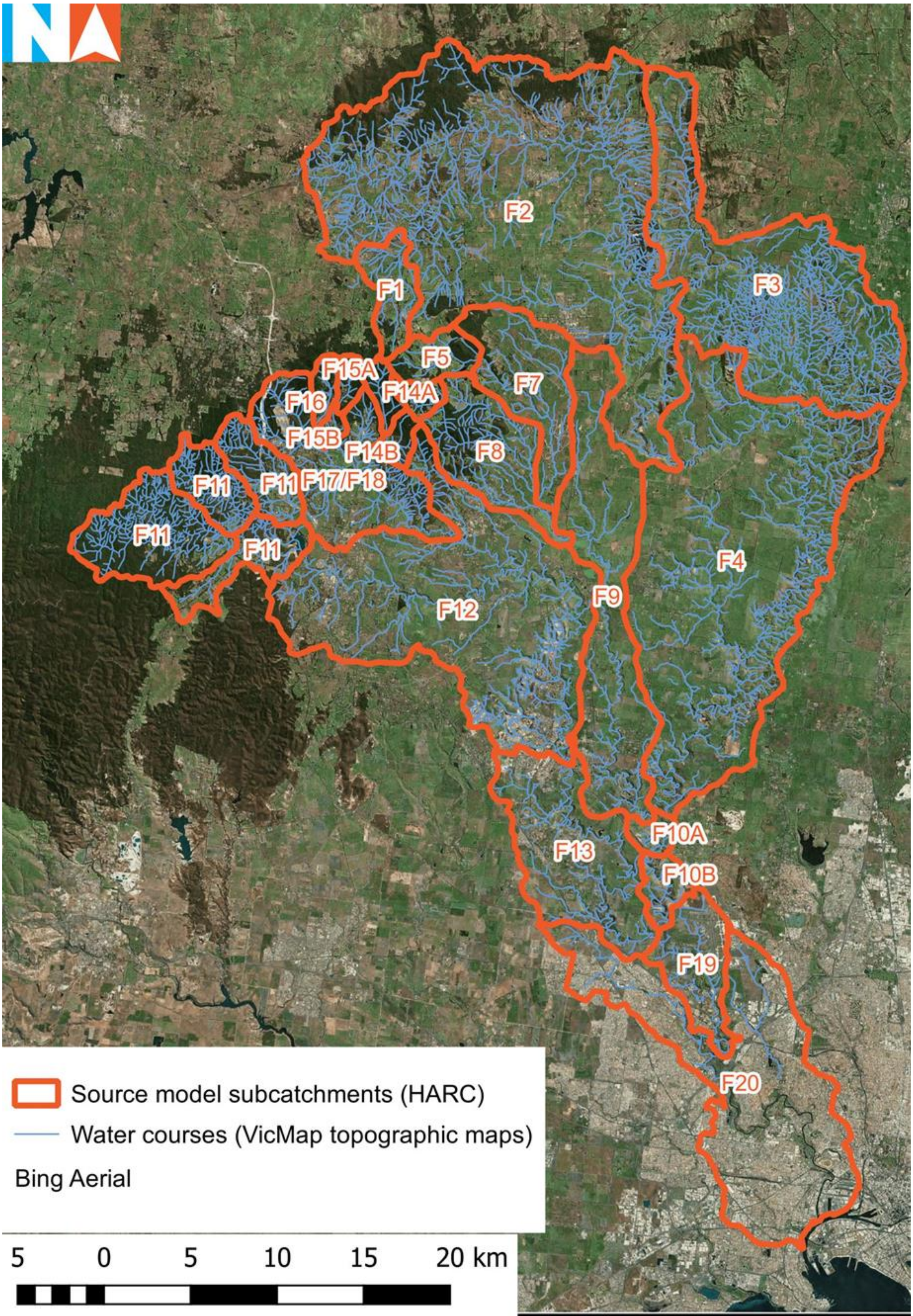

Figure 6 *Maribyrnong subcatchment map*

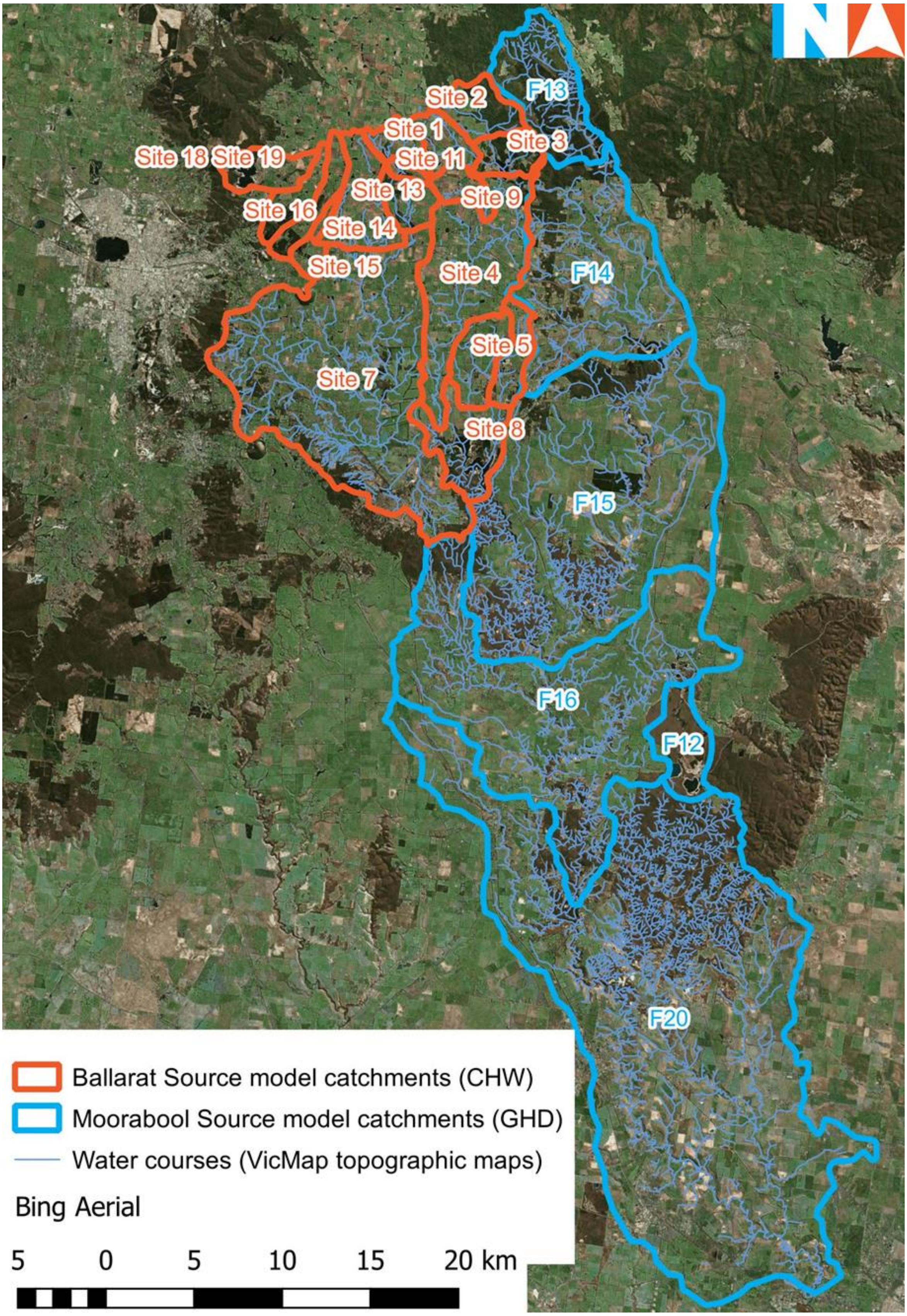

Figure 7 *Moorabool subcatchment map*

STEDI was used to explicitly model farm dam impacts in 19 subcatchments of the Maribyrnong system and 16 subcatchments of the Moorabool system to estimate the historical impact of farm dams, which has evolved over time. These were then added back to the streamflow time series that were recorded at flow gauges.

The conceptual structure of the STEDI model is shown in Figure 8. The water balance for each farm dam is characterised by inflows; net evaporation (the difference between evaporation from the dam surface area and rainfall directly falling on the dam); extractions from the dam to supply demands; seepage losses and spills. Spills from upstream dams may be intercepted by dams that are further downstream. Low-flow bypasses may be installed on some or all dams in a catchment, which will divert inflows up to the flow capacity of the bypass around the dam. Low flow bypasses are relatively uncommon in the Maribyrnong and Moorabool catchments. Farm dams in a catchment have a cumulative impact, which affects the overall hydrograph of inflows at locations further down the catchment.

Inflows to runoff dams may be contributed by surface runoff from the upstream catchment area, capture of excess runoff from irrigated areas upstream of the dam, discharge from groundwater via springs, diversion from a nearby stream, pumping from groundwater and/or spills from upstream dams.

Water that may otherwise have flowed into a farm dam may also be intercepted by features in the catchment upstream of the dam, such as natural lakes, depressions or wetlands. Gauging of inflows to individual runoff dams is rare and spatial and temporal variations in the above aspects contribute uncertainty to estimates of inflows to individual dams.

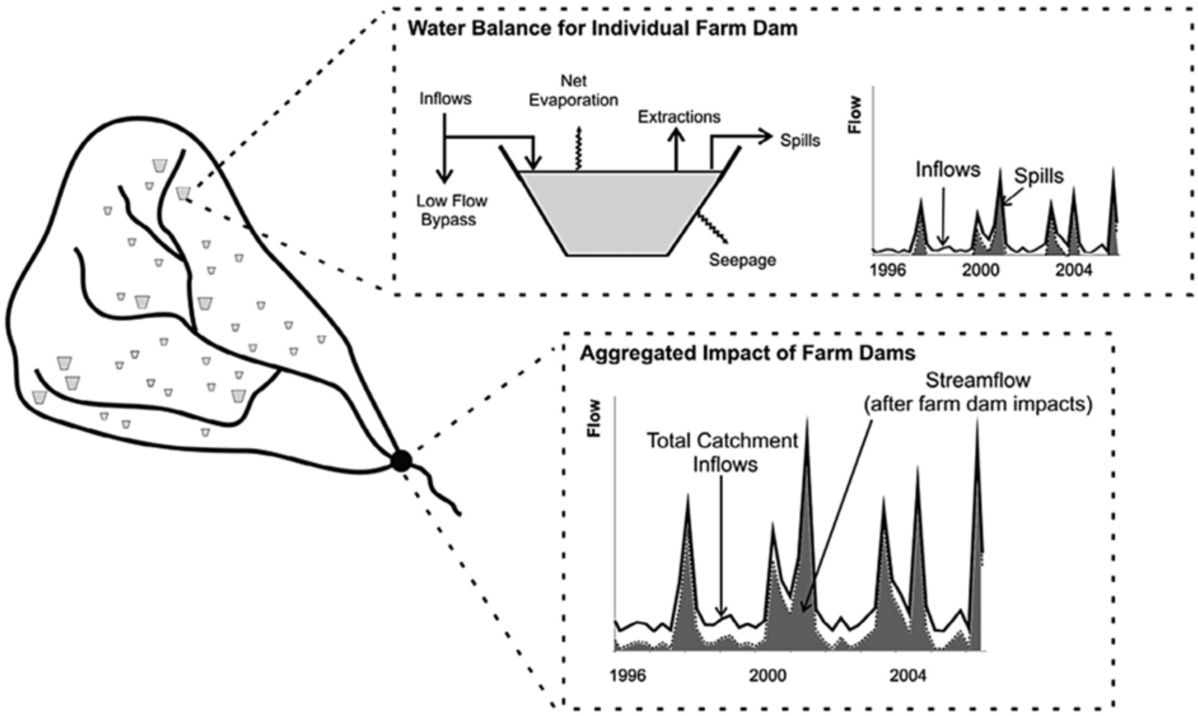

Figure 8 *Conceptual representation of farm dam impacts in the STEDI model* (from Fowler et al., 2016)

STEDI models apply data on the maximum surface area of water bodies in the catchment captured from aerial photography or satellite imagery, to estimate the maximum storage volume of each farm dam. There are uncertainties in estimating the volume of each water body and in being sure about which water bodies are farm dams and which are other water bodies, such as natural wetlands or wastewater treatment ponds. The STEDI models also make assumptions about the demand that is extracted from each farm dam for use in each year (normally as a function of each dam's estimated storage volume), the catchment area upstream of each farm dam (which influences the volume of inflow that each dam captures), rainfall on and evaporation from the surface area of each dam and the spatial connectivity of dam impacts in each subcatchment.

The existing Maribyrnong and Moorabool Source models available to inform this study previously included STEDI models to represent the small catchment dams in each subcatchment. That is, there are 19 existing STEDI models for catchments in the Maribyrnong system and 16 existing STEDI models for subcatchments in the Moorabool system. These models were "level 1" STEDI models, which made relatively simple assumptions about the spatial arrangement and catchment areas of each individual farm dams. The previous level 1 STEDI models ignored the spatial connectivity of farm dams in each subcatchment (i.e. ignoring the fact that dams are often in chains along a stream, where one farm dam may fill and then water spilling from that dam, along with local inflows, would be captured by dams that are further downstream along the chain) and that the local catchment area draining to each farm dam is a simple linear function of the storage volume of the dam (i.e. the upstream catchment area for each dam is not known; instead it is assumed that farm dams with larger volumes collect runoff from a larger upstream area).

Level 2 STEDI models were set up for every subcatchment in the Maribyrnong and Moorabool basin. These level 2 STEDI models explicitly represented the catchment draining to every water body in the catchment. The level 2 STEDI models demand factors by water body type as shown in Table2. Note that all water bodies lose water via evaporation but gain water via direct rainfall on their surface. The previous level 1 STEDI models also assumed that the mean annual usage from each D&S farm dam was 50% of the estimated dam storage volume and that mean annual usage from each irrigation farm dam was 84% of the estimated dam storage volume.

Table 2 *Proposed demand factors for water bodies in level 2 STEDI models*

Water body type	Ratio of mean annual demand to storage volume
Licensed irrigation dams	0.84
Domestic and stock unlicensed dams	0.5
Quarry pits	0
Natural pools and wetlands	0
Aesthetic lakes	0
Wastewater treatment lagoons	0 (and no external catchment inflows or overflows)

Assumptions and limitations of small catchment dam impact modelling

An overview of the main limitations and sources of uncertainty in surface water interception models for small catchment dams is given below

Identification, location classification and extent of runoff dams – Modelling runoff dam impact requires an understanding of the number, location and extent (catchment area and surface area) of runoff dams. The spatial data analysis used for this purpose is influenced by the resolution and quality of the spatial imagery and data used, the period or periods for which data is available, the method of identification, the catchment conditions at the time of data acquisition, and the quality of any regulatory or other water body data available to support identification and classification.

Historical change in the number of dams – Modelling requires assumptions to be made about which of the dams were present over the period that was concurrent with modelled or gauged streamflow data for the catchment. There is often some uncertainty about the trajectory of runoff dam development over time, and this contributes uncertainty to how the model would scale impacts from historical periods, when there may have been fewer dams and with lower aggregate storage volume, to current and forecast future numbers and storage volumes of dams.

Runoff dam inflow – Uncertainties in spatial and temporal variations of inflow to runoff dams are influenced by catchment characteristics, including soils, vegetation cover, land use, agricultural practices, hydrogeology of underlying aquifers and stream networks. Uncertainty in the estimation of inflow has been reduced, at a catchment level, by calibrating a catchment model to gauged streamflow at several locations within the

Maribyrnong and Moorabool catchments. However, a component of uncertainty will remain around the inflow to each dam, due to spatial and temporal variations in surface runoff and other inflows to each dam.

Spatial and temporal variation of rainfall and evapotranspiration within a catchment – Uncertainties in spatial and temporal variations of rainfall and evapotranspiration within a catchment contribute to uncertainties in spatial and temporal variations of inflow to runoff dams

Demands and usage – Demand and usage is not metered from D&S farm dams or from almost all other small water bodies in Victoria. The typical annual volume of usage and pattern of demand, across the year, is therefore estimated as a proportion of the estimated storage volume in the STEDI model. Demand is likely to vary significantly between dams and from year to year for each dam.

Storage volume – A contributor to uncertainty in the impact of runoff dams is the uncertainty in the volumetric storage capacity of each dam, as accurate survey data is rarely available for runoff dams and their storage volumes must therefore be estimated from their surface area.

Volume stored – Uncertainty in estimating the volume stored in each farm contributes to uncertainty in usage and net evaporation losses. It will also contribute to uncertainty in the estimation of inflow if the runoff dam storage volume is used as a predictor of the area of the upstream contributing catchment.

Net evaporation – Uncertainty in net evaporation from dams is typically viewed as a relatively small component of the overall uncertainty. This is because (a) direct rainfall on the surface area of the dams counterbalances much of the evaporation losses and (b) the total surface area of all runoff dams in a catchment is a small proportion of the overall catchment area.

Seepage losses – Seepage losses from runoff dams are difficult to estimate and there is minimal credible data available on seepage losses from small catchment dams. The majority of seepage losses, if any, would recharge groundwater and therefore contribute to baseflow downstream of the small catchment dam. Seepage losses were therefore ignored in models of runoff dam impacts for this project.

Groundwater flows / Ingress – While typically assumed to be negligible due to the use of clay, plastic or geo-textile liners, inflow from groundwater can impact the overall water balance of runoff dams, i.e., the volume stored and, therefore, influences the uncertainty outlined above.

Losses and hydrologic connection – seepage rates from dams and each dam's location in the landscape can contribute significantly, in some cases, to take by runoff dams. It is difficult to generalise dam characteristics across a region and levels of hydrologic connection to downstream waterways may vary significantly between dams in a catchment. The modelling assumes that all of the modelled impact at each individual dam translates directly to an impact on flows in the waterway, but in many cases, particularly during dry times, the level of hydrologic connection will be significantly less than 100%.

Spatial resolution of flow regimes from Source models - Source models are focussed on assessing flow regimes and environmental water deliveries for the major streams in each system, which generally run from downstream of the major reservoirs. Spatial and temporal variations in water take across the catchments may present different levels of risk to in-stream flows and environmental values in the tributary streams that are not explicitly represented in the Source models.

Climate change projections - There are large variations in projected mean annual rainfall and runoff between climate change scenarios. The low projection scenarios expect increases in rainfall and runoff for the Maribyrnong and Moorabool basins, whilst the high projection scenarios indicate decreases in runoff of up to 45% to 55% by 2065 under the high climate change projection for RCP8.5. The proposed 2065 RCP 4.5 medium scenario provides for a reasonable assessment of the sensitivity of how the influence of small catchment dams might be modulated by projected climate change.

6.3 Changes in catchment response after the Millennium drought

In some catchments, runoff decreased more than expected for the given amount of rainfall during and after the Millennium Drought. The reductions in runoff generation are widespread across central and Western Victoria and are observed in catchments where flow conditions are not impacted by farm dam growth, changes in land use, extractions or other flow regulation. About one-third of the Victorian catchments studied are still in this drought-like state, including catchments in the upper Maribyrnong and other catchments in the vicinity of this study. The drivers for these reductions in streamflow are currently unclear and this continues to be subject to ongoing research. The scientific community perspective is summarised in Fowler et al (2022).

6.4 Modelling scenarios

The Source and STEDI models in the Barwon-Moorabool and Maribyrnong systems have been calibrated to recorded streamflow and climate data over the full historical period of record.

In accordance with the *Guidelines for assessing the impact of climate change on water availability in Victoria* (Department of Environment Land Water and Planning, 2020), the representation of current conditions uses data on inflows and climate for the full historical period but with data recorded prior to 1975 adjusted to be statistically equivalent to data from the post-1975 period.

The scenarios were as follows:

- Unimpacted by small catchment dams scenario: current Source models but with all small catchment dam impacts set to zero (baseline scenario).
- 2009/2010 level of development of small catchment dams: small catchment dam impacts derived using the spatially explicit (Level 2) STEDI models and water body inputs from the DELWP (2012) data set.
- 2025 level of development of small catchment dams: small catchment dam impacts derived from the spatially explicit (Level 2) STEDI models with current (2025) spatial data on water bodies.
- 2025 level of development of small catchment dams with projected climate change scenario: as for the previous scenario (using current spatial data on water bodies) but with all climate and inflow data re-scaled to represent the 2065 RCP 4.5 Medium sensitivity climate change projections (see Table 3).

All model scenarios included the same assumptions for current water corporation owned dams and water infrastructure, current licensed entitlements and demands, and current operational and environmental flow rules.

Future growth scenarios for small catchment dams were not included in the scope of the project, however the impacts of the growth between 2009/10 and 2025 are clearly modelled and can be used to illustrate potential future impacts if the trend in small catchment dam development remains the same in the next 15 years (noting also the modelled climate change impacts).

The unimpacted scenario was run as the baseline scenario to which other scenarios can be compared. This approach allows the impact of the farm dams and climate change of each scenario to be isolated and focussed on when comparing scenario results.

Table 3 *Projected changes in mean annual rainfall and inflows for 2065 Representative Concentration Pathway 4.5 W/m² (RCP 4.5) Medium climate change sensitivity scenario, relative to mid-point of post-1975 period* (DELWP, 2020)

Projection	Maribyrnong mean annual rainfall	Moorabool mean annual rainfall	Maribyrnong mean annual streamflow	Moorabool mean annual streamflow
2065 RCP4.5 Medium	-3.3%	-3.2%	-9.7%	-7.1%

6.5 Catchment modelling results

Summary of estimated small catchment dam impacts in the Maribyrnong

Table 4 summarises the statistics of small catchment dam numbers, volume and estimated mean annual impact across the Maribyrnong catchment between 2009 and 2025 levels of development.

There are over 7,000 rural small catchment dams in the Maribyrnong basin (as at 2025), an increase in number of 2% since the 2009 level of development. The total storage capacity of rural small catchment dams has increased in the Maribyrnong basin by 6% since 2009 and is now approximately 14,000 ML. The estimated mean annual impact of those small catchment dams has increased by 5% between the 2009 and 2025 levels of development.

Whilst some small catchment dams have increased in storage volume over the 16-year period, the overall estimated impact of those small catchment dams is limited by overall inflows, particularly in dry years and in parts of the catchment with already high densities of small catchment dam development. At the 2025 level of small catchment dam development, the estimated impact is currently 8% of mean annual inflows.

Table 4 *Comparisons of number, storage volume and estimated mean annual impact of small catchment dams in the Maribyrnong catchment between 2009 and 2025 level of development*

Statistic	2009 Level of small catchment dam development	2025 Level of small catchment dam development	Change between 2009 and 2025	% Change between 2009 and 2025
Number of rural small catchment dams	6,889	7,048	159	2%
Storage volume of rural small catchment dams (ML)	13,238	14,088	850	6%
Estimated mean annual impact of small catchment dams (ML/year)	6,559	6,907	348	5%
Mean annual impact as proportion of unimpacted inflows	7.6%	8%	0.4 percentage points	5%

The increase in the number and volume of small catchment dams between 2009 and 2025 level of development, has increased the mean annual take across the Maribyrnong catchment from 7.6% to 8% of mean annual inflows (see Table 4 and Table 5). Even without any further change in small catchment dams, climate change mean annual small catchment dam impacts are projected to increase by a further 500 ML by 2065, to 11.8% of mean annual inflows (see Table 5). It was noted that the total storage volumes increased by a higher percentage than the increase in dam numbers, showing the significance of dam enlargement on total storage volume.

Table 5 *Comparisons of estimated mean annual impact of small catchment dams in the Maribyrnong catchment between 2009 and 2025 level of development and 2025 level of development with projected climate change*

Statistic	2009 Level of small catchment dam development	2025 Level of small catchment dam development	2025 Level of small catchment dam development with projected climate change (2065 Medium RCP 4.5)	Change due to projected climate change
Estimated mean annual impact of small catchment dams (ML/year)	6,559	6,907	7,407	500
Mean annual impact as proportion of unimpacted inflows	7.6%	8.0%	9.5%	19%

Investigation into the season variability of small catchment dam influence on river flows showed that small catchment dams have a greater impact as a proportion of inflow during summer and autumn than they do during winter and spring across all scenarios (see Attachment 7 for more detail).

Summary of estimated small catchment dam impacts in the Moorabool

Table 6 summarises the statistics of small catchment dam numbers, volume and estimated mean annual impact across the Moorabool catchment between 2010 and 2025 levels of development. As of 2025, there are almost 6,300 rural small catchment dams in the Moorabool basin, an increase in number of 4% since the 2010 level of development. The total storage capacity of rural small catchment dams has increased in the Moorabool basin by 20% since 2010 to approximately 20,500 ML. The estimated mean annual impact of those small catchment dams has increased by 9% between the 2010 and 2025 levels of development.

Whilst some small catchment dams have increased in storage volume over the 15-year period, the overall estimated impact of those small catchment dams is limited by overall inflows, particularly in dry years and in parts of the catchment with already high densities of small catchment dam development. At the 2025 level of small catchment dam development, the estimated impact is currently 9.6% of mean annual inflows. It was again noted that the total storage volumes increased by a higher percentage than the increase in dam numbers, showing the significance of dam enlargement on total storage volume.

Table 6 *Comparisons of number, storage volume and estimated mean annual impact of small catchment dams in the Moorabool catchment between 2010 and 2025 level of development*

Statistic	2010 Level of small catchment dam development	2025 Level of small catchment dam development	Change between 2010 and 2025	% Change between 2010 and 2025
Number of rural small catchment dams	6,043	6,294	251	4%
Storage volume of rural small catchment dams (ML)	17,057	20,517	3,460	20%
Estimated mean annual impact of small catchment dams (ML/year)	7,172	7,788	616	9%
Mean annual impact as proportion of unimpacted inflows	8.8%	9.6%	0.8 percentage points	9%

Table 7 shows that the overall density of small catchment dams and projected reductions in inflow under climate change are such that the estimated volume of mean annual impact is projected to reduce slightly by 2065 due to reductions in runoff volume. However, the take is projected to increase from 8.8% to 9.6% of mean annual inflows under the 2065 medium RCP 4.5 climate change projection as the total volume of inflows are projected to decline in the Moorabool catchment. As was noted in the Maribyrnong, small catchment dams have a greater impact as a proportion of inflow during summer and autumn than they do during winter and spring across all scenarios (see Attachment 7 for more detail).

Table 7 *Comparisons of estimated mean annual impact of small catchment dams in the Moorabool catchment between 2010 and 2025 level of development and 2025 level of development with projected climate change*

Statistic	2010 Level of small catchment dam development	2025 Level of small catchment dam development	2025 Level of small catchment dam development with projected climate change (2065 Medium RCP 4.5)	Change due to projected climate change
Estimated mean annual impact of small catchment dams (ML/year)	7,172	7,788	7,412	376
Mean annual impact as proportion of unimpacted inflows	8.8%	9.6%	10.6%	11%

7 Risk Assessment

The initial risk assessment conducted for both the Moorabool and Maribyrnong catchments is based on the results of the modelling described in Section 6.

For this assessment, risks were defined as *the potential for negative impacts on catchment values identified*. In this application, the risk was identified as the risk of detrimental effects under each modelled scenario, which is applied to values across environmental, economic, social and cultural areas.

Using a standard approach to risk assessment, the project focussed on the combination of the likelihood of an event occurring, and the consequence rating of that event. The two ratings could then be applied to a risk matrix to determine the risk to the value (see Figure 9 and Table 8).

Figure 9 *Risk assessment framework showing relationship between modelled factors and the likelihood and consequences that make up a risk*

This process was applied across the environmental, economic, social and cultural values. As each of these themes were informed by different information sources, the approaches were tailored to the specific theme to determine the likelihood and consequence rating. The approach for each theme is outlined in detail below.

In some instances (particularly in the social and cultural themes), the use of a quantitative assessment was not considered appropriate as there were no specific flow thresholds that can be used for quantitative analysis. In these instances, a qualitative discussion on the potential impacts of the modelled results was used to inform risk rating.

Table 8 *Likelihood and consequence table for assignment of risk used in this assessment*

		Consequence			
		Minor	Moderate	Major	Extreme
Likelihood	Rare	Low	Low	Medium	Significant
	Unlikely	Low	Medium	Medium	Significant
	Possible	Medium	Medium	Significant	Significant
	Likely	Medium	Significant	Significant	High
	Almost certain	Significant	Significant	High	High

7.1 Value based risk assessment approaches

Environmental approach

The environmental assessments for both the Moorabool and Maribyrnong catchments were informed by the most recent FLOWS studies for each of the rivers (completed in 2015 by Jacobs for the Moorabool catchment, and by Alluvium in 2025 for the Maribyrnong catchment). These FLOWS studies have informed the identification of values in each of the catchments and the specific flow target that supports the values.

Using the information available on those studies, an approach was developed to best identify the likelihood and consequence to each value under each of the flow components.

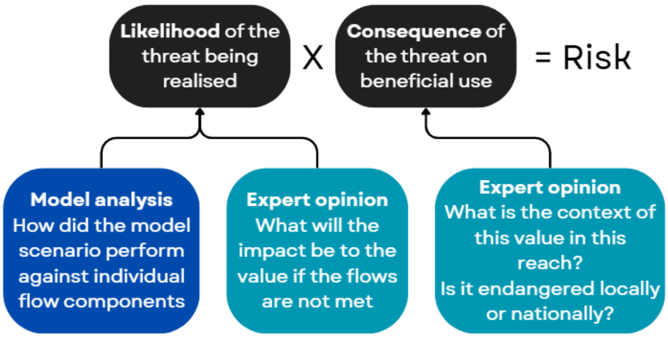

Figure 10 *Risk assessment framework and assessment methodology of environmental values*

Using the likelihood vs consequence approach previously described, Figure 10 shows the way that logic has been applied for environmental values.

The identification of likelihood is built on assessment of how well the flows meet the individual flow recommendations, combined with an expert assessment on how reliant the value is on the particular flow component. Meeting flow recommendations is determined through quantitative analysis based on the modelling results, whilst regional significance is based on the expert opinion of the project team ecologist.

Additionally, the consequence is based on the regional significance of the value, to determine if the impacts will be felt locally, or at a wider scale, if the flows are not met.

The environmental assessment used the elements of the flow regime that has been recommended in the FLOWS study, incorporating low flow, fresh and high flow events into the flow recommendations (see Figure 6).

Based on this, the process illustrated in Figure 10 was implemented by applying each of the three elements individually as follows:

- The model analysis compared the flow requirements outlined in the FLOWS studies with the flow regime of each modelled scenario. This allowed for the identification of a percentage compliance for each scenario with each flow component
- Expert opinion was conducted separately to determine how important each of the flow components are to support the individual environmental values. This was then combined with the model analysis to identify a likelihood rating in line with elements of Table 8.
- Expert opinion was also conducted to identify the potential consequence of the value not being supported in each reach. This means that if a value is not supported in a reach, then the role that reach plays in supporting the values more broadly can be applied. For example, the impact of not supporting a species that is extremely common locally and nationally will be impacted differently from a species that is endangered and relies on the reach to survive. This allowed for the development of a consequence rating in line with the elements of Table 8.

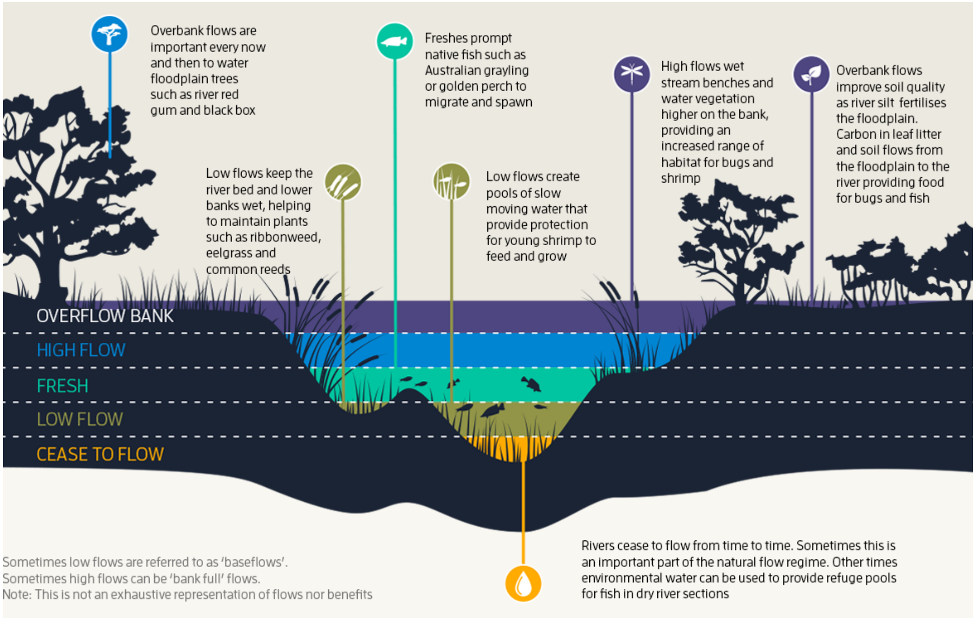

Figure 11 *Types of flows* (VEWH, 2025)

In order to determine how well environmental values within the catchments can be supported, the assessment looks at water availability in the river against the specific flow requirements of the values. Wildlife and vegetation values depend on flows to sustain ecosystems, provide habitat and maintain migration pathways. These values are assessed using the modelled flow at specific locations to determine system performance under each model scenario. This assessment also considers the operational capacity to deliver water to support environmental values, in line with the regulatory and entitlement frameworks. As such, a measurement of ability to deliver environmental entitlements for the purpose of meeting the environmental flow requirements from the FLOWS study is considered.

Compliance against environmental flow requirements was conducted using inputs derived from the Source models and the FLOWs studies for the Maribyrnong and Moorabool catchments. The full list of environmental flow requirements is included in Attachment 2. These assessments were carried out based on modelled flow in the rivers at compliance points, which align to gauge locations on river reaches.

eFlow Predictor was the primary tool used to assess compliance flow recommendations. eFlow predictor uses information about the types of flows, including volume of water, frequency, duration and timing of flows from the FLOWs studies. It also uses a climate condition score to vary the minimum requirement to be met. The climate condition scores were developed based on the rainfall received each year. Further details about the assumptions applied to environmental flow recommendations and development of climate conditions are provided in Attachment 2. The output of eFlow predictor is a compliance percentage for each FLOWs recommendation per year.

Additional analysis of the Source modelled inputs was undertaken using custom Python code, which included an assessment of flow metrics and spells, including:

- A count of cease to flow or low flow periods
- A spells analysis of cease to flow or low flow events
- Timing and magnitude of peak flow events
- Average end of season flow (in February and August) to indicate the condition at the end of dry or wet season

This analysis provides insight into how the different scenarios may impact the flow regime that supports water dependent environmental values such as fish, vegetation, and river health.

Economic approach

The economic assessments for the Moorabool and Maribyrnong catchments were conducted using the measure of access to water under existing water licence conditions. Run of river irrigation access and D&S water use under Section 8 licencing are values attributed to water demands that are explicitly measured in the Source models.

For the risk assessment of values of Section 51 licences, the risk was defined as the reduction in reliability of water access limiting the ability to pump water to support irrigation. Measures of demand reliability determine how much of the absolute demand from licenced water holders is able to be met under each scenario. The assessment of reliability is an annual or seasonal measure of ability to access 100% of the water demand as per licence rules. The measurement of magnitude and duration of water demand shortfall identifies the significance of the impact to the value of licenced water access.

For D&S Section 8 water use, the risk being assessed was the risk of reduced access to on farm water (available in small catchment dam storage) for the purposes of domestic and household use and stock watering. The ability to access water through D&S (Section 8) licences was measured through the modelled levels of storage of the small catchment dams in the STEDI models. At the end of the dry and wet seasons, the average storage levels indicate the volume of water available for D&S users. Limiting access to this water use was considered to have greater consequence in summer due to the greater need for stored water and lower inflow volumes for recharge.

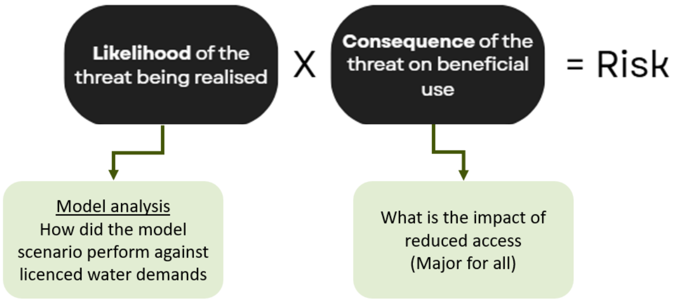

Figure 12 *Risk assessment framework and assessment methodology of economic values*

Social approach

The social assessments for the Moorabool and Maribyrnong catchments were assessed through both a qualitative and quantitative approach. The quantitative portion of this risk assessment relate to the level of service of water supply to meet urban and rural access. This was conducted using the measure of river management targets set out by water corporations in Urban Water Strategies and Local Management Plans.

In rural areas, the level of service metric that was used to determine a risk to social values was the number of years that a ban is enforced, which is explicitly modelled in Source. For urban areas, the measure is restriction level.

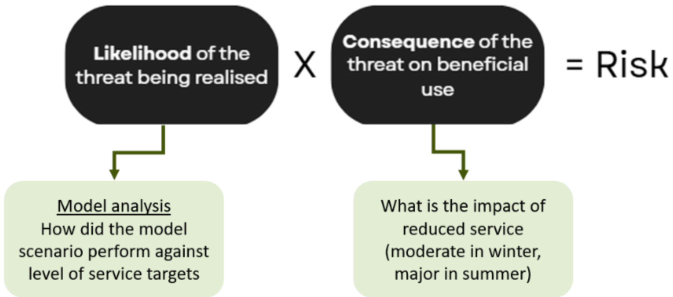

Figure 13 *Risk assessment framework and assessment methodology of social values*

Note that the approach in Figure 13 is only relevant for the quantitative results. The qualitative assessment is an inferred understanding of how the results are likely to impact the value in instances where a specific flow threshold is not known. For example, it is known that flowing rivers have positive impacts on the mental and physical wellbeing of the local community, however a specific flow volume is not known where this impact occurs. Instead, changes in overall flows can be examined, and risk ratings for low flows, freshes and the elements of the environment assessment, to inform a qualitative discussion.

Flow metrics to support Economic and Social values

Economic and social values can be measured through modelled access availability to water under bulk entitlements, Section 51 licences, domestic and stock use and urban potable water supply. These demands or water use types are explicitly modelled in Source, and have been extracted and assessed to determine:

- Ability to pump under Section 51 licence rules
- Ability to pump under Section 8 (D&S) licence rules
- D&S small catchment dam storage water availability for on-farm use
- Number of times and duration of restrictions measured against level of service targets
- Bans on section 51 licences
- Water level passing the most downstream point to support values in the lower catchment

Risk to values is informed by the assessment of the above conditions against the specific access criteria of the value. The conditions that relate to water access to support irrigation or rural water use (Section 51 and Section 8 licences, D&S use) have financial consequences if they are impacted by the model scenario and are therefore considered economic values. The impact is quantified by inability to meet this demand, as a measure of seasonal or annual shortfall in demand volume supplied.

The restriction level condition for urban supply relates to the achievement of level of service targets that have been developed in consultation with community under the Urban Water Strategies. This gives a defined metric for assessing social impact of living in dry or drought conditions and can also indicate times where water utilities enact water saving rules or drought response actions (CHW, 2022), including requesting emergency transfers of water in storage, or ration supply for essential services such as firefighting or water quality management.

The scope of this assessment considers the catchments upstream of Batesford Quarry and Keilor gauges for the Moorabool and Maribyrnong rivers respectively. Both systems generate flow that supports values in the downstream reaches, such as waterway condition, amenity and recreation. The impact to these values are determined using flow through the respective downstream gauges, assessing flow metrics as an indicator of downstream waterway condition. The criteria for flow metrics offer a proxy for the range of flow requirements in the downstream catchments, as they support a wide range of values.

Urban water supply levels of service

Performance criteria for restriction level are set by water utilities and are developed and agreed as part of their Urban Water Strategies, which include levels of service for providing long-term water supply security to customers.

Central Highlands Water and Barwon Water extract urban water supply from the Moorabool catchment. Central Highlands Water describes the level of service targets in their Urban Water Strategy (from CHW, 2022):

The current agreed level of service for CHW water supply systems is an assurance of a reliable supply of water based on how frequently water restrictions are expected to occur in that system. For the Ballarat, Maryborough and Daylesford systems, the agreed level of service is 95%, meaning that water restrictions are not expected to occur more than once in every 20 years. For our other water supply systems, the agreed level of service is 90%, meaning that water restrictions are not expected to occur more than once in every 10 years. Our systems must also have the capacity to provide a base level of water supply in our storages so that Stage 3 and Stage 4 water restrictions are never triggered, even during the worst dry conditions. For the Ballarat system, additional criteria are applied to our modelling to determine the frequency of reaching critical storage levels at our two major reservoirs.

Barwon Water's 2022 Urban Water Strategy states that over the subsequent 5 years the expectation is that water restrictions will be very rare (<1%) in most systems and rare (<5%) for Lorne and Apollo Bay. The strategy aims for restrictions to occur less than 5% of the time in dry/drought periods over the next 50 years.

The Maribyrnong catchment is used for urban water supply by Greater Western Water. The Greater Western region is on same Level of Service as Melbourne, and local systems may be vulnerable to restrictions due to demand increases/seasonal dry conditions. Reduced river flows (and storage inflows) from a range of factors (including small catchment dams) could increase pressure on urban supply levels or service. Urban water companies assess and respond to changing water resource availability and demands in their Urban Water Strategies. The potential risk to urban water supply values from small catchment dams has been noted in this report however it is beyond the scope of the project to undertake detailed quantitative assessment of this aspect.

Cultural approach

The cultural assessment was informed by discussion with Traditional Owner corporation representatives on the SRG and assessed using a qualitative approach in a similar way to that described for the social approach. The values were identified through review of the existing documentation available and the interpretation confirmed with the relevant representatives. A stressed or degraded waterway means cultural values are inevitably impacted, and this is acknowledged.

7.2 Results of quantitative results

The assessment of risk had some limitations, which were highlighted in the results. When the results were achieved using the method described above and drawing the highest risk for either the individual reaches or values, the risk ratings were high across all tests. While this may be the case, uniform risk results don't provide the value for informed decision making. This is particularly true as the 'unimpacted' scenario also resulted in uniform high-risk rating, making it impossible to adequately determine the impact of small catchment dams in the catchments.

Due to this limitation a series of tests were conducted to determine the role that small catchment dams are playing on the risks to water dependant values in the catchments. A summary of the results is detailed below, highlighting the key outcomes of the assessment.

Summary of quantitative results

Using the method described in Section 7.1, an initial risk assessment was undertaken on all the scenarios. As has been described, the initial assessment conducted drew risks to reaches and values by returning the highest risk rating. As each of the value tests had at least one high risk rating returned, the outcome was a uniform set of results that displayed high risk ratings across all values. This uniformity in results stretched into the unimpacted scenario, as shown in Table 9 and Table 10, demonstrating that 'background risk' (or the risk created by all of the other influences on flow, whether natural or human-induced) was having enough of an impact on flows that all catchment values were showing a high-risk rating. This confirms that there are risks to water resources in these catchments irrespective of small catchment dams.

The only value that did not return a significant- or high-risk rating was the urban water supply in both catchments. This was because the assessment was linked to changes in restrictions for urban supply. The modelling results found that while there was some shortfall in availability for urban supply, there was no resulting change in restriction level. As such urban water supply was rated at a medium risk.

Table 9 Maribyrnong risk results - first assessment

Maribyrnong		Maximum risk and reach(es)			
Theme	Value	Undeveloped	LOD 2009	LOD 2025	Future Climate
Environmental	Vegetation	High	High	High	High
Environmental	Fish	Significant	Significant	High	High
Environmental	Frogs	Significant	Significant	Significant	Significant
Environmental	Invertebrates	High	High	High	High
Economic	Access for Irrigation	High (Lower end of the catchment only)	High (Lower end of the catchment only)	High (Lower end of the catchment only)	High (Lower end of the catchment only)
Economic	Access for D&S (summer)	N/A	High	High	High
Economic	Access for D&S (winter)	N/A	Significant	Significant	Significant
Social	Reliability of urban water access	Medium	Medium	Medium	Medium
Social	Reliability of rural water access	High	High	High	High
Social	Access to water downstream	High	High	High	High
Social	Delivery of low flow events past downstream gauge (summer)	Significant	Significant	Significant	Significant
Social	Delivery of fresher flow events past downstream gauge (winter)	Significant	Significant	Significant	Significant

Table 10 Moorabool risk results - first assessment

Moorabool		Maximum risk and reach(s)			
Theme	Value	Undeveloped	LOD 2009	LOD 2025	Future Climate
Environmental	Vegetation	Significant	Significant	Significant	Significant
Environmental	Fish	High	High	High	High
Environmental	Invertebrates	Significant	Significant	Significant	Significant
Environmental	Turtles	High	High	High	High
Environmental	Frogs	Significant	Significant	Significant	Significant
Economic	Access for Irrigation	High	High	High	High
Economic	Access for D&S (summer)	N/A	High	High	High
Economic	Access for D&S (winter)	N/A	Medium	Medium	Medium
Social	Reliability of urban water access	Medium	Medium	Medium	Medium
Social	Reliability of rural water access	High	High	High	High
Social	Access to water downstream	High	High	High	High
Social	Delivery of low flow events past downstream gauge (summer)	High	High	High	High
Social	Delivery of fresher flow events past downstream gauge (winter)	Significant	High	High	High

Noting that a) it is recognised that there are other works and projects planned or underway aimed at reducing impacts of the other factors impacting flows, and b) the scope of this project is small catchment dams and D&S use, it was determined that additional assessments were required to determine the role that the areas in scope play in risks to catchment values.

The high-risk baseline result in the undeveloped scenario meant the impact of adding in small catchment dams to the catchments was not visible in the results, as there was no measurable change to the risks identified (with high being the highest rating). The undeveloped scenario created a starting point where large numbers of values started at either significant or high, making the changes between scenarios less obvious and therefore harder to assess. Regardless, the results show an increase in risk rating in the 2025 and climate change scenario, consistent with the trend in hydrological impacts.

Based on this assessment, an additional risk assessment approach was undertaken, removing the background stressors and focusing on the incremental impact of small catchment dams. This was conducted for the environmental values only as the results of the compliance with flow recommendations provided the level of detail required for the incremental comparison.

Summary of incremental assessment

To further test the results, an incremental assessment was conducted by subtracting the environmental compliance results of the no development scenario from the developed scenario results. This was conducted for the environmental values only as the results of the compliance with flow recommendations provided the level of detail required for the incremental comparison. The results of the incremental assessment are shown in Table 11 and Table 12.

This method created a change in compliance from the undeveloped scenario. For example, if flow targets are met 72% of the time in an undeveloped scenario, but only 67% of the time in a 2025 development scenario, the new compliance rating used would be 5% (72% - 67% = 5%). This was intended to isolate the changes in risk created by small catchment dams in the modelled results by applying the assessment with the new approach to likelihood development. Note that under this approach, only the ratings of likelihood used in the risk assessments were modified to reflect the *change* in the performance against flow targets. As shown in Section 7.1, it is only the performance against the flow targets that changes in each of the scenarios, as the consequence of that change remains consistent.

This method was important as it allowed the risk assessment to be conducted on the focal point of this project, the impact of small catchment dams on the catchment values. When interpreting the outcomes of the two approaches, both can be seen valuable to the project questions:

- The initial assessment showed catchments in stress, with water dependant values at high risk under the current conditions. It shows that current river flows are currently not supporting water dependant values and it is likely that multiple interventions are required
- The incremental assessment showed that once small catchment dams are isolated in the results, it is able to see that they are playing a role in that high level of risk to water dependant values. While the initial test showed that multiple interventions are required, the incremental test shows that small catchment dam management opportunities need to be part of that suite of responses.

Table 11 Maribyrnong risk results - incremental assessment

Maribyrnong				
Theme	Value	LOD 2009	LOD 2025	Future Climate
Environmental	Vegetation	Significant	Significant	High
Environmental	Fish	Significant	Significant	Significant
Environmental	Frogs	Medium	Medium	Significant
Environmental	Invertebrates	High	High	High
Economic	Access for Irrigation	High (Lower end of the catchment only)	High (Lower end of the catchment only)	High (Lower end of the catchment only)
Economic	Access for D&S (summer)	High	High	High
Economic	Access for D&S (winter)	Significant	Significant	Significant
Social	Reliability of urban water access	Medium	Medium	Medium
Social	Reliability of rural water access	High	High	High
Social	Access to water downstream	High	High	High
Social	Delivery of low flow events past downstream gauge (summer)	Significant	Significant	Significant
Social	Delivery of fresher flow events past downstream gauge (summer)	Significant	Significant	Significant

Table 12 Moorabool risk results - incremental assessment

Moorabool				
Theme	Value	LOD 2009	LOD 2025	Future Climate
Environmental	Vegetation	Significant	Significant	Significant
Environmental	Fish	High	High	High
Environmental	Invertebrates	Significant	Significant	Significant
Environmental	Turtles	High	High	High
Environmental	Frogs	Significant	Significant	Significant
Economic	Access for Irrigation	High	High	High
Economic	Access for D&S (summer)	High	High	High
Economic	Access for D&S (winter)	Medium	Medium	Medium
Social	Reliability of urban water access	Medium	Medium	Medium
Social	Reliability of rural water access	High	High	High
Social	Access to water downstream	High	High	High
Social	Delivery of low flow events past downstream gauge (summer)	High	High	High
Social	Delivery of fresher flow events past downstream gauge (summer)	High	High	High

Spread of results

The incremental assessment provided some important insights into the risks to water dependant values created by the proliferation of small catchment dams, namely that there are risks created, and that those risks are meaningful. However, it was determined that more analysis was required on the risks created to each of the values to best inform the opportunities to be developed by the SRG.

While a value-by-value assessment was not considered feasible (there are 194 environmental value-flow component combinations in the Moorabool alone), analysis on the way the risk results statistics changed in each of the scenarios was conducted to give more information into how the risk rating were being influenced. This was only conducted on the environmental results as they were the values that had a large enough spread of results to provide meaningful analysis.

To assess the changing impact of small catchment dams in the modelling, the portion of environmental values were graphed by each risk level. This was done for each combination of values and flow component. For example, fish value had a risk rating for each of the low flow, fresh and high flow recommendations, for each of the summer and winter flow periods (see Attachment 8 for detail). This approach allowed a visualisation of the risk responses across all values and reaches within each catchment to show any change in the overall risk profile. The summary graphs are shown below in Figures 9 to 15, with each showing the number of low, medium or high-risk rating returned in each scenario. The results are shown in stacked bars, demonstrating the portion of each flow component-value combinations that returned each of the risk ratings.

The results of the initial assessment show the stresses on the river created by small catchment dams in numerous ways. In the Maribyrnong the low flows show the presence of a low-risk value that quickly rises out of low risk with the presence of small catchment dams. Even high flows show a decline in the results, with the risk ratings increasing as small catchment dams are included. In the Moorabool, freshes were the portion of the flow regime that showed a notable increase in risk, with a step change in risk from a medium rating to significant and high.

However, the graphed spread of initial results includes a high degree of “background risk”, particularly in the low flows, from the influences on flow within the catchment that exist outside of the small catchment dams.

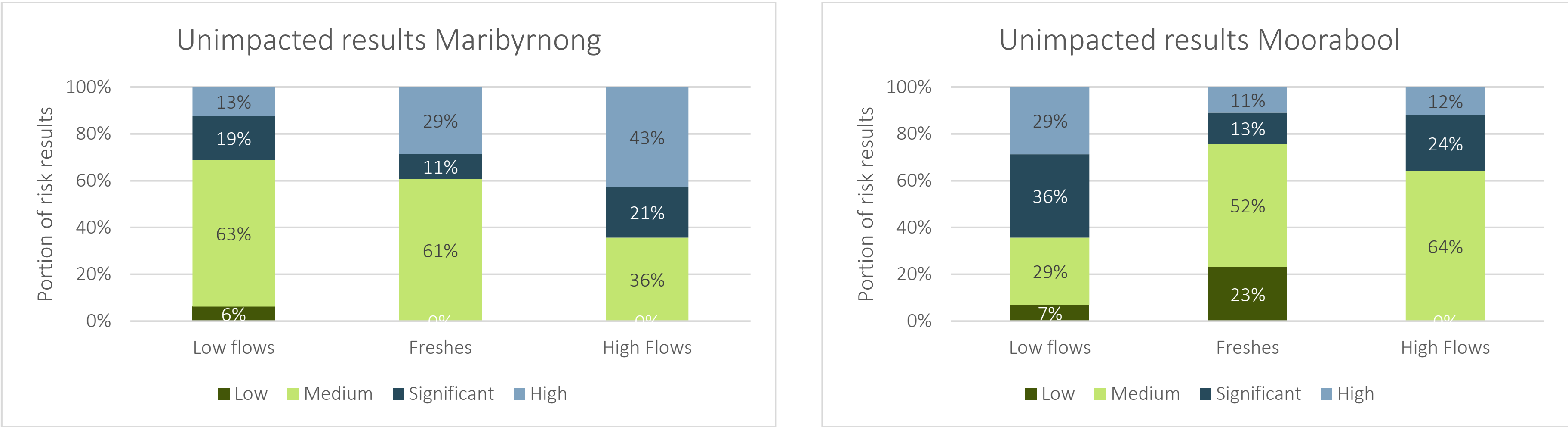

Figure 14 *Distribution of* environmental *risk results in the unimpacted model scenario*

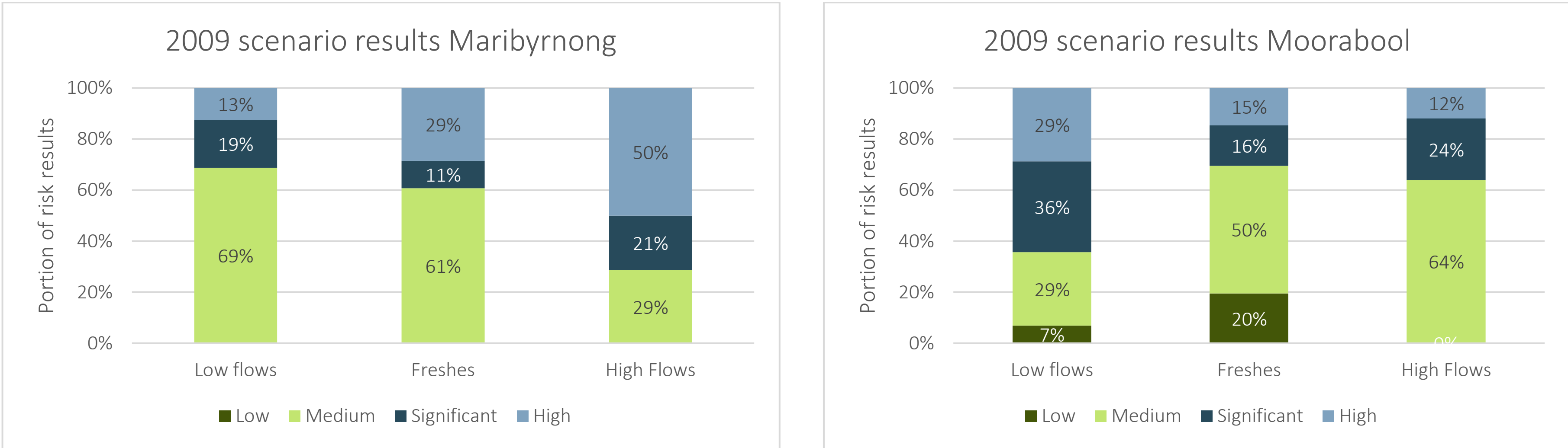

Figure 15 *Distribution of environmental risk results in the 2009 model* scenario

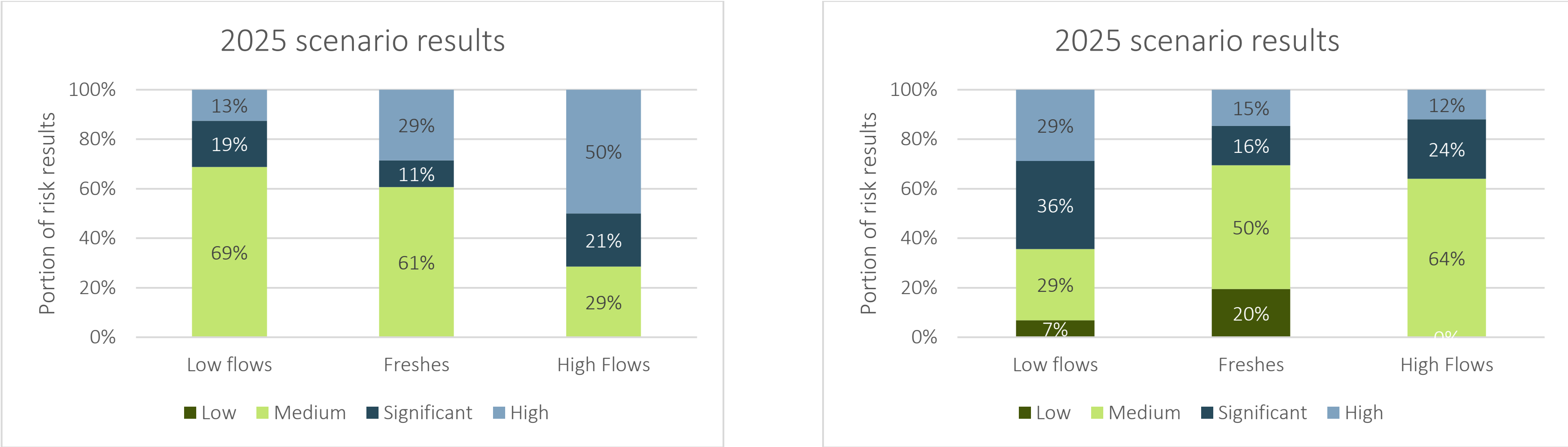

Figure 16 *Distribution of environmental risk results in the 2025 model scenario*

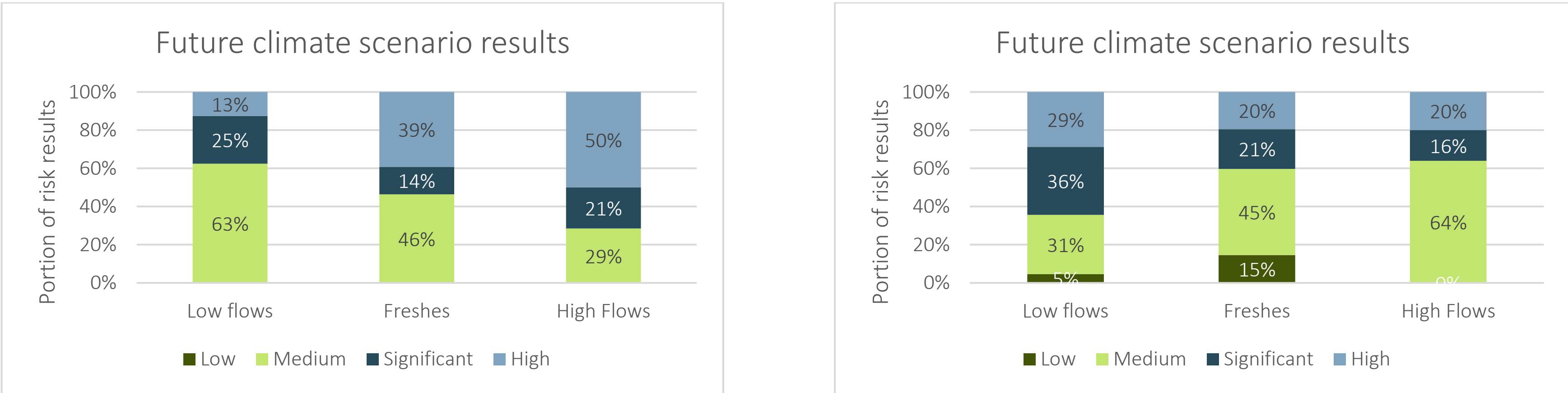

Figure 17 *Distribution of environmental risk results in the future climate model scenario*

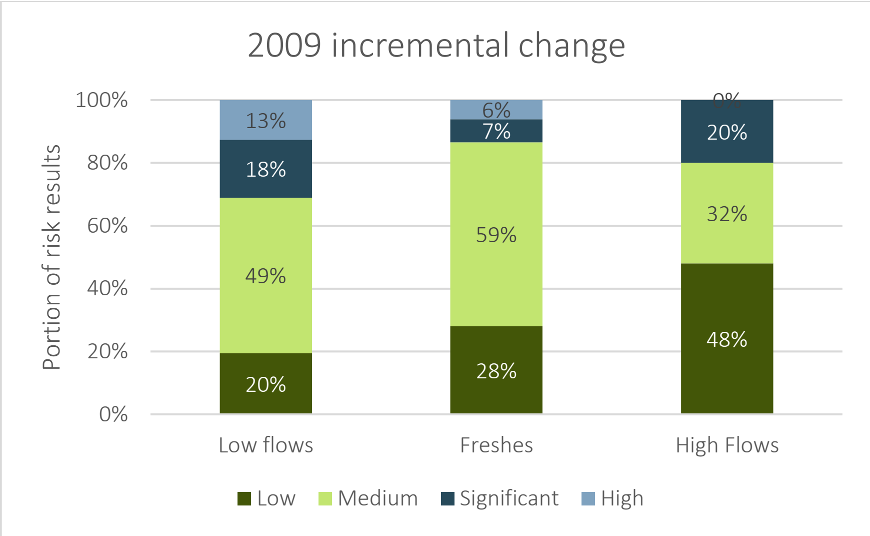

Figure 18 *Distribution of incremental environmental risk results in the 2009 model scenario*

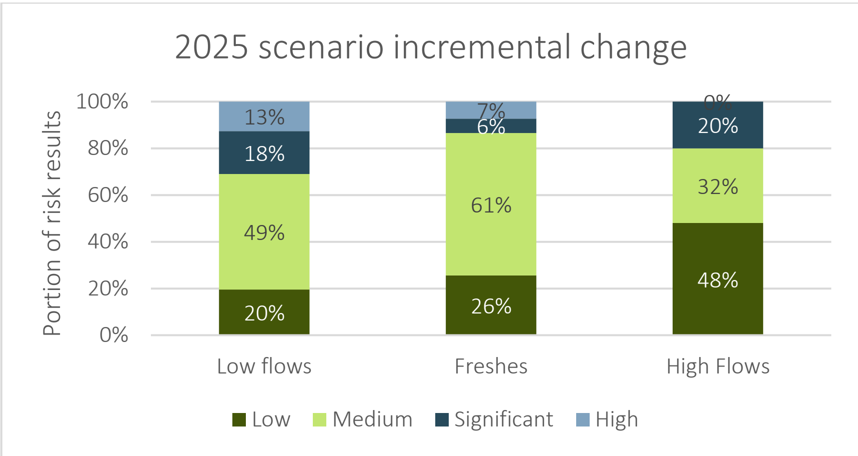

Figure 19 *Distribution of incremental environmental risk results in the 2025 model scenario*

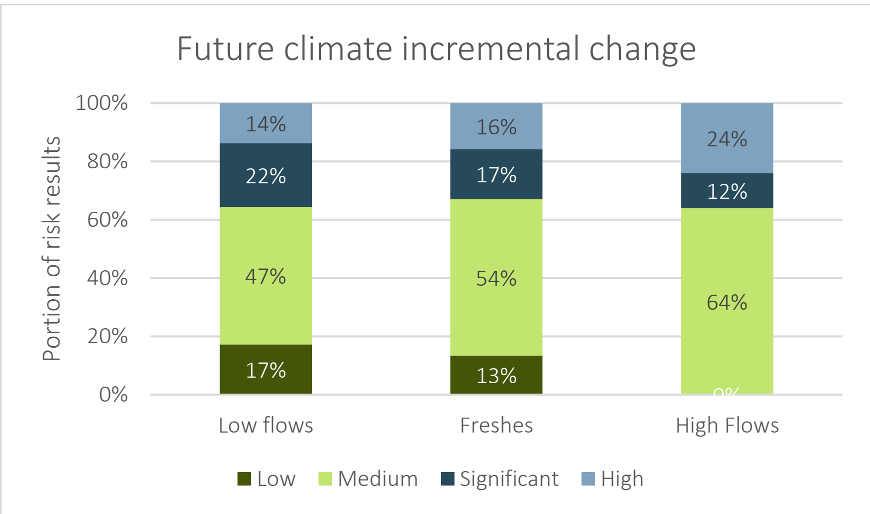

Figure 20 *Distribution of incremental environmental risk results in the future climate model scenario*

The spread of results for the incremental assessment gave some interesting insight into the impact of small catchment dams. The proliferation of small catchment dams appears to push more of the value tests into higher risk rating demonstrating the stress that dams place on flows. Some of the changes show how the flows may have been influenced, particularly where the risk to low flows improves in some instances. This change appears to contradict the expected results of increased small catchment dam development but needs to be considered in conjunction with the other results. The increase performance in lows flows appears to align with the reduced performance for freshes and high flows, indicating that while the increased low flow performance appears positive, it is likely that the higher flow rate of freshes and high flows are being reduced to the point that they are able to support low flow targets albeit at the expense of other flows.

As with the previous results the risk spread in all parts of the flow regime will be impacted further under a future climate scenario, making the role that small catchment dams play on river flows and any potential mitigations of even stronger importance.

7.3 Qualitative results discussion

A number of values were not able to be assessed in a qualitative manner due to limited qualitative data, and the lack of a clear flow threshold that could be tested. A qualitative assessment of risks has still been included because this provides important overall context of the risk posed by small catchment dams.

Environmental

Low flow impacts on river connectivity, fish migration, terrestrial vegetation and the effectiveness of environmental releases.

Feedback relating to the Moorabool through the SRG highlighted the risk that lower flows can have on:

- Loss of longitudinal connectivity during extended low-flow periods.
- Expansion of terrestrial vegetation into the channel due to chronic flow suppression.
- Exacerbation of fish migration barriers during low-flow seasons.
- Declining effectiveness of environmental releases under intercepted baseflows.

These risks are also likely to apply to the Maribyrnong River catchment.

Potential impacts on bird populations (Maribyrnong and Moorabool)

The risk to birds in the area is likely to be increased under all scenarios. Bird populations that would utilise these catchments for food and habitat are noted to have other catchments in the region that may be able to support the populations (such as in the nearby Ramsar sites). The significant and high risks identified to the vegetation and invertebrate values are likely to have impacts on the capacity to support bird populations.

Potential impacts on water quality (Maribyrnong and Moorabool)

Water quality risk in both catchments is likely to be impacted by the changes in flow regime. While the modelling does not model water quality or consider the quality of runoff into the rivers, there are elements of the flow that may play a role in water quality outcomes.

As lower flows are the components that show the greatest impact in each of the scenarios, it may be inferred that the rivers have a reduced capacity to flush the system out when required. Additionally, pooling and slower flows resulting from the lower volumes passing through the catchment could result in warmer waters creating algal bloom issues, or other water quality issues such as the Azolla outbreak near the mouth of the Moorabool River in 2025 (Figure 21).

Figure 21 Image of the Azolla outbreak near the mouth of the Moorabool River in 2025 (image supplied by PALM)

Economic

Potential impacts on tourism (Maribyrnong and Moorabool)

With tourism values in riverine areas dependant on a healthy river, the significant and high risks identified for vegetation, fish and the inferred impacts on birds have the potential to impact the draw of tourism to the region.

Social

Potential impacts on human wellbeing outcomes (Maribyrnong and Moorabool)

A review conducted in 2024 for Melbourne Water by Mosaic Insights investigated the relationship between the flow dependant values of a catchment and the human wellbeing outcomes they support. The primary influences were quality of vegetation (noted as significant and high risk), biodiversity (significant and high risk for invertebrates, fish, frogs and the inferred impacts on birds) and water quality/flow regime (see above). Based on those assessments it could be assumed that human wellbeing outcomes would be impacted.

One notable piece of feedback from the community (SRG) is that human wellbeing impacts arise as much from the degradation of a valued living system as from reduced opportunities for direct use. There is a strong local community feeling of stewardship and responsibility for these river systems and communities are impacted socially by declining river flows. Framing wellbeing outcomes solely as an inferred consequence of ecological decline risks overlooking these.

Cultural

Potential impacts on Traditional Owner values

Cultural values have been considered as they relate to the values across the environmental, economic and social themes, however this assessment does not intend to capture the full range of Traditional Owner values or reflect the Traditional Owner definition of values. The health of the waterway and the broader health of Country and all beings connected to it is an inherent part of cultural values. Specific cultural values cannot be fully assessed without Traditional Owners undertaking their own cultural values assessments, which require access to waterways and surrounding Country.

7.4 Outcomes

The key findings identified in the risk assessment are:

- The approach used identified limitations in the way risks are currently assessed, linked to;
  - The whole of catchment approach and the use of the maximum risk rating hides much of the change that is occurring
  - Impacts of small catchment dams are not always visible using this methodology as the incremental change may not change the risk range used
- The change in risks for each of the flow components showed that the highest risk element of the flow regime are the low flow and freshes
- Climate change exacerbates the risks posed to low and fresh flows and will increase the risk to high flow events.
- While multiple factors are impacting risks to water dependant values in the catchment, the incremental risk results showed that small catchment dams are playing a role in the stresses being placed on water dependent values

Ultimately the risk assessment has shown that small catchment dams increase risks to environmental, economic, social and cultural values, with these risks primarily in the lower flow ranges.

When assessing the management targets, it was noted that the incremental risk created by small catchment dams in the catchment is not clearly visible in the risk rating approach when evaluated along with the total risks that the catchments are facing. The incremental change in risk is currently not captured very well in the tables as the definition for the low, medium, significant and high-risk rating are set as ranges and the change in risks may not result in a change of risk range (though they do provide useful information regarding the presence of risk).

When further assessment was done into what the incremental risks were, the main drivers causing impact were:

- As per the hydrological analysis, under drier conditions (i.e. during summer periods and drought years), small catchment dams are typically less full, so they capture a larger proportion of the available runoff
- For the projected climate change scenario (to 2065), average inflow and rainfall are projected to decrease and evaporation is projected to increase. Under these projected drier conditions with climate change, the impact of small catchment dams as a proportion of runoff will increase but the absolute volumes of water captured and taken by most small catchment dams are lower, due to an overall reduction in volumes of water flowing into the small catchment dams
- Increased number and volume of small catchment dams across catchments results in less water available to support:
  - Economic values – lower stream water availability reduces access to irrigation and entitlement take
  - Social values – While level of service targets are able to be met under all scenarios for urban areas, rural level of service sees increases in number of times bans are enforced
- Small catchment dams have the greatest impact at the low flow range. This means that for environmental values Individual flow recommendations that relate to low flows and freshers are less supported under a more developed catchment. This assessment is based on impact on a species level, with consideration for how localised that species is, with the results aggregated to give an overall ranking of severity.

8 Management Opportunities

8.1 Overview of opportunities

The identification of values within the catchments, hydrologic modelling and assessment of flow components provided a detailed evidence base with which to assess the risks that exist within the catchments and identify areas that require attention or action. This information, through the risk assessment, provided a view of the major stressors and impacts of hydrological risks in the catchments caused by the expansion and growth in numbers of small catchment dams. Risks to values as discussed in Section 7 were explored with the SRG and provided the basis for determining opportunities for management of waterways and resources to improve resilience and better support the water dependent values in the catchment.

Opportunities were identified to address risks that arise due to gaps in legislation, compliance aspects, unclear or ambiguous definitions, or lack of information. The opportunities range from structural or engineering solutions, to management or governance related mechanisms, to create an enabling environment to support structural and regulatory change. The focus of this exploration of opportunities was on the mechanisms that are available to address the challenges relating to licenced dams, unlicenced dams and areas of ambiguity that may enable issues to persist.

The discussion prompts that were shared with the group were (summary headings highlighted):

- ***Water Policy and Legislation*** related opportunities, including amendment to the *Water Act 1989* (Vic) to better define reasonable use for Domestic and Stock water
- ***Operations***, such as a review of the waterway determination guidelines
- Opportunities relating to ***information and education,*** such as the provision of water efficiency information to farmers in relation to small catchment dams
- ***Research and innovation***, to investigate alternative remote sensing opportunities to identify and track small catchment dam growth
- ***Other*** opportunities, such as the review of surface water local management rules for the Maribyrnong catchment relating to take and use of licences.

8.2 SRG identification of opportunities

Group discussions were conducted around tables at the 5th meeting of the SRG and documented on sticky notes pasted around the room under each category. The discussion focused on opportunities to address the complex issue of small catchment dam expansion (whether through enlargement or number) within the catchment through different mechanisms or lenses. Opportunities explored a range of topics such as the need to establish clarity and delegation of responsibility under existing policy and legislation, improvements to data, measurement and information gathering, and the need to instil behaviour change, establishing a common understanding and incentive to act.

The opportunities identified in the session are shown in Table 13.

Note: - the numbering of the opportunities does not reflect priority of preference, the opportunities are numbered solely to allow easier referencing.

The opportunities have not been assessed yet and although initial discussions through the project SRG have been held about potential challenges and benefits with implementation, no opportunities have been targeted yet and no actions are proposed until the Opportunities have been fully assessed.

Table 13 *Opportunities developed by the SRG at Meeting 5*

Item	Opportunities	Description
		Water policy and legislation
1	Revise "Your dam, your responsibility" guidelines to reflect environmental and catchment implications.	This option is focused on changing the way that guidelines describe small catchment dams. It is intended that any approach to small catchment dam management incorporates a recognition of the whole of catchment implications of dams and would require a higher level of landholder responsibility for any impacts caused to downstream landholders and environmental flows. No distinction is currently made in the identification of dams using current methodology.
2	Review, update and improve the waterway determination guidelines.	This option seeks to address some of the ambiguity around the trigger for requirements for application approval before constructing a new dam on a waterway.
3	Better and more consistent definition of waterway e.g. explicit documentation of waterways in the subject catchment. Establish a central "single source of truth" for waterway definition and how it is applied.	This would involve amending the reporting, interpretation and processes for waterway definition - or the definition itself – as it relates to the trigger for assessment of a new dam licence.
4	Develop a registry of approved earthmovers	This seeks to track and maintain the dam construction activity within the catchment.
5	Clarify and establish consistency and understanding of 'reasonable use', and the definition across planning zones and catchments	This relates to the way that reasonable use is currently defined (or not defined) in the legislation. The option was discussed as requiring clarity in its definition (though other parts of the group noted that the definition is clear). Majority of the views held that the definition reasonableness is the best place to ensure effective change to water use in the catchments, through additions to the definition such as*: • Limitations on the dam scale when identified as firefighting storage • Incorporating alternative access options into a reasonableness test (for example a domestic use storage may not be reasonable if alternative sources are available) • Development of size limits on ornamental dams, and vegetation types used within it (prioritising low evapotranspiration species) • Limit size of small catchment dams based on property size and upstream catchment (as they do in NSW)

Item	Opportunities	Description
		• Inclusion of stock scale limitations to bring stock use into line with domestic use definitions and interpretation of reasonable use *Noting that some of these additions are included elsewhere in the list, however discussions suggested that the 'reasonable use' definition would be an effective place for the change. For dams within rights (not on a waterway, not for commercial use), implement greater control, constraint or restrictions where appropriate. This includes D&S dams that are not on a waterway such as ornamental lakes and refining the definition of 'reasonable use' to address opportunities to conserve water. An example of this is a suggestion that domestic use of D&S dams should not be reasonable if there is a reticulated water supply. Other examples include limiting or restricting the size of ornamental lakes, and limits on the scale of harvesting and storage.
6	Cap and trade system for small catchment dams	This would involve restricting new licence applications and promoting a sharing system between existing licences. Licences would need to be transferred between licence holders, and new licences only available when others are forfeited (which may create opportunities to reduce licenced volumes by incorporating a transfer factoring)
7	Consistent waterway definition	Review all legislation referencing "waterways" to establish a common whole-of-government definition.
8	Use ministerial tools (e.g. Statements of Obligation) to align treatment of waterways across all Water Act and planning authorities.	To ensure consistency of authority decisions for licensed and unlicensed dams
9	Introduce a mechanism to identify, declare and protect flow-stressed or "hotspot" catchments.	This could mirror the Water Supply Protection Area (WSPA) model but with an explicit focus on protecting environmental flows, and on recognising the environment as a legitimate water user in its own right.
10	Adopt one statewide waterway dataset (to address waterway identification) used by all agencies for planning and enforcement.	e.g. spatial layer which would be formalised (gazetted or similar). Use the Moorabool and Maribyrnong catchments as pilot areas to refine an existing spatial dataset and produce an accurate, fit for purpose statewide waterway mapping product.

Item	Opportunities	Description
11	Amend the Water Act 1989 to mandate registration of all domestic and stock dams in declared catchments.	This would ensure water managers can fully account for their cumulative impact.
12	Require publication of dam data, and integrate dam registry with the Victorian Water Register, WMIS and Digital Twin.	This would be a public facing portal that displays all registered dams (including D&S), accurate special parameters, clearly identified waterways and compliance status of the dam. This would allow landholders to confirm whether nearby dam works are authorised, provide up to date, transparent information to the community and support community understanding of cumulative impacts and catchment conditions.
13	Impose a catchment-wide cumulative volumetric cap	Could be similarly to a Permissible Consumptive Volume but with specific application to private on-farm storages.
14	Strictly limit the approval of new dams in declared flow stressed catchments; all applications for new dams in declared catchments must be assessed against a fair use criterion and environmental impacts.	All new dam applications in flow stressed catchment should undergo two clear statutory tests. Fair Use Criterion: Applicants must demonstrate a reasonable and justifiable use of the water proposed to be intercepted. The water should be necessary for essential activities (e.g. household supply or stock watering) and consistent with efficient and sustainable use guidelines. Cumulative Environmental Impact Test: The proposed dam must not, in conjunction with existing dams and diversions, cause material harm to catchment flows, aquatic ecosystems, or the reliability of existing downstream entitlements. These tests must be codified within the Water Act to ensure consistency and enforceability. In practical terms, this would shift the onus onto the applicant to prove the proposal is justified not simply assumed to be acceptable.
15	Restrict the enlargement of existing dams.	The same "fair use" and cumulative environmental impact tests proposed for new dams should apply equally to dam enlargements. In practice, if a landholder wanted to double the size of a D&S dam in a stressed catchment, they would need to apply for approval. The application would be assessed against the catchment cap and environmental flow objectives. In overallocated systems, such proposals would likely be refused or

Item	Opportunities	Description
		approved only where offsetting reductions can be demonstrated elsewhere. This approach would help stop the incremental creep of interception that, in aggregate, undermines environmental outcomes and equitable water sharing.
16	Amend Section 32A(3)(c) of the Water Act to allow WSPA plans to include rules for D&S dams where cumulative impacts are significant.	Section 32A(3)(c) of the Act allows WSPA plans to apply rules to private dams that are not already licensed — but explicitly excludes D&S dams. The WSPA model provides a sound legislative precedent and structural foundation for the concept of formally declaring and managing Flow-Stressed catchments.
17	Establish a Victorian Water Compliance and Monitoring Authority.	This body would serve as the dedicated regulator for water use compliance, modelled closely on the NSW Natural Resources Access Regulator.
18	Consider establishing penalties allowing enforcement beyond the criminal limitation period. Broaden and strengthen the use of existing Ministerial Directions and Notices of Contravention (ss.78, 80, 151) as ongoing compliance tools	This would empower the Authority to issue compliance directions, improvement notices, and binding undertakings.
19	Develop a public compliance reporting register similar to that deployed by NRAR in NSW	This would enhance transparency and deter breaches.
20	Amend the statewide compliance policy framework (e.g. include flow-stressed catchments, unregulated D&S dams, associated metering obligations)	Include flow-stressed catchments, unregulated D&S dams, and any associated metering obligations
21	Include small catchment dams in the statewide monitoring strategy – integrate hydrological data, satellite imagery, remote sensing, and telemetry.	Integrate hydrological data, satellite imagery, remote sensing, and telemetry.
22	Defining catchments at most risk and focussing compliance. Funding the additional compliance with a levy on licence holders and D&S users	Defining catchments most at risk and focussing compliance. Funding the additional compliance with a levy on licence holders and D&S users
	Operations	
23	Provide resourcing and capacity support for compliance functions.	Support mobilisation of funding to be efficient and effective. Additional efforts are required to ensure compliance with regulations is maintained.

Item	Opportunities	Description
24	Farm planning and water planning	Initiatives to support more effective use of water on farm, to maximise the efficiency of limited available supply and reduce the overreliance on held water in storage.
25	Review and integrate existing waterway / water source datasets to avoid duplication or gaps and align to other work programs such as the Cultural Heritage definition of a watercourse.	This relates to the suggestion of a clearer definition of a waterway and includes integration with other works that reference waterways. An example is the Cultural Heritage definition of a watercourse which includes the waterway, floodplain and surrounding country. Alignment to other definitions enables compatibility and interaction with other important works that take place. This was discussed as an area that Victoria needs to catch up compared to other states that have a complete and publicly available watercourse data set, including river order, and a clear definition of the width that the definition applies (to cover both riparian areas and mitigate risks of data inaccuracy)
26	Metering of bores pumping into Domestic and Stock dams	This intends to instil an element of control and monitoring to support both information gathering and generate insights that can feed into better management of water resources and risks.
27	Incentivise dam decommissioning and consolidation	To reduce the total volume of impact of small catchment dams.
28	Promote low-flow bypasses or seasonal passing flow mechanisms	To reduce the impact of small catchment dam capture in the low flow range to preserve the most vulnerable flow range and protect the dependent values. This item is focused at a site scale, where infrastructure can be used to limit the capture of runoff within an initial low-flow runoff period
29	Clarify roles and responsibilities for the establishment of new dams or expansion of existing dams – communicate landholder responsibilities and implications, agencies role in approvals and compliance, and where there may be gaps.	This would clarify areas that are currently unclear, relating to the responsibilities of different parties in requesting and approving licences, compliance with regulations, and in managing and addressing gaps or enacting change. Note potential linkages to Item 1
30	Separate the responsibilities of licencing and enforcement	This option would bring the Victorian approach into line with other states (and create robust governance structures) where the departments that are responsible for assessing and granting licences are not the same as those responsible for the monitoring and enforcement of licence rules and requirements, creating a separation of powers and reduce risks to operational staff.

Item	Opportunities	Description
31	Communicate guidelines, responsibilities, risks and opportunities to landholders to promote awareness and support buy in.	This would aim to socialise the issue and improve public literacy about the scale and severity of the problem, promoting community buy in and understanding about the need for action. Engaging community will support a bottom-up response to addressing the water risks within the catchments.
32	Adopt restriction protocols similar to SRW irrigation bans during low flow periods for D&S use.	This could be achieved by amending Part 3, Division 3 of the Water Act 1989, or by introducing a new division, to allow the Minister to declare a catchment as flow-stressed based on clear criteria — such as low streamflow indices, high proportions of runoff intercepted by small catchment dams, or indicators of ecological stress.
33	Revegetation and fencing	Provide rebates or reduced licence fees for fenced dams; offer CMA or Landcare grants for revegetation and fencing.
34	Better Access to Satellite Imagery and Remote Sensing to aid monitoring and inform compliance.	Enhanced monitoring should adopt key elements of the NSW NRAR model, including: • A Statewide Water Monitoring Strategy integrating hydrological data, satellite imagery, remote sensing, and telemetry • Near-real-time detection of unauthorised interception or dam construction • Capacity to investigate illegal works within the 12-month statute of limitations • Use of AI-assisted analytics and high-resolution imagery to detect structural changes or enlargements • to assist the involvement of community in monitoring activities to support regulators
	Information and education	
35	Update and maintain the Water Register to provide public and accessible information about small catchment dams, including metrics of size, dimension, depth, volume, purpose.	This would provide better estimates of scale of the challenge and allow more detailed monitoring of catchment changes. Similar projects could be informed by better quality data. Inclusion of sizing reporting requirements in licencing was a potential implementation method, with dams not requiring a licence still requiring registration. Inclusion of registration status
36	Improve streamflow monitoring information	Improving streamflow monitoring information would improve the quality and validity of models

Item	Opportunities	Description
		and provide deeper insights into the state of water resources in the catchments.
37	Public education (especially to new landholders) on the *Water Act 1989* (Vic), the current frameworks and rights, and the context of water risks due to small catchment dams	This would socialise the issue and build buy-in from community to promote bottom-up action to address identified challenges. It is also anticipated that some landholders are unaware of the impacts of the dams (particularly those with ornamental dams) and may change practices with education.
38	Provide better public access to information relating to water rights, waterways and small catchment dams	This would support community members to take leadership and be equipped with information to be able to manage their water use sustainably.
39	Articulate what the challenge is and why things need to change, to establish common understanding of the issue	This would socialise the issue and build buy-in from community to promote bottom-up action to address identified challenges.
40	Review how other states (e.g. NSW) approach management of small catchment dams - application, assessment, licencing and regulation.	This would leverage learnings from other states where there are many parallels with risks to water dependent values due to small catchment dam development in catchments.
41	Establish a complete, accurate record of all existing dams, their spatial dimensions including perimeter and area, and their functional characteristics (D&S, irrigation, aesthetic, passing flow compliant).	DEECA's small catchment dam Boundaries dataset contains perimeter and area estimates, though with varying accuracy. A full audit is required, supported by Alluvium's recently developed datasets. Currently, multiple Victorian government portals provide inconsistent information. Instead of attempting to repair each independently, government should prioritise elevating a single authoritative database as the state standard.
43	Develop a portal to contain statewide visual guide and map layer of waterways, accessible to agencies, planners and landholders.	This would be a public facing portal that displays all registered dams (including D&S), accurate special parameters, clearly identified waterways and compliance status of the dam. Requires implementation of item 7
	Research and innovation	
44	Improve efficiency of water use on farms	The focus of this opportunity is to minimise the losses of water stored in a small catchment dam. This could be done through on farm practices such as controlling livestock access by fencing dams and providing troughs, managing the surrounding catchment to reduce erosion and sediment, and implementing strategies to decrease evaporation, such as covering or merging water storage.
45	Look at ways to reduce costs, such as funding infrastructure change	This would support mobilisation of initiatives to promote water efficiency and uptake of actions in targeted high-risk areas. Long term strategies could

Item	Opportunities	Description
		consider replacing many small shallow dams with fewer larger, deeper, sheltered dams.
46	A D&S pipeline to deliver water for farmers	This would increase water security for farmers and reduce the impact on the river systems.
47	Use new technologies such as AI or remote sensing to gather data and conduct ongoing monitoring and tracking of small catchment dam growth	This would provide better estimates of scale of the challenge and allow more detailed monitoring of catchment changes, while improving the data availability through assessment of imagery and data.
48	Better understanding of surface water groundwater interactions	This would provide better estimates of scale of the challenge and allow more detailed monitoring of catchment changes, particularly with how it relates to the interdependency of groundwater. This would address knowledge gaps in the interaction and sensitivities of groundwater dependent ecosystems.
49	Continual research to improve validation or sensitivity testing of modelling methods	This would provide improved modelling for better estimates of the scale of the challenge and allow more detailed monitoring of catchment changes.
50	Revegetation and fencing research	Draw on recent research demonstrating that fencing and revegetating small catchment dams improves biodiversity, enhances water quality, and reduces methane emissions (Bell et al. 2025; Evans et al. 2024; Odebiri et al. 2024). Use these findings to inform state programs and incentive schemes.
51	Dam restoration	Include fenced dam restoration in carbon and biodiversity credit schemes.
52	Conduct research on seasonal water source shifts and impacts on baseflows in stressed catchments	Victoria must establish a formal process to identify and protect Flow-Stressed Catchments, comparable to the Water Supply Protection Area (WSPA) model but focused on preserving environmental flows and sustainable yield in vulnerable systems.
	Other	
53	Consider alternative water sources (treated wastewater, groundwater)	Consider recycled water or groundwater to fill dams and supply on farm non-potable uses. There are acknowledged challenges with source and delivery of this type of water, but there may be opportunities where this is feasible in certain locations.
54	Protection of low flows and returning flows	Allowing low flows, and the first flows following a dry period, to bypass dams in the catchment and rivers to ensure protection of the flow regime noted to be most impacted

Item	Opportunities	Description
		This option is a wholistic, catchment focus approach where a policy approach would protect a targeted river flow and rainfall runoff. This may include the efforts in item 28, but could be expanded to protect rainfall events that follow an extended dry, extraction rights, or protection of the first flush rainfall through other means
55	Consistent advice from responsible authority	Concerns were raised about varying advice from within and across agencies. This was discussed as likely to be able to be mitigated through other options such as improved education.
56	Turkey Nest dams that are elevated so they have limited runoff capture (for seasonal winterfill only)	To control and limit the amount of water intercepted from small catchment dams in critical locations.
57	Review wide range of funding sources to mobilise actions	As explored in the reflections session, funding for mitigation options and adaptation poses a challenge. The funding sources should be diversified, and cover implementation of actions, data gathering, Monitoring and & Evaluation and support for farmers to adopt and maintain new practices.
58	For licensed dams, no new small catchment dams (water use) in fully allocated systems.	Focus options on categories of dams, to provide appropriate measures for controlling the proliferation of new dams. Possibly through limiting licences but allowing cap and trade frameworks as described in item 6, allowing a more efficient use of the water in storage.
59	Target grey area between regulated and within rights dams	This option is likely to be considered in conjunction with the consideration of reasonableness. The option relates to the areas considered loopholes within the rules, such as the development of ornamental dams under firefighting usage.
60	Increase understanding of issues and options	Some discussions highlighted the potential value in investigating the role of small catchment dams, and the mitigation of risks they influence. This could be through further improvement of the modelling, or conducting an investigation into how other jurisdictions deal with the issues being considered, to see if there is an opportunity to apply any of the lessons learned from those areas.
61	Agency policy working group	Create a Dam Management Working Group (DEECA, SRW, CMAs, Community, Traditional Owners) to oversee policy alignment and implementation.
62	Leverage off DEECA's Water resources knowledge and access program as a suitable	DEECA's Water resources knowledge and access program as a suitable vehicle for funding for the

Item	Opportunities	Description
	vehicle for funding for the uplift in monitoring and reporting of small catchment dam development and compliance	above items. It is charged with: Improving Victoria's water resources knowledge and access. The 'Improving Victoria's water resources knowledge and access' initiative provides $135.75 million over 4 years. Funded from EC6, this initiative is designed to give Victorians continued confidence that water is shared effectively and fairly, and that decisions on how to share water have integrity. Its 3 programs are: • water resource strategy policy and frameworks • water resource strategy data, analysis and assessments, and • Victorian Water Register systems and processes.

An important element of the opportunities discussions with the SRG was a recognition that many of the opportunities articulated would be best suited to combined delivery. Many of the items are complementary and emergent benefits may be achieved if considered together.

Important Traditional Owner context was provided during the consultation, that a cultural approach to improved water management should include mechanisms for increased Traditional Owner participation, supported through documents like Healthy Waterways, FLOWS, and Integrated Catchment Management Plans. Future direction should incorporate Traditional Owner perspectives across categories such as Water Policy, Information & Education, and Research & Innovation.

9 Challenges with implementation of opportunities

The SRG were encouraged to identify the full range of opportunities and not be constrained by potential deliverability and cost aspects. A reflection session unpacked where the challenges lie in implementing some of these opportunities, and what influence the suggested opportunities may have on the management and mitigation of future risks.

Outcomes from this session are documented below:

Challenges in delivery

- The costs of actions is a challenge, in terms of who bears the cost (i.e. decommissioning, water efficiency programs), where does the funding come from (i.e. to support research and innovation) and how is it considered in justifying actions (i.e. business cases assessed using a single bottom line approach)
- Willingness to change is a challenge, as there are different perspectives of the issue and different buy in across the catchments
- Red tape around complex processes limits efficiency
- Political reticence to change, especially for actions that are drastic or require ministerial approval
- Confusion of the responsibility of water regulation versus cultural heritage protection
- Reticulated network for alternative water supply is expensive and takes time to establish
- Challenges associated with monitoring and compliance
- Groundwater as an alternative supply as it's not an unlimited resource
- Technical challenges in implementing change, such as defining a waterway
- New research and innovation opportunities must be tested and verified before being mainstreamed, which takes time and cost

- Concerns around data quality for existing and new technologies, and the limitations of information that relies on broad assumptions
- Challenges in capturing the outcomes from the wide range of existing programs that are underway through the Drought Resilience Fund
- Prioritisation of actions, especially where programs take a long time to mobilise
- Across different stakeholder groups there are differing opinions of the need for change. This extends to the need for clarification of terms and definitions, such as ‘reasonable use’. There is disagreement of the effectiveness of the current definition and whether it needs to change.

Additional feedback on the draft report was provided by several farmer representatives. This feedback highlighted that:

- Small catchment dams are a vital source of water for farmers, particularly in dry seasons, and they play an important role in supporting the resilience of the farming industry

- Restricting access to small catchment dams is challenging for farmers during dry periods; infrastructure costs and water security concerns must be acknowledged.

- Many proposed actions may be viewed negatively by farmers. In progressing actions the Agency’s should avoid an “us vs them” dynamic by focusing on farm-scale modelling and win-win solutions that support both waterway health and farm water security.

- Long term, fair and collaborative solutions are essential.

How effective might the opportunities be? What impacts could they have on catchment values?

- Change requires supporting farmers with the transition, and bringing them along the process to keep them empowered and not alienated
- Enabling actions support improved clarity and understanding of the water risks, importance of actions, and current rights and responsibilities
- Enabling actions support improved water literacy of a broad range of stakeholder groups
- Action to reduce small catchment dam impacts can become incentivised and garner widespread support
- Management mechanisms can make beneficial use of citizen scientists in the catchment by embedding mechanisms to incorporate community-based data, giving community action legitimacy and creates a pathway for effective use of on ground data
- Improved technology and investigation give a better understanding of knowledge gaps and existing assumptions. As technology evolves there may be a need to do further sensitivity testing to improve the accuracy of models, but this will build further confidence in the evidence base
- Definitions and rules are currently written from a consumptive use water rights/ access perspective. The level of support or impact that operations have on other catchment functions such as environment or cultural are not the primary consideration.

10 Summary of key outcomes

This report delivers on the Central and Gippsland Region Sustainable Water Strategy Action 4-13: Review of water resource risks in small, dry, peri-urban catchments.

This study has examined the impact of small catchment dams on river flows and the associated cultural, environmental, social and economic values in the upper Moorabool and upper Maribyrnong catchments.

The project has confirmed that the cumulative impact of small catchment dams on river flows and the associated values is significant in these two catchments, particularly in dry years. The study has also recorded that the number (and enlargement) of small catchment dams has continued to grow in the Moorabool and Maribyrnong catchments, since the last review in 2009/10.

The Stakeholder Reference Group established for this project provided a key role in informing the project outcomes including the identification of a range of opportunities to help improve the management of small catchment dams, waterways and water resources, now and into the future. The opportunities have not been prioritised or assessed.

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Attachments

Attachment 1 – SRG paper on D&S policy and legislation produced by Southern Rural Water

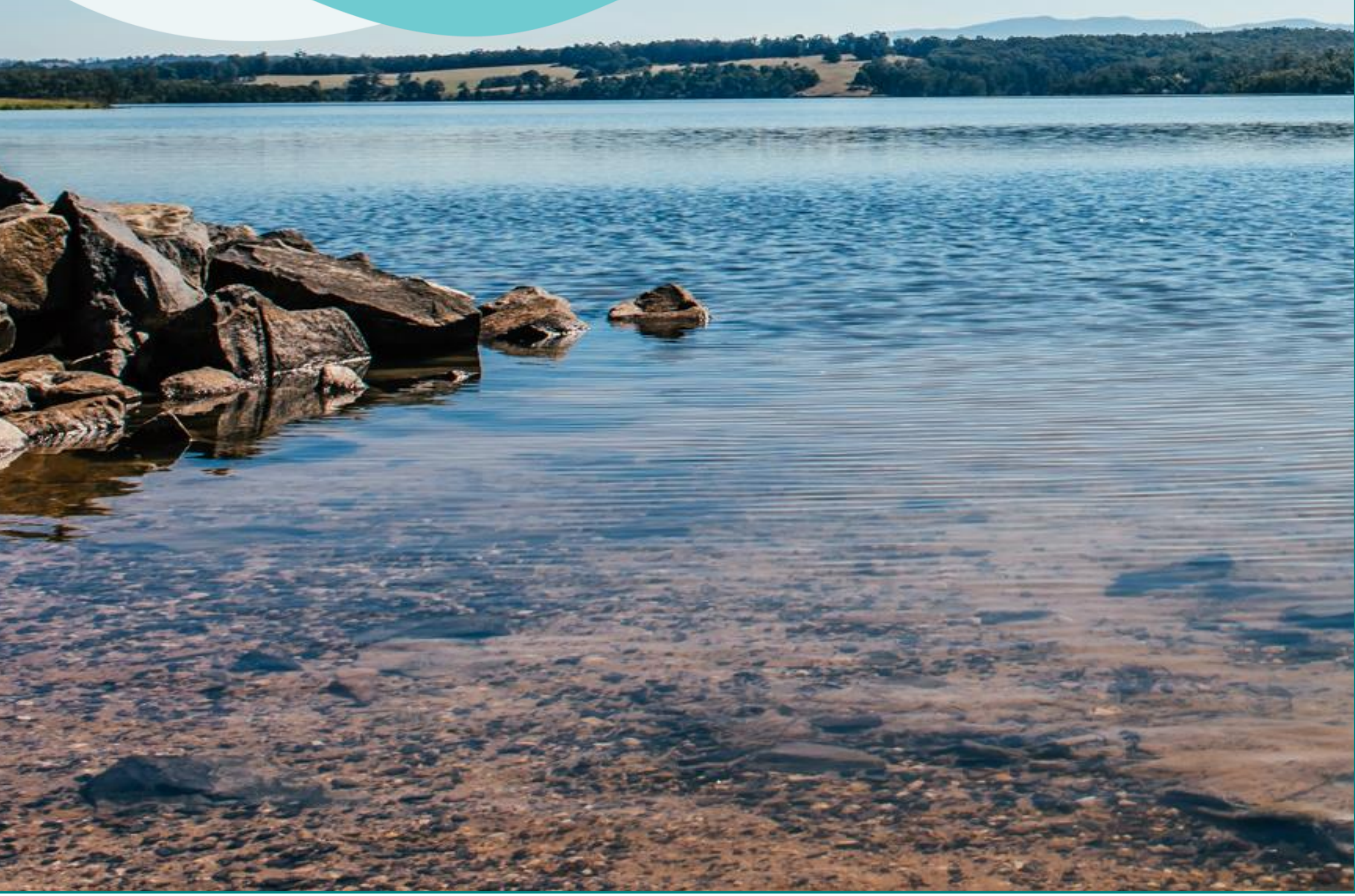
Southern Rural Water

Water Resource Risks in the Maribyrnong and Moorabool Catchments

Stakeholder Reference Group 2

18 March 2025

Domestic and stock water use



Author	Date
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Version	Description
3	Final

Scope

The focus of this paper is to provide a brief overview of the key legislative, regulatory and policy aspects that relate to the management of domestic and stock water use (section 8 rights), along with a summary of how Southern Rural Water (SRW) currently implements these requirements.

This paper does not discuss managing safety risks posed by dams, nor does it contain details of broader legislative, policy or operational aspects relating to other forms of take, such as Section 51 take and use licences or Bulk Entitlements enabled under the *Water Act 1989* (the Act).

This paper does not include a review of historical approaches within SRW for determining licences or whether a waterway is present, and it is focused on the current implementation approach.

Domestic and stock legislation

Private rights and licence requirements

Private rights to take water for domestic and stock purposes are defined in Section 8 of the Water *Act 1989* (the Act). Section 8 of the Act enables the take of water from a bore, a waterway, from surface water flowing across a property, and rainwater harvested from a roof.

Private rights apply where access to the waterway or bore is:

a. By a public road or reserve
b. Because that person occupies the land water is flowing on
c. Because that person occupies land adjacent to Crown Land covering the bed and
banks of a waterway
d. Because that person occupies the land where a bore is located

These private rights sit outside the State's entitlement framework, and there are no volumetric limits on take under these rights, only the limitation that the water is used only for domestic purposes or stock watering.

While the volume is not limited, a works licence is required in certain circumstances under State policies for the construction of bores and dams, the diversion and extraction from rivers and creeks, and the construction of small catchment dams. The following requirements relate to domestic and stock works:

- Bores greater than 3m depth require a bore construction licence under Section 67 of the Act
- Construction of a dam on a waterway (including a stock and domestic dam) requires a works licence (to construct) under Section 67 of the Act
- Works on a waterway may require a construction licence under section 67 of the Act.
- The take of water from a river or creek where the land adjacent to the waterway is owned by the crown requires a Section 51 take and use licence

Domestic and stock use definitions

Section 3 of the Act defines “domestic and stock use” as water that is used for:

(a) household purposes; or

(b) watering of animals kept as pets; or

(c) watering of cattle or other stock; or

(ca) in the case of the curtilage of a house and any outbuilding, watering an area not exceeding 1.2 hectares for fire prevention purposes with water obtained from a spring or soak or water from a dam; or

(d) irrigation of a kitchen garden.

The definition explicitly outlines domestic and stock use *“does not include use for dairies, piggeries, feed lots, poultry or any other intensive or commercial use”*

Section 3 of the Act also clearly defines the meaning of a kitchen garden as a garden:

(a) that is used solely in connection with a dwelling; and

(b) no produce from which is sold.

Section 3 of the Act also defines size limits for kitchen gardens. These limits are a function of the source/s of water used to irrigate the garden and when the land on which the garden is located was sold by the Crown (alienated from the Crown). These size limits are per the Act are defined below:

0.1 Ha if it is irrigated only with surface water and not on an allotment that was alienated from the Crown before 15 December 1886

0.4 Ha if it is irrigated by both surface water and groundwater and not on an allotment that was alienated from the Crown before 15 December 1886

0.4 Ha if it is irrigated solely with groundwater

1.2 Ha if it is part of an allotment that was alienated from the Crown before 15 December 1886.

Domestic and stock policy context

Water resources actions relating to domestic and stock uses

Contemporary policy on domestic and stock use has evolved through the development and publication by DEECA of various Sustainable Water Strategies (SWS) since 2006, including the Central Region SWS (2006), Northern Region SWS (NRSWS), published in 2009, the Western Region SWS, and Central and Gippsland Region SWS(CGRSWS) in 2022, as well as broader state water policy documents such as Water for Victoria (2016).

The focus of DEECA actions over this period has been to:

- improve data and information on water resource impacts of domestic and stock use, and
- to explore more robust guidance on ‘reasonable’ domestic and stock use to assist Rural Water Corporations (RWCs) in their activities

The outputs of this work have included improved methods for estimating domestic and stock use and a consideration of ‘reasonable’ domestic and stock use. In the case of any reasonable use guidelines being developed it was concluded that there are limited legislative powers to enforce any guidelines.

Action 4.13 in the CGRSWS relates to the current Water Risks in the Upper Moorabool and Maribyrnong Project, focused on reviewing resource risks from domestic and stock uses and identifying management improvements.

Licensing policies and guidelines relating to domestic and stock uses

The Minister's Policies for Managing Works Licences (2016) provides guidance relevant to stock and domestic activities, including:

- Construction of domestic and stock bores. The policies include various aspects such as minimum construction standards and prevention of pollution.
- Construction of dams on waterway (including domestic and stock dams), noting that dams on waterways should only be allowed if no other options/locations possible. This includes guidance on the need for an environmental report by a qualified consultant, by-pass mechanisms and minimum passing flow rates.
- Construction of off-waterway dams (including domestic and stock dams). This includes guidance on the need for bypass mechanisms to be installed and maintained in good working order to ensure no run-off is harvested outside a specified take period.
- Domestic and stock activities are currently exempt from a Section 67 operating licence (except hazardous dams).

Clause 23 of the ministerial Policies for Managing Works Licenses (2016) provides guidance to the delegated licensing authorities on the circumstances in which on-waterway dams might be considered and potentially licensed. Fundamental to the consideration of whether a dam is on a waterway or not are the 'Waterway Identification Guidelines', the most recent version signed by the Minister for Water in February 2022. SRW is the delegated licencing authority for determining if works are on a waterway for the Moorabool and Maribyrnong catchments, except for the Maribyrnong downstream of the confluence of Deep Creek and Jacksons Creek (this is Melbourne Water).

Waterway identification guidelines

Whether or not the take of water is from a waterway is a key factor in determining the licensing requirements. A waterway is defined in the Act under Section 7 and the process for identifying waterways is therefore fundamental to the ability to manage water resource impacts
resulting from take and use and the construction of works on a waterway (including the construction of private dams).

The definition of a waterway in the Act is complex and also open to interpretation. Ministerial guidance on the determination of a waterway for licensing purposes was originally developed in 2002 and these have evolved over time. The latest version of the Waterway Identification Guidelines was updated and approved by the Minister for Water in 2022.

The guidelines include:

- The definitions of a waterway in the Act and guidance on how to interpret this

- A guide on identifying a waterway, including factors to consider, and a detailed step by step decision pathway and flowchart.

Current operational practice - Southern Rural Water

SRW has a role in various aspects of domestic and stock water use, and these can be broadly grouped into:

- Licensing
- Compliance
- Water resources management

Licensing

Domestic and stock bore construction licences are applied for online via the Victorian Water Register website and these licences are issued automatically, with the exception of bores which may be in pressurised aquifers (which are referred to SRW for a drilling inspector review and typically require a higher class of driller to construct). Once a bore is drilled, the driller submits a bore completion report, and this is checked by SRW's drilling inspector to ensure compliance with the minimum construction standards.

A works licence (to construct) is required for domestic and stock access to a river or creek if the works include significant works such as excavations. SRW will consider the nature of the proposed works and undertake a field inspection as required as part of the application to determine any special required conditions on the works licence.

An application for a Section 51 take and use licence is required if the access to the river/creek crosses crown land (with certain exemptions where . In capped systems this may require a trade of entitlement from another licence holder.

To determine whether a domestic and stock dam requires a Section 67 works licence SRW undertakes a waterway determination. The onus is on the landholder to contact SRW to enquire whether a licence is required prior to a dam being constructed. Prior to assessing any potential waterway, the SRW field staff ensure that other suitable locations are considered by the proponent, as it is only permissible to build an on-stream dam if there are no other options. In some cases, this results in the domestic and stock dam being constructed well away from the potential waterway. In this instance SRW does not require a Section 67 works licence.

Where there is any doubt, SRW field staff follow the current (2022) guidelines when determining whether a waterway is present. This includes the following key steps:

- Examining whether a watercourse exists on site
- Assessing whether a natural channel is present where a regular water flow occurs
- Considering a range of other matters including (but not limited to) flows from waterways onto adjacent land, and the presence of springs, swamps, lagoons, historical information on the presence of waterways etc.

In assessing whether a waterway exists and whether regular flows occur, the area upstream of the proposed dam is examined by our field staff. This includes:

- a walkover over the catchment area to identify topography, watercourse and drainage aspects

- the identification of topographic highs with the elevations being recorded by handheld GPS
- the derivation of the catchment area to the proposed dam
- a review of current and historical satellite imagery determined using available contour maps and by taking spot elevation readings on site.

Compliance and enforcement

The Victorian Government and SRW have a zero-tolerance approach to non-compliance (unauthorised water take).

SRW has a strong risk-based approach to compliance that is focused on working with customers so that they better understand and comply with their obligations, with clear escalation pathways from these activities up to and including formal enforcement actions where appropriate. SRW has recently appointed two senior water resources compliance investigators as part of our uplift on compliance action.

SRW has a role to ensure that domestic and stock take is not being undertaken beyond what is defined within the Act. This is challenging from a compliance perspective because private rights to take water for domestic and stock purposes do not generally require a licence, do not have a volumetric limit and are not metered. SRW will take action to investigate whether domestic and stock use is in accordance with the definitions in the Water Act (and whether it requires licensing). When SRW are notified of a potential concern, and/or where our field staff observe an activity that is of concern an investigation will take place. Further action may be required to ensure compliance is achieved. This could result in the users requiring a licence and may result in enforcement action depending upon the seriousness of any alleged breach.

Where SRW is aware of a potentially non-compliant dam (e.g. a domestic and stock dam on a waterway), we will undertake a waterway determination.

When considering use SRW staff consider a range of matters related to the Water Act definition of domestic and stock use, including the number and type of stock on a property, the area of land water is used on (gardens), and whether the use of water is for domestic purposes.

Water resource management

There are two notable aspects of water resource management that relate to domestic and stock use, for SRW.

When developing groundwater or surface water management plans SRW will consider the overall estimated water use from domestic and stock sources when determining water licensing/trading rules and water sharing arrangements. DEECA also considers estimated domestic and stock use when setting caps on water availability.

During extended dry periods SRW can also impose restrictions on take on licensed customers in certain areas (mainly surface water customers), and it also has on occasion restricted domestic and stock use through a Declaration of Water Shortage and a Temporary

Qualification of Rights under Section 33AAA of the Act. This has occurred on more than one occasion in the upper Riddles Creek system.

Attachment 2 - FLOWS study recommendations

Assessment Locations

Assessment locations below are taken from the relevant FLOWS studies and indicate where the flows are intended to be representative of.

Table 14 *Moorabool assessment locations*

FLOWS Reach	FLOWS Reach Location	FLOWS Site	FLOWS Assessment Site Location	Flow Compliance Point
1	East Moorabool River, Bostock Reservoir to the confluence with west Moorabool River	1	Egerton Bungeeltap Road	East Moorabool River at Egerton-Bungeeltap Road
2	West Moorabool River between Moorabool and Lal Lal Reservoirs	2	No site surveyed in this reach	West Moorabool River at Hunts Bridge (Elaine-Egerton Road)
3	West Moorabool and Moorabool River, Lal Lal Reservoir to Sharps Road, She Oaks	3	Immediately downstream of She Oaks Weir at Sharps Road	Moorabool River at Sharps Crossing, Sharps Road She Oaks
4	Moorabool River, Sharps Road, She Oaks downstream to the confluence with the Barwon River	4	Downstream of Bakers Bridge Road	Moorabool River at Bakers Bridge Rd

Table 15 *Maribyrnong assessment locations*

Reach	Gauge Number	Gauged Period	Analysed Period	Number of Gaps	Total Gaps (days)	Longest Single (days)
MarR1	230232	19/05/1993 – 19/05/2024	1/6/1993 – 19/05/2024	3	8	4
MarR2	230107A	13/10/1979 – 17/06/2024	1/6/1993 – 31/5/2024	131	4380	542

Reach	Gauge Number	Gauged Period	Analysed Period	Number of Gaps	Total Gaps (days)	Longest Single (days)
MarR3	230211A	05/06/1975 – 20/07/2024	5/6/1975 – 31/5/2024	10	556	268
MarR4	230205	26/06/1955 – 17/06/2024	1/6/1975 – 31/5/2024	3	11	6
MarR5	230204	15/09/1933 – 17/06/2024	1/6/1975 – 31/5/2024	3	128	117
MarR6	230206	10/05/1960 – 17/06/2024	1/6/1975 – 31/5/2024	0	0	0
MarR7	230202C	06/11/2003 – 01/08/2023	1/6/2004 – 31/5/2023	13	671	647*

*Longest gap from 03/01/2021 – 11/10/2022

Table 16 *All updated environmental flow recommendations for the Maribyrnong Catchment*

Component	Reach #	Timing	Magnitude	Frequency	Duration	Key values and functions supported
JACKSONS CREEK						
Low flows	6	Dec-May	4 ML/d	Continuous	Continuous	Refugia habitat and water quality for small-bodied native fish and diadromous species, macroinvertebrates, vegetation, and frogs. Prevent encroachment of terrestrial or riparian plants into aquatic habitat
		Jun-Nov	20 ML/d	Continuous	Continuous	Refugia and maintain wetted areas for vegetation, fish and frogs. Plant growth and reproduction for submerged, floating-leaved vegetation and emergent vegetation. Reduce thermal stratification and maintaining gross channel size.
	7	Dec-May	8 ML/d	Continuous	Continuous	Refugia habitat, water quality for platypus, Growling Grass Frog (shallow stream margin and deep pools), small-bodied native fish and diadromous species and macroinvertebrates. Provide longitudinal connectivity for platypus. Plant growth and reproduction for submerged and emergent vegetation. Prevent encroachment of terrestrial or riparian plants into aquatic habitat

Component	Reach #	Timing	Magnitude	Frequency	Duration	Key values and functions supported
		Jun-Nov	40 ML/d	Continuous	Continuous	Refugia and provide longitudinal connectivity for Platypus, Growling Grass Frogs, vegetation and fish. Promote plant growth for submerged and emergent vegetation. Maintain gross channel size
Freshes	6	Dec – May	20 ML/d	DRY: 1 AVE: 2 WET: 3	DRY: 3 days AVE: 4 days WET: 4 days	Connectivity of habitat and propagule dispersal. Migration of juvenile diadromous species from estuarine reach and adult diadromous species to estuarine reach. Habitat condition for macroinvertebrates, vegetation diversity and vertical zonation (submerged, emergent, fringing). Water quality in pools and transport of silts, salts and nutrients
		Jun – Nov	215 ML/d	DRY: 1 AVE: 2 WET: 3	DRY: 2 days AVE: 3 days WET: 3 days	Connectivity of habitat (frogs) and propagule dispersal. Migration of juvenile diadromous species from estuarine reach and adult diadromous species to estuarine reach. Plant reproduction, diversity and vertical zonation (submerged, emergent, fringing vegetation). Water quality in pools
		Jun – Nov	350 ML/d	DRY: 1 AVE: 2 WET: 3	DRY: 2 days AVE: 3 days WET: 3 days	Connectivity of habitat (frogs) and propagule dispersal. Migration of juvenile diadromous species from estuarine reach and adult diadromous species to estuarine reach. Habitat complexity for macroinvertebrates (which as resource for platypus, and also inundate vegetation), plant reproduction, diversity and vertical zonation (submerged, emergent, fringing vegetation). Water quality in pools and transport of silts, salts and nutrients
	7	Dec – May	40 ML/d	DRY: 1 AVE: 2 WET: 3	DRY: 3 days AVE: 4 days WET: 4 days	Migration of juvenile and adult diadromous species. Connectivity of habitat (Platypus, Growling Grass Frog and fish) and propagule dispersal. Habitat for macroinvertebrates (resource for platypus), vegetation diversity and vertical zonation (submerged, emergent, fringing) and to support tadpole and frog (thermoregulation and breeding opportunity). Water quality in pools and transport of silts, salts and nutrients
		Jun – Nov	400 ML/d	DRY: 1 AVE: 2 WET: 3	DRY: 2 days AVE: 3 days WET: 3 days	Longitudinal connectivity, breeding and recruitment, brumation cues (Growling Grass Frog). Maintaining geomorphic conditions (habitat complexity for macroinvertebrates), habitat for macroinvertebrates (resource for platypus), plant growth and propagule dispersal, vertical zonation
High flows	6	Anytime	1,000 ML/d	3 in every 4 years	2 days	Eroding banks and maintain woody habitat for macroinvertebrates, emergent and fringing woody vegetation
	7	Anytime	2,000 ML/d	3 in every 4 years	2 days	Eroding banks and maintain woody habitat for macroinvertebrates, emergent (fringing non-woody) and fringing woody vegetation, provide connectivity to adjoining wetlands (frogs)

Component	Reach #	Timing	Magnitude	Frequency	Duration	Key values and functions supported
DEEP CREEK						
Low flows	1	Dec-May	2 ML/d	Continuous	Continuous	Refugia habitat and water quality for Yarra Pygmy Perch, small-bodied native fish and diadromous species, macroinvertebrates and vegetation. Prevent encroachment of terrestrial or riparian plants into aquatic habitat
	2		3 ML/d	Continuous	Continuous	Pool habitat and water quality for small-bodied native fish and diadromous species, macroinvertebrates and vegetation. Prevent encroachment of terrestrial or riparian plants into aquatic habitat
	4		6 ML/d	Continuous	Continuous	Pool habitat and water quality for small-bodied native fish and diadromous species, macroinvertebrate, vegetation, platypus and frogs. Prevent encroachment of terrestrial or riparian plants into aquatic habitat. Maintain groundwater (for floodplain vegetation)
	1	Jun-Nov	20 ML/d	Continuous	Continuous	Refugia habitat for Yarra Pygmy Perch and water quality. Maintain wetted areas for vegetation (plant growth for submerged and emergent). Prevent encroachment of terrestrial or riparian plants into aquatic habitat. Maintain gross channel size (physical disturbance)
	2		17 ML/d	Continuous	Continuous	Refugia habitat for fish and water quality. Maintain wetted areas for vegetation (plant growth for submerged). Prevent encroachment of terrestrial or riparian plants into aquatic habitat. Maintain gross channel size (physical disturbance)
	4		25 ML/d	Continuous	Continuous	Refugia habitat for fish and platypus and water quality. Maintain wetted areas for vegetation (plant growth for submerged and emergent) and frogs. Prevent encroachment of terrestrial or riparian plants into aquatic habitat. Maintain gross channel size (physical disturbance) and groundwater (floodplain vegetation)
Freshes	1	Dec- May	50 ML/d	DRY: 1 AVE: 2 WET: 2	DRY: 4 days AVE: 4 days WET: 6 days	Fish dispersal (adult and juvenile diadromous species), refugia habitat and water quality for small-bodied fish (Yarra Pygmy Perch) and macroinvertebrates, vegetation diversity and plant growth for submerged, emergent, fringing woody vegetation, flush propagules and prevent encroachment of terrestrial or riparian plants into aquatic habitat.
	2		17 ML/d	DRY: 1 AVE: 2 WET: 2	DRY: 4 days AVE: 4 days WET: 6 days	Fish dispersal, refugia habitat and water quality for fish and macroinvertebrates, vegetation diversity and plant growth for submerged, emergent, fringing woody vegetation, flush propagules and prevent encroachment of terrestrial or riparian plants into aquatic habitat.
	4		100 ML/d	DRY: 1 AVE: 2 WET: 2	DRY: 3 days AVE: 3 days WET: 5 days	Fish dispersal, refugia habitat and water quality for fish and macroinvertebrates, vegetation diversity and plant growth for submerged, emergent, fringing woody vegetation, flush propagules and prevent encroachment of terrestrial or riparian plants into aquatic habitat.

Component	Reach #	Timing	Magnitude	Frequency	Duration	Key values and functions supported
	1	Jun - Nov	150 ML/d	DRY: 3 AVE: 4 WET: 5	DRY: 5 days AVE: 5 days WET: 5 days	Habitat refugia and water quality for Yarra Pygmy Perch and other small-bodied native fish, connectivity and migratory cues (fish), physical disturbance and habitat complexity (macroinvertebrates), vegetation diversity and vertical zonation for vegetation, flush propagules and prevent encroachment of terrestrial or riparian plants into aquatic habitat. Maintain gross channel size
	2		175 ML/d	DRY: 3 AVE: 4 WET: 5	DRY: 5 days AVE: 5 days WET: 5 days	Habitat refugia and water quality for small-bodied native fish, connectivity and migratory cues (fish and frogs), physical disturbance and habitat complexity (macroinvertebrates), vegetation diversity and vertical zonation for vegetation, flush propagules and prevent encroachment of terrestrial or riparian plants into aquatic habitat. Maintain gross channel size
	4		250 ML/d	DRY: 3 AVE: 4 WET: 4	DRY: 6 days AVE: 6 days WET: 7 days	Habitat refugia and water quality for small-bodied native fish, connectivity and migratory cues (fish and frogs), physical disturbance and habitat complexity (macroinvertebrates and its resource for platypus), vegetation diversity and vertical zonation for vegetation, flush propagules. Maintain gross channel size
High flows	1	Anytime	1,000 ML/d	1 per year	2 days	Eroding banks and maintain woody habitat for macroinvertebrates, emergent (fringing non-woody) and fringing woody vegetation
	2		500 ML/d	1 per year	2 days	Eroding banks and maintain woody habitat for macroinvertebrates, emergent (fringing non-woody) and fringing woody vegetation
	4		2,000 ML/d	1 per year	2 days	Eroding banks and maintain woody habitat for macroinvertebrates, emergent (fringing non-woody) and fringing woody vegetation
EMU CREEK						
Low flows	3	Dec-May	6 ML/d	Continuous	Continuous	Habitat condition (water quality) and breeding opportunity for Growling Grass Frogs. Pool habitat and water quality for small bodied native fish, macroinvertebrates and vegetation
		Jun-Nov	14 ML/d	Continuous	Continuous	Habitat condition (water quality) and breeding opportunity and prevention of chytrid fungus for Growling Grass Frogs. Pool habitat and water quality for small bodied native fish, macroinvertebrates, vegetation (emergent and floodplain). Maintain gross channel size (physical disturbance) and groundwater for floodplain vegetation
Freshes		Dec-May	14 ML/d	DRY: 1 AVE: 2 WET: 3	DRY: 1 day AVE: 3 days WET: 3 days	Refuge pool habitat (water quality, Growling Grass Frogs, fish), Growling Grass Frog breeding, thermoregulation and protection. Migration cue for small bodied native fish and diadromous species. Habitat condition for macroinvertebrates, prevent terrestrialisation of vegetation and propagule dispersal.
		Jun – Nov	100 ML/d	DRY: 2 AVE: 3	DRY: 4 days AVE: 4 days	Refuge pool habitat (water quality, Growling Grass Frogs, fish). Breeding, thermoregulation, protection, connectivity and brumation opportunities for Growling Grass Frog. Migration cue for

Component	Reach #	Timing	Magnitude	Frequency	Duration	Key values and functions supported
				WET: 4	WET: 4 days	small bodied native fish and diadromous species. Habitat condition for macroinvertebrates, prevent terrestrialisation of vegetation and propagule dispersal. Maintain gross channel size (physical disturbance)
High flows		Anytime	1,000 ML/d	2 per 3 years	2 days	Eroding banks and maintain woody habitat for macroinvertebrates, emergent (fringing non-woody) and fringing woody vegetation, provide connectivity to adjoining wetlands (Growling Grass Frogs)
RIDDELLS CREEK						
Low flows	5	Dec-May	2 ML/d	Continuous	Continuous	Pool habitat and water quality for small-bodied native fish and diadromous species, macroinvertebrate, vegetation and frogs. Plant growth for submerged and emergent vegetation. Prevent encroachment of terrestrial or riparian plants into aquatic habitat
		Jun-Nov	10 ML/d	Continuous	Continuous	Pool habitat and water quality for small-bodied native fish and diadromous species, macroinvertebrate, vegetation and frogs. Plant growth for submerged and emergent vegetation. Prevent encroachment of terrestrial or riparian plants into aquatic habitat. Maintain gross channel size (physical disturbance)
Freshes		Dec - May	20 ML/d	DRY: 1 AVE: 2 WET: 3	DRY: 2 days AVE: 2 days WET: 4 days	Refuge pool habitat (water quality and fish), habitat condition for macroinvertebrates, migration cues for adult and juvenile diadromous species. Prevent encroachment of terrestrial or riparian plants into aquatic habitat. Vegetation diversity, vertical zonation and propagule dispersal
		Jun - Nov	50 ML/d	DRY: 3 AVE: 4 WET: 5	DRY: 4 days AVE: 4 days WET: 5 days	Refuge pool habitat (water quality and fish), habitat condition for macroinvertebrates, migration cues for adult and juvenile diadromous species. Prevent encroachment of terrestrial or riparian plants into aquatic habitat. Vegetation diversity, vertical zonation and propagule dispersal. Maintain gross channel size (physical disturbance). Connectivity for frogs
High flows		Anytime	400 ML/d	1 per 2 years	2 days	Eroding banks and maintain woody habitat for macroinvertebrates, emergent (fringing non-woody) and fringing woody vegetation

Table 17 *All updated environmental flow recommendations for the Moorabool Catchment*

Season	Flow	Regime	Magnitude	Frequency and timing	Duration	Key values and functions supported
Reach 1						
Summer / Autumn (Dec-May)	Low flow	All	1.2 ML/d	December to May	Continuous	Maintain pool and riffle habitats for fish, macroinvertebrates, Platypus and submerged aquatic vegetation. Maintain water quality.
	Fresh	Dry	2 ML/d	Every 8 weeks	2-3 days	Water fringing marginal zone vegetation. Allow fish and Platypus movement through the reach and maintain access to habitat. Prevent low dissolved oxygen conditions and elevated EC conditions during low flow periods.
Winter / Spring (Jun-Nov)	Low flow	All	8 ML/d	June to November	Continuous	Allow fish movement throughout the reach. Maintain clear flow path and control intrusions by terrestrial vegetation.
	Fresh	Wet/Ave	37 ML/d	1 event May to August 2 events September to November	5 days	Allow fish and Platypus movement through the reach and maintain access to habitat. Trigger downstream spawning migration of adult Tupong. Upstream migration of juvenile Galaxias, Tupong, Short-finned Eel and Grayling. Flush silt, and scour biofilms and algae from streambed and transport of organic matter. Promote growth and recruitment of native riparian vegetation including woody shrubs and promote strong vegetation zonation on the banks.
		Dry	37 ML/d	1 event May to August 1 event September to November	5 days	
	High	Wet/Ave	500 ML/d	1 event every 2 to 3 years	2 days	Scour pools and maintain channel form and dimensions. Inundate benches and inset floodplains. Flushing of sediment to improve spawning sites.
Reach 2						
Summer / Autumn (Dec-May)	Low flow	Wet/Ave	5 ML/d	December to May	Continuous	Maintain pool and riffle habitats for fish, macroinvertebrates, Platypus and submerged aquatic vegetation. Maintain water quality.
		Dry	2.5 ML/d			
	Fresh	Wet/Ave	30 ML/d	3 events	3 days	Flush silt, and scour biofilms and algae from streambed. Water fringing marginal zone vegetation. Allow fish and Platypus movement through the reach and maintain access to habitat.
		Dry		1 event every 2 to 3 years		
Winter / Spring (Jun-Nov)	Low flow	Wet / Average	5 ML/d	June to November	Continuous	Allow fish movement throughout the reach. Maintain clear flow path and control intrusions by terrestrial vegetation.
		Dry	2.5 ML/d			
	Fresh	Wet / Average	40 ML/d	3 events	3 days	Allow fish and Platypus movement through the reach and maintain access to habitat. Flush silt, and scour biofilms and algae from streambed and transport of organic
		Dry		1 event		

Season	Flow	Regime	Magnitude	Frequency and timing	Duration	Key values and functions supported
						matter. Promote growth and recruitment of native riparian vegetation including woody shrubs and promote strong vegetation zonation on the banks.
	High	Wet / Average	250 ML/d	1 event every 2 years	1-2 days	Scour pools and maintain channel form and dimensions. Inundate benches and inset floodplains.
Reach 3a						
Summer / Autumn (Dec-May)	Low flow	Wet / Ave	10 ML/d	December to May	Continuous	Maintain pool and riffle habitats for fish, macroinvertebrates, Platypus and submerged aquatic vegetation. Maintain water quality.
		Dry	5 ML/d			
	Fresh	Wet / Ave	60 ML/d	2 events, April/May and January/February	5 days	Flush silt, and scour biofilms and algae from streambed. Water fringing marginal zone vegetation. Allow fish and Platypus movement through the reach and maintain access to habitat. Trigger downstream spawning migration of adult Short-finned Eel and Grayling.
			30 ML/d	1 event in February/March	3 days	
		Dry	60 ML/d	1 event every 2-3 years	5 days	
Winter / Spring (Jun-Nov)	Low flow	Wet / Ave	10 ML/d	June to November	Continuous	Allow fish movement throughout the reach. Maintain clear flow path and control intrusions by terrestrial vegetation.
		Dry	5 ML/d			
	Fresh	Wet/Ave	80 ML/d	1 event May to August 2 events September to November	5 days	Allow fish and Platypus movement through the reach and maintain access to habitat. Trigger downstream spawning migration of adult Tupong. Upstream migration of juvenile Galaxias, Tupong, Short-finned Eel and Grayling. Flush silt, and scour biofilms and algae from streambed (M1) and transport of organic matter. Promote growth and recruitment of native riparian vegetation including woody shrubs and promote strong vegetation zonation on the banks.
		Dry		1 event May to August 1 event September to November	5 days	
	High	Wet/Ave	500 ML/d	1 event every 2-3 years	1-2 days	Scour pools and maintain channel form and dimensions. Inundate benches and inset floodplains. Flushing of sediment to improve spawning sites.
Reach 3b						
Summer / Autumn (Dec-May)	Low flow	Wet / Ave	20 ML/d	December to May	Continuous	Maintain pool and riffle habitats for fish, macroinvertebrates, Platypus and submerged aquatic vegetation. Maintain water quality.
		Dry	10 ML/d			
	Fresh	Wet / Average	60 ML/d	2 events, January/February and April/May	5 days	Flush silt, and scour biofilms and algae from streambed. Water fringing marginal zone vegetation. Allow fish and Platypus movement through the reach and maintain access

Season	Flow	Regime	Magnitude	Frequency and timing	Duration	Key values and functions supported
			30 ML/d	1 event in February/March	3 days	to habitat. Trigger downstream spawning migration of adult Short-finned Eel and Grayling.
		Dry	60 ML/d	1 event every 2 to 3 years, April/May	5 days	
			30 ML/d	1 event as require	3 days	Freshen water quality when DO < 5 mg/L.
Winter / Spring (Jun-Nov)	Low flow	All	20 ML/d	June to November	Continuous	Allow fish movement throughout the reach. Maintain clear flow path and control intrusions by terrestrial vegetation.
		Dry	10 ML/d	June to November		
	Fresh	Wet/Ave	80 ML/d	1 event May to August 2 events September to November	5 days	Allow fish and Platypus movement through the reach and maintain access to habitat. Trigger downstream spawning migration of adult Tupong. Upstream migration of juvenile Galaxias, Tupong, Short-finned Eel and Grayling. Flush silt, and scour biofilms and algae from streambed and transport of organic matter. Promote growth and recruitment of native riparian vegetation including woody shrubs and promote strong vegetation zonation on the banks.
		Dry		1 event May to August 1 event September to November		
	High	Wet/Ave	1000 ML/d	1 event every 2 years	1-2 days	Scour pools and maintain channel form and dimensions. Maintain inset floodplains. Flushing of sediment to improve spawning sites.
Reach 4						
Summer / Autumn (Dec-May)	Low flow	Wet/Ave	20 ML/d	December to May	Continuous	Maintain pool and riffle habitats for fish, macroinvertebrates, Platypus and submerged aquatic vegetation. Maintain water quality.
		Dry	10 ML/d			
	Fresh	Wet/Ave	60 ML/d	2 events, January/February and April/May	5 days	Flush silt, and scour biofilms and algae from streambed. Water fringing marginal zone vegetation. Allow fish and Platypus movement through the reach and maintain access to habitat. Trigger downstream spawning migration of adult Short-finned Eel and Grayling.
			30 ML/d	1 event, February/March	3 days	
		Dry	60 ML/d	1 event every 2 to 3 years, April/May	5 days	
			20 ML/d	1 event as required	2 days	Freshen water quality when DO < 5 mg/L.
Winter / Spring	Low flow	Wet/Ave	20 ML/d	June to November	Continuous	Allow fish movement throughout the reach. Maintain clear flow path and control intrusions by terrestrial vegetation.
		Dry	10 ML/d			

Season	Flow	Regime	Magnitude	Frequency and timing	Duration	Key values and functions supported
(Jun-Nov)	Fresh	Wet/Ave	80 ML/d	1 event May to August 2 events September to November	5 days	Allow fish and Platypus movement through the reach and maintain access to habitat (). Trigger downstream spawning migration of adult Tupong. Upstream migration of juvenile Galaxias, Tupong, Short-finned eel and Grayling. Flush silt, and scour biofilms and algae from streambed and transport of organic matter. Promote growth and recruitment of native riparian vegetation including woody shrubs and promote strong vegetation zonation on the banks.
		Dry		1 event May to August 1 event in September to November	5 days	
	High	80	3000 ML/d	1 event every 2 years	1-2 days	Scour pools and maintain channel form and dimensions. Flushing of sediment to improve spawning sites. Inundate billabongs.

Attachment 3 – Environmental Flows Analysis Technical Notes

The notes below detail the technical notes for the consideration of flow recommendations detailed in the relevant FLOWS study reports.

Water year

The water year was defined as 1 June - 31 May. This provided alignment with seasons and the more recent Maribyrnong FLOWs study.

Analysis data and dates

The analysis was conducted from 01/06/1900 to 31/05/2021. The analysis aligned with the shortest period of Source data available, for consistency between the catchments. The input data and period of data available are described in **Error! Reference source not found.**. The Environmental Flow Node records were used for this a nalysis.

eFlow Predictor

eFlow Predictor was used to compare flows for each scenario with the flow recommendations published in the Moorabool and Maribyrnong FLOWs studies. The following assumptions and adjustments to the FLOWs recommendations were used in the risk assessment process:

- Low flows across all reaches were analysed as continuous and therefore recommended to occur 100% of the time within the specified month range.
- Spell independence was set to 7 days for the rules that did not specify otherwise.

Maribyrnong

- Recommendations that specified flow frequency as 3 in every 4 years, 2 per 3 years, or similar are not in a format accepted by eFlow Predictor. These recommendations were analysed as an event every year.

Moorabool

- Rise and fall specifications were not implemented, consistent with the Maribyrnong analysis.
- Used the Minimum flow magnitude, where an Aspirational value was also provided.
- Used the minimum of duration (e.g. if 1 to 2 days, used 1 day).
- Used minimum frequency (e.g. if 1 event every 2 to 3 years, used 1 event every 3 years).
- Where frequency and timing were "Every 8 weeks" it was calculated that between Dec-May this would result in 3 events with 15 days left over, and spell independence of 7*8=56 days. It was run as 3 events of 2 days duration with a 56-day spell independence.
- Recommendations of 1 event every 2 years, preferably in Winter to avoid risks to Platypus (no control over timing). The rule was applied for the winter/spring duration of Jun-Nov.
- For Reach 3a, 3b and 4 freshes where it specified 2 events, April/May and Jan/Feb. The recommendation was implemented as one event in each month pair: one event in April/May and one event in January/February.
- Water Quality Fresh recommendations were analysed as 1 event in the period of Dec-May. eFlow Predictor does not take into account water quality or dissolved oxygen levels.

Climate condition scores

Maribyrnong

Climate conditions scores were developed per the method described in Attachment 2 sub-section Derivation of annual climate condition (dry, average, wet) of the FLOWs study.

Moorabool

Climate condition scores for the Moorabool adapted the method in Section 6.1.2 of the FLOWs study to better align with the Maribyrnong method. A key change was calculating the condition scores based on the water year rather than calendar year. The length of this data was extended to align with the investigation period.

Attachment 4 – Social and Economic Analysis Technical Notes

Water year

The water year was defined as 1 June - 31 May. This provided alignment with the environmental flows analysis.

Analysis data and dates

The analysis was conducted from 01/06/1900 to 31/05/2021 for Source based assessments. The analysis aligned with the shortest period of Source data available, for consistency between the catchments.

Economic: Section 51 licences

Average annual reliability

The analysis used the Source model output for each irrigation and rural water user in the catchment. The two variables used were:

- Unrestricted demand: the water volume that a user would request if there were no limitations.
- Demand shortfall: the volume of demand that could not be met due to water availability and allocation rules.

Consecutive shortfall days

The longest duration of consecutive shortfall days per water year was selected and used to form an average across the investigation period.

Economic: Rural dam reliability

STEDI was used to model the filling of dams based on rainfall and run-off. The STEDI analysis provides information on how full dams are as a percentage. For example, dams may be 80% full.

This analysis focused on the dam's percentage full in the sub-catchments of each catchment at the end of the summer and winter season. To support this, the end of month percentage fill data for August and February was used.

Social: Urban level of service for Moorabool

This analysis was only conducted for the Moorabool catchment as the Maribyrnong is managed by flow outside the scope catchments.

The analysis used the Source model output for each urban water location. The two variables used were:

- Geelong Stage 2 restriction levels
- Ballarat Stage 1 restriction levels.

Social: Rural level of service

Maribyrnong

The analysis used the Source model output for the catchment. The two variables used were:

- Irrigation User Ban
- Rural User Ban

Moorabool

The analysis used the Source model output for the catchment. The two variables used were:

- Lal Lal DS Restriction Stage

- Lal Lal US Restriction Stage

This data was assigned a Level of 0-5. A Level 5 Restriction Stage corresponds to a ban in accordance with the Moorabool River Basin Local Management Plan (May 2014) Management of Licences.

Management of Licences

There is a five stage roster in place, which is detailed in the table below.

Restriction Level	Trigger Flow ML/day at Batesford gauging station For all months	Allocation (% of maximum daily extraction rate as specified on licence)
Stage 1	12<10	100
Stage 2	10<8	75
Stage 3	8<6	50
Stage 4	6<4	25
Stage 5	<2	Ban

Social: River amenities and on river recreation

Maribyrnong

The analysis used the Source model output for the catchment, specifically the gauged flow at Keilor. The Maribyrnong FLOWs study recommends a Summer low flow volume of 30ML/d in Reach 8 was applied during the 2015 FLOWs study. The updated FLOWs study (2025) makes caveats that this volume may be more than the reach typically receives. Nevertheless, as the updated flows study did not set a new volume, the 2015 volume of 30ML/day has been applied.

Moorabool

The analysis used the Source model output for the catchment, specifically the gauged flow at Batesford. The Moorabool FLOWs study recommends a Summer low flow volume of 20ML per day during an Average or Wet year for Reach 4. A 10ML/d Summer low flow volume is recommended in a Dry year. For simplicity the average year volume of 20ML/d was applied to the Batesford gauge.

Cease to flow and low flow spells

- The days cease to flow and low flow spells analysis assumed a spell independence of 0 days.
- The cease to flow volume threshold was set at 0.1ML/d, which is equivalent to the volume of a garden hose.

Attachment 5 - Risk assessment overview

The risk assessment conducted for both the Moorabool and Maribyrnong catchments was based on the modelling results and the changes in flows across the different scenarios. The process that was used and the values that are tested are described below.

Risks were defined as *the potential for negative impacts on the values identified*. In this application, the risk was identified as the risk of detrimental effects under each modelled scenario to the environmental, economic, social and cultural values.

For the purpose of this risk assessment, risk was considered in terms of causes, threats and beneficial uses whereby a cause (represented by model scenarios) may result in a threat (e.g. reduced water availability to a value that relies on it) that impacts on a beneficial use (e.g. consumptive use) of water.

For example, there may be a risk associated with an increased number of small catchment dams ('cause'), that leads to a reduction in volume of surface water available ('threat'), adversely impacting on the environment ('beneficial use').

Cause – *An event (and specific scenario*) that gives rise to or generates a threat. For this risk assessment, the causes are described as the events that lead to the development of a threat. Causes can be changes in levels of development such as increased utilisation of existing rights and entitlements, or events such as climate change or bushfires.

Threat – A threat is a *deviation from an agreed starting point that may affect beneficial uses*. For this risk assessment, a deviation from an agreed starting point includes:

- Adverse changes in the volume or pattern of water, and
- Continuation or changes in water quality or ecosystems that renders them not fit for purpose.

Beneficial use – The *use to which water resources are applied* which are defined using the assessment of water use against each value type.

This study has explored the challenges that the Moorabool and Maribyrnong catchments are facing being placed under stress from recent land use and climatic changes, which are likely to continue into the future. For the purposes of this assessment, a number of scenarios were assessed to determine the level of hydrologic impact of each scenario, defined as a 'cause'. The causes, that are the source of the stress or 'threat' under assessment, align to the model scenarios discussed in Section 6.

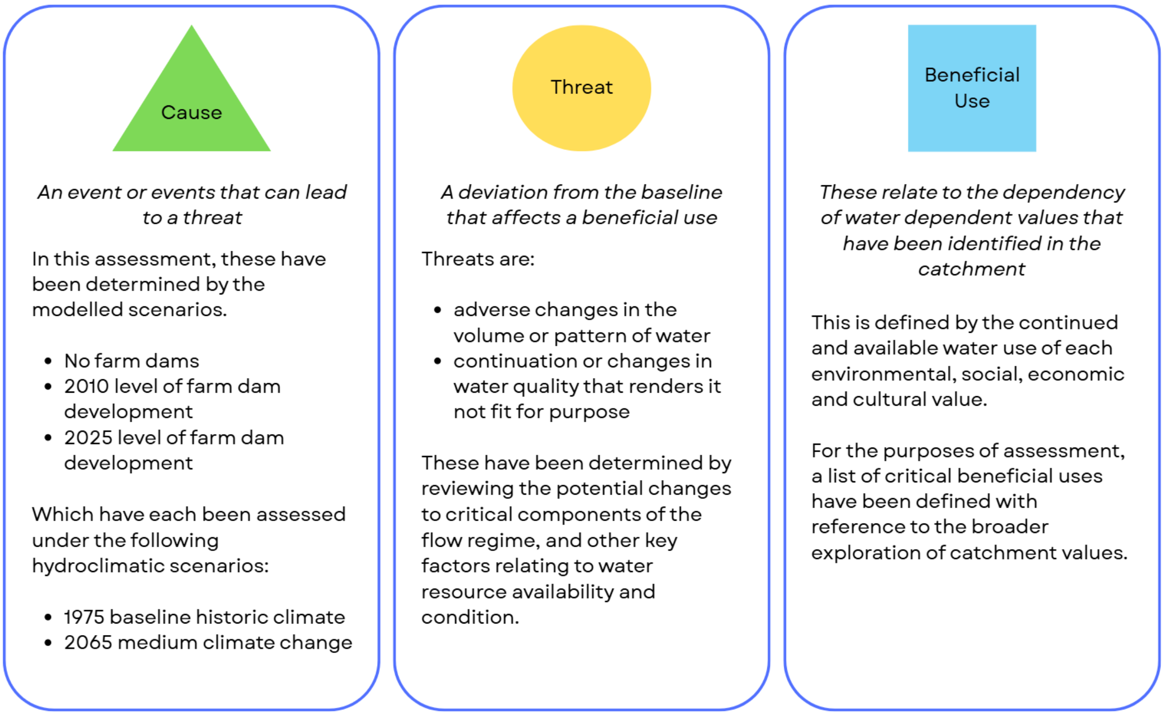


Figure 22 *Elements of the study that describe components of the risk assessment*

This assessment considered a finite list of threats, which were determined by assessing the possible changes within the catchment that would contribute to the detrimental impact to water resources availability and condition. These threats are the translation of changes observed between each hydrological scenario, in terms of the difference in statistics, compliance measurement against flow conditions, and indirect connection to changes in condition such as water quality or ecosystems that render the system worse in the given scenario. They relate to adverse changes to the volume or pattern of water delivery or availability, or changes in water quality or waterway condition, that is critical to that value.

The beneficial uses are established relationships between waterway health, condition and resource with broad uses or values within the catchment. The beneficial uses draw links between the critical water dependent values that have been identified through this study, and the sensitivity to defined threats, to establish a definition of consequence.

A framework was developed and adopted for the preliminary risk assessment based on ISO 31000:2009, in particular the concept of likelihood and consequence. In this assessment, the level of risk was considered to be a product of the likelihood of a threat occurring, and the consequence of that threat.

For the purpose of this risk analysis:

- The *likelihood* was determined based on the probability of a cause and susceptibility of a threat to that cause
- The *consequence* was determined based on the susceptibility of a threat to the cause and the sensitivity of the beneficial use to that threat

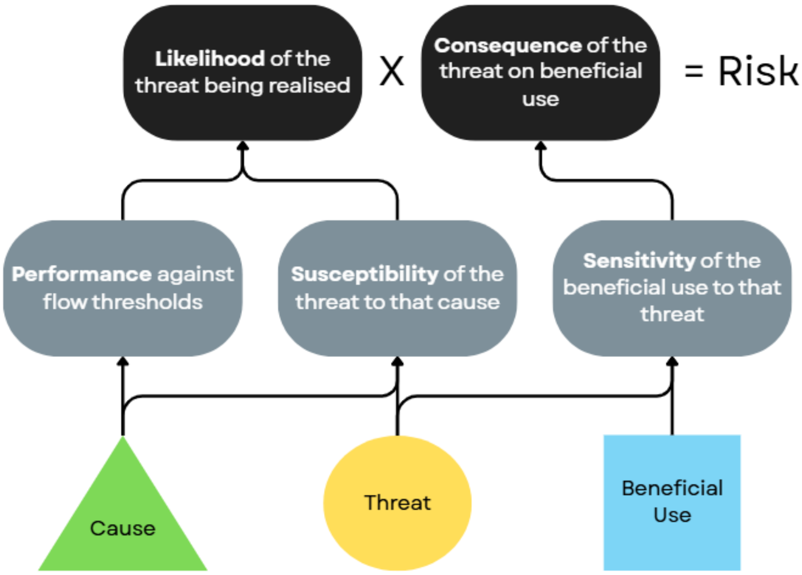


Figure 23 *Key components of the risk assessment framework used to determine level of risk of water dependent values under each scenario*

The **performance**, in this instance, was a factor of the statistical analysis of modelled scenarios against flow thresholds. For example, if a value had a flow dependency of at least X ML per day in summer, assessment to determine the likelihood this can be achieved may consider the number of summer days on average that flow is more than X ML per day over the model period.

The **susceptibility** considered how susceptible a threat was to a particular cause. For example, if that cause (flow is less than X ML per day in summer) were to occur, to what extent would it cause a threat because flow dependency cannot be achieved leading to the river being unable to maintain pool and riffle habitats for fish, macroinvertebrates, platypus and submerged aquatic vegetation. The susceptibility measure considers how significant a change is, based on *magnitude, spatial extent and duration*.

The **sensitivity** measure is a metric that determines how vulnerable or resilient a use case is to the projected change. In the case that a threat (dry spell) were to occur, the sensitivity determines *how* it would affect the beneficial use (local impact, widespread critical reduction in habitat).

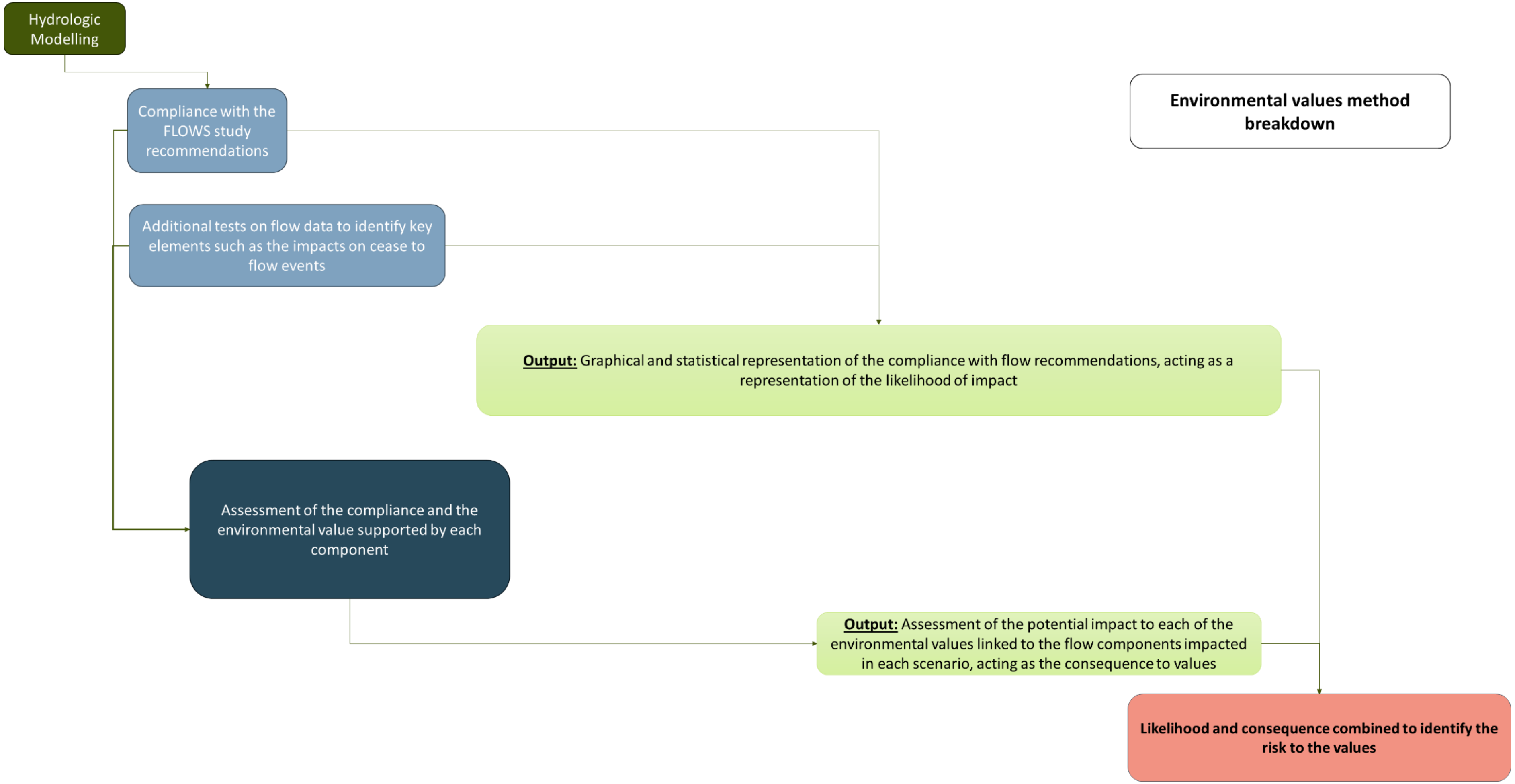
These factors were used to assess likelihood and consequence of each combination of scenarios against a given threat, and to assess the level of risk to each beneficial use (value) using Table 18**Error! Reference source not found.** below.

Table 18 *Likelihood and consequence table for assignment of risk* (as per ISO 31000:2009)

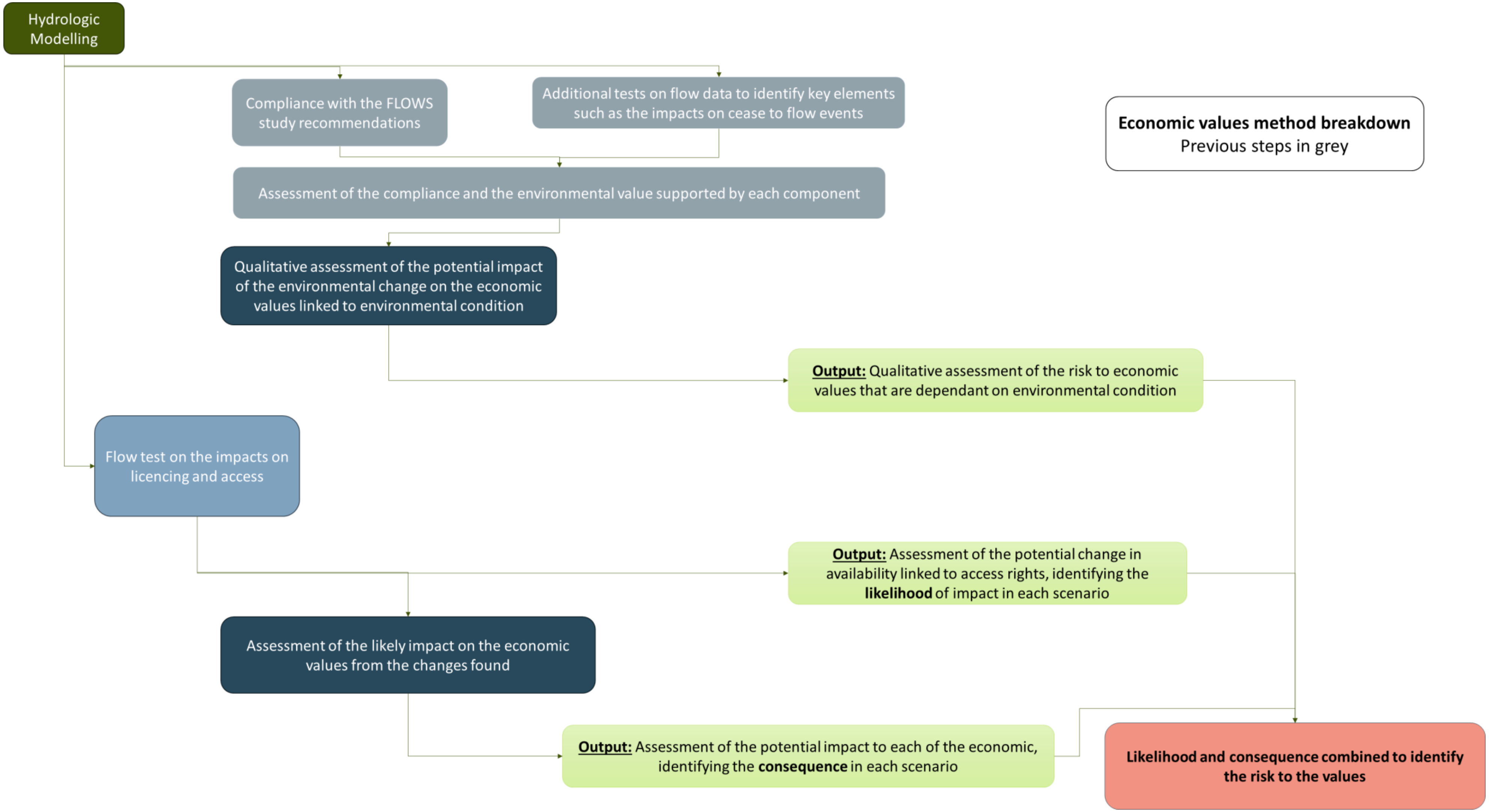
		Consequence				
		Negligible	Minor	Moderate	Major	Extreme
Likelihood	Rare	Low	Low	Low	Medium	Significant
	Unlikely	Low	Low	Medium	Medium	Significant
	Possible	Low	Medium	Medium	Significant	High
	Likely	Medium	Medium	Significant	High	High
	Almost certain	Medium	Significant	High	High	High

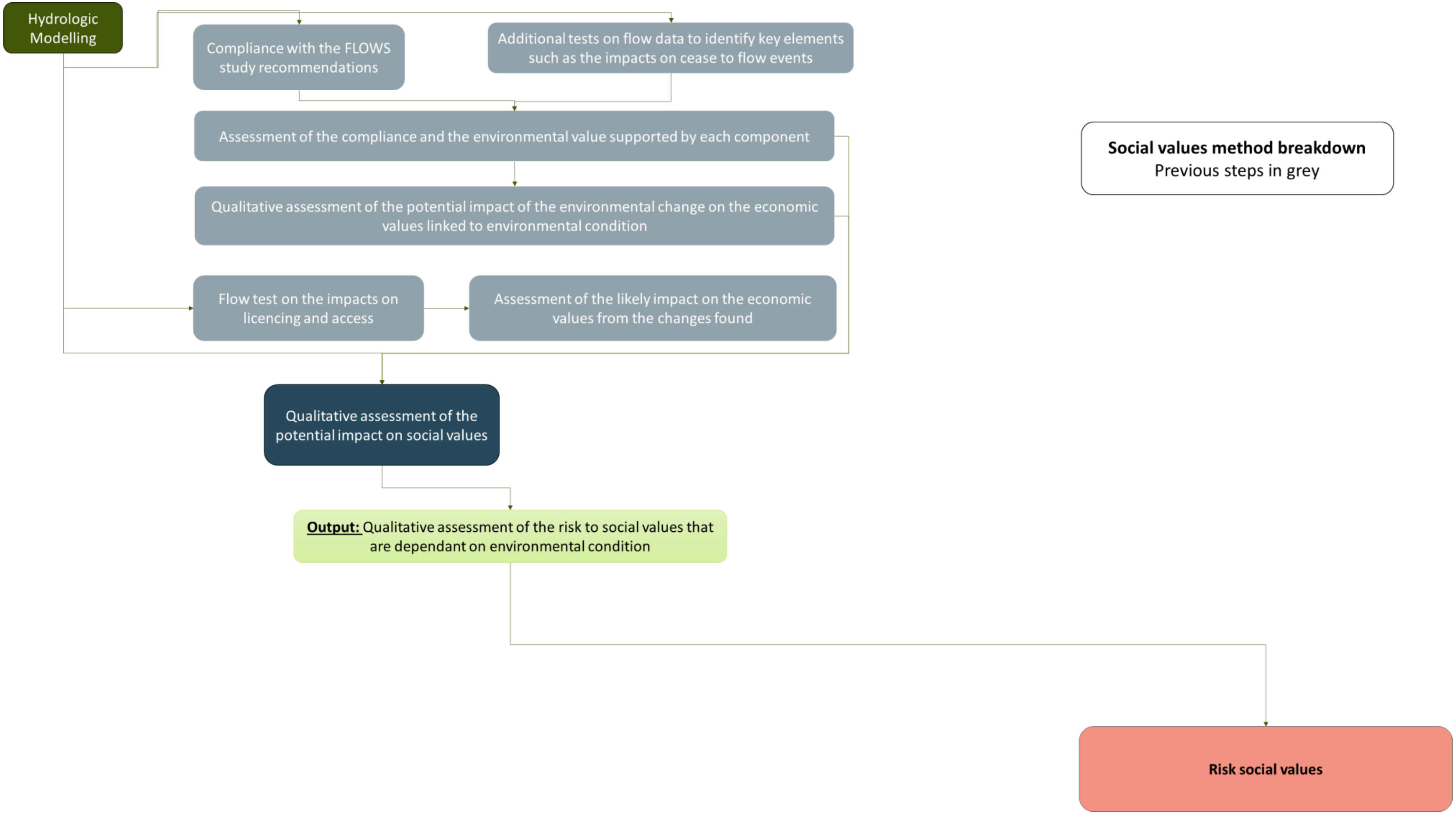
Assessment process

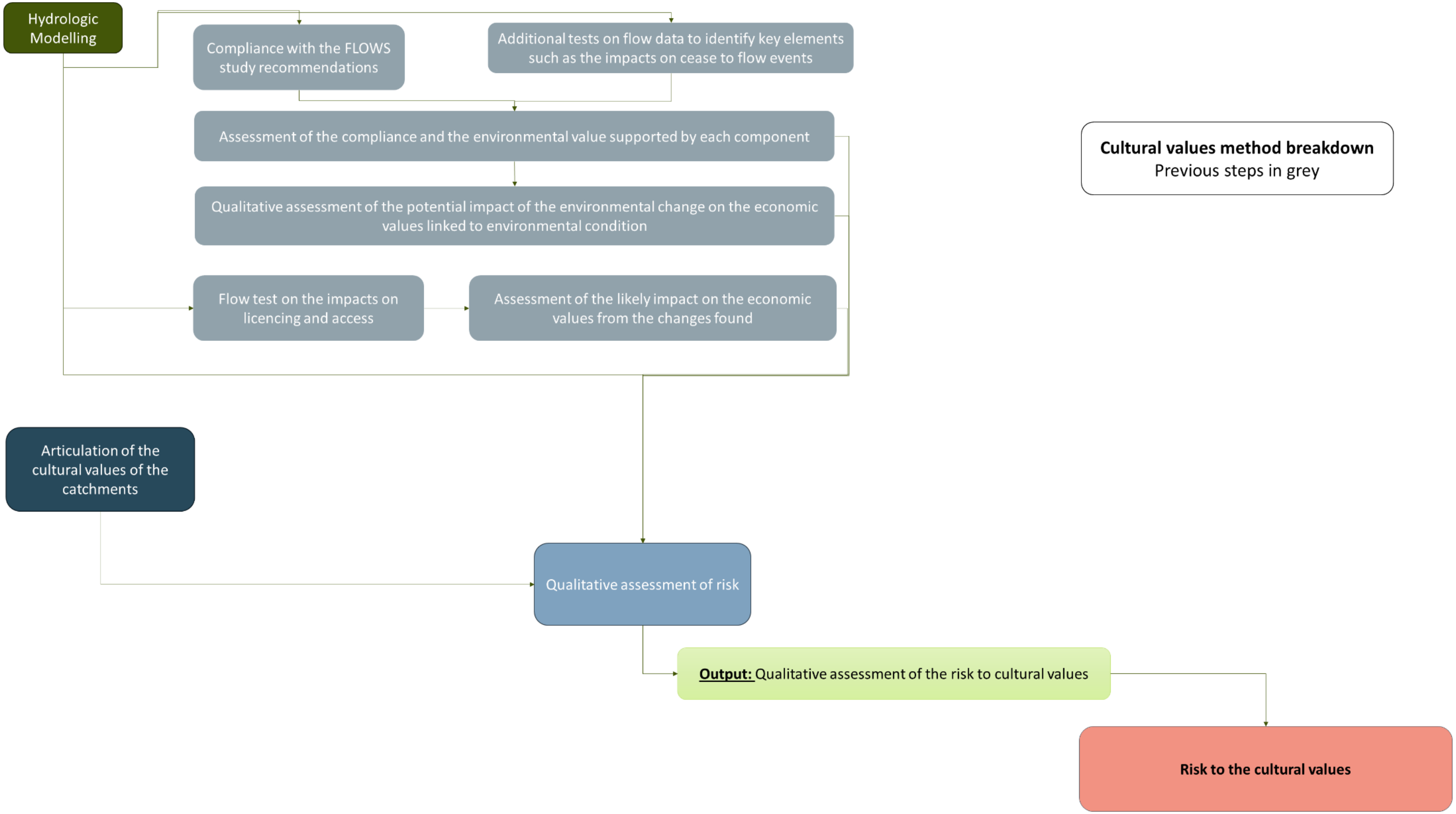
Process flow charts displaying how the information for the assessment was obtained and used are shown below, with more detailed descriptions following.



Hydrologic Modelling
Environmental values method breakdown
Compliance with the FLOWS study recommendations
Additional tests on flow data to identify key elements such as the impacts on cease to flow events
Output: Graphical and statistical representation of the compliance with flow recommendations, acting as a representation of the likelihood of impact
Assessment of the compliance and the environmental value supported by each component
Output: Assessment of the potential impact to each of the environmental values linked to the flow components impacted in each scenario, acting as the consequence to values
Likelihood and consequence combined to identify the risk to the values


Hydrologic Modelling
Compliance with the FLOWS study recommendations
Additional tests on flow data to identify key elements such as the impacts on cease to flow events
Economic values method breakdown
Previous steps in grey
Assessment of the compliance and the environmental value supported by each component
Qualitative assessment of the potential impact of the environmental change on the economic values linked to environmental condition
Output: Qualitative assessment of the risk to economic values that are dependant on environmental condition
Flow test on the impacts on licencing and access
Output: Assessment of the potential change in availability linked to access rights, identifying the likelihood of impact in each scenario
Assessment of the likely impact on the economic values from the changes found
Output: Assessment of the potential impact to each of the economic, identifying the consequence in each scenario
Likelihood and consequence combined to identify the risk to the values


Hydrologic Modelling
Compliance with the FLOWS study recommendations
Additional tests on flow data to identify key elements such as the impacts on cease to flow events
Assessment of the compliance and the environmental value supported by each component
Qualitative assessment of the potential impact of the environmental change on the economic values linked to environmental condition
Flow test on the impacts on licencing and access
Assessment of the likely impact on the economic values from the changes found
Qualitative assessment of the potential impact on social values
Output: Qualitative assessment of the risk to social values that are dependant on environmental condition
Social values method breakdown
Previous steps in grey
Risk social values


Hydrologic Modelling
Compliance with the FLOWS study recommendations
Additional tests on flow data to identify key elements such as the impacts on cease to flow events
Assessment of the compliance and the environmental value supported by each component
Qualitative assessment of the potential impact of the environmental change on the economic values linked to environmental condition
Flow test on the impacts on licencing and access
Assessment of the likely impact on the economic values from the changes found
Cultural values method breakdown
Previous steps in grey
Articulation of the cultural values of the catchments
Qualitative assessment of risk
Output: Qualitative assessment of the risk to cultural values
Risk to the cultural values

Environmental application

Based on the framework outlined above, the risks to environmental values were assessed using the results from the Source modelling and environmental flow compliance.

- The **performance** was taken from the frequency of meeting flow targets with the recommendations of the relevant FLOWS study. This varied across the modelled scenarios.
- The **susceptibility** was determined through the relationship between the flow component in each reach and the individual values. This was a constant representation determined by expert review.

The performance (Table 19) and the susceptibility (Table 20) was combined using the table below to determine the **likelihood** rating (Table 21).

- The **sensitivity** is represented by the anticipated impact if the scenario does not support the values. This was a constant representation determined by expert review.
    - Significance of different species and communities
    - Significance of the location in relation to the broader reach, system and region.

Sensitivity was taken through the two elements identified from expert review and assigned a consequence rating based on the determination in (

Table 22). The criteria were adopted from the FLOWS study documents.

Table 19 *Performance criteria*

Performance rating	Criteria
High performance	Over 70% compliance
Medium – high performance	Over 55% compliance
Medium – low performance	Over 40% compliance
Low performance	Below 40% compliance

Table 20 *Susceptibility criteria*

Susceptibility rating	Criteria
Strong	Changes in hydrological indicator will cause a significant change in the value
Moderate	Changes in condition will cause moderate change in the key value or change only occurs under some circumstances
Low	Changes in condition will cause minor change in the key value or change only occurs under some circumstances

Table 21 *Likelihood assessment*

		Susceptibility		
		Low	Moderate	Strong
Performance	High performance	Rare Event only occurring in exception circumstances	Rare Event only occurring in exception circumstances	Unlikely The event may occur as any performance issue is impactful but there is little opportunity for occurrence
	Medium-high performance	Rare Event only occurring in exception circumstances	Unlikely The event may occur	Possible The event could be expected to occur
	Medium-low performance	Unlikely The event may occur	Possible The event could be expected to occur	Likely The event should be expected to occur as the
	Low performance	Possible The event could be expected to occur	Likely The event should be expected to occur	Almost Certain The event should be expected to occur as the

Table 22 *Consequence table*

	Habitat is critical to the value in the reach	*Habitat* is critical to the value in the broader catchment	*Habitat* is critical to the value across at a state or national scale
The *value* has a high local significance	Minor	Moderate	Major
The *value* has a high state or national significance	Moderate	Major	Extreme

Economic application

Based on the risk assessment framework, the risks to economic values were assessed using the results from the Source modelling.

- The **performance** was taken from the frequency of meeting performance criteria of demand reliability levels determined.
- The **susceptibility** of shortfalls in irrigation demand are constant. Inability to access water for irrigation under licences means the economic value is unable to be supported.

The performance (Table 23) and the susceptibility (Table 24) was combined using the table below to determine the **likelihood** rating (Table 25).

- The **sensitivity** is represented by the anticipated impact if the scenario does not support the values. This was a constant representation determined by expert review.
  - Significance of shortfall in supply to meet irrigation demand
  - Significance of the location of the shortfall, in terms of widespread or localised impact.

Sensitivity will be taken through the two elements identified from expert review and assigned a consequence rating based on the determination in (

Table 22).

Table 23 *Performance criteria*

Performance rating	Criteria
High performance	95% reliability
Medium – high performance	90% reliability
Medium – low performance	85% reliability
Low performance	80% reliability

Table 24 *Susceptibility criteria*

Susceptibility rating	Criteria
Strong	Changes in hydrological indicator will cause a significant change in the value
Moderate	Changes in condition will cause moderate change in the key value or change only occurs under some circumstances
Low	Changes in condition will cause minor change in the key value or change only occurs under some circumstances

Table 25 *Likelihood assessment*

		Susceptibility		
		Low	Moderate	Strong
Performance	High performance	Rare Event only occurring in exception circumstances	Rare Event only occurring in exception circumstances	Unlikely The event may occur as any performance issue is impactful but there is little opportunity for occurrence
	Medium-high performance	Rare Event only occurring in exception circumstances	Unlikely The event may occur	Possible The event could be expected to occur
	Medium-low performance	Unlikely The event may occur	Possible The event could be expected to occur	Likely The event should be expected to occur as the
	Low performance	Possible The event could be expected to occur	Likely The event should be expected to occur	Almost Certain The event should be expected to occur as the

Table 26 *Consequence table*

	Habitat is critical to the value in the reach	*Habitat* is critical to the value in the broader catchment	*Habitat* is critical to the value across at a state or national scale
The *value* has a high local significance	Minor	Moderate	Major
The *value* has a high state or national significance	Moderate	Major	Extreme

Social application

Based on the risk assessment framework, the risks to social values were assessed using the results from the Source modelling.

- The **performance** of social values relating to urban water supply was taken from the frequency of meeting level of service criteria determined in development of the Urban Water Strategy. This assessment was limited to urban centres within the Moorabool catchment.
- The **performance** of water delivery to support the downstream social values was taken from the performance criteria measured against the flow targets.
- The **susceptibility** of shortfalls in irrigation demand are constant. Inability to access water for irrigation under licences means the economic value is unable to be supported.

The performance (Table 23) and the susceptibility (Table 24) was combined using the table below to determine the **likelihood** rating (Table 25Table 21).

- The **sensitivity** is represented by the anticipated impact if the scenario does not support the values. This was a constant representation determined by expert review.

Sensitivity was taken through the two elements identified from expert review and assigned a consequence rating based on the determination in (

Table 22).

Table 27 *Performance criteria - initial*

Performance rating	Criteria
High performance	70% reliability
Medium – high performance	55% reliability
Medium – low performance	40% reliability
Low performance	Below 40% reliability

Table 28 *Performance criteria - incremental*

Performance rating	Criteria
High performance	Less than 2% change in reliability
Medium – high performance	Between 2% and 5% change in reliability
Medium – low performance	Between 5% and 10% change in reliability
Low performance	Above 10% change in reliability

Table 29 *Susceptibility criteria*

Susceptibility rating	Criteria
Strong	Changes in hydrological indicator will cause a significant change in the value
Moderate	Changes in condition will cause moderate change in the key value or change only occurs under some circumstances
Low	Changes in condition will cause minor change in the key value or change only occurs under some circumstances

Table 30 *Likelihood assessment*

		Susceptibility		
		Low	Moderate	Strong
Performance	High performance	Rare Event only occurring in exception circumstances	Rare Event only occurring in exception circumstances	Unlikely The event may occur as any performance issue is impactful but there is little opportunity for occurrence
	Medium-high performance	Rare Event only occurring in exception circumstances	Unlikely The event may occur	Possible The event could be expected to occur
	Medium-low performance	Unlikely The event may occur	Possible The event could be expected to occur	Likely The event should be expected to occur as the
	Low performance	Possible The event could be expected to occur	Likely The event should be expected to occur	Almost Certain The event should be expected to occur as the

Table 31 *Consequence table*

	Habitat is critical to the value in the reach	*Habitat* is critical to the value in the broader catchment	*Habitat* is critical to the value across at a state or national scale
The *value* has a high local significance	Minor	Moderate	Major
The *value* has a high state or national significance	Moderate	Major	Extreme

Environmental Consequence Ratings

Table 32 *Moorabool consequence ratings*

Item	Reach #	Value	Consequence	Rationale	Value	Habitat
1	1	Vegetation	Minor	Instream, fringing and riparian vegetation that rely on the flows.	Local	Reach
2	1	Fish	Major	Flows facilitate cover and movement up and down stream, access to veg. Some endangered species	State	Catchment
3	1	Frogs	Moderate	Some endangered species in the catchment but primarily swamp and rain dependant	State	Reach
4	1	Platypus	Extreme	Flow regime is important, species is important	State	National
5	1	Invertebrates	Moderate	Mainly terrestrial invertebrates identified that rely on water availability (ie issues if completely dried)	Local	Catchment
6	1	Turtles	Extreme	Supporting ELN and MRT	State	National
7	2	Vegetation	Minor	Instream, fringing and riparian vegetation that rely on the flows.	Local	Reach
8	2	Fish	Major	Flows facilitate cover and movement up and down stream, access to veg. Some endangered species	State	Catchment
9	2	Frogs	Moderate	Some endangered species in the catchment but primarily swamp and rain dependant	State	Reach
10	2	Platypus	Extreme	Flow regime is important, species is important	State	National

Item	Reach #	Value	Consequence	Rationale	Value	Habitat
11	2	Invertebrates	Moderate	Mainly terrestrial invertebrates identified that rely on water availability (ie issues if completely dried)	Local	Catchment
12	2	Turtles	Extreme	Supporting ELN and MRT	State	National
13	3a	Vegetation	Minor	Instream, fringing and riparian vegetation that rely on the flows.	Local	Reach
14	3a	Fish	Major	Flows facilitate cover and movement up and down stream, access to veg. Some endangered species	State	Catchment
15	3a	Frogs	Moderate	Some endangered species in the catchment but primarily swamp and rain dependant	State	Reach
16	3a	Platypus	Extreme	Flow regime is important, species is important	State	National
17	3a	Invertebrates	Moderate	Mainly terrestrial invertebrates identified that rely on water availability (ie issues if completely dried)	Local	Catchment
18	3a	Turtles	Extreme	Supporting ELN and MRT	State	National
19	3b	Vegetation	Minor	Instream, fringing and riparian vegetation that rely on the flows.	Local	Reach
20	3b	Fish	Major	Flows facilitate cover and movement up and down stream, access to veg. Some endangered species	State	Catchment
21	3b	Frogs	Moderate	Some endangered species in the catchment but primarily swamp and rain dependant	State	Reach
22	3b	Platypus	Extreme	Flow regime is important, species is important	State	National
23	3b	Invertebrates	Moderate	Mainly terrestrial invertebrates identified that rely on water availability (ie issues if completely dried)	Local	Catchment
24	3b	Turtles	Extreme	Supporting ELN and MRT	State	National

Item	Reach #	Value	Consequence	Rationale	Value	Habitat
25	4	Vegetation	**Minor**	Instream, fringing and riparian vegetation that rely on the flows.	Local	Reach
26	4	Fish	**Major**	Flows facilitate cover and movement up and down stream, access to veg. Some endangered species	State	Catchment
27	4	Frogs	**Moderate**	Some endangered species in the catchment but primarily swamp and rain dependant	State	Reach
28	4	Platypus	**Extreme**	Flow regime is important, species is important	State	National
29	4	Invertebrates	**Moderate**	Cease to flow a disturbance Low flow promotes abundance and biomass. Fresh scours algae, improving food quality	Local	Catchment
30	4	Turtles	**Extreme**	Supporting ELN and MRT	State	National

Table 33 *Maribyrnong consequence ratings*

Item	Location	Reach #	Value	Consequence	Rationale	Value	Habitat
1	Deep Creek	1	Fish	Moderate	Primarily based on supporting YPP and Grayling. Vulnerable/endagered.	Local	Catchment
2	Deep Creek	2	Fish	Moderate	Primarily based on supporting YPP and Grayling. Vulnerable/endagered.	Local	Catchment
3	Emu Creek	3	Fish	Moderate	Primarily based on supporting YPP and Grayling. Vulnerable/endagered.	Local	Catchment
4	Deep Creek	4	Fish	Moderate	Primarily based on supporting YPP and Grayling. Vulnerable/endagered.	Local	Catchment
5	Riddells Creek	5	Fish	Moderate	Primarily based on supporting YPP and Grayling. Vulnerable/endagered.	Local	Catchment
6	Jacksons Creek	6	Fish	Moderate	Primarily based on supporting YPP and Grayling. Vulnerable/endagered.	Local	Catchment
7	Jacksons Creek	7	Fish	Moderate	Primarily based on supporting YPP and Grayling. Vulnerable/endagered.	Local	Catchment
8	Deep Creek	1	Frog	Moderate	Includes the GGF, Brown Toadlet and Southern Toadlet. Mostly rainfall rather than flow dependant. Some rely on swamp and wetlands that are not present	State	Reach
9	Deep Creek	2	Frog	Moderate	Includes the GGF, Brown Toadlet and Southern Toadlet. Mostly rainfall rather than flow dependant. Some rely on swamp and wetlands that are not present	State	Reach
10	Deep Creek	4	Frog	Moderate	Includes the GGF, Brown Toadlet and Southern Toadlet. Mostly rainfall rather than flow dependant. Some rely on swamp and wetlands that are not present	State	Reach

Item	Location	Reach #	Value	Consequence	Rationale	Value	Habitat
11	Jacksons Creek	6	Frog	Moderate	Includes the GGF, Brown Toadlet and Southern Toadlet. Mostly rainfall rather than flow dependant. Some rely on swamp and wetlands that are not present	State	Reach
12	Jacksons Creek	7	Frog	Moderate	Includes the GGF, Brown Toadlet and Southern Toadlet. Mostly rainfall rather than flow dependant. Some rely on swamp and wetlands that are not present	State	Reach
13	Deep Creek	1	Invertebrates	Major	Mainly terrestrial invertabrates identified that rely on water availability (ie isses if completely dried)	State	Catchment
14	Deep Creek	2	Invertebrates	Major	Mainly terrestrial invertabrates identified that rely on water availability (ie isses if completely dried)	State	Catchment
15	Emu Creek	3	Invertebrates	Major	Mainly terrestrial invertabrates identified that rely on water availability (ie isses if completely dried)	State	Catchment
16	Deep Creek	4	Invertebrates	Major	Mainly terrestrial invertabrates identified that rely on water availability (ie isses if completely dried)	State	Catchment
17	Riddells Creek	5	Invertebrates	Major	Mainly terrestrial invertabrates identified that rely on water availability (ie isses if completely dried)	State	Catchment
18	Jacksons Creek	6	Invertebrates	Major	Mainly terrestrial invertabrates identified that rely on water availability (ie isses if completely dried)	State	Catchment
19	Jacksons Creek	7	Invertebrates	Major	Mainly terrestrial invertabrates identified that rely on water availability (ie isses if completely dried)	State	Catchment
20	Deep Creek	1	Vegetation	Minor	Mainly dependant on rainfall in this reach	Local	Reach
21	Deep Creek	2	Vegetation	Major	Morebecoming more dependant on flows in the riparian areas and stream bank in particular. Some endagered species reliant on flows	State	Catchment

Item	Location	Reach #	Value	Consequence	Rationale	Value	Habitat
22	Emu Creek	3	Vegetation	Major	Morebecoming more dependant on flows in the riparian areas and stream bank in particular. Some endagered species reliant on flows	State	Catchment
23	Deep Creek	4	Vegetation	Major	Morebecoming more dependant on flows in the riparian areas and stream bank in particular. Some endagered species reliant on flows	State	Catchment
24	Riddells Creek	5	Vegetation	Major	Morebecoming more dependant on flows in the riparian areas and stream bank in particular. Some endagered species reliant on flows	State	Catchment
25	Jacksons Creek	6	Vegetation	Major	Morebecoming more dependant on flows in the riparian areas and stream bank in particular. Some endagered species reliant on flows	State	Catchment
26	Jacksons Creek	7	Vegetation	Major	Morebecoming more dependant on flows in the riparian areas and stream bank in particular. Some endagered species reliant on flows	State	Catchment

Environmental Value Strength Ratings

Table 34 *Moorabool strength table*

ID	Component	Reach #	Timing	Magnitude	Value	Strength rating	Comment
1	Low flow	1	Summer / Autumn (Dec-May)	1.2 ML/d	Vegetation	Strong	Important for instream vegetation habitat and longer-lived riparian vegetation.
2	Low flow	1	Summer / Autumn (Dec-May)	1.2 ML/d	Invertebrates	Strong	Maintains habitat and food for invertebrates
3	Low flow	1	Summer / Autumn (Dec-May)	1.2 ML/d	Fish	Strong	Maintains habitat and refuges for fish
4	Low flow	1	Summer / Autumn (Dec-May)	1.2 ML/d	Turtles	Strong	Maintains habitat and refuges
5	Low flow	1	Summer / Autumn (Dec-May)	1.2 ML/d	Frogs	Weak	Limited interaction with frog habitats
6	Fresh	1	Summer / Autumn (Dec-May)	2 ML/d	Vegetation	Weak	Mixed outcomes for instream vegetation, may improve soil moisture for fringing vegetation.
7	Fresh	1	Summer / Autumn (Dec-May)	2 ML/d	Invertebrates	Moderate	Disturbance (bad) but longer-term improvements in habitat and food.
8	Fresh	1	Summer / Autumn (Dec-May)	2 ML/d	Fish	Moderate	Improves water quality and may provide an opportunity for movement.
9	Fresh	1	Summer / Autumn (Dec-May)	2 ML/d	Frogs	Weak	Wont influence frog habitat
10	Low flow	1	Winter / Spring (Jun-Nov)	8 ML/d	Vegetation	Strong	Important for instream vegetation habitat and longer-lived riparian vegetation.
11	Low flow	1	Winter / Spring (Jun-Nov)	8 ML/d	Invertebrates	Strong	Maintains habitat diversity and food for invertebrates
12	Low flow	1	Winter / Spring (Jun-Nov)	8 ML/d	Fish	Strong	Maintains minimum habitat for fish
13	Low flow	1	Winter / Spring (Jun-Nov)	8 ML/d	Frogs	Weak	Limited interaction with frog habitats
14	Fresh	1	Winter / Spring (Jun-Nov)	37 ML/d	Vegetation	Weak	In-stream – disturbance (bad). Fringing – disturbance (good) soil moisture.
15	Fresh	1	Winter / Spring (Jun-Nov)	37 ML/d	Invertebrates	Moderate	Disturbance (bad) longer term habitat and food benefits
16	Fresh	1	Winter / Spring (Jun-Nov)	37 ML/d	Fish	Strong	Opportunity to move important for some species. Benefits for bugs provide food in long term
17	Fresh	1	Winter / Spring (Jun-Nov)	37 ML/d	Frogs	Weak	Unlikely to affect their habitats

ID	Component	Reach #	Timing	Magnitude	Value	Strength rating	Comment
18	High	1	Winter / Spring (Jun-Nov)	500 ML/d	Vegetation	Strong	Disturbance (good) soil moisture, nutrients. Disturbance (bad) long-term improvements in habitat and food. Important for floodplain bugs
19	High	1	Winter / Spring (Jun-Nov)	500 ML/d	Invertebrates	Moderate	
20	High	1	Winter / Spring (Jun-Nov)	500 ML/d	Fish	Moderate	
21	High	1	Winter / Spring (Jun-Nov)	500 ML/d	Frogs	Moderate	
22	High	1	Winter / Spring (Jun-Nov)	500 ML/d	Turtles	Strong	
23	Low flow	2	Summer / Autumn (Dec-May)	5 ML/d	Vegetation	Strong	Important for instream vegetation habitat and longer-lived riparian vegetation.
24	Low flow	2	Summer / Autumn (Dec-May)	5 ML/d	Invertebrates	Strong	Maintains habitat and food for invertebrates
25	Low flow	2	Summer / Autumn (Dec-May)	5 ML/d	Fish	Strong	Maintains habitat and refuges for fish
26	Low flow	2	Summer / Autumn (Dec-May)	5 ML/d	Turtles	Strong	Maintains habitat and refuges
27	Low flow	2	Summer / Autumn (Dec-May)	5 ML/d	Frogs	Weak	Limited interaction with frog habitats
28	Low flow	2	Summer / Autumn (Dec-May)	2.5 ML/d	Vegetation	Strong	Important for instream vegetation habitat and longer-lived riparian vegetation.
29	Low flow	2	Summer / Autumn (Dec-May)	2.5 ML/d	Invertebrates	Strong	Maintains habitat and food for invertebrates
30	Low flow	2	Summer / Autumn (Dec-May)	2.5 ML/d	Fish	Strong	Maintains habitat and refuges for fish
31	Low flow	2	Summer / Autumn (Dec-May)	2.5 ML/d	Turtles	Strong	Maintains habitat and refuges
32	Low flow	2	Summer / Autumn (Dec-May)	2.5 ML/d	Frogs	Weak	Limited interaction with frog habitats
33	Fresh	2	All	30 ML/d	Vegetation	Weak	Mixed outcomes for instream vegetation, may improve soil moisture for fringing vegetation.
34	Fresh	2	All	30 ML/d	Invertebrates	Moderate	Disturbance (bad) but longer-term improvements in habitat and food.
35	Fresh	2	All	30 ML/d	Fish	Moderate	Improves water quality and may provide an opportunity for movement.
36	Fresh	2	All	30 ML/d	Frogs	Weak	Wont influence frog habitat
37	Low flow	2	Winter / Spring (Jun-Nov)	5 ML/d	Vegetation	Strong	Important for instream vegetation habitat and longer-lived riparian vegetation.

ID	Component	Reach #	Timing	Magnitude	Value	Strength rating	Comment
38	Low flow	2	Winter / Spring (Jun-Nov)	5 ML/d	Invertebrates	Strong	Maintains habitat diversity and food for invertebrates
39	Low flow	2	Winter / Spring (Jun-Nov)	5 ML/d	Fish	Strong	Maintains minimum habitat for fish
40	Low flow	2	Winter / Spring (Jun-Nov)	5 ML/d	Frogs	Weak	Limited interaction with frog habitats
41	Low flow	2	Winter / Spring (Jun-Nov)	2.5 ML/d	Vegetation	Strong	Important for instream vegetation habitat and longer-lived riparian vegetation.
42	Low flow	2	Winter / Spring (Jun-Nov)	2.5 ML/d	Invertebrates	Strong	Maintains habitat diversity and food for invertebrates
43	Low flow	2	Winter / Spring (Jun-Nov)	2.5 ML/d	Fish	Strong	Maintains minimum habitat for fish
44	Low flow	2	Winter / Spring (Jun-Nov)	2.5 ML/d	Frogs	Weak	Limited interaction with frog habitats
45	Fresh	2	all	40 ML/d	Vegetation	Weak	In-stream – disturbance (bad) Fringing – disturbance (good) soil moisture.
46	Fresh	2	all	40 ML/d	Invertebrates	Moderate	Disturbance (bad) longer term habitat and food benefits
47	Fresh	2	all	40 ML/d	Fish	Strong	Opportunity to move important for some species. Benefits for bugs provide food in long term
48	Fresh	2	all	40 ML/d	Frogs	Weak	Unlikely to affect their habitats
49	High	2	1 event every 2 years	250 ML/d	Vegetation	Strong	Disturbance (good) soil moisture, nutrients.
50	High	2	1 event every 2 years	250 ML/d	Invertebrates	Moderate	Disturbance (bad) long-term improvements in habitat and food. Important for floodplain bugs
51	High	2	1 event every 2 years	250 ML/d	Fish	Moderate	Opportunity to move important for some species. Benefits for bugs provide food in long term
52	High	2	1 event every 2 years	250 ML/d	Frogs	Moderate	Unlikely to affect their habitats
53	High	2	1 event every 2 years	250 ML/d	Turtles	Strong	Important for SNL, provides lateral connectivity
54	Low flow	3a	Summer / Autumn (Dec-May)	10 ML/d	Vegetation	Strong	Important for instream vegetation habitat and longer-lived riparian vegetation.
55	Low flow	3a	Summer / Autumn (Dec-May)	10 ML/d	Invertebrates	Strong	Maintains habitat and food for invertebrates
56	Low flow	3a	Summer / Autumn (Dec-May)	10 ML/d	Fish	Strong	Maintains habitat and refuges for fish
57	Low flow	3a	Summer / Autumn (Dec-May)	10 ML/d	Turtles	Strong	Maintains habitat and refuges
58	Low flow	3a	Summer / Autumn (Dec-May)	10 ML/d	Frogs	Weak	Limited interaction with frog habitats

ID	Component	Reach #	Timing	Magnitude	Value	Strength rating	Comment
59	Low flow	3a	Summer / Autumn (Dec-May)	5 ML/d	Vegetation	Strong	Important for instream vegetation habitat and longer-lived riparian vegetation.
60	Low flow	3a	Summer / Autumn (Dec-May)	5 ML/d	Invertebrates	Strong	Maintains habitat and food for invertebrates
61	Low flow	3a	Summer / Autumn (Dec-May)	5 ML/d	Fish	Strong	Maintains habitat and refuges for fish
62	Low flow	3a	Summer / Autumn (Dec-May)	5 ML/d	Turtles	Strong	Maintains habitat and refuges
63	Low flow	3a	Summer / Autumn (Dec-May)	5 ML/d	Frogs	Weak	Limited interaction with frog habitats
64	Fresh	3a	Summer / Autumn (Dec-May)	60 ML/d	Vegetation	Weak	Mixed outcomes for instream vegetation, may improve soil moisture for fringing vegetation.
65	Fresh	3a	Summer / Autumn (Dec-May)	60 ML/d	Invertebrates	Moderate	Disturbance (bad) but longer-term improvements in habitat and food.
66	Fresh	3a	Summer / Autumn (Dec-May)	60 ML/d	Fish	Moderate	Improves water quality and may provide an opportunity for movement.
67	Fresh	3a	Summer / Autumn (Dec-May)	60 ML/d	Frogs	Weak	Wont influence frog habitat
68	Fresh	3a	Summer / Autumn (Dec-May)	30 ML/d	Vegetation	Weak	Mixed outcomes for instream vegetation, may improve soil moisture for fringing vegetation.
69	Fresh	3a	Summer / Autumn (Dec-May)	30 ML/d	Invertebrates	Moderate	Disturbance (bad) but longer-term improvements in habitat and food.
70	Fresh	3a	Summer / Autumn (Dec-May)	30 ML/d	Fish	Moderate	Improves water quality and may provide an opportunity for movement.
71	Fresh	3a	Summer / Autumn (Dec-May)	30 ML/d	Frogs	Weak	Wont influence frog habitat
72	Fresh	3a	Summer / Autumn (Dec-May)	60 ML/d	Vegetation	Weak	Mixed outcomes for instream vegetation, may improve soil moisture for fringing vegetation.
73	Fresh	3a	Summer / Autumn (Dec-May)	60 ML/d	Invertebrates	Moderate	Disturbance (bad) but longer-term improvements in habitat and food.
74	Fresh	3a	Summer / Autumn (Dec-May)	60 ML/d	Fish	Moderate	Improves water quality and may provide an opportunity for movement.
75	Fresh	3a	Summer / Autumn (Dec-May)	60 ML/d	Frogs	Weak	Wont influence frog habitat
76	Low flow	3a	Winter / Spring (Jun-Nov)	10 ML/d	Vegetation	Strong	Important for instream vegetation habitat and longer-lived riparian vegetation.
77	Low flow	3a	Winter / Spring (Jun-Nov)	10 ML/d	Invertebrates	Strong	Maintains habitat diversity and food for invertebrates

ID	Component	Reach #	Timing	Magnitude	Value	Strength rating	Comment
78	Low flow	3a	Winter / Spring (Jun-Nov)	10 ML/d	Fish	Strong	Maintains minimum habitat for fish
79	Low flow	3a	Winter / Spring (Jun-Nov)	10 ML/d	Frogs	Weak	Limited interaction with frog habitats
80	Low flow	3a	Winter / Spring (Jun-Nov)	10 ML/d	Turtles	Strong	Provides habitat and refuge
81	Low flow	3a	Winter / Spring (Jun-Nov)	5 ML/d	Vegetation	Strong	Important for instream vegetation habitat and longer-lived riparian vegetation.
82	Low flow	3a	Winter / Spring (Jun-Nov)	5 ML/d	Invertebrates	Strong	Maintains habitat diversity and food for invertebrates
83	Low flow	3a	Winter / Spring (Jun-Nov)	5 ML/d	Fish	Strong	Maintains minimum habitat for fish
84	Low flow	3a	Winter / Spring (Jun-Nov)	5 ML/d	Frogs	Weak	Limited interaction with frog habitats
85	Low flow	3a	Winter / Spring (Jun-Nov)	5 ML/d	Turtles	Strong	Provides habitat and refuge
86	Fresh	3a	Winter / Spring (Jun-Nov)	80 ML/d	Vegetation	Weak	In-stream – disturbance (bad). Fringing – disturbance (good) soil moisture.
87	Fresh	3a	Winter / Spring (Jun-Nov)	80 ML/d	Invertebrates	Moderate	Disturbance (bad) longer term habitat and food benefits
88	Fresh	3a	Winter / Spring (Jun-Nov)	80 ML/d	Fish	Strong	Opportunity to move important for some species. Benefits for bugs provide food in long term
89	Fresh	3a	Winter / Spring (Jun-Nov)	80 ML/d	Frogs	Weak	Unlikely to affect their habitats
90	High	3a	Winter / Spring (Jun-Nov)	500 ML/d	Vegetation	Strong	Disturbance (good) soil moisture, nutrients.
91	High	3a	Winter / Spring (Jun-Nov)	500 ML/d	Invertebrates	Moderate	Disturbance (bad) long-term improvements in habitat and food. Important for floodplain bugs
92	High	3a	Winter / Spring (Jun-Nov)	500 ML/d	Fish	Moderate	Opportunity to move, habitat and productivity improvements
93	High	3a	Winter / Spring (Jun-Nov)	500 ML/d	Frogs	Moderate	May improve habitat by extending wet phase
94	High	3a	Winter / Spring (Jun-Nov)	500 ML/d	Turtles	Strong	Provides habitat for SNT
95	Low flow	3b	Summer / Autumn (Dec-May)	20 ML/d	Vegetation	Strong	Important for instream vegetation habitat and longer-lived riparian vegetation.
96	Low flow	3b	Summer / Autumn (Dec-May)	20 ML/d	Invertebrates	Strong	Maintains habitat and food for invertebrates

ID	Component	Reach #	Timing	Magnitude	Value	Strength rating	Comment
97	Low flow	3b	Summer / Autumn (Dec-May)	20 ML/d	Fish	Strong	Maintains habitat and refuges for fish
98	Low flow	3b	Summer / Autumn (Dec-May)	20 ML/d	Turtles	Strong	Maintains habitat and refuges
99	Low flow	3b	Summer / Autumn (Dec-May)	20 ML/d	Frogs	Weak	Limited interaction with frog habitats
100	Low flow	3b	Summer / Autumn (Dec-May)	10 ML/d	Vegetation	Strong	Important for instream vegetation habitat and longer-lived riparian vegetation.
101	Low flow	3b	Summer / Autumn (Dec-May)	10 ML/d	Invertebrates	Strong	Maintains habitat and food for invertebrates
102	Low flow	3b	Summer / Autumn (Dec-May)	10 ML/d	Fish	Strong	Maintains habitat and refuges for fish
103	Low flow	3b	Summer / Autumn (Dec-May)	10 ML/d	Turtles	Strong	Maintains habitat and refuges
104	Low flow	3b	Summer / Autumn (Dec-May)	10 ML/d	Frogs	Weak	Limited interaction with frog habitats
105	Fresh	3b	Summer / Autumn (Dec-May)	60 ML/d	Vegetation	Weak	Mixed outcomes for instream vegetation, may improve soil moisture for fringing vegetation.
106	Fresh	3b	Summer / Autumn (Dec-May)	60 ML/d	Invertebrates	Moderate	Disturbance (bad) but longer-term improvements in habitat and food.
107	Fresh	3b	Summer / Autumn (Dec-May)	60 ML/d	Fish	Moderate	Improves water quality and may provide an opportunity for movement.
108	Fresh	3b	Summer / Autumn (Dec-May)	60 ML/d	Frogs	Weak	Wont influence frog habitat
109	Fresh	3b	Summer / Autumn (Dec-May)	30 ML/d	Vegetation	Weak	Mixed outcomes for instream vegetation, may improve soil moisture for fringing vegetation.
110	Fresh	3b	Summer / Autumn (Dec-May)	30 ML/d	Invertebrates	Moderate	Disturbance (bad) but longer-term improvements in habitat and food.
111	Fresh	3b	Summer / Autumn (Dec-May)	30 ML/d	Fish	Moderate	Improves water quality and may provide an opportunity for movement.
112	Fresh	3b	Summer / Autumn (Dec-May)	30 ML/d	Frogs	Weak	Wont influence frog habitat
113	Fresh	3b	Summer / Autumn (Dec-May)	60 ML/d	Vegetation	Weak	Mixed outcomes for instream vegetation, may improve soil moisture for fringing vegetation.
114	Fresh	3b	Summer / Autumn (Dec-May)	60 ML/d	Invertebrates	Moderate	Disturbance (bad) but longer-term improvements in habitat and food.
115	Fresh	3b	Summer / Autumn (Dec-May)	60 ML/d	Fish	Moderate	Improves water quality and may provide an opportunity for movement.

ID	Component	Reach #	Timing	Magnitude	Value	Strength rating	Comment
116	Fresh	3b	Summer / Autumn (Dec-May)	60 ML/d	Frogs	Weak	Wont influence frog habitat
117	Fresh	3b	Summer / Autumn (Dec-May)	30 ML/d	Vegetation	Weak	Mixed outcomes for instream vegetation, may improve soil moisture for fringing vegetation.
118	Fresh	3b	Summer / Autumn (Dec-May)	30 ML/d	Invertebrates	Moderate	Disturbance (bad) but longer-term improvements in habitat and food.
119	Fresh	3b	Summer / Autumn (Dec-May)	30 ML/d	Fish	Moderate	Improves water quality and may provide an opportunity for movement.
120	Fresh	3b	Summer / Autumn (Dec-May)	30 ML/d	Frogs	Weak	Wont influence frog habitat
121	Low flow	3b	Winter / Spring (Jun-Nov)	20 ML/d	Vegetation	Strong	Important for instream vegetation habitat and longer-lived riparian vegetation.
122	Low flow	3b	Winter / Spring (Jun-Nov)	20 ML/d	Invertebrates	Strong	Maintains habitat diversity and food for invertebrates
123	Low flow	3b	Winter / Spring (Jun-Nov)	20 ML/d	Fish	Strong	Maintains minimum habitat for fish
124	Low flow	3b	Winter / Spring (Jun-Nov)	20 ML/d	Turtles	Strong	Maintains habitat and refuge for turtles
125	Low flow	3b	Winter / Spring (Jun-Nov)	20 ML/d	Frogs	Weak	Limited interaction with frog habitats
126	Low flow	3b	Winter / Spring (Jun-Nov)	10 ML/d	Vegetation	Strong	Important for instream vegetation habitat and longer-lived riparian vegetation.
127	Low flow	3b	Winter / Spring (Jun-Nov)	10 ML/d	Invertebrates	Strong	Maintains habitat diversity and food for invertebrates
128	Low flow	3b	Winter / Spring (Jun-Nov)	10 ML/d	Fish	Strong	Maintains minimum habitat for fish
129	Low flow	3b	Winter / Spring (Jun-Nov)	10 ML/d	Turtles	Strong	Maintains habitat and refuge for turtles
130	Low flow	3b	Winter / Spring (Jun-Nov)	10 ML/d	Frogs	Weak	Limited interaction with frog habitats
131	Fresh	3b	Winter / Spring (Jun-Nov)	80 ML/d	Vegetation	Weak	In-stream – disturbance (bad). Fringing – disturbance (good) soil moisture.
132	Fresh	3b	Winter / Spring (Jun-Nov)	80 ML/d	Invertebrates	Moderate	Disturbance (bad) longer term habitat and food benefits
133	Fresh	3b	Winter / Spring (Jun-Nov)	80 ML/d	Fish	Strong	Opportunity to move important for some species. Benefits for bugs provide food in long term
134	Fresh	3b	Winter / Spring (Jun-Nov)	80 ML/d	Frogs	Weak	Unlikely to affect their habitats

ID	Component	Reach #	Timing	Magnitude	Value	Strength rating	Comment
135	Fresh	3b	Winter / Spring (Jun-Nov)	80 ML/d	Vegetation	Weak	In-stream – disturbance (bad). Fringing – disturbance (good) soil moisture.
136	Fresh	3b	Winter / Spring (Jun-Nov)	80 ML/d	Invertebrates	Moderate	Disturbance (bad) longer term habitat and food benefits
137	Fresh	3b	Winter / Spring (Jun-Nov)	80 ML/d	Fish	Strong	Opportunity to move important for some species. Benefits for bugs provide food in long term
138	Fresh	3b	Winter / Spring (Jun-Nov)	80 ML/d	Frogs	Weak	Unlikely to affect their habitats
139	High	3b	Winter / Spring (Jun-Nov)	1000 ML/d	Vegetation	Strong	Disturbance (good) soil moisture, nutrients.
140	High	3b	Winter / Spring (Jun-Nov)	1000 ML/d	Invertebrates	Moderate	Disturbance (bad) long-term improvements in habitat and food. Important for floodplain bugs
141	High	3b	Winter / Spring (Jun-Nov)	1000 ML/d	Fish	Moderate	Disturbance (bad) but opportunity to move, habitat and food benefits long term.
142	High	3b	Winter / Spring (Jun-Nov)	1000 ML/d	Frogs	Moderate	Flow may maintain habitat
143	High	3b	Winter / Spring (Jun-Nov)	1000 ML/d	Turtles	Strong	Provides lateral connectivity for SNT
144	Low flow	4	Summer / Autumn (Dec-May)	20 ML/d	Vegetation	Strong	Important for instream vegetation habitat and longer-lived riparian vegetation.
145	Low flow	4	Summer / Autumn (Dec-May)	20 ML/d	Invertebrates	Strong	Maintains habitat and food for invertebrates
146	Low flow	4	Summer / Autumn (Dec-May)	20 ML/d	Fish	Strong	Maintains habitat and refuges for fish
147	Low flow	4	Summer / Autumn (Dec-May)	20 ML/d	Turtles	Strong	Maintains habitat and refuges
148	Low flow	4	Summer / Autumn (Dec-May)	20 ML/d	Frogs	Weak	Limited interaction with frog habitats
149	Low flow	4	Summer / Autumn (Dec-May)	10 ML/d	Vegetation	Strong	Important for instream vegetation habitat and longer-lived riparian vegetation.
150	Low flow	4	Summer / Autumn (Dec-May)	10 ML/d	Invertebrates	Strong	Maintains habitat and food for invertebrates
151	Low flow	4	Summer / Autumn (Dec-May)	10 ML/d	Fish	Strong	Maintains habitat and refuges for fish
152	Low flow	4	Summer / Autumn (Dec-May)	10 ML/d	Turtles	Strong	Maintains habitat and refuges
153	Low flow	4	Summer / Autumn (Dec-May)	10 ML/d	Frogs	Weak	Limited interaction with frog habitats

ID	Component	Reach #	Timing	Magnitude	Value	Strength rating	Comment
154	Fresh	4	Summer / Autumn (Dec-May)	60 ML/d	Vegetation	Moderate	Fringing: Disturbance (good), increase in soil moisture
155	Fresh	4	Summer / Autumn (Dec-May)	60 ML/d	Invertebrates	Moderate	Disturbance (bad), longer term improvements in habitat and food
156	Fresh	4	Summer / Autumn (Dec-May)	60 ML/d	Fish	Moderate	Opportunity to move, improvements in habitat and food
157	Fresh	4	Summer / Autumn (Dec-May)	60 ML/d	Frogs	Weak	Limited influence on habitat
158	Fresh	4	Summer / Autumn (Dec-May)	30 ML/d	Vegetation	Moderate	Fringing: Disturbance (good), increase in soil moisture
159	Fresh	4	Summer / Autumn (Dec-May)	30 ML/d	Invertebrates	Moderate	Disturbance (bad), longer term improvements in habitat and food
160	Fresh	4	Summer / Autumn (Dec-May)	30 ML/d	Fish	Moderate	Opportunity to move, improvements in habitat and food
161	Fresh	4	Summer / Autumn (Dec-May)	30 ML/d	Frogs	Weak	Limited influence on habitat
162	Fresh	4	Summer / Autumn (Dec-May)	60 ML/d	Vegetation	Moderate	Fringing: Disturbance (good), increase in soil moisture
163	Fresh	4	Summer / Autumn (Dec-May)	60 ML/d	Invertebrates	Moderate	Disturbance (bad), longer term improvements in habitat and food
164	Fresh	4	Summer / Autumn (Dec-May)	60 ML/d	Fish	Moderate	Opportunity to move, improvements in habitat and food
165	Fresh	4	Summer / Autumn (Dec-May)	60 ML/d	Frogs	Weak	Limited influence on habitat
166	Fresh	4	Summer / Autumn (Dec-May)	20 ML/d	Vegetation	Moderate	Fringing: Disturbance (good), increase in soil moisture
167	Fresh	4	Summer / Autumn (Dec-May)	20 ML/d	Invertebrates	Strong	Refreshes pools and water quality
168	Fresh	4	Summer / Autumn (Dec-May)	20 ML/d	Fish	Strong	Opportunity to move and improvements in water quality
169	Fresh	4	Summer / Autumn (Dec-May)	20 ML/d	Frogs	Moderate	May benefit habitat
170	Low flow	4	Winter / Spring (Jun-Nov)	20 ML/d	Vegetation	Strong	Important for instream vegetation habitat and longer-lived riparian vegetation.
171	Low flow	4	Winter / Spring (Jun-Nov)	20 ML/d	Invertebrates	Strong	Maintains habitat and food for invertebrates
172	Low flow	4	Winter / Spring (Jun-Nov)	20 ML/d	Fish	Strong	Maintains habitat and refuges for fish

ID	Component	Reach #	Timing	Magnitude	Value	Strength rating	Comment
173	Low flow	4	Winter / Spring (Jun-Nov)	20 ML/d	Turtles	Strong	Maintains habitat and refuges
174	Low flow	4	Winter / Spring (Jun-Nov)	20 ML/d	Frogs	Weak	Limited interaction with frog habitats
175	Low flow	4	Winter / Spring (Jun-Nov)	10 ML/d	Vegetation	Strong	Important for instream vegetation habitat and longer-lived riparian vegetation.
176	Low flow	4	Winter / Spring (Jun-Nov)	10 ML/d	Invertebrates	Strong	Maintains habitat and food for invertebrates
177	Low flow	4	Winter / Spring (Jun-Nov)	10 ML/d	Fish	Strong	Maintains habitat and refuges for fish
178	Low flow	4	Winter / Spring (Jun-Nov)	10 ML/d	Turtles	Strong	Maintains habitat and refuges
179	Low flow	4	Winter / Spring (Jun-Nov)	10 ML/d	Frogs	Weak	Limited interaction with frog habitats
180	Fresh	4	Winter / Spring (Jun-Nov)	80 ML/d	Vegetation	Strong	Disturbance (good) soil moisture, nutrients.
181	Fresh	4	Winter / Spring (Jun-Nov)	80 ML/d	Invertebrates	Moderate	Disturbance (bad) long-term improvements in habitat and food. Important for floodplain bugs
182	Fresh	4	Winter / Spring (Jun-Nov)	80 ML/d	Fish	Moderate	Disturbance (bad) but opportunity to move, habitat and food benefits long term.
183	Fresh	4	Winter / Spring (Jun-Nov)	80 ML/d	Frogs	Moderate	Flow may maintain habitat
184	Fresh	4	Winter / Spring (Jun-Nov)	80 ML/d	Turtles	Strong	Provides lateral connectivity for SNT
185	Fresh	4	Winter / Spring (Jun-Nov)	80 ML/d	Vegetation	Strong	Disturbance (good) soil moisture, nutrients.
186	Fresh	4	Winter / Spring (Jun-Nov)	80 ML/d	Invertebrates	Moderate	Disturbance (bad) long-term improvements in habitat and food. Important for floodplain bugs
187	Fresh	4	Winter / Spring (Jun-Nov)	80 ML/d	Fish	Moderate	Disturbance (bad) but opportunity to move, habitat and food benefits long term.
188	Fresh	4	Winter / Spring (Jun-Nov)	80 ML/d	Frogs	Moderate	Flow may maintain habitat
189	Fresh	4	Winter / Spring (Jun-Nov)	80 ML/d	Turtles	Strong	Provides lateral connectivity for SNT
190	High	4	Winter / Spring (Jun-Nov)	3000 ML/d	Vegetation	Strong	Disturbance (good) soil moisture, nutrients.
191	High	4	Winter / Spring (Jun-Nov)	3000 ML/d	Invertebrates	Moderate	Disturbance (bad) long-term improvements in habitat and food. Important for floodplain bugs

ID	Component	Reach #	Timing	Magnitude	Value	Strength rating	Comment
192	High	4	Winter / Spring (Jun-Nov)	3000 ML/d	Fish	Moderate	Disturbance (bad) but opportunity to move, habitat and food benefits long term.
193	High	4	Winter / Spring (Jun-Nov)	3000 ML/d	Frogs	Moderate	Flow may maintain habitat
194	High	4	Winter / Spring (Jun-Nov)	3000 ML/d	Turtles	Strong	Provides lateral connectivity for SNT

Table 35 *Maribyrnong strength table*

ID	Location	Component	Reach #	Timing	Magnitude	Value	Strength rating	Comment
1	Jacksons Creek	Low flows	6	Dec-May	4 ML/d	Invertebrates	Strong	Important to sustain range of habitats, including riffle-runs
2	Jacksons Creek	Low flows	6	Dec-May	4 ML/d	Fish	Strong	Important to maintain water quality over summer-autumn
3	Jacksons Creek	Low flows	6	Jun-Nov	20 ML/d	Invertebrates	Weak	Emulating increased flows in late winter spring, benefit would depend on change in habitat between 2 and 10 ML/d.
4	Jacksons Creek	Low flows	6	Jun-Nov	20 ML/d	Fish	Moderate	Increased low flows through winter-spring will improve condition of fish, but represents an opportunity cost.
5	Jacksons Creek	Low flows	7	Dec-May	8 ML/d	Invertebrates	Strong	Important to sustain range of habitats, including riffle-runs
6	Jacksons Creek	Low flows	7	Dec-May	8 ML/d	Fish	Strong	Important to maintain water quality over summer-autumn

ID	Location	Component	Reach #	Timing	Magnitude	Value	Strength rating	Comment
7	Jacksons Creek	Low flows	7	Jun-Nov	40 ML/d	Invertebrates	Weak	Emulating increased flows in late winter spring, benefit would depend on change in habitat between 2 and 10 ML/d.
8	Jacksons Creek	Low flows	7	Jun-Nov	40 ML/d	Fish	Weak	Increased low flows through winter-spring will improve condition of fish, but represents an opportunity cost.
9	Jacksons Creek	Freshes	6	Dec – May	20 ML/d	Vegetation	Moderate	Increase in soil moisture.
10	Jacksons Creek	Freshes	6	Dec – May	20 ML/d	Invertebrates	Moderate	Disturbance, but will improve habitat
11	Jacksons Creek	Freshes	6	Dec – May	20 ML/d	Fish	Moderate	Provide opportunity for fish to move among pools.
12	Jacksons Creek	Freshes	6	Jun – Nov	215 ML/d	Vegetation	Moderate	Disturbance, increase in soil moisture and provision of nutrients
13	Jacksons Creek	Freshes	6	Jun – Nov	215 ML/d	Invertebrates	Moderate	Disturbance but habitat and possible food improvements afterward
14	Jacksons Creek	Freshes	6	Jun – Nov	215 ML/d	Fish	Weak	Would support movements of Mudfish, lamprey and spawning of galaxias, but not sure if relevant to this reach.
15	Jacksons Creek	Freshes	6	Jun – Nov	215 ML/d	Frog	Weak	Inundation of riparian vegetation may replenish moist habitat for toadlets.
16	Jacksons Creek	Freshes	6	Jun – Nov	350 ML/d	Vegetation	Moderate	Disturbance (good), increase in soil moisture and provision of nutrients

ID	Location	Component	Reach #	Timing	Magnitude	Value	Strength rating	Comment
17	Jacksons Creek	Freshes	6	Jun – Nov	350 ML/d	Invertebrates	Moderate	Disturbance but habitat improvements afterward
18	Jacksons Creek	Freshes	6	Jun – Nov	350 ML/d	Fish	Weak	Disturbance (bad) likely to dominate outcome. Particularly important for Pygmy perch that rely on vegetation which is susceptible to scour.
19	Jacksons Creek	Freshes	6	Jun – Nov	350 ML/d	Frog	Weak	Inundation of riparian vegetation may replenish moist habitat for toadlets.
20	Jacksons Creek	Freshes	7	Dec – May	40 ML/d	Vegetation	Moderate	Most riparian plants resistant to short inundation. Increase in soil moisture. Disturbance (good), but will improve habitat
21	Jacksons Creek	Freshes	7	Dec – May	40 ML/d	Invertebrates	Moderate	Disturbance (bad) initially but will improve habitat and possibly food.
22	Jacksons Creek	Freshes	7	Dec – May	40 ML/d	Fish	Weak	Improvements in habitat and food. Pygmy perch may be affected by changes in aquatic vegetation which is susceptible to scour.
23	Jacksons Creek	Freshes	7	Jun – Nov	400 ML/d	Vegetation	Moderate	Disturbance (good), increase in soil moisture and provision of nutrients
24	Jacksons Creek	Freshes	7	Jun – Nov	400 ML/d	Invertebrates	Moderate	Disturbance (bad) but habitat and productivity improvements afterward
25	Jacksons Creek	Freshes	7	Jun – Nov	400 ML/d	Fish	Weak	Opportunity to move and potential increases in productivity..

ID	Location	Component	Reach #	Timing	Magnitude	Value	Strength rating	Comment
26	Jacksons Creek	Freshes	7	Jun – Nov	400 ML/d	Frog	Moderate	Inundation of riparian vegetation likely to replenish moist habitat for toadlets. Possible inundation of GGF habitat to sustain permanent water.
27	Jacksons Creek	1000	7	Anytime	1,000 ML/d	Vegetation	Strong	Disturbance (good), increase in soil moisture and provision of nutrients.
28	Jacksons Creek	1000	7	Anytime	1,000 ML/d	Invertebrates	Moderate	Channel forming flows will influence subsequent habitat availability. Riparian/floodplain habitat refresh.
29	Jacksons Creek	1000	7	Anytime	1,000 ML/d	Fish	Weak	Habitat and productivity improvements afterward. Opportunity to move.
30	Jacksons Creek	1000	7	Anytime	1,000 ML/d	Frog	Moderate	Inundation of riparian vegetation may replenish moist habitat for toadlets. Possible inundation of GGF habitat to sustain permanent water.
31	Jacksons Creek	2000	7	Anytime	2,000 ML/d	Vegetation	Strong	Disturbance (good), increase in soil moisture and provision of nutrients.
32	Jacksons Creek	2000	7	Anytime	2,000 ML/d	Invertebrates	Moderate	Channel forming flows will influence subsequent habitat availability. Riparian/floodplain habitat refresh.
33	Jacksons Creek	2000	7	Anytime	2,000 ML/d	Fish	Weak	Habitat and productivity improvements afterward.
34	Jacksons Creek	2000	7	Anytime	2,000 ML/d	Frog	Moderate	Inundation of riparian vegetation may replenish moist habitat for toadlets. Possible inundation of GGF habitat to sustain permanent water.

ID	Location	Component	Reach #	Timing	Magnitude	Value	Strength rating	Comment
35	Deep Creek	Low flows	1	Dec-May	2 ML/d	Invertebrates	Strong	Important to sustain range of habitats, including riffle-runs
36	Deep Creek	Low flows	1	Dec-May	2 ML/d	Fish	Strong	Important to maintain water quality over summer-autumn
37	Deep Creek	Low flows	2	Dec-May	3 ML/d	Invertebrates	Strong	Important to sustain range of habitats, including riffle-runs
38	Deep Creek	Low flows	2	Dec-May	3 ML/d	Fish	Strong	Important to maintain water quality over summer-autumn.
39	Deep Creek	Low flows	4	Dec-May	6 ML/d	Invertebrates	Strong	Important to sustain range of habitats, including riffle-runs
40	Deep Creek	Low flows	4	Dec-May	6 ML/d	Fish	Strong	Important to maintain water quality over summer-autumn.
41	Deep Creek	Low flows	1	Jun-Nov	20 ML/d	Invertebrates	Moderate	Emulating higher flows in late winter-spring, benefit would depend on change in habitat between 2 and 10 ML/d.
42	Deep Creek	Low flows	1	Jun-Nov	20 ML/d	Fish	Moderate	Additional habitat will provide additional resources for fish, but represents an opportunity cost for fresh and high flows
43	Deep Creek	Low flows	2	Jun-Nov	17 ML/d	Invertebrates	Moderate	Emulating higher flows in late winter-spring. Extra habitat and resources for bugs.
44	Deep Creek	Low flows	2	Jun-Nov	17 ML/d	Fish	Moderate	Disturbance (bad), with additional habitat will provide additional resources for fish, but represents an opportunity cost for fresh and high flows

ID	Location	Component	Reach #	Timing	Magnitude	Value	Strength rating	Comment
45	Deep Creek	Low flows	4	Jun-Nov	25 ML/d	Invertebrates	Moderate	Emulating higher flows in late winter-spring. Extra habitat and resources for bugs.
46	Deep Creek	Low flows	4	Jun-Nov	25 ML/d	Fish	Moderate	Additional habitat will provide additional resources for fish, but represents an opportunity cost for fresh and high flows
47	Deep Creek	Freshes	1	Dec- May	50 ML/d	Vegetation	Weak	Disturbance (good) increase in soil moisture for littoral and aquatic plants.
48	Deep Creek	Freshes	1	Dec- May	50 ML/d	Invertebrates	Moderate	Disturbance (bad), but will improve water quality and habitat
49	Deep Creek	Freshes	1	Dec- May	50 ML/d	Fish	Moderate	Disturbance (bad).
50	Deep Creek	Freshes	2	Dec- May	17 ML/d	Vegetation	Weak	Disturbance (good), increase in soil moisture.
51	Deep Creek	Freshes	2	Dec- May	17 ML/d	Invertebrates	Moderate	Disturbance (Bad), but will improve water quality and habitat
52	Deep Creek	Freshes	2	Dec- May	17 ML/d	Fish	Weak	Disturbance (Bad), but possible opportunity to move.
53	Deep Creek	Freshes	4	Dec- May	100 ML/d	Vegetation	Weak	Disturbance (good), soil moisture.
54	Deep Creek	Freshes	4	Dec- May	100 ML/d	Invertebrates	Moderate	Disturbance (bad), but will improve water quality, habitat and food.
55	Deep Creek	Freshes	4	Dec- May	100 ML/d	Fish	Moderate	Disturbance (bad), but opportunity to move and longer term habitat improvement.
56	Deep Creek	Freshes	1	Jun - Nov	150 ML/d	Vegetation	Moderate	Disturbance (good), increase in soil moisture and provision of nutrients

ID	Location	Component	Reach #	Timing	Magnitude	Value	Strength rating	Comment
57	Deep Creek	Freshes	1	Jun - Nov	150 ML/d	Invertebrates	Moderate	Disturbance but improved habitat and food afterward
58	Deep Creek	Freshes	1	Jun - Nov	150 ML/d	Fish	Moderate	Disturbance (bad) likely to dominate outcome. May represent an opportunity to move but difficult given river style.
59	Deep Creek	Freshes	1	Jun - Nov	150 ML/d	Frog	Weak	Inundation of riparian vegetation likely to replenish moist habitat for toadlets.
60	Deep Creek	Freshes	2	Jun - Nov	175 ML/d	Vegetation	Moderate	Disturbance (good), increase in soil moisture and provision of nutrients
61	Deep Creek	Freshes	2	Jun - Nov	175 ML/d	Invertebrates	Moderate	Disturbance (bad) but improved habitat and food afterward
62	Deep Creek	Freshes	2	Jun - Nov	175 ML/d	Fish	Moderate	Disturbance (bad) but likely improved habitat and food afterward. Potentially an opportunity to move, but challenging in confined channel.
63	Deep Creek	Freshes	2	Jun - Nov	175 ML/d	Frog	Weak	Inundation of riparian vegetation may replenish moist habitat for toadlets.
64	Deep Creek	Freshes	4	Jun - Nov	250 ML/d	Vegetation	Moderate	Disturbance (good), increase in soil moisture and provision of nutrients
65	Deep Creek	Freshes	4	Jun - Nov	250 ML/d	Invertebrates	Moderate	Disturbance (bad) but likely improved habitat and food afterward
66	Deep Creek	Freshes	4	Jun - Nov	250 ML/d	Fish	Weak	Disturbance (bad) but likely improved habitat and food afterward. Impacts on aquatic vegetation will influence habitat for Pygmy perch. Possible

ID	Location	Component	Reach #	Timing	Magnitude	Value	Strength rating	Comment
								opportunity to move, but tricky given confined channel
67	Deep Creek	Freshes	4	Jun - Nov	250 ML/d	Frog	Weak	Inundation of riparian vegetation may replenish moist habitat for toadlets.
68	Deep Creek	High flows	1	Anytime	1,000 ML/d	Vegetation	Strong	Disturbance (good). Increase in soil moisture and provision of nutrients.
69	Deep Creek	High flows	1	Anytime	1,000 ML/d	Invertebrates	Moderate	Disturbance (bad), but channel forming flows will influence subsequent habitat availability. Riparian/floodplain habitat refresh.
70	Deep Creek	High flows	1	Anytime	1,000 ML/d	Fish	Weak	Disturbance (bad) but habitat and productivity improvements afterward
71	Deep Creek	High flows	1	Anytime	1,000 ML/d	Frog	Moderate	Inundation of riparian vegetation likely to replenish moist habitat for toadlets. Possible inundation of GGF habitat to sustain permanent water.
72	Deep Creek	High flows	2	Anytime	500 ML/d	Vegetation	Strong	Disturbance (good), increase in soil moisture and provision of nutrients.
73	Deep Creek	High flows	2	Anytime	500 ML/d	Invertebrates	Moderate	Disturbance (bad), channel forming flows will influence subsequent habitat availability. Riparian/floodplain habitat refresh.
74	Deep Creek	High flows	2	Anytime	500 ML/d	Fish	Weak	Disturbance (bad) but habitat and productivity improvements afterward

ID	Location	Component	Reach #	Timing	Magnitude	Value	Strength rating	Comment
75	Deep Creek	High flows	2	Anytime	500 ML/d	Frog	Moderate	Inundation of riparian vegetation likely to replenish moist habitat for toadlets. Possible inundation of GGF habitat to sustain permanent water.
76	Deep Creek	High flows	4	Anytime	2,000 ML/d	Vegetation	Strong	Increase in soil moisture and provision of nutrients.
77	Deep Creek	High flows	4	Anytime	2,000 ML/d	Invertebrates	Moderate	Channel forming flows will influence subsequent habitat availability. Riparian/floodplain habitat refresh.
78	Deep Creek	High flows	4	Anytime	2,000 ML/d	Fish	Weak	Disturbance (bad) but habitat and productivity improvements afterward. Potential for fish to move.
79	Deep Creek	High flows	4	Anytime	2,000 ML/d	Frog	Moderate	Inundation of riparian vegetation may replenish moist habitat for toadlets. Possible inundation of GGF habitat to sustain permanent water.
80	Emu Creek	Low flows	3	Dec-May	6 ML/d	Invertebrates	Strong	Important to sustain range of habitats, including riffle-runs
81	Emu Creek	Low flows	3	Dec-May	6 ML/d	Fish	Strong	Important to maintain water quality over summer-autumn
82	Emu Creek	Low flows	3	Jun-Nov	14 ML/d	Invertebrates	Weak	Emulating increased flows in late winter spring, benefit would depend on change in habitat between 6 and 14 ML/d.
83	Emu Creek	Low flows	3	Jun-Nov	14 ML/d	Fish	Moderate	Increased low flows through winter-spring will improve condition of fish, but represents an opportunity cost.
84	Emu Creek	Freshes	3	Dec-May	14 ML/d	Invertebrates	Strong	Disturbance (bad), but subsequent improvements in habitat and food

ID	Location	Component	Reach #	Timing	Magnitude	Value	Strength rating	Comment
85	Emu Creek	Freshes	3	Dec-May	14 ML/d	Fish	Strong	Important to maintain water quality and replenish pools over summer-autumn
86	Emu Creek	Freshes	3	Jun – Nov	100 ML/d	Vegetation	Moderate	Disturbance (good) and increase in soil moisture for riparian plants
87	Emu Creek	Freshes	3	Jun – Nov	100 ML/d	Invertebrates	Weak	Disturbance (bad) with subsequent improvements in habitat and productivity.
88	Emu Creek	Freshes	3	Jun – Nov	100 ML/d	Fish	Moderate	Disturbance (bad) but also an opportunity to move.
89	Emu Creek	High flows	3	Anytime	1,000 ML/d	Vegetation	Moderate	Disturbance (good) with an increase in soil moisture and nutrient delivery.
90	Emu Creek	High flows	3	Anytime	1,000 ML/d	Invertebrates	Moderate	Disturbance (Bad) but will improve habitat and food.
91	Emu Creek	High flows	3	Anytime	1,000 ML/d	Fish	Strong	Disturbance but also an opportunity to disperse. Important for catadromous / amphidromous fish (maybe not relevant in this reach)
92	Riddells Creek	Low flows	5	Dec-May	2 ML/d	Invertebrates	Strong	Important to sustain range of habitats, including riffle-runs
93	Riddells Creek	Low flows	5	Dec-May	2 ML/d	Fish	Strong	Important to maintain water quality over summer-autumn
94	Riddells Creek	Low flows	5	Jun-Nov	10 ML/d	Invertebrates	Weak	Emulating increased flows in late winter spring, benefit would depend on change in habitat between 2 and 10 ML/d.
95	Riddells Creek	Low flows	5	Jun-Nov	10 ML/d	Fish	Weak	Increased low flows through winter-spring will improve condition of fish, but represents an opportunity cost.

ID	Location	Component	Reach #	Timing	Magnitude	Value	Strength rating	Comment
96	Riddells Creek	Freshes	5	Dec - May	20 ML/d	Invertebrates	**Strong**	Initial disturbance, but overall improvements in habitat
97	Riddells Creek	Freshes	5	Dec - May	20 ML/d	Fish	**Strong**	Important to maintain water quality over summer-autumn
98	Riddells Creek	Freshes	5	Jun - Nov	50 ML/d	Vegetation	**Moderate**	Increase in soil moisture for riparian plants
99	Riddells Creek	Freshes	5	Jun - Nov	50 ML/d	Invertebrates	**Weak**	Variable responses due to mix of disturbance, habitat and productivity changes.
100	Riddells Creek	Freshes	5	Jun - Nov	50 ML/d	Fish	**Weak**	Disturbance but also an opportunity to disperse.
101	Riddells Creek	High flows	5	Anytime	400 ML/d	Vegetation	**Strong**	Increase in soil moisture.
102	Riddells Creek	High flows	5	Anytime	400 ML/d	Invertebrates	**Moderate**	Disturbance, but will improve habitat and productivity
103	Riddells Creek	High flows	5	Anytime	400 ML/d	Fish	**Moderate**	Increases in available habitat and productivity.

Attachment 6 – Environmental flow compliance results

Compliance approach

The following graphs illustrate the degree of compliance with the flow recommendations over time for a specific river, reach and scenario. The x-axis represents years, displayed at ten-year intervals, while the y-axis represents the cumulative number of flow recommendations that could potentially be satisfied, ranging from zero to the total number of flow recommendations. Compliance for each flow recommendation is expressed as a proportion between 0 and 1, where a value of 1 corresponds to full compliance. For example, 78% compliance is represented as 0.78. The stacked bars display the contribution of individual flow recommendations to overall compliance each year, with each colour corresponding to a set of rules.

The combined height of the stacked segments indicates the extent to which the flow recommendations are met each year. Taller bars therefore reflect higher overall compliance across rules, while shorter bars indicate lower compliance. Examination of bar height and composition over time allows for the identification of temporal trends, as well as the relative contribution of individual components.

Note: Climate condition scores were applied during analysis and the results aggregated for the creation of these graphs. This means that a flow occurring in a dry year would be measured for duration rather than in an average or wet year. For example, in the Maribyrnong River Reach 6 the recommendation duration for a 215 ML/day winter fresh in an average or wet year is three days, while in dry year the recommended duration is two days.

Summary of compliance results

Overall, periods of higher bar heights correspond to wetter years when more of the flow recommendations were achieved. Conversely, shorter bars indicate drier years with limited flow events and reduced compliance with events require to support ecological objectives.

Maribyrnong

Reach 1

Fresh compliance fluctuates across the analysis period with reductions during dry seasons and declines in compliance evident in some scenarios. High flow compliance remained comparatively stable across scenarios. Winter low-flow compliance is high; however, several scenarios introduce or prolong periods of reduced or intermittent compliance. Summer low-flow has lower compliance overall and is more variable with stretches where this flow is absent.

Reach 2

Fresh compliance is stronger in Summer than Winter (noting threshold volumes) with clear reduction in fresh flows during dry periods and for some scenarios. High-flow compliance has strong presence in wetter years and is absent during dry years, some scenarios extend the periods of reduced performance. Winter low-flow compliance is moderate to high, though some scenarios introduce more frequent low or unmet years. Summer low-flow compliance is more variable with stretches of low or absent compliance. Several periods show only partial compliance with one or both low-flow thresholds.

Reach 3

Fresh compliance cycles between periods of reduced and improved performance, with some scenarios contributing additional or extended low compliance periods. High-flow compliance is relatively stable, except for the 2025LOD Medium climate change scenario where compliance is reduced. Winter low-flow compliance is moderately variable, with high compliance during wet periods and reduced compliance during dry years. Summer low-flow compliance varies year to year, with several stretches where compliance is very low or absent. In this reach, there are several sequences of 2-3 years with very limited compliance.

Reach 4

Fresh compliance varies through time, with distinct dry-period reductions and declines in 2010LOD scenario. High-flow compliance occurred consistently in wet periods of most scenarios and is reduced substantially in the 2010LOD scenario. Winter low-flow compliance is high to moderate in wet years and low during dry years.

Summer low-flow compliance is more variable and includes multiple periods of reduced or limited performance. Especially in LOD2010, low flows are sometimes all that is partially compliant, and, in a few years, there is an absence of compliance.

Reach 5

Compliance in Reach 5 varies in multi-year cycles with clearer low compliance periods interspersed between periods of high compliance compared. Fresh compliance is stronger in Summer than Winter in several years with the scenarios showing clear reductions. High-flow compliance is more stable with decreases in dry periods and some extension of absence periods. Winter low-flow varies moderately and has extended periods of lowered compliance across in some scenarios. Summer low-flow compliance is more variable and frequently lower, with some scenarios also having lower performance.

Reach 6

Fresh and high-flow compliance is notably sparse in Reach 6 with some scenario related decline. Winter low-flow has consistent moderate-high compliance in most years. There are fewer years with very or absent low low-flow compliance compared to some reaches. Summer low-flow compliance is generally low with multiple stretches of low or unmet compliance.

Reach 7

Fresh compliance has strong temporal variation, with reduced performance in dry periods and further declines in some scenarios. High-flow compliance remains comparatively stable, though some periods show modest reductions for some scenarios. Winter low-flow compliance varies across the record and includes notable periods of reduced performance. Summer low-flow compliance varies between moderately compliant and limited compliance in some years. There are some years where only low flows occur to an extent.

Moorabool

The series of graphs for the Moorabool River show how compliance with flow recommendations varies over time for each reach and scenario. The height and composition of the stacked bars fluctuates from year to year, reflecting hydrological variability as well as the influence of climatic conditions on the flow thresholds. For example, many flow recommendations also have lower thresholds in dry years (e.g. 10 ML/day) and higher thresholds in wet years (e.g. 20 ML/day), meaning that apparent changes in compliance can result from both flow magnitude and varying thresholds applied.

Reach 1

Fresh in Summer compliance is absent for most of the scenarios. Autumn and winter fresh compliance fluctuates across the record, with dry sequences and scenarios showing clear reductions. High-flow compliance remains comparatively stable with only minor variation. Winter low-flow compliance is generally low to moderate, though several scenarios introduce prolonged lower or absent periods. Summer low-flow compliance is more variable and includes extended intervals of where only these flows are occurring.

Reach 2

Fresh compliance shows multi-year cycles of reduction and higher flows, with scenarios intensifying the lower periods. High-flow compliance remains comparatively stable across scenarios with most years receiving this flow. Winter low-flow compliance has moderate-high flow compliance in most years, with the lower threshold being met in drier years. Summer low-flow compliance is more variable, with frequent stretches of reduced or unmet performance, scenario effects intensify the reductions.

Reach 3a

April to May fresh flows were consistently compliant, being absent in dry years. The other timed fresh flows are more variable with multi-year cycles of reduced and improved compliance, and scenarios contributing additional low compliance. High-flow compliance occurs during wetter periods and is absent during dry periods. Winter and Summer low-flow compliance is moderate to high in most years, with the lower flow threshold met or partly met during drier years.

Reach 3b

Fresh compliance fluctuates substantially, with reductions aligned with dry periods and further decreases with some scenarios. High-flow compliance in winter remains relatively stable but includes intervals of reduced performance under some scenarios. Winter low-flow compliance shows moderate variation, while summer low-flow compliance is noticeably lower and more variable, scenario sequences add further reductions across low-flow components.

Reach 4

Fresh compliance across multiple thresholds were rather variable with dry periods and scenarios contributing to reductions. High-flow compliance is moderately to highly compliant in about half of years and displays minor declines in some scenarios. Winter low-flow compliance has moderate variability and includes extended lower compliance periods. Summer low-flow compliance is often more compliant. Low flows have some years with very low compliance and were lower in some scenarios.

Compliance graphs

Maribyrnong

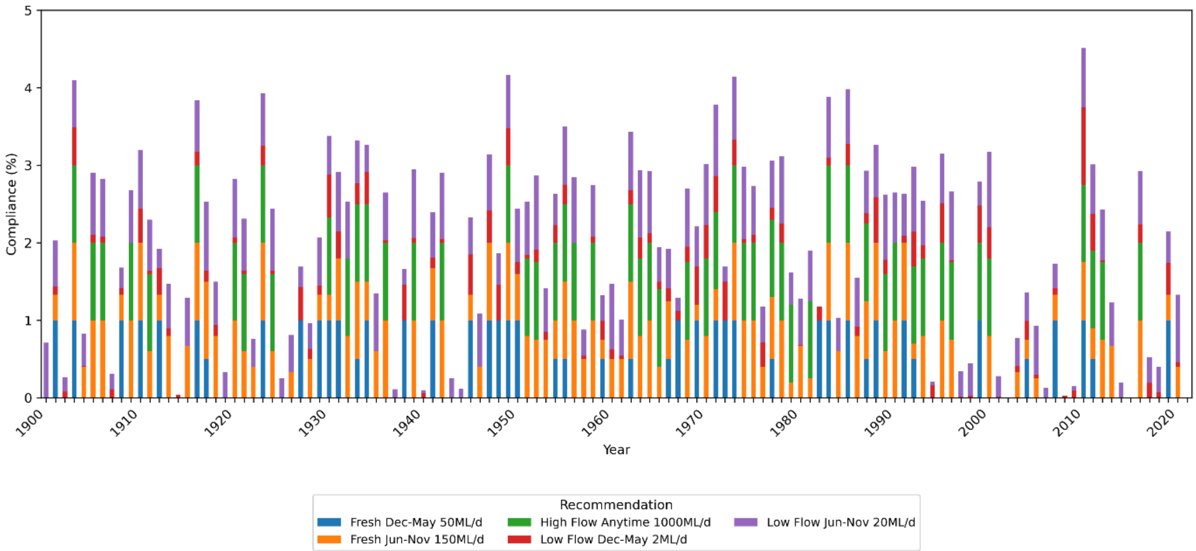


Figure 24 *Compliance for Maribyrnong Reach 1, 2010 Level of Development with Historical climate*

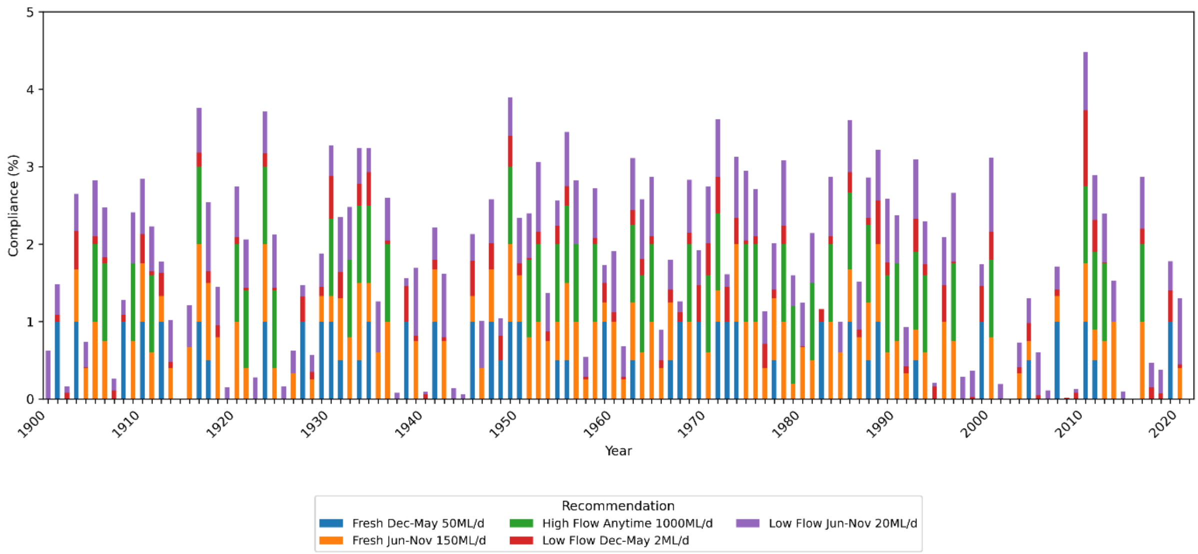


Figure 25 *Compliance for Maribyrnong Reach 1, 2025 Level of Development with Medium climate*

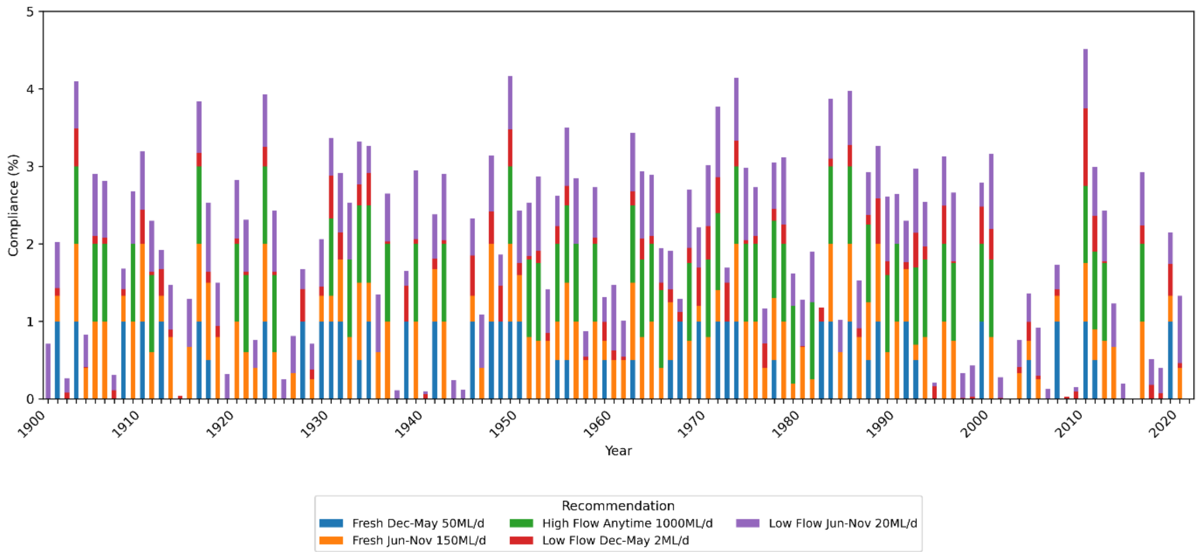


Figure 26 *Compliance for Maribyrnong Reach 1, 2025 Level of Development with Historical climate*

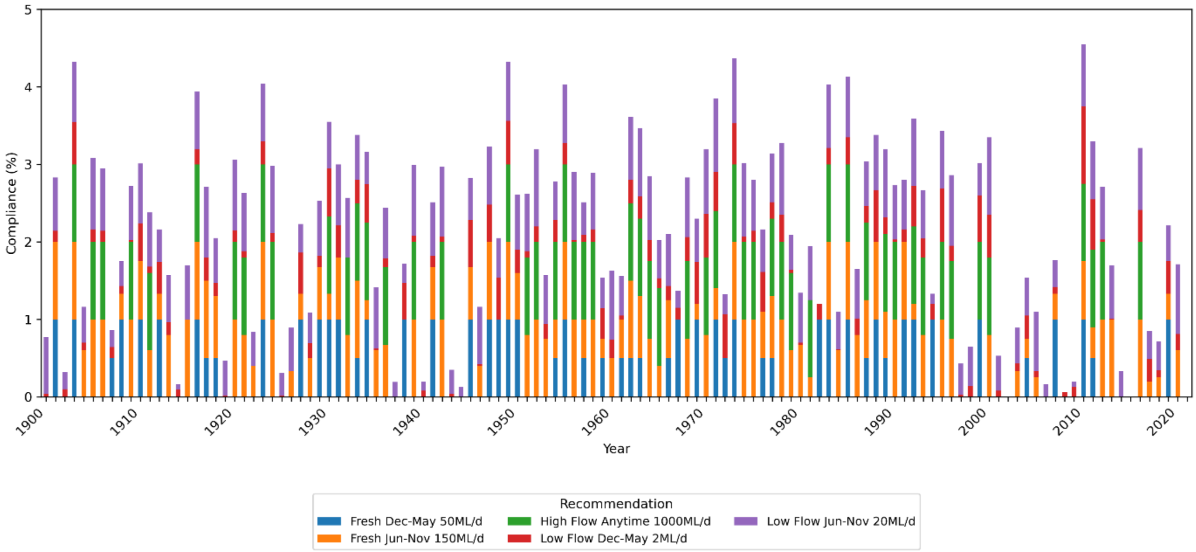


Figure 27 *Compliance for Maribyrnong Reach 1, Unimpacted Level of Development with Historical climate*

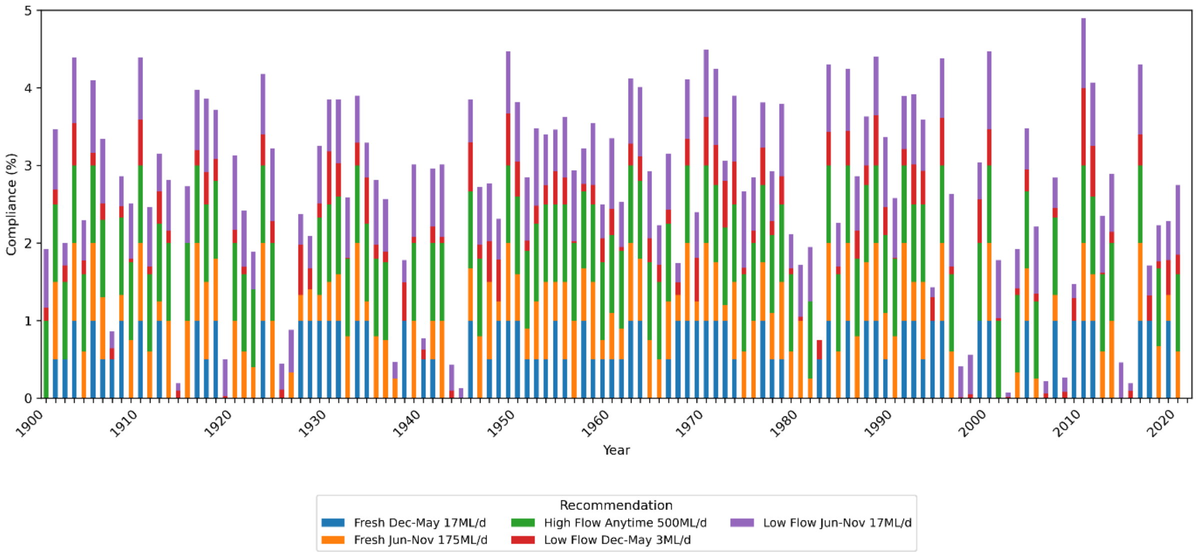


Figure 28 *Compliance for Maribyrnong Reach 2, 2010 Level of Development with Historical climate*

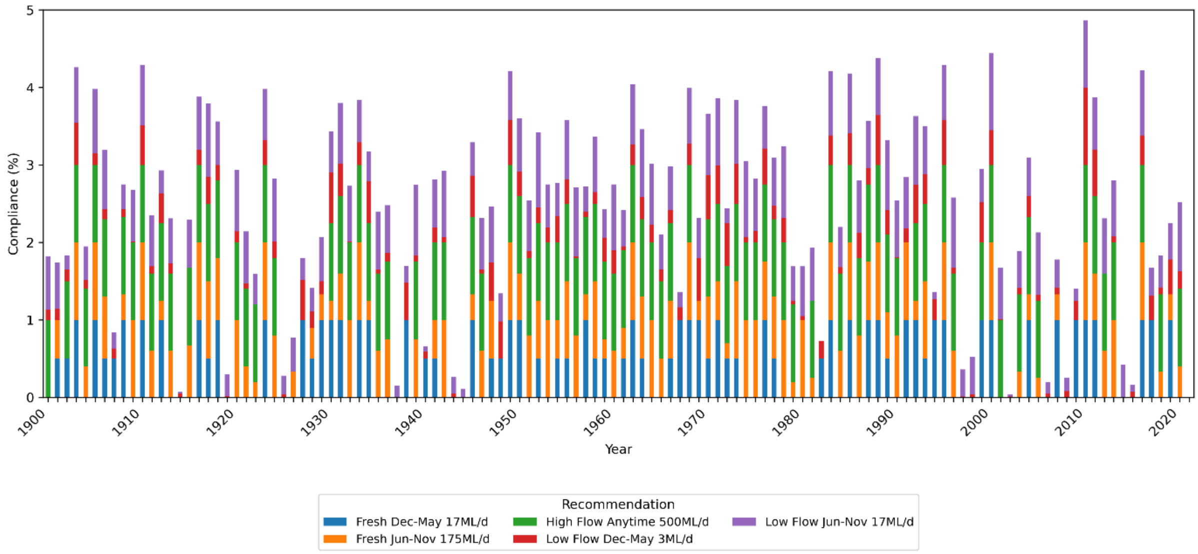


Figure 29 *Compliance for Maribyrnong Reach 2, 2025 Level of Development with Medium climate*

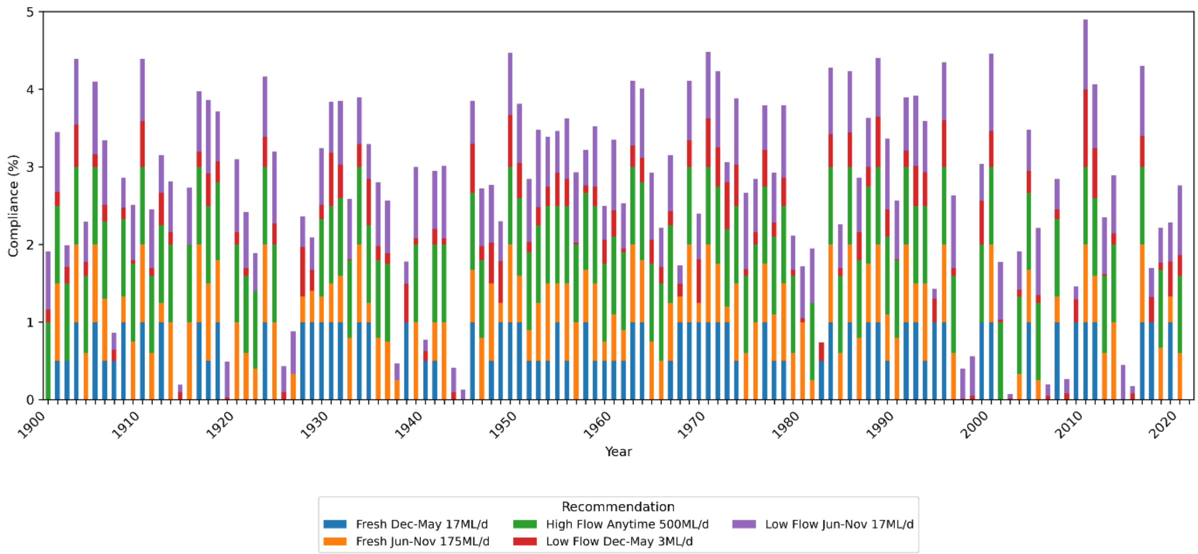


Figure 30 *Compliance for Maribyrnong Reach 2, 2025 Level of Development with Historical climate*

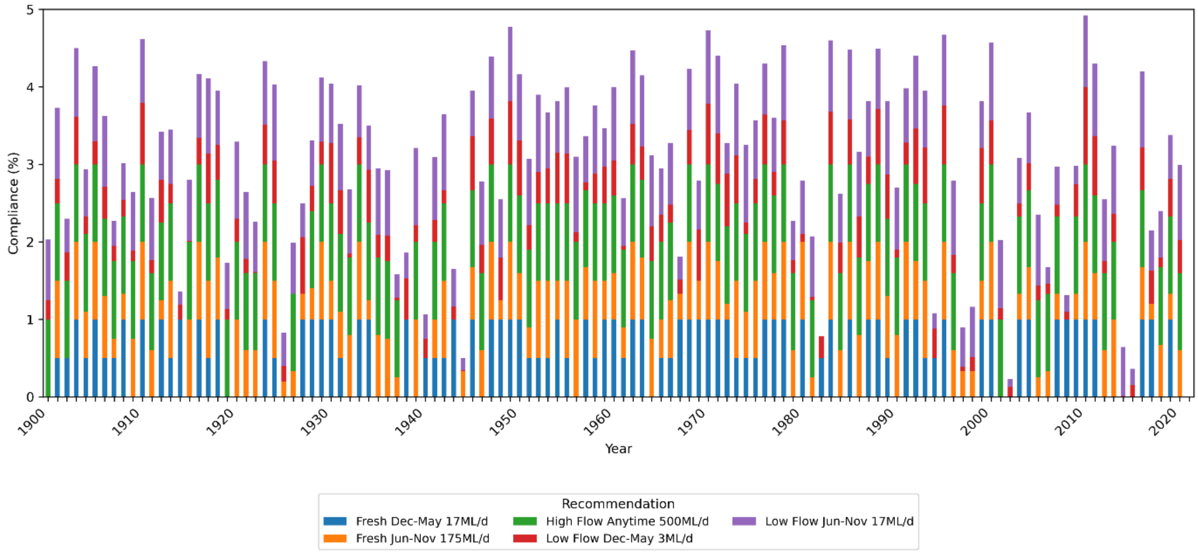


Figure 31 *Compliance for Maribyrnong Reach 2, Unimpacted Level of Development with Historical climate*

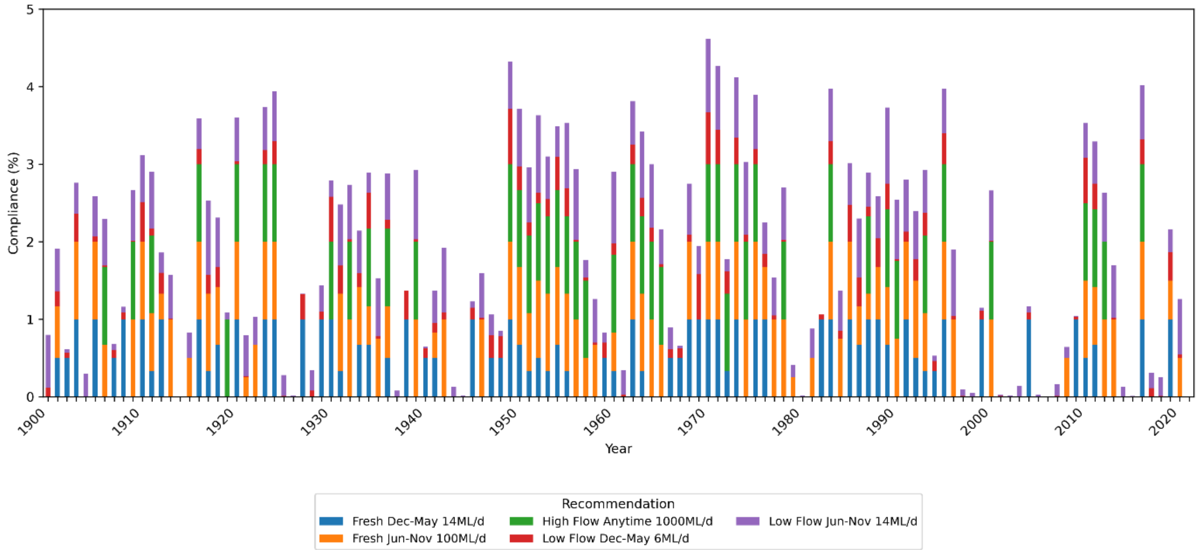


Figure 32 *Compliance for Maribyrnong Reach 3, 2010 Level of Development with Historical climate*

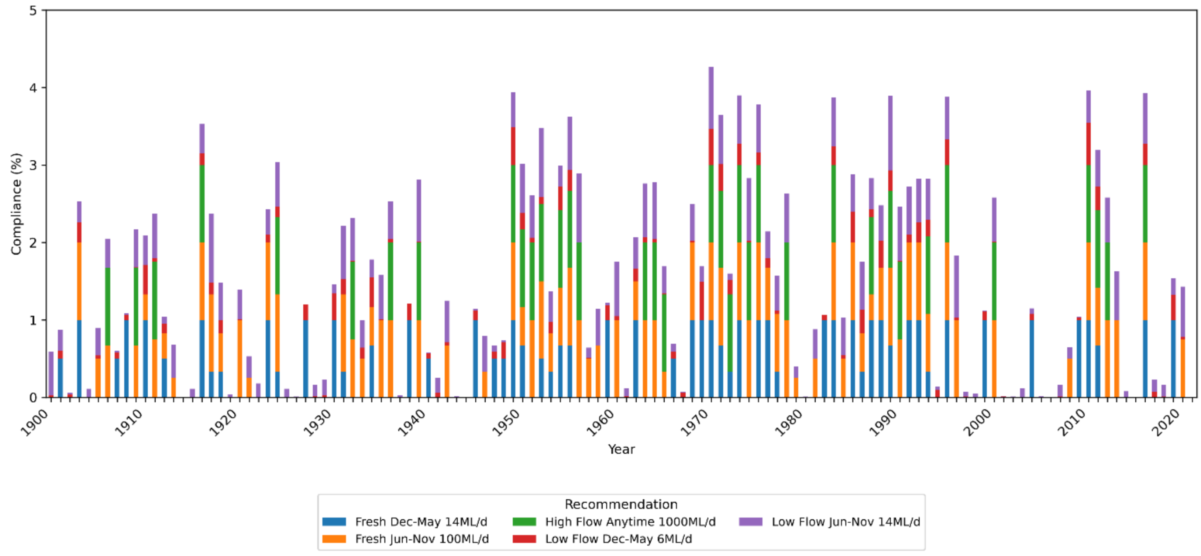


Figure 33 *Compliance for Maribyrnong Reach 3, 2025 Level of Development with Medium climate*

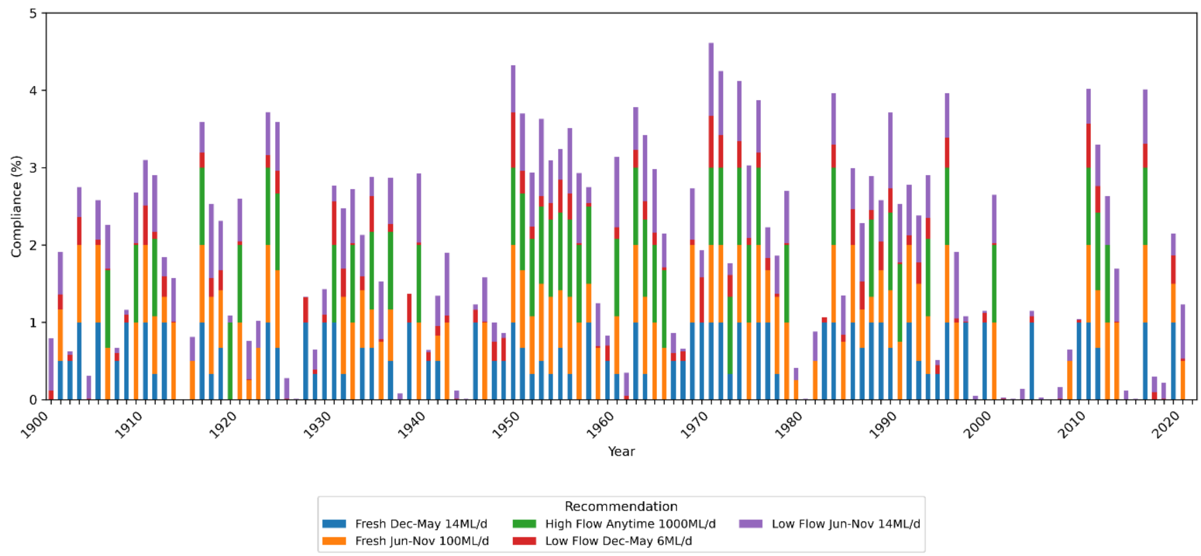


Figure 34 *Compliance for Maribyrnong Reach 3, 2025 Level of Development with Historical climate*

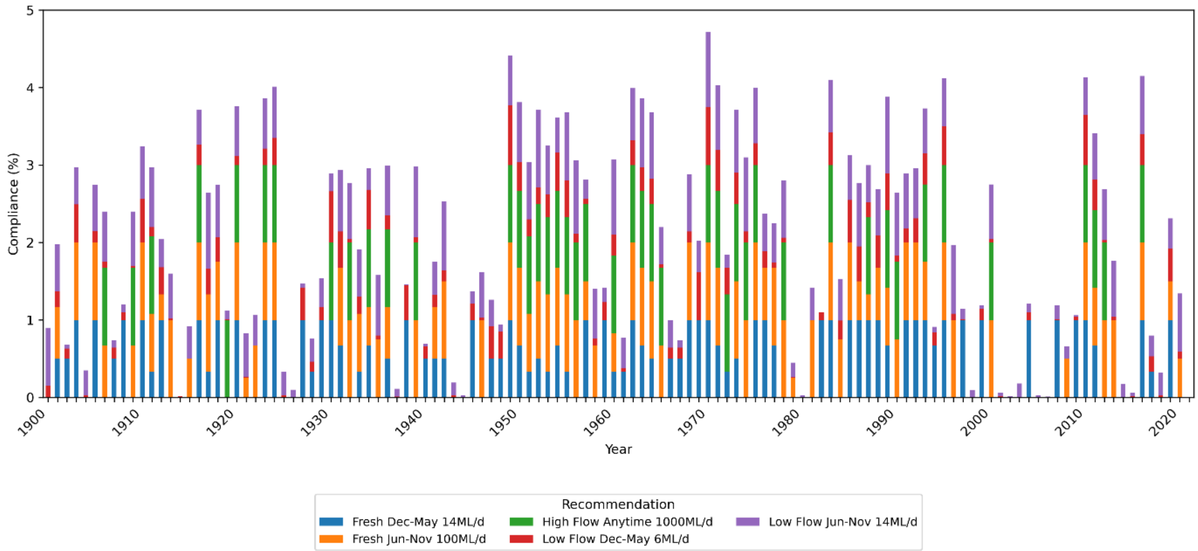


Figure 35 *Compliance for Maribyrnong Reach 3, Unimpacted Level of Development with Historical climate*

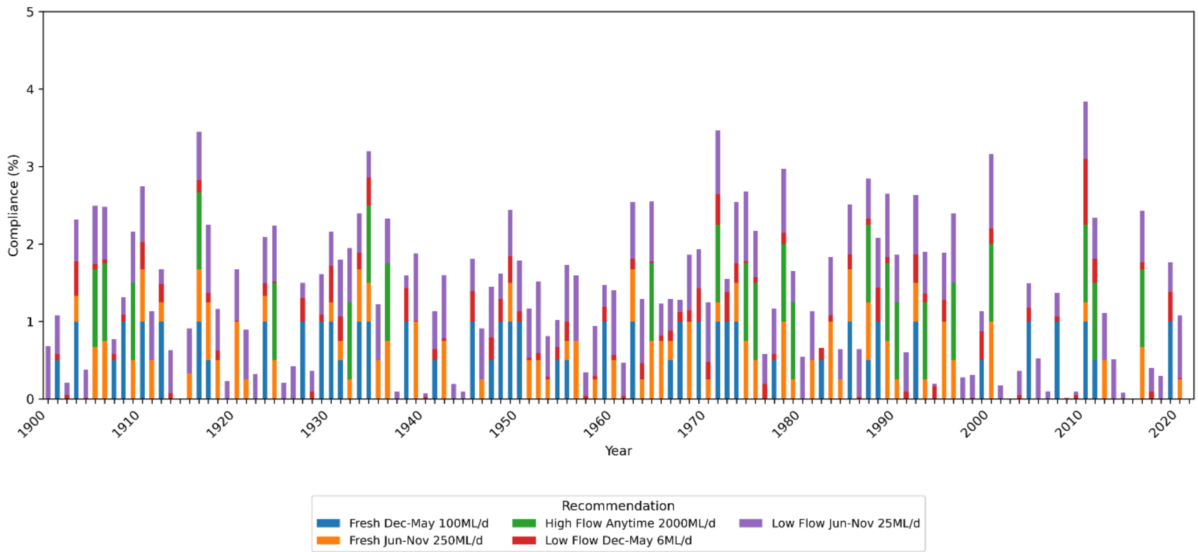


Figure 36 *Compliance for Maribyrnong Reach 4, 2010 Level of Development with Historical climate*

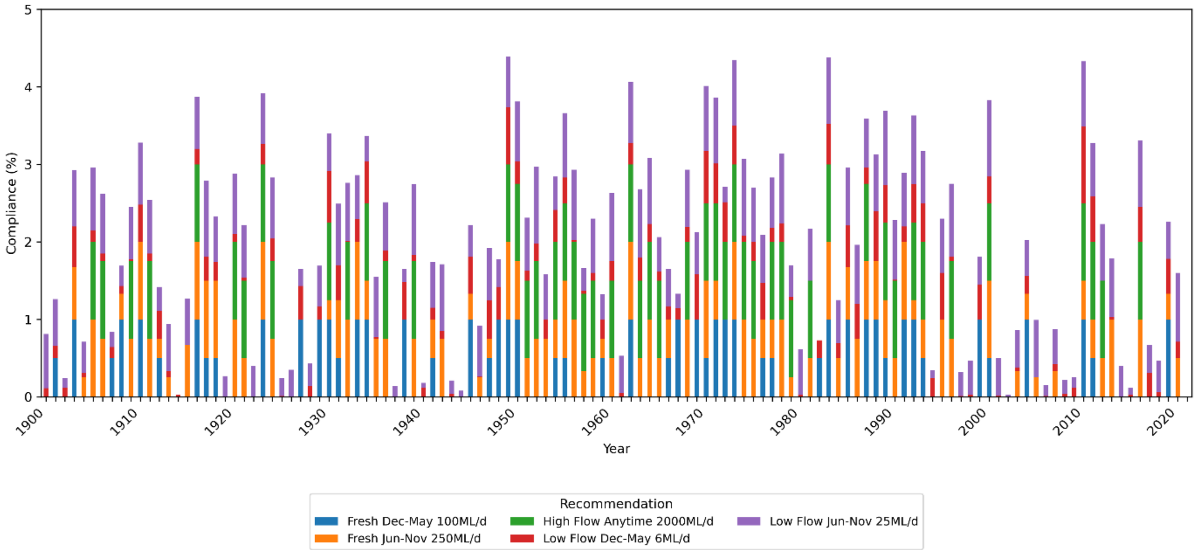


Figure 37 *Compliance for Maribyrnong Reach 4, 2025 Level of Development with Medium climate*

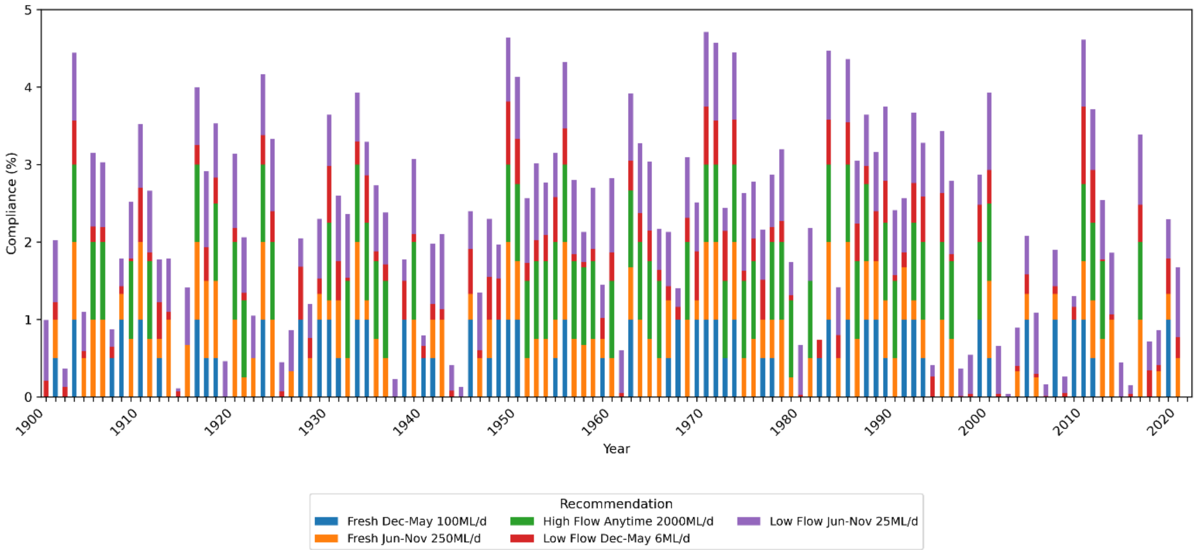


Figure 38 *Compliance for Maribyrnong Reach 4, 2025 Level of Development with Historical climate*

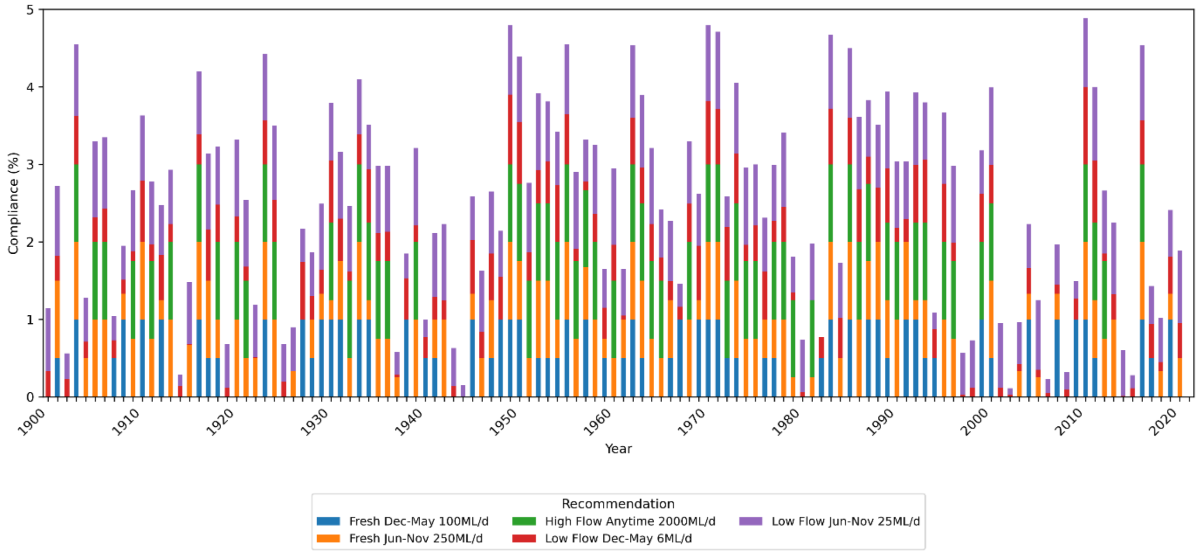


Figure 39 Compliance for Maribyrnong Reach 4, Unimpacted Level of Development with Historical climate

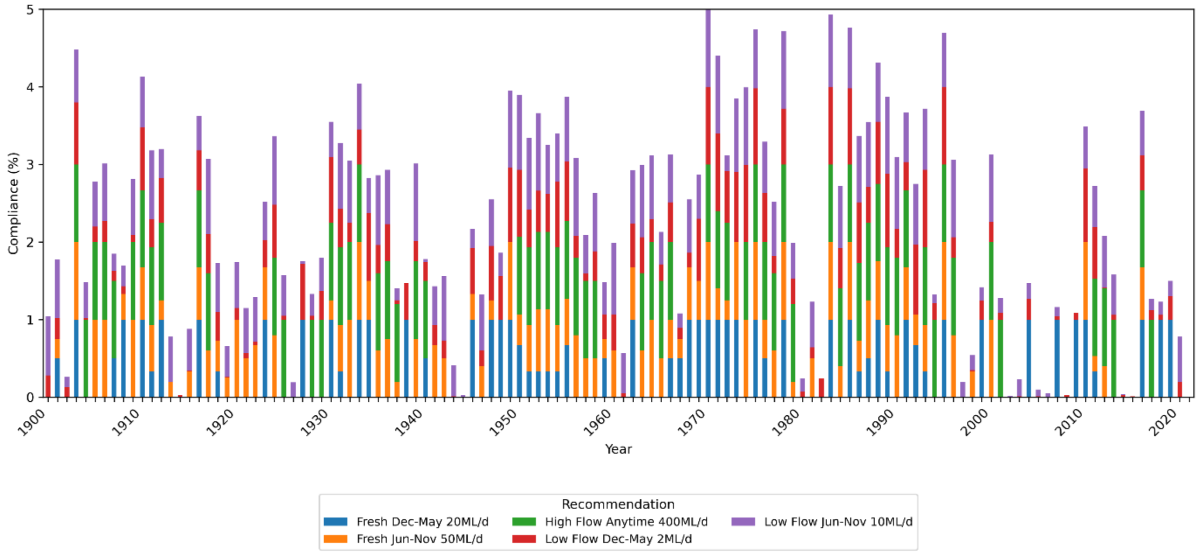


Figure 40 *Compliance for Maribyrnong Reach 5, 2010 Level of Development with Historical climate*

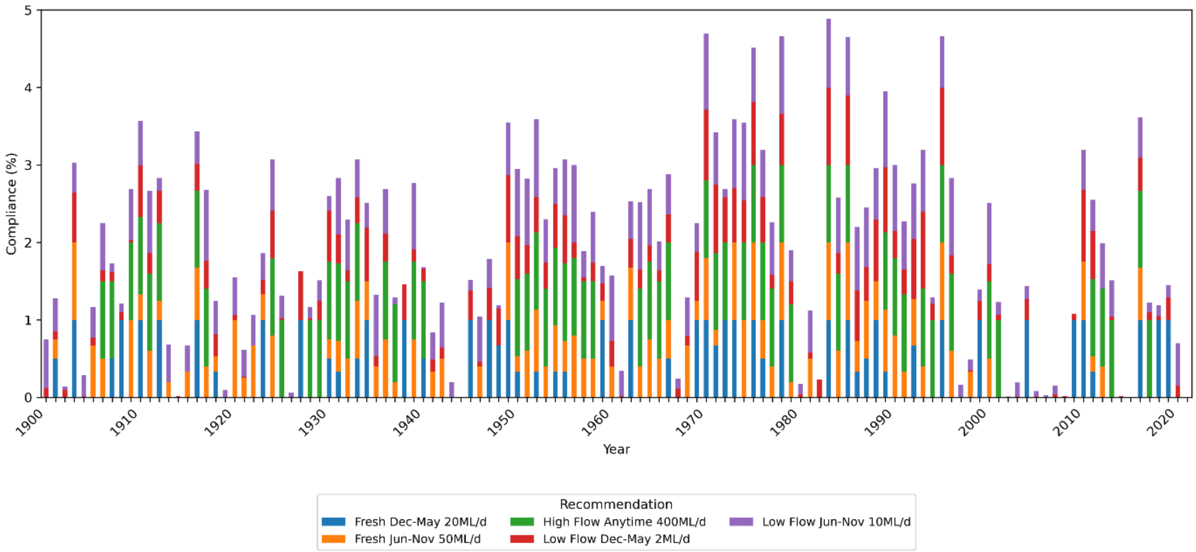


Figure 41 *Compliance for Maribyrnong Reach 5, 2025 Level of Development with Medium climate*

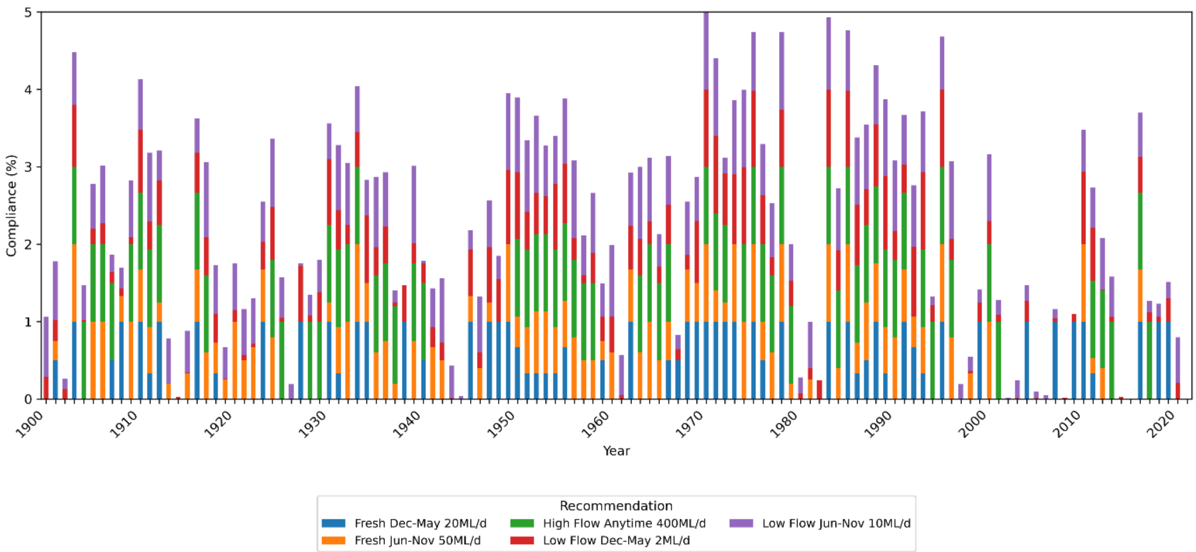


Figure 42 *Compliance for Maribyrnong Reach 5, 2025 Level of Development with Historical climate*

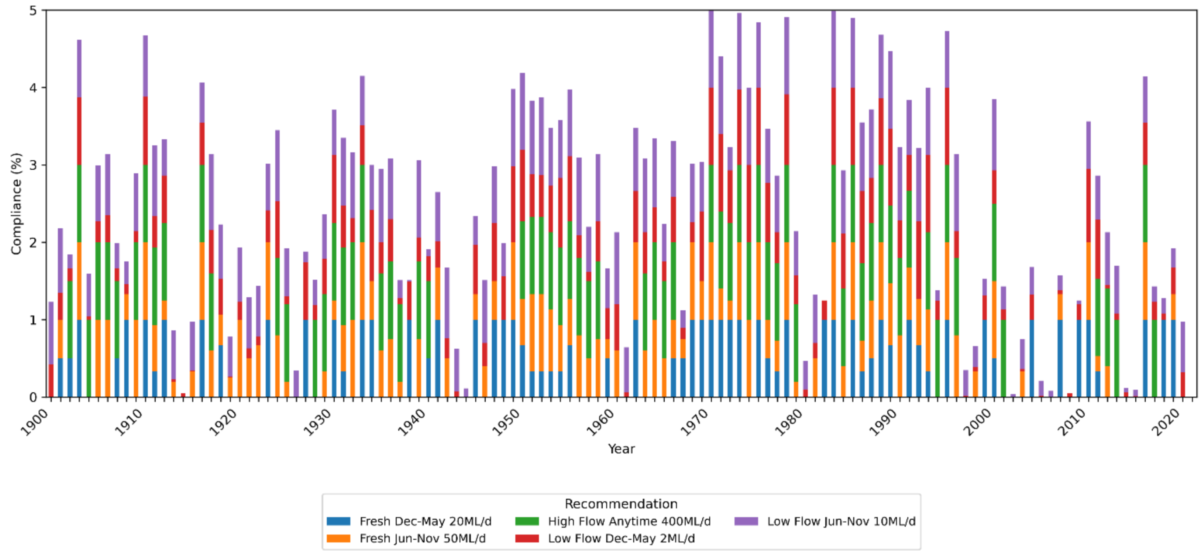


Figure 43 *Compliance for Maribyrnong Reach 5, Unimpacted Level of Development with Historical climate*

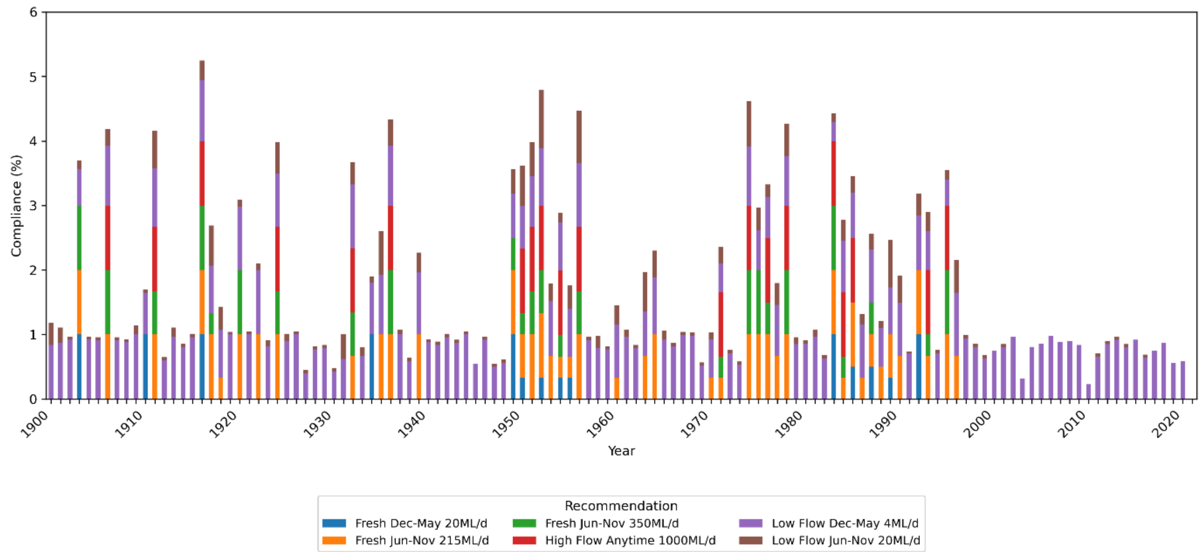


Figure 44 *Compliance for Maribyrnong Reach 6, 2010 Level of Development with Historical climate*

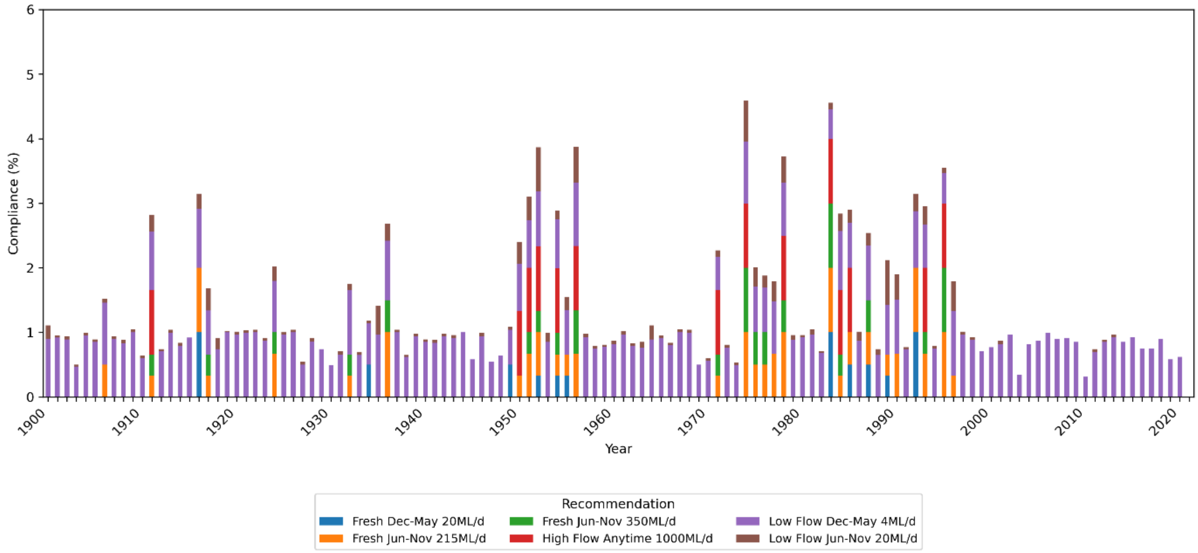


Figure 45 *Compliance for Maribyrnong Reach 6, 2025 Level of Development with Medium climate*

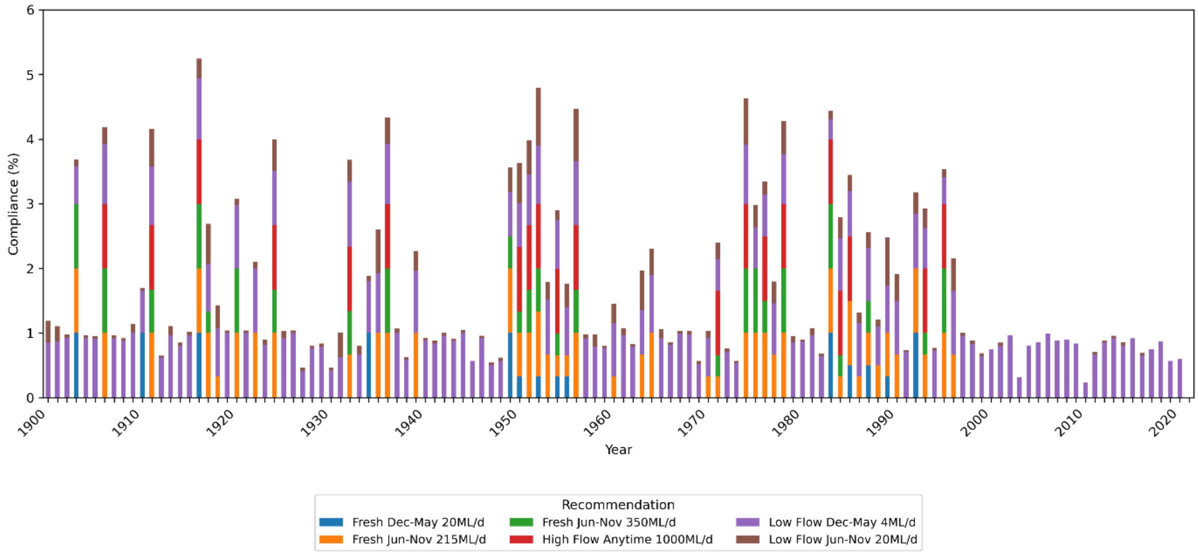


Figure 46 *Compliance for Maribyrnong Reach 6, 2025 Level of Development with Historical climate*

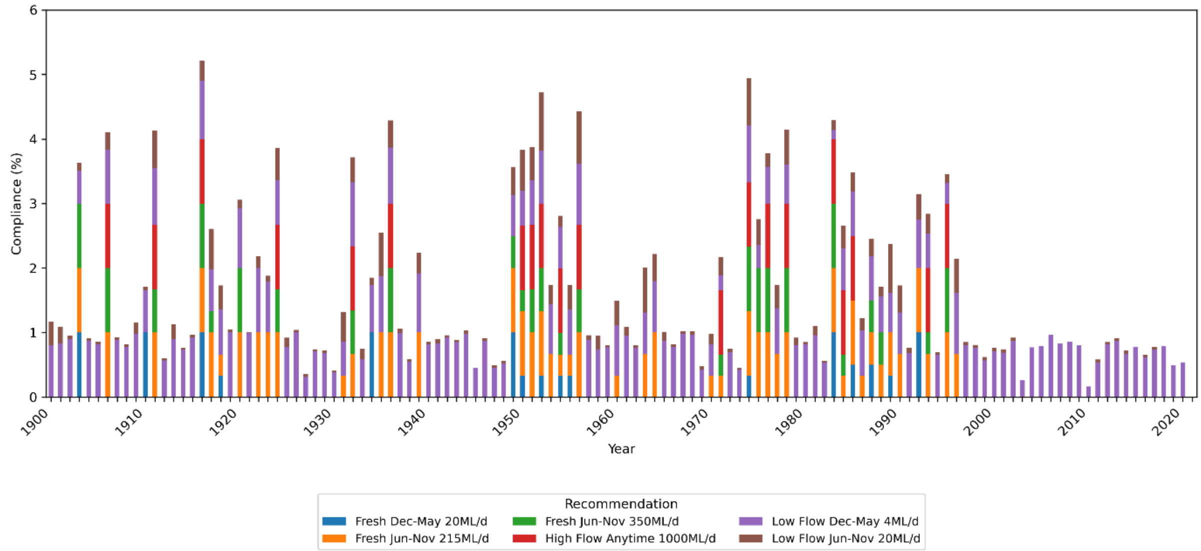


Figure 47 *Compliance for Maribyrnong Reach 6, Unimpacted Level of Development with Historical climate*

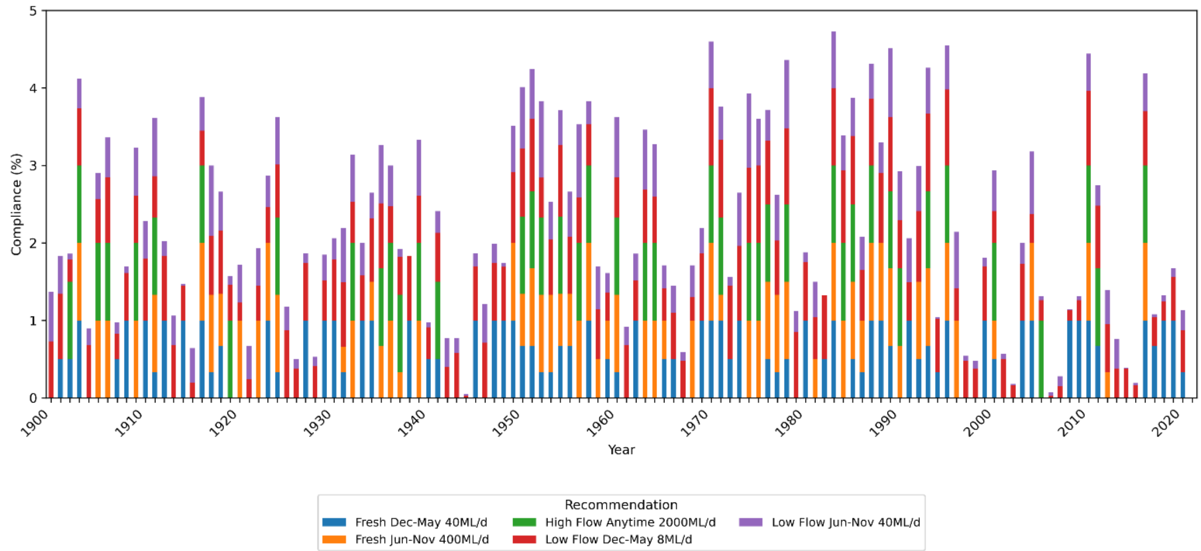


Figure 48 *Compliance for Maribyrnong Reach 7, 2010 Level of Development with Historical climate*

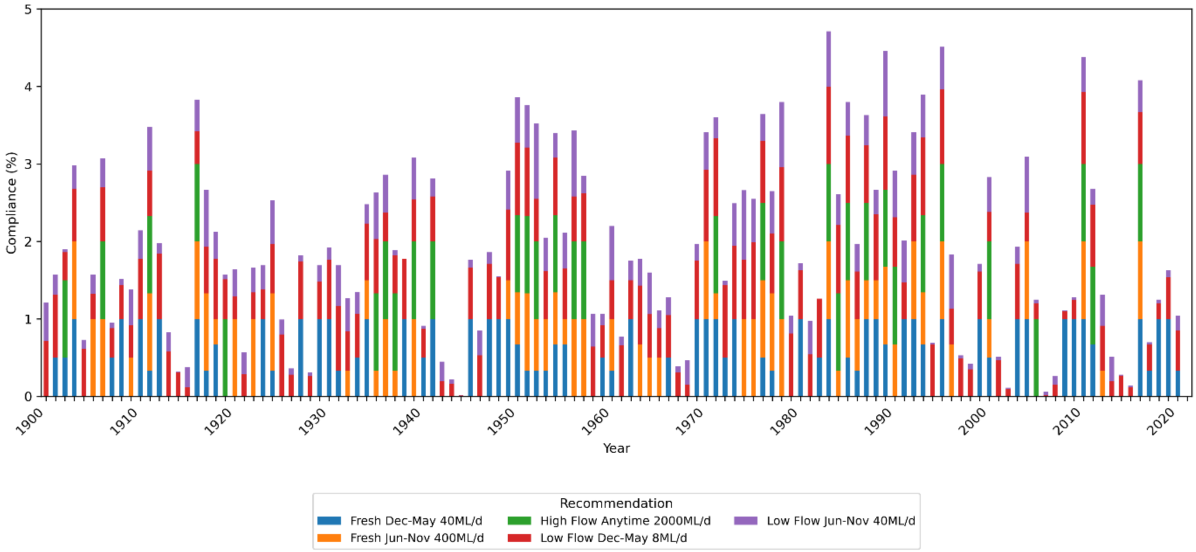


Figure 49 *Compliance for Maribyrnong Reach 7, 2025 Level of Development with Medium climate*

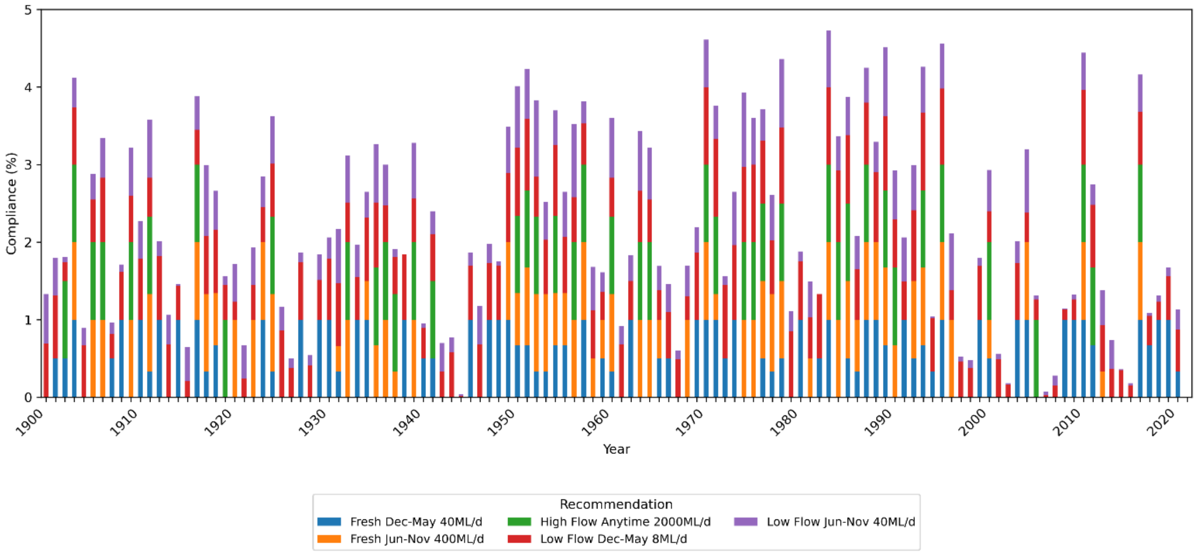


Figure 50 *Compliance for Maribyrnong Reach 7, 2025 Level of Development with Historical climate*

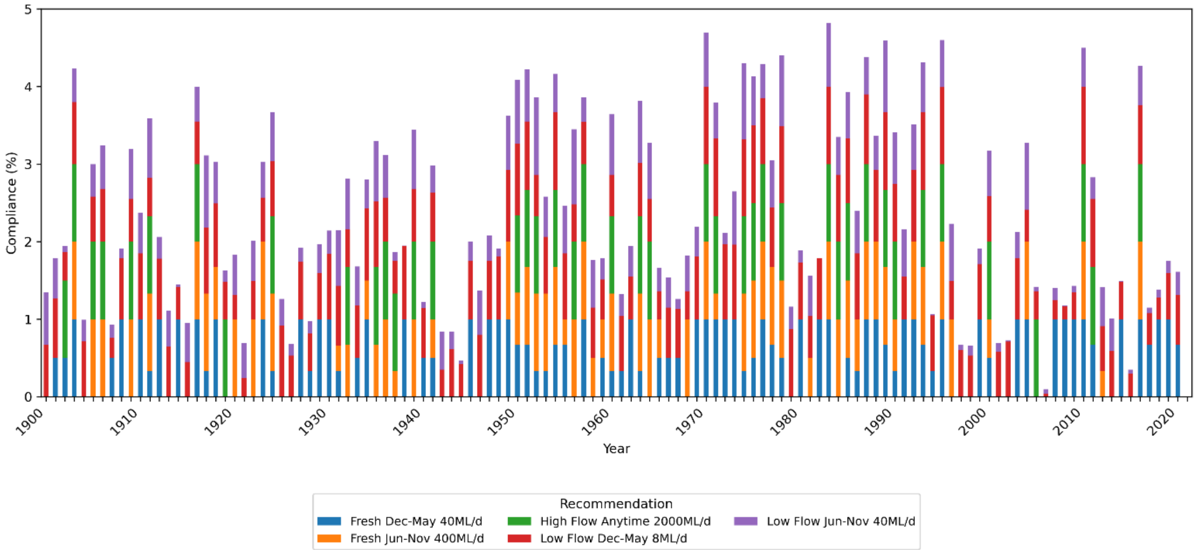


Figure 51 *Compliance for Maribyrnong Reach 7, Unimpacted Level of Development with Historical climate*

Moorabool

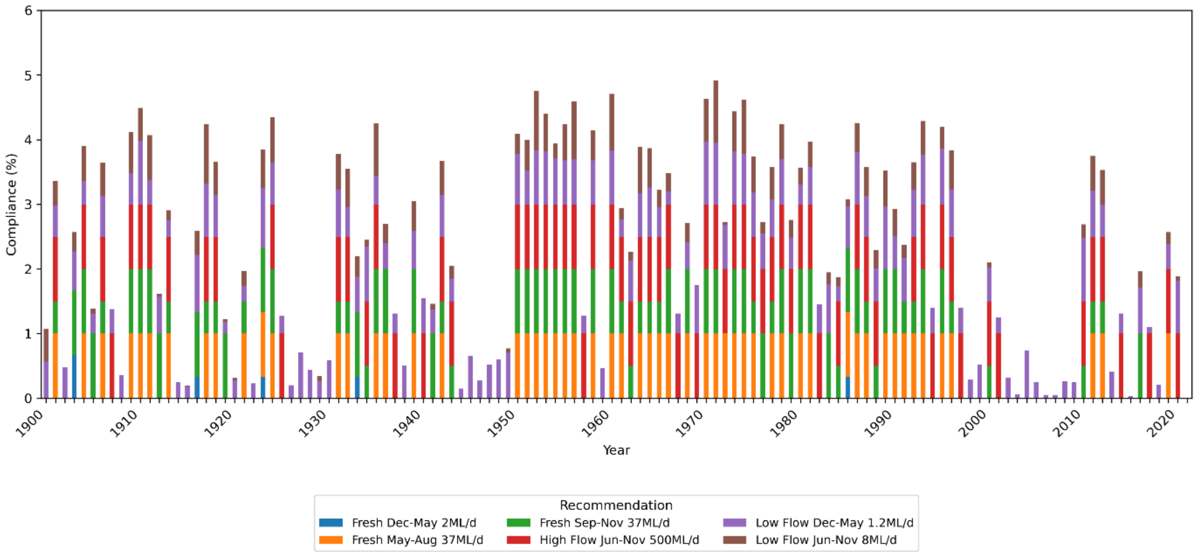


Figure 52 *Compliance for Moorabool Reach 1, 2010 Level of Development with Historical climate*

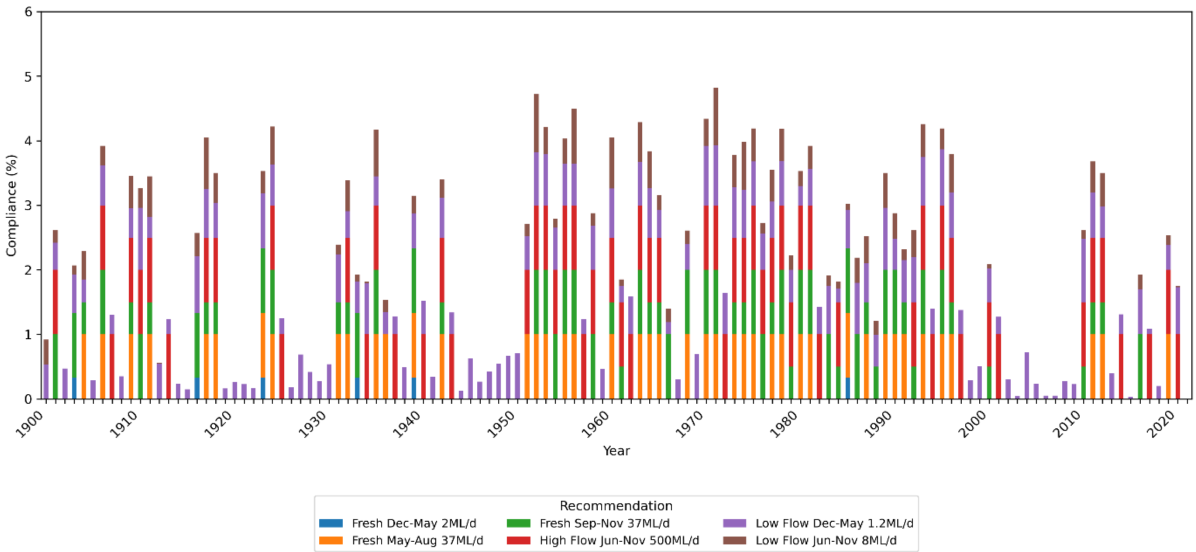


Figure 53 *Compliance for Moorabool Reach 1, 2025 Level of Development with Medium climate*

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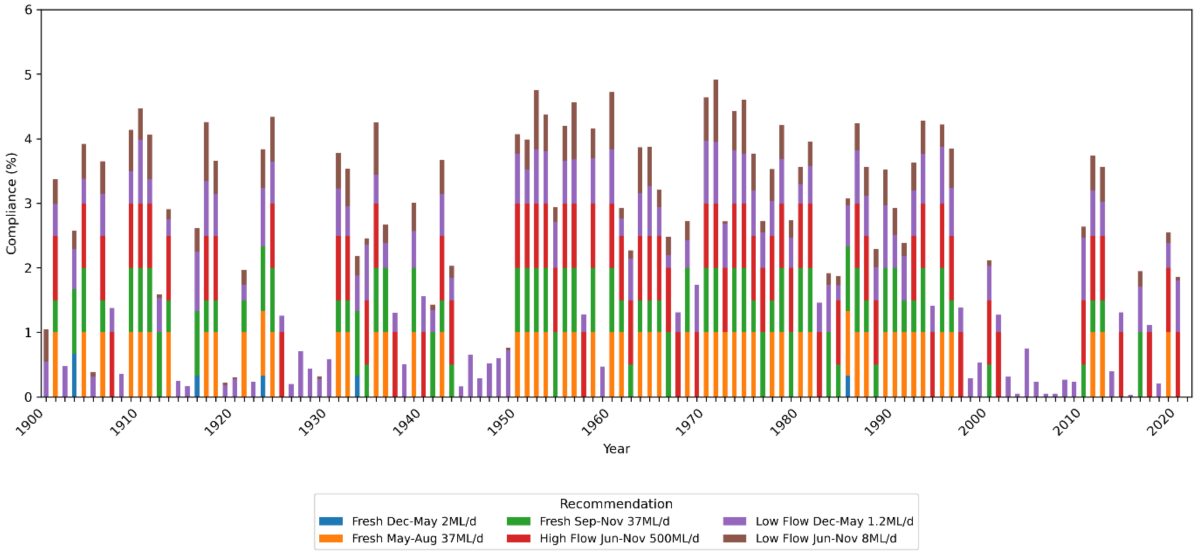

Figure 54 *Compliance for Moorabool Reach 1, 2025 Level of Development with Historical climate*

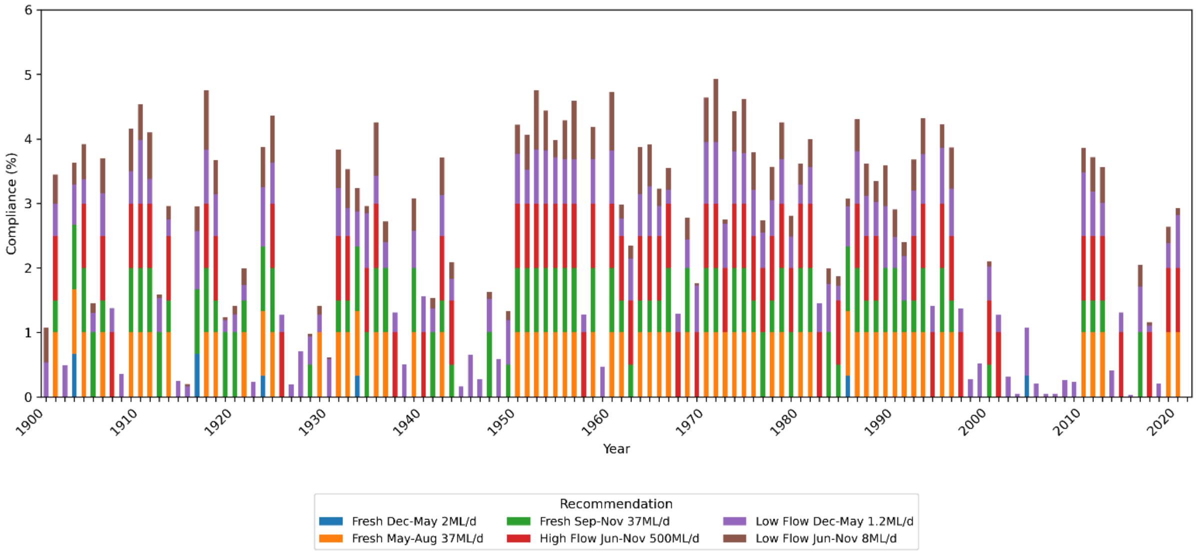

Figure 55 *Compliance for Moorabool Reach 1, Unimpacted Level of Development with Historical climate*

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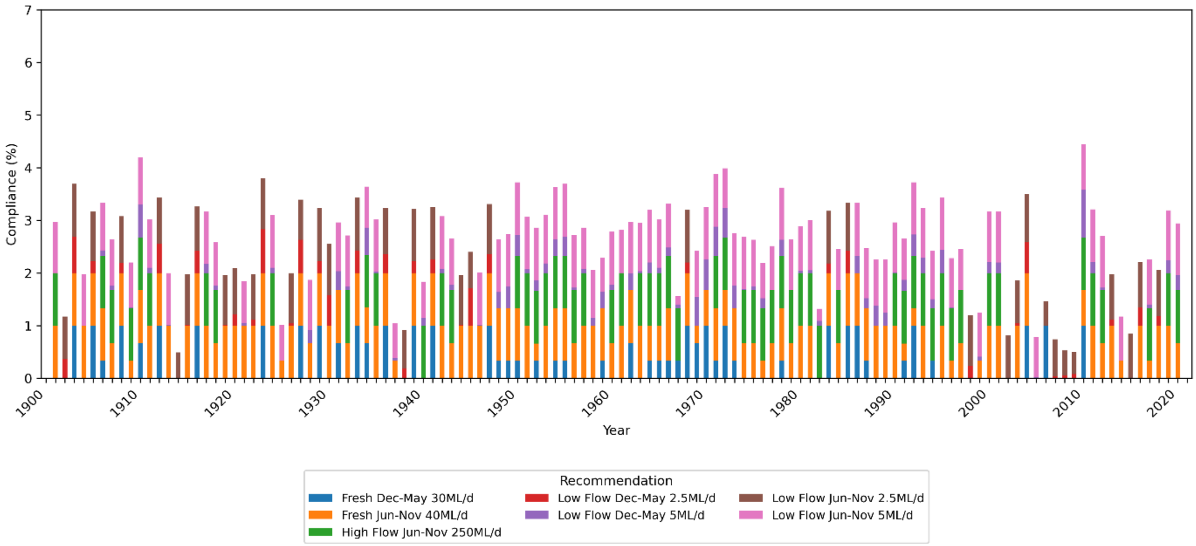

Figure 56 *Compliance for Moorabool Reach 2, 2010 Level of Development with Historical climate*

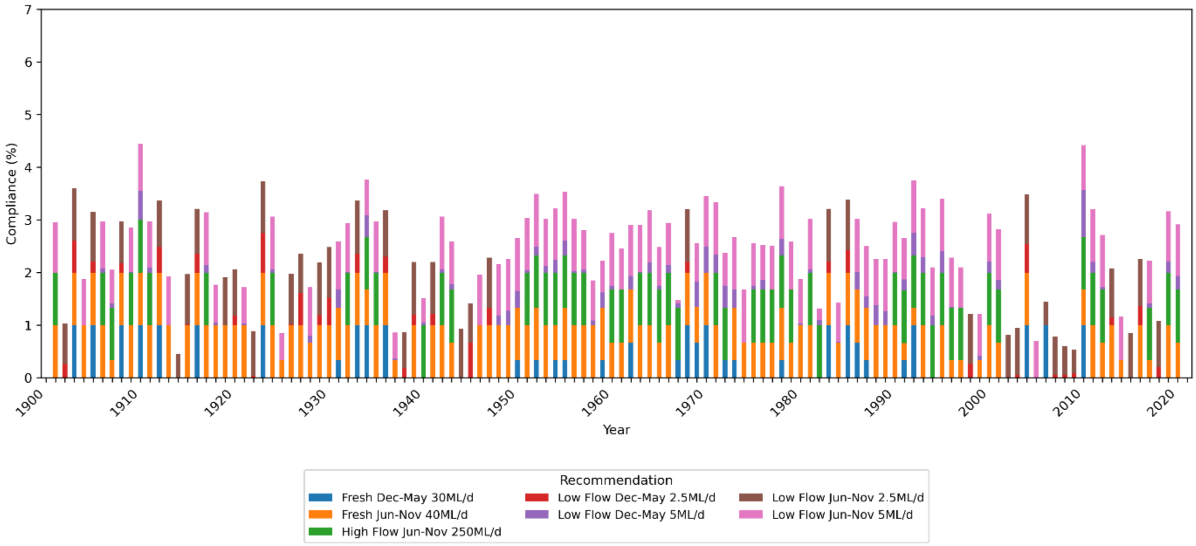

Figure 57 *Compliance for Moorabool Reach 2, 2025 Level of Development with Medium climate*

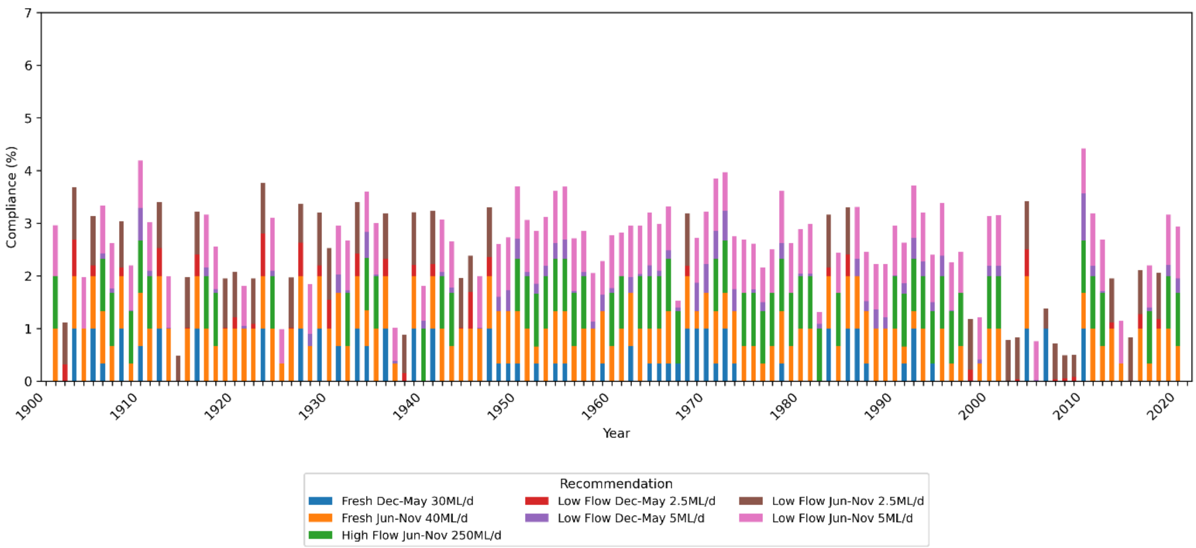

Figure 58 *Compliance for Moorabool Reach 2, 2025 Level of Development with Historical climate*

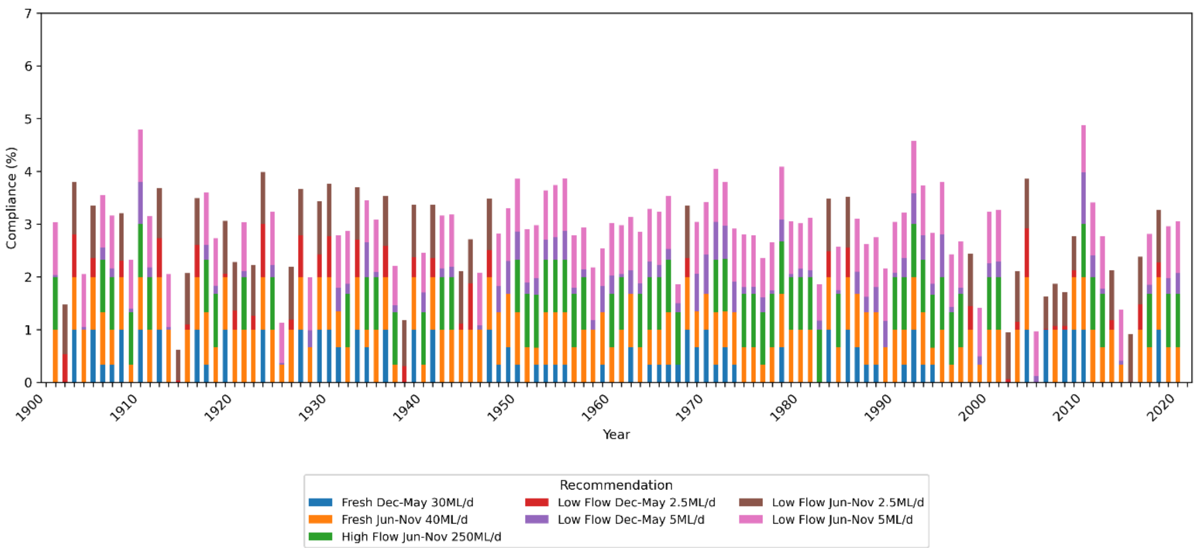

Figure 59 *Compliance for Moorabool Reach 2, Unimpacted Level of Development with Historical climate*

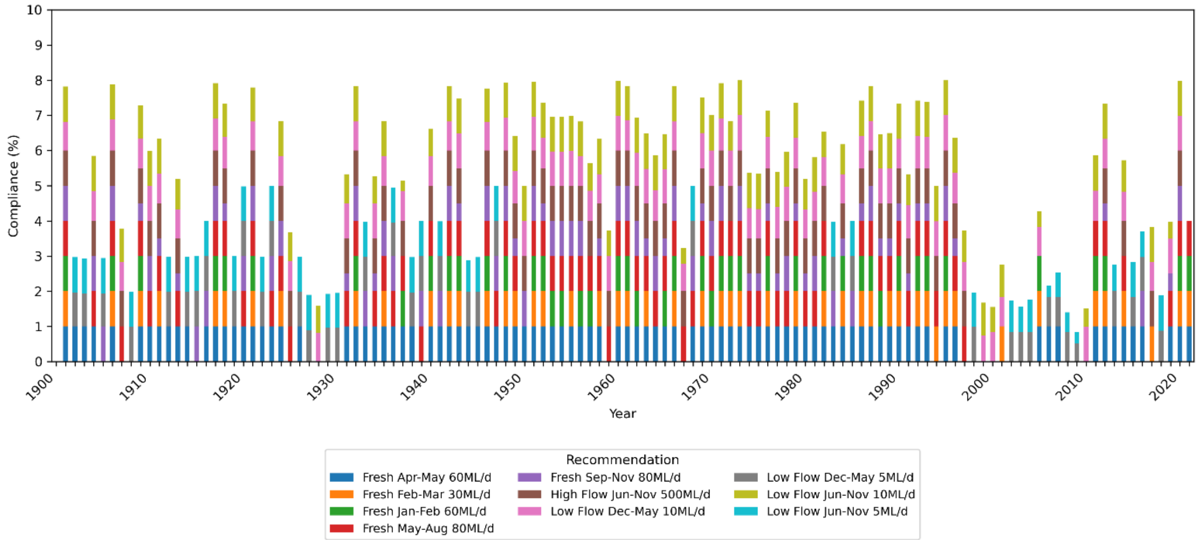

Figure 60 *Compliance for Moorabool Reach 3a, 2010 Level of Development with Historical climate*

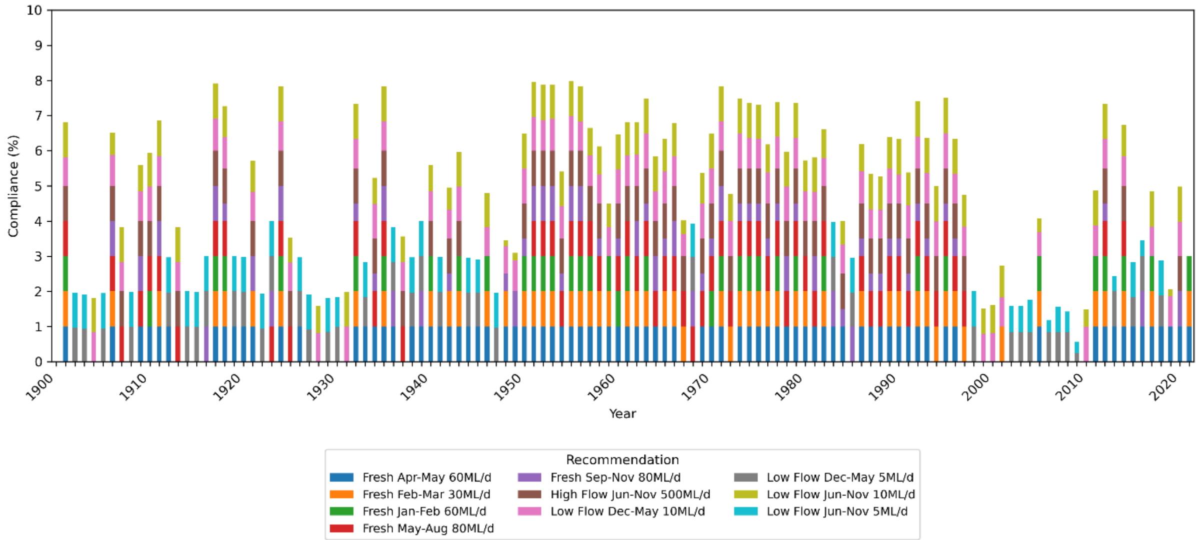

Figure 61 *Compliance for Moorabool Reach 3a, 2025 Level of Development with Medium climate*

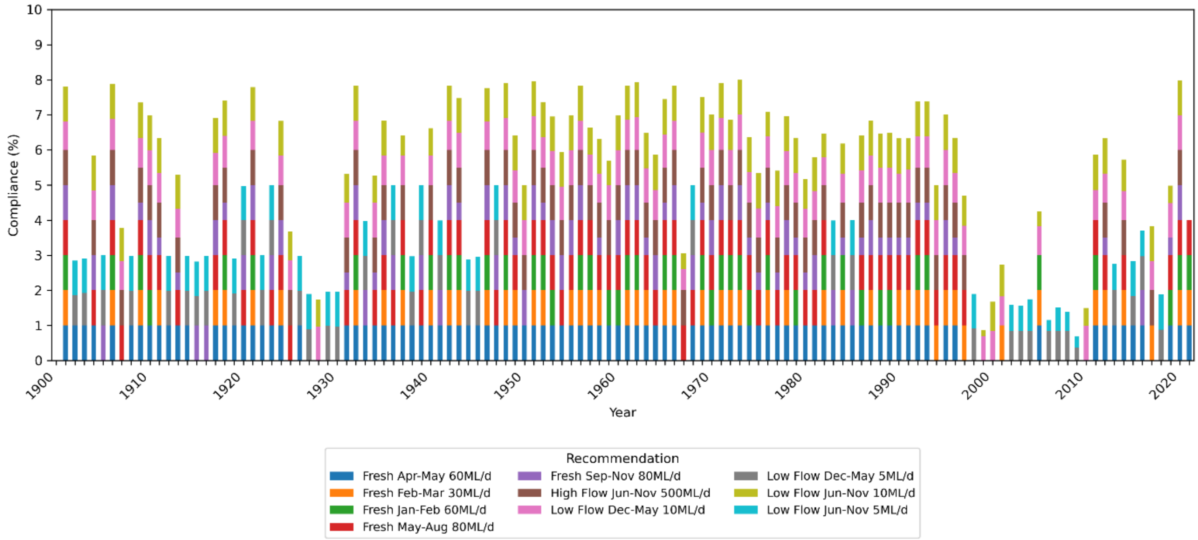

Figure 62 *Compliance for Moorabool Reach 3a, 2025 Level of Development with Historical climate*

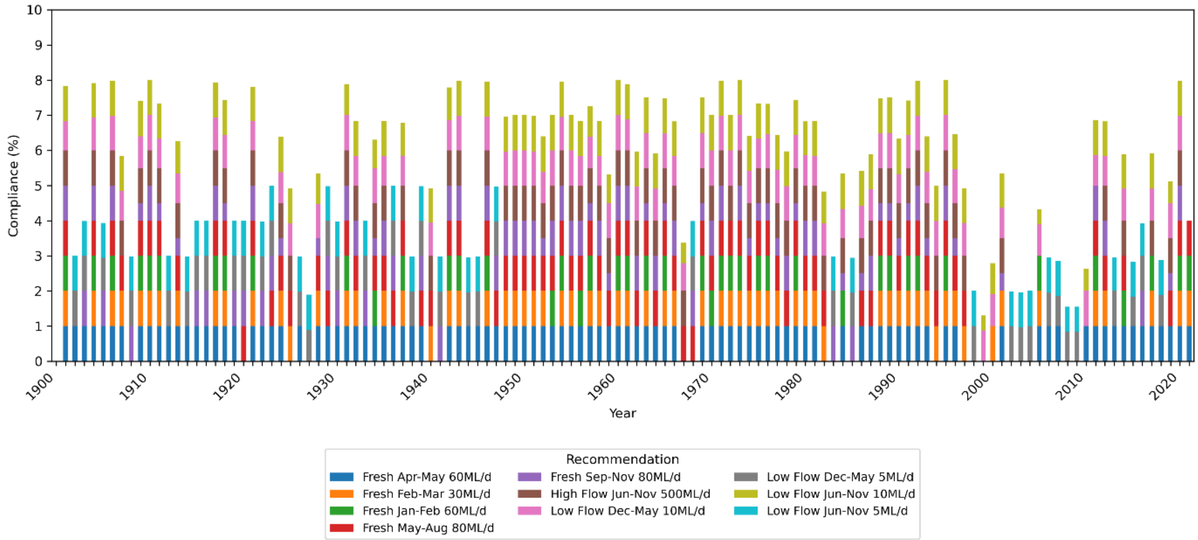

Figure 63 *Compliance for Moorabool Reach 3a, Unimpacted Level of Development with Historical climate*

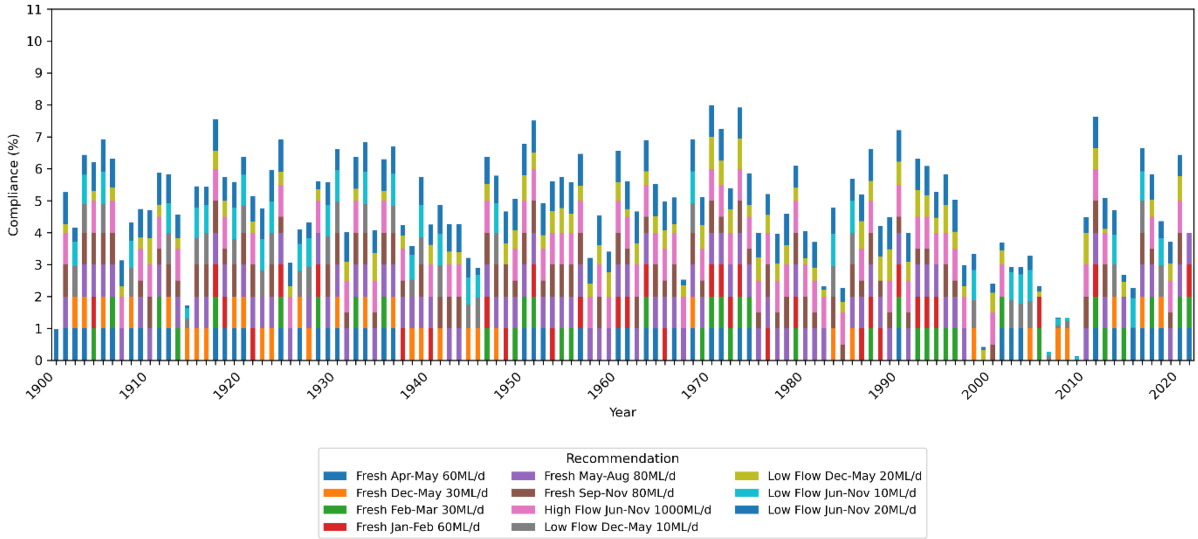

Figure 64 *Compliance for Moorabool Reach 3b, 2010 Level of Development with Historical climate*

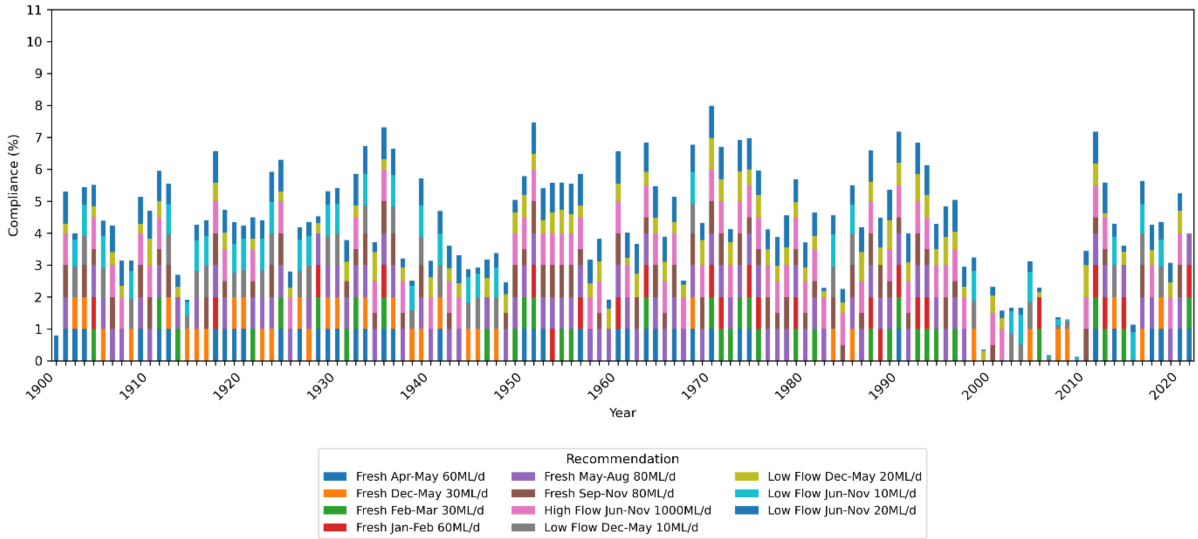

Figure 65 *Compliance for Moorabool Reach 3b, 2025 Level of Development with Medium climate*

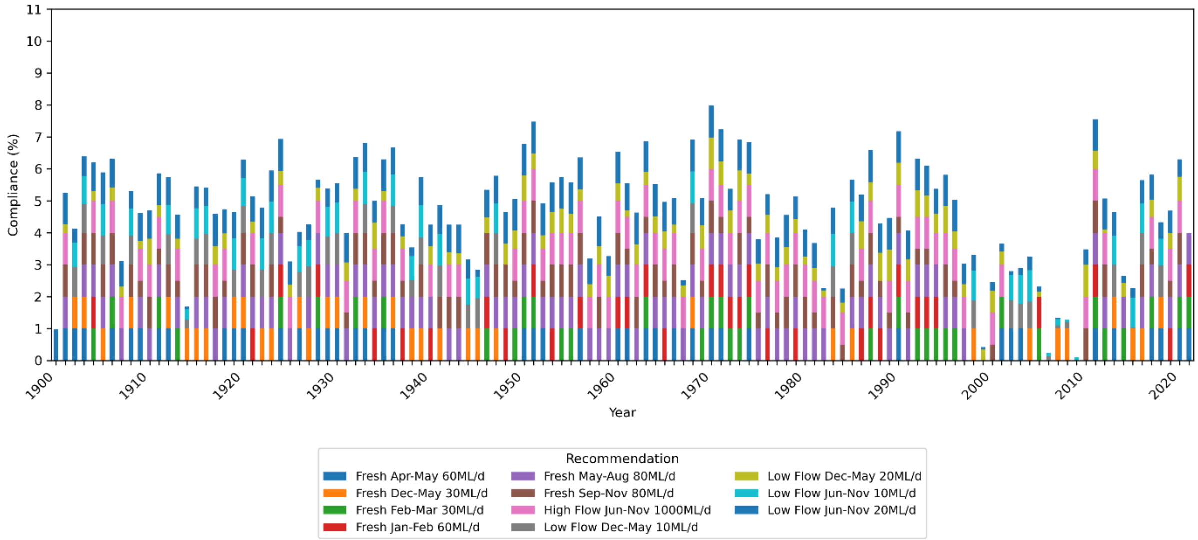

Figure 66 *Compliance for Moorabool Reach 3b, 2025 Level of Development with Historical climate*

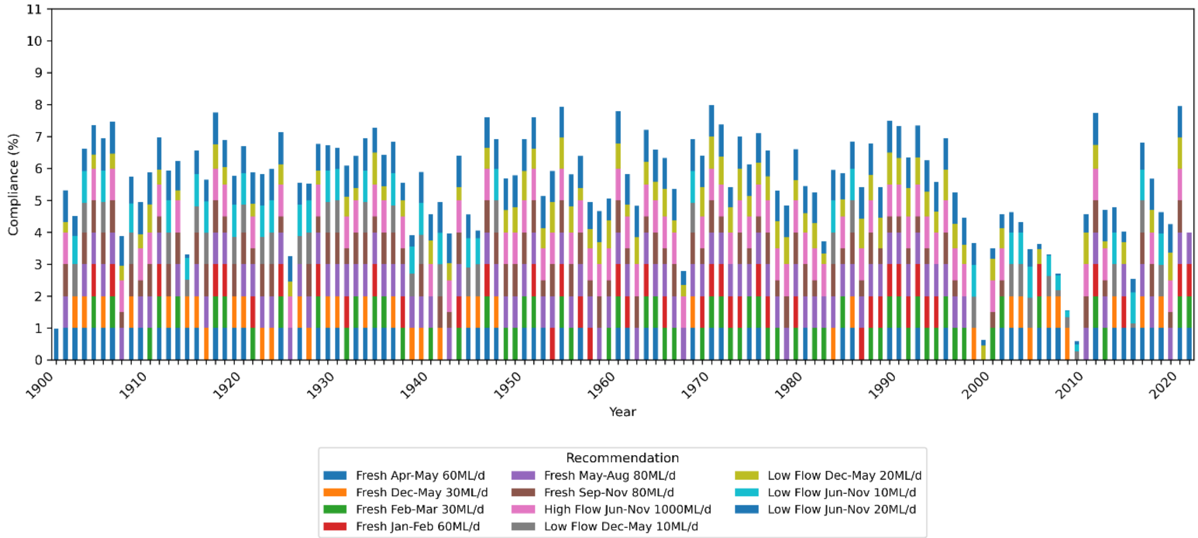

Figure 67 *Compliance for Moorabool Reach 3b, Unimpacted Level of Development with Historical climate*

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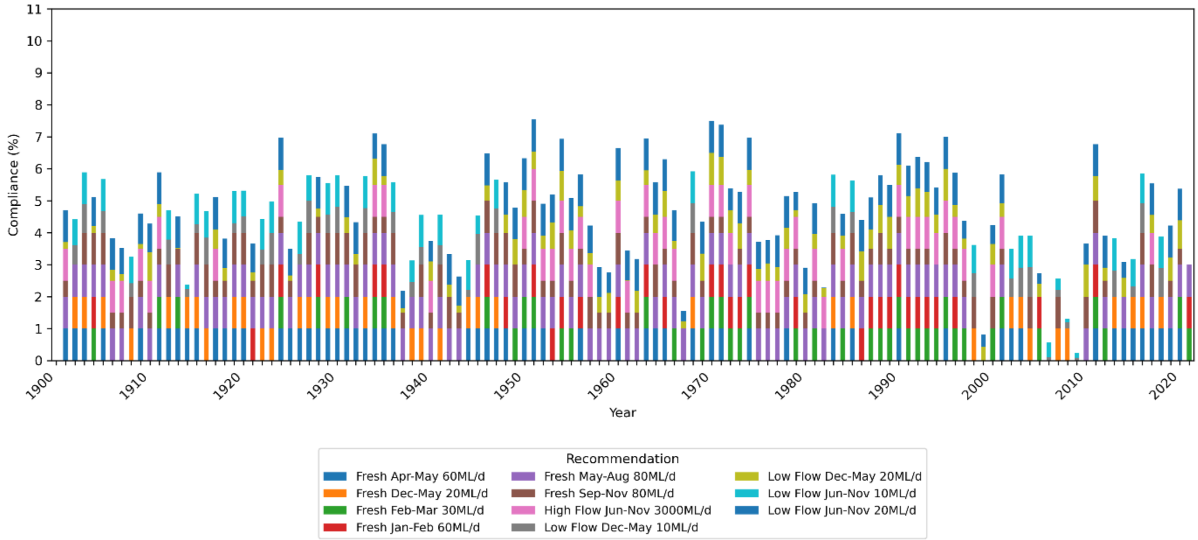


Figure 68 *Compliance for Moorabool Reach 4, Unimpacted Level of Development with Historical climate*

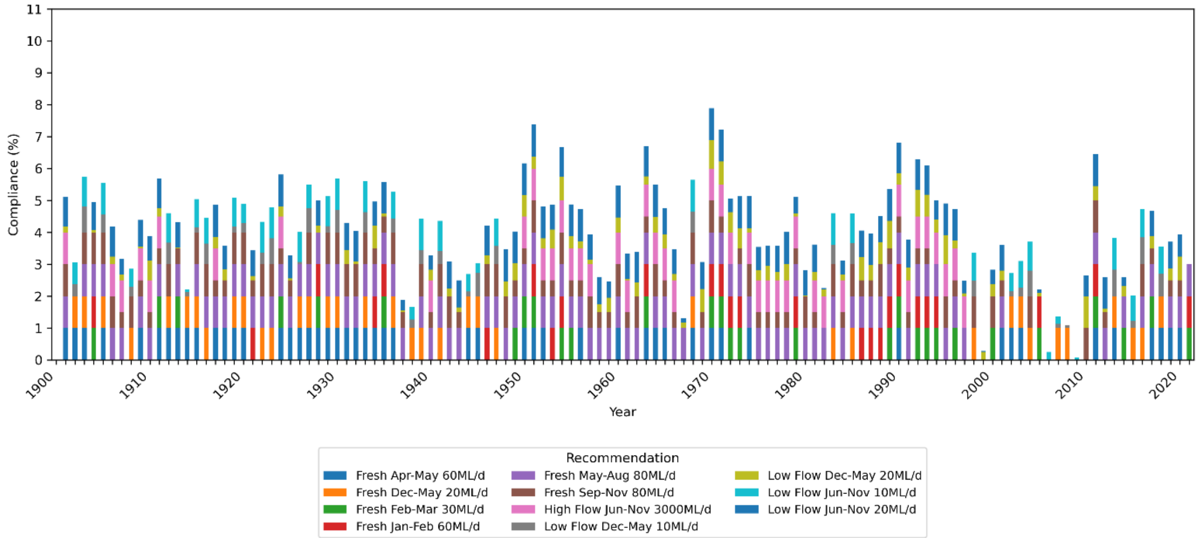


Figure 69 *Compliance for Moorabool Reach 4, 2010 Level of Development with Historical climate*

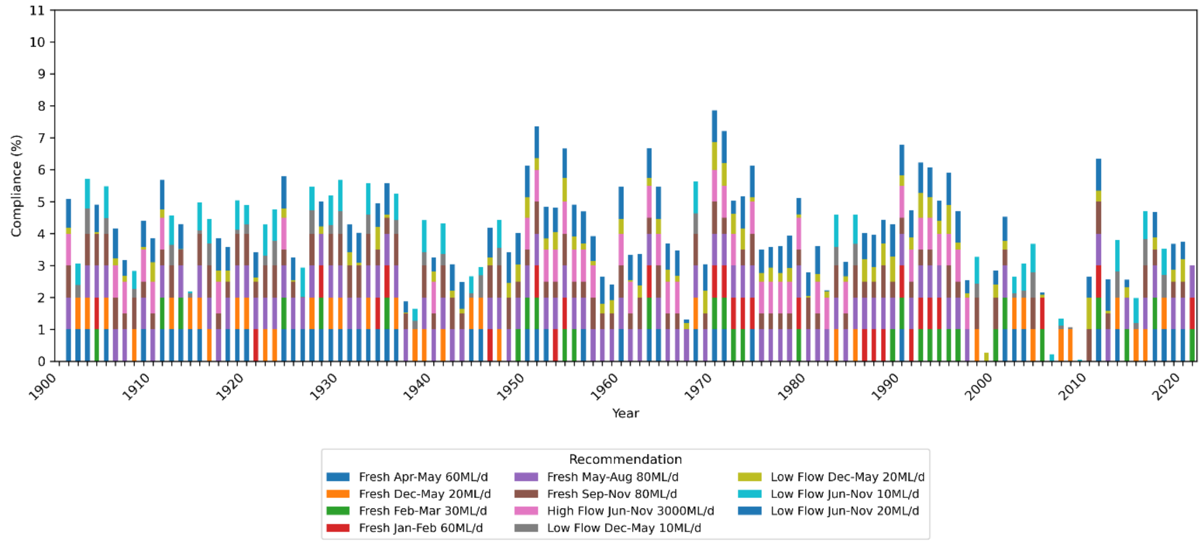


Figure 70 *Compliance for Moorabool Reach 4, 2025 Level of Development with Historical climate*

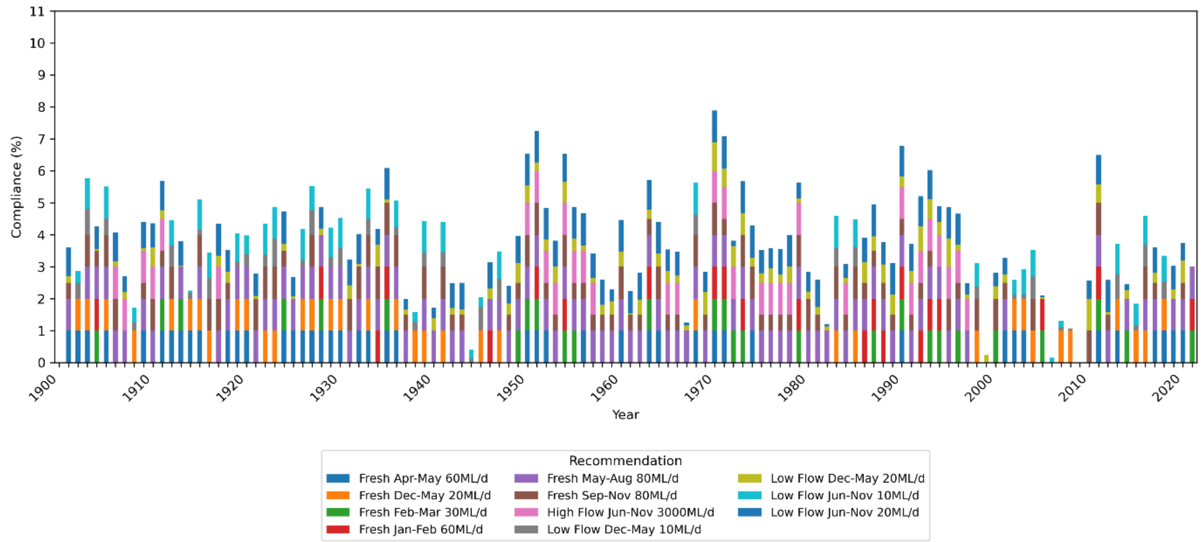
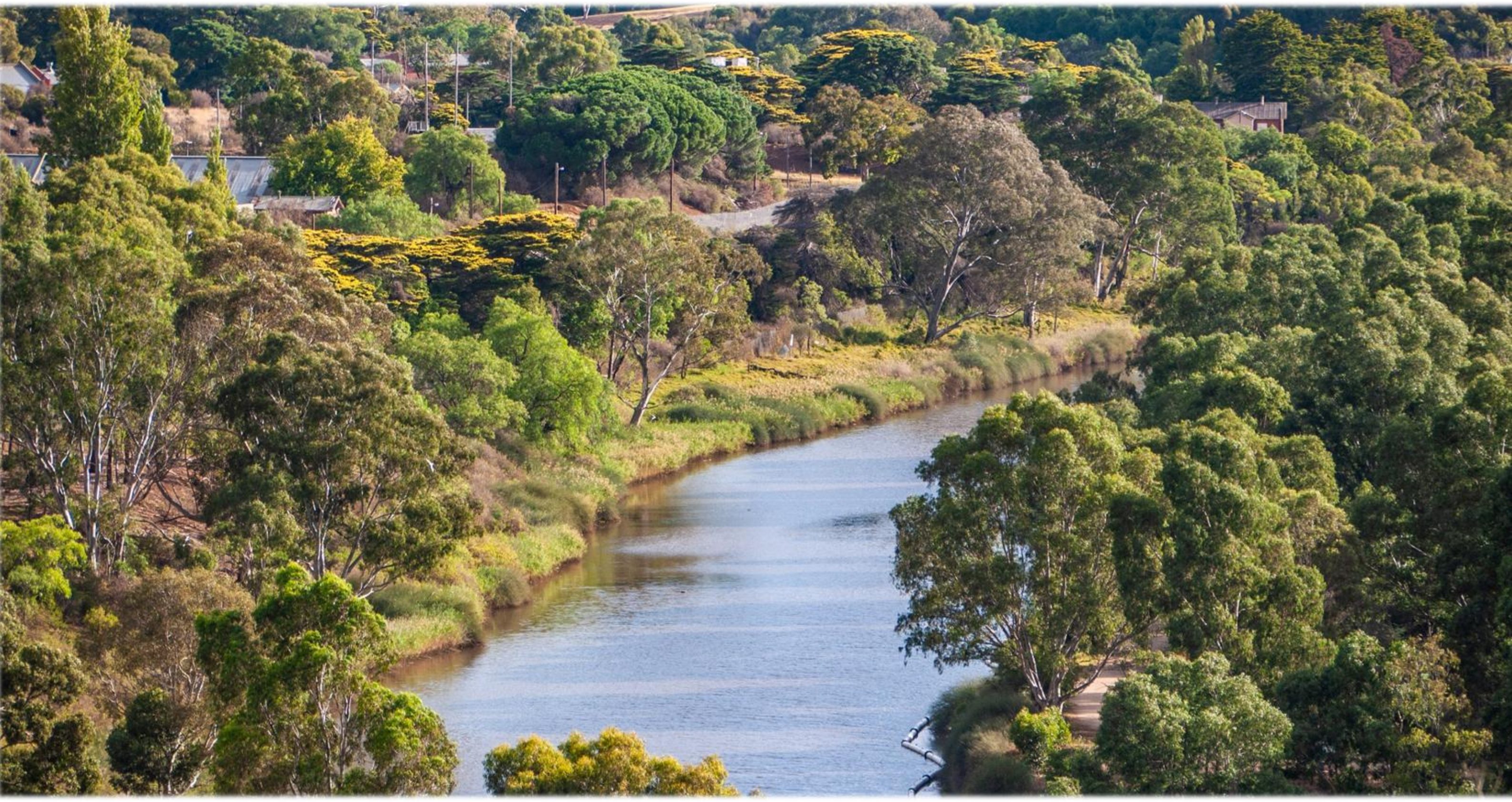


Figure 71 *Compliance for Moorabool Reach 4, 2025 Level of Development with Medium climate*

Attachment 7 – HARC Modelling Report



Water Resource Risks in the Maribyrnong and Moorabool Catchments

Impact of farm dams on streamflow

Version 3

31 March 2026

Document status

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Project manager	Phillip Jordan
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Document history

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Briefing papers for Stakeholder Reference Group Meetings	17 Jun 2025, 6 Aug 2025, 3 Sep 2025	Alluvium, SRW, DEECA	Alluvium, SRW, DEECA and Stakeholder Reference Group	Briefing papers contain most of the content of this report
Version 1	24 Nov 2025	Kate Austin	Alluvium, SRW, DEECA and Stakeholder Reference Group	Minor updates to address issues raised during Stakeholder Reference Group meetings
Version 2	16 Feb 2026	Kate Austin	Alluvium, SRW, DEECA and Stakeholder Reference Group	Update map formats to add background locations of towns and roads; Minor changes to calculation of percentage impacts on inflows for the Maribyrnong.
Version 3	31 Mar 2026	Kate Austin	Alluvium, SRW and DEECA	Resolution of minor inconsistencies between tables and text

Copyright and Limitation

Contents

1. Introduction

The Central and Gippsland Region Sustainable Water Strategy (CGRSWS) (DELWP, 2023) identified that water resources within peri-urban catchments are facing increasing pressure from small-scale agriculture and changing land use, with increasing urban and semi-rural development, against the backdrop of a changing climate.

Increasing urbanisation within small, dry catchments has resulted in an increase in small catchment dams (also known as farm dams or runoff dams), which are being used for domestic and stock (D&S) purposes, as well as increasing D&S usage from rivers and creeks, and groundwater bores. These forms of accessing water are not subject to formal licensing under the *Water Act* (Victoria, 1989). Unlicensed taking of water for purposes other than D&S also presents an additional risk to the resource, as well as presenting compliance challenges. The cumulative impact of many small volume take activities from unlicensed users (both compliant and non-compliant) poses an increasing risk to water dependent catchment values, and as usage and pressure on the water resource increases, it is recognised that the approach to measuring the volume taken from these sources needs to be improved commensurately. Accordingly, a key action of the CGRSWS is to 'review water resource risk in small, dry peri-urban catchments'. The CGRSWS identified the upper Maribyrnong and upper Moorabool catchments as hotspots where land uses are transitioning from agriculture to increased urbanisation, which brings an increased risk to water dependent catchment values due to unlicenced take and other activities.

Southern Rural Water (SRW) engaged Alluvium Consulting and HARC to undertake a review of the risks, consequences, and mitigation options to understand and manage the cumulative effects of these forms of take in the Maribyrnong and Moorabool catchments. The project builds a shared understanding by working with key stakeholders and communities. The focus of the project was on the take and use via those mechanisms which do not require a licence such as D&S, as well as considering the risks posed by the take of water via activities which are considered non-compliant within the regulatory framework provided by the *Water Act 1989*.

Overall reporting was prepared to address the wholistic assessment of risk across the catchments. This report addresses the hydrology and water resources assessment and modelling across the Maribyrnong and Moorabool catchments. This report includes:

- An overview of models used for water resources planning in the Maribyrnong and Moorabool basins (see Section 2)
- Modelling the estimated impact of farm dams and other small water bodies on inflows (see Section 3)
- Projections and scenarios modelled, including climate change (see Section 4)
- Changes in the number and storage volumes of farm dams across the Maribyrnong and Moorabool catchments over time (see Section 5)
- Estimated impact of farm dams on streamflow in the Maribyrnong and Moorabool catchments, which have been assessed from the models in each catchment (see Section 6) and
- An overall summary of changes in farm dam numbers, storage volumes and estimated impact in the Maribyrnong and Moorabool catchments (see Section 7).

2. Water resources planning and modelling overview

The study areas for this project are the catchments of the Maribyrnong and Moorabool basins:

- Maribyrnong River catchment upstream of Keilor gauge (230200)
- Moorabool River catchment upstream of Batesford gauge (232202)

DEECA and Southern Rural Water review and update water resources plans for the basins and supply systems within their areas of responsibility. These plans are underpinned by water resources systems models. The models represent features such as catchment inflows, farm dam impacts, supply to licensed users, supply to meet environmental water needs, large dams and reservoirs and rules representing transfer of water to simulate a water resource system. Modelling in the Barwon-Moorabool and Maribyrnong systems is undertaken using the Source water resources modelling package, which is developed and supported by eWater. Source is the industry-standard software for modelling hydrology and water resources across Australia.

DEECA have developed water resources planning models, using the Source modelling package, for the Barwon-Moorabool and Maribyrnong basins. These models are used by DEECA, in consultation with stakeholders, to:

- Inform planning and development of water resources allocation policies
- Assess volumes, reliability and pattern of delivery of environmental flows
- Assess yields to bulk entitlement holders (such as Barwon Water and Melbourne Water) and the reliability of those yields
- Assess the impacts on water availability of larger scale Integrated Water Management projects in urban areas
- Assess the impacts of climate change and climate variability on these factors

A map of the subcatchments represented in the Maribyrnong Source model is shown in Figure 2-1. The Keilor streamflow gauge (230200) is at the downstream boundary of subcatchment F19, so subcatchment F20 is not included in the scope of the current project, even though it is within the extent of the water resources planning model (Source – see below) for the Maribyrnong system.

A map of the Moorabool portion of the Barwon-Moorabool Source model is shown in Figure 2-2. The Source model for the Barwon-Moorabool system includes catchments in the Barwon part of the system that are outside of the Moorabool catchment, which are not shown on Figure 2-2. Within the Barwon part of the system, part of the model and inputs were developed as part of the Ballarat Source model (for Central Highlands Water, CHW), which are labelled site 1 to 19 and shown in orange on Figure 2-2. Inputs for some Moorabool subcatchments, labelled F12 to F20 and shown in blue on Figure 2-2, were developed as part of a separate project. Inflows for CHW sites 14 to 19 are included in the Barwon Moorabool Source model but are outside of the Moorabool basin. Similarly, subcatchment F12 for inflows to Stony Creek reservoir is also outside of the Moorabool basin.

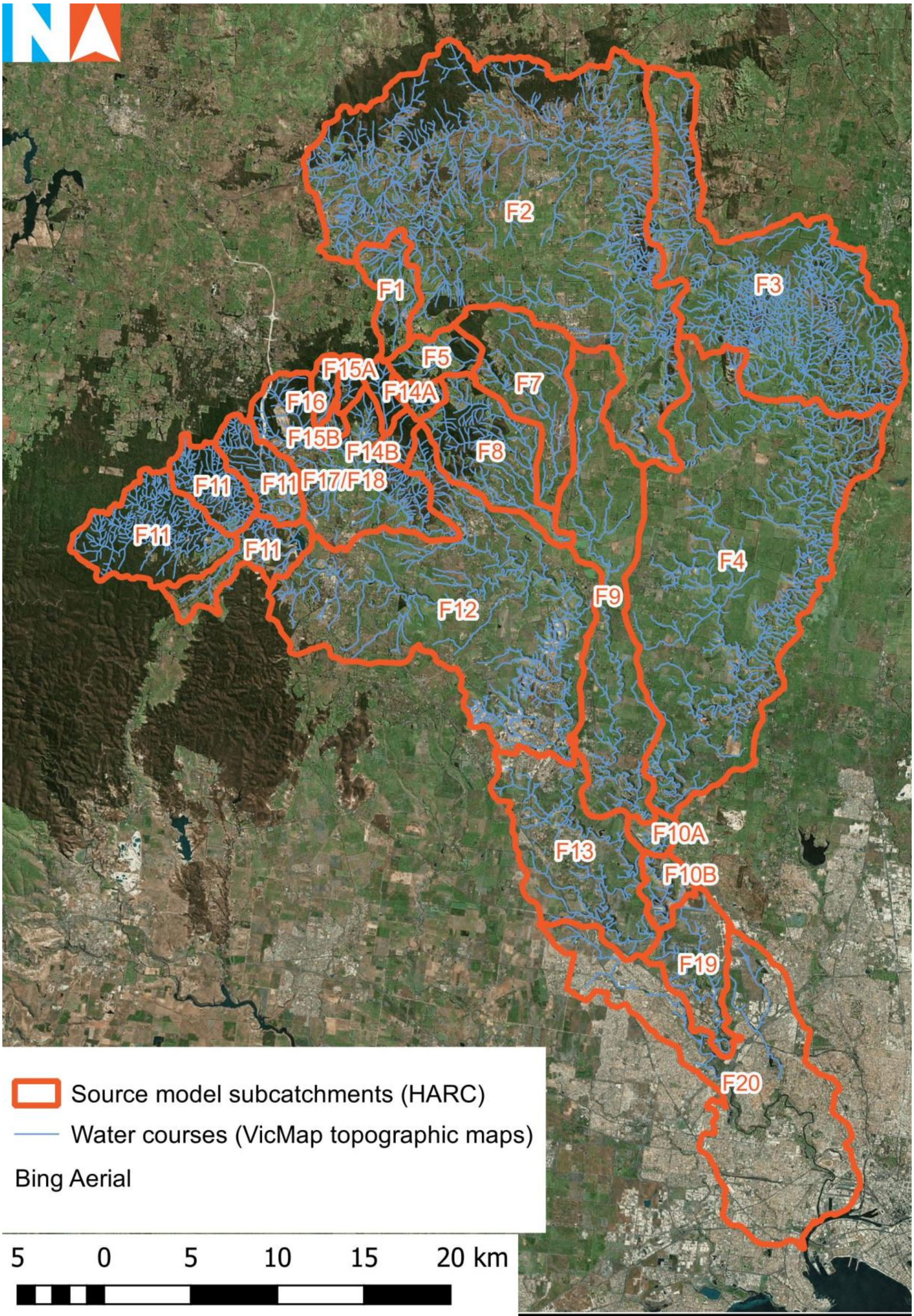

Figure 2-1 Maribyrnong subcatchment map

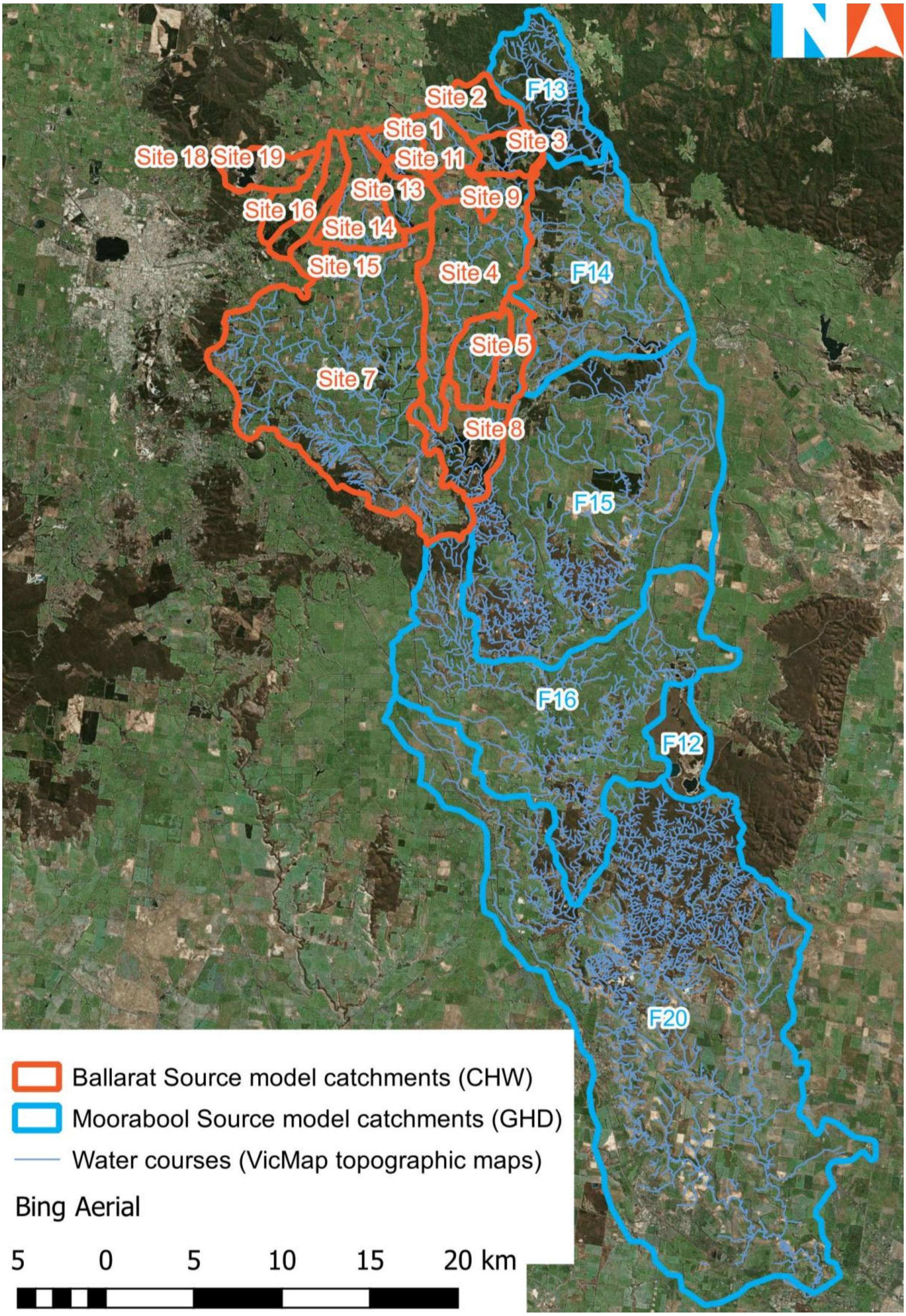

Figure 2-2 Moorabool subcatchment map

Figure 2-3 shows a schematic diagram of the Maribyrnong system Source model (DELWP and HARC, 2021; HARC, 2023a, 2023b). The level of detail represented within the model is demonstrated by the number of components of the model, such that it is difficult to read the details of any one component at this high level. The different types of nodes within the Source model are provided in the legend of Figure 2-3. The dashed connector arrows represent flows of water within the system. The Maribyrnong Source model runs on a daily timestep, representing the status of the system for every day in the climatic period between January 1900 and June 2021 under current levels of development and operating rules.

Figure 2-4 shows a schematic diagram of the Barwon-Moorabool system Source model (SKM, 2006; HARC, 2019, 2024; DELWP and GHD, 2022; Central Highlands Water and HARC, 2023). The Barwon-Moorabool Source model runs on a daily timestep, representing the status of the system for every day in the climatic period between January 1889 and June 2021 under current levels of development and operating rules. The dashed line in Figure 2-4 surrounds the Moorabool section of the model, which is in focus for this project.

Both Source models represent the current water management rules that operate in each system, including:

- Storage curves and operating rules for large dams
- Requirements for passing flow and other releases under Bulk Entitlements
- Diversions, pumping and transfer rules
- Constraints such as the capacities of pumps, pipelines and open channels
- Restrictions of urban demands
- Restrictions on licensed irrigation and other rural demands during low flow periods

Further details on farm dam impact modelling using STEDI are discussed in Section 3.

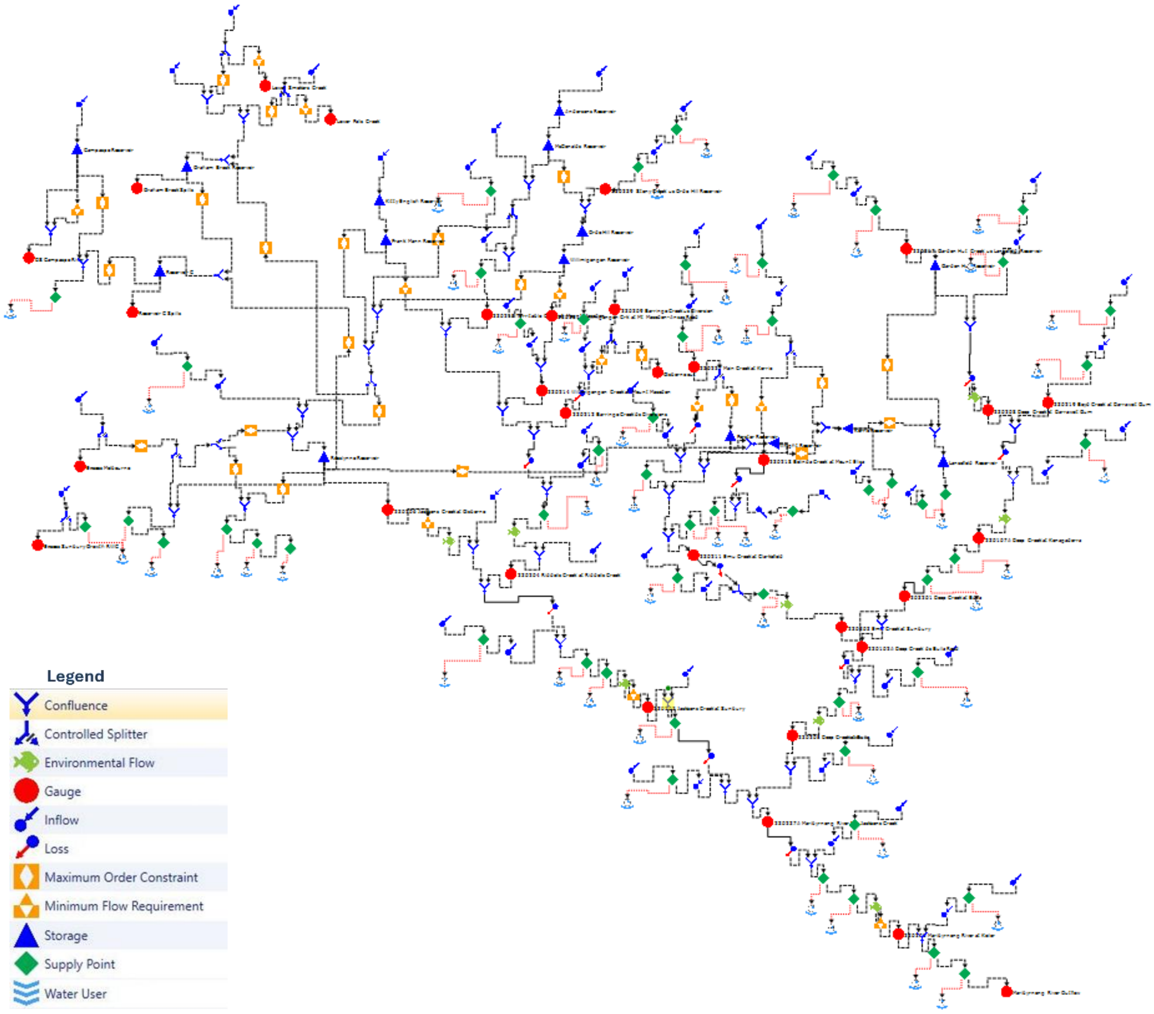

Figure 2-3 Schematic of Maribyrnong Source model

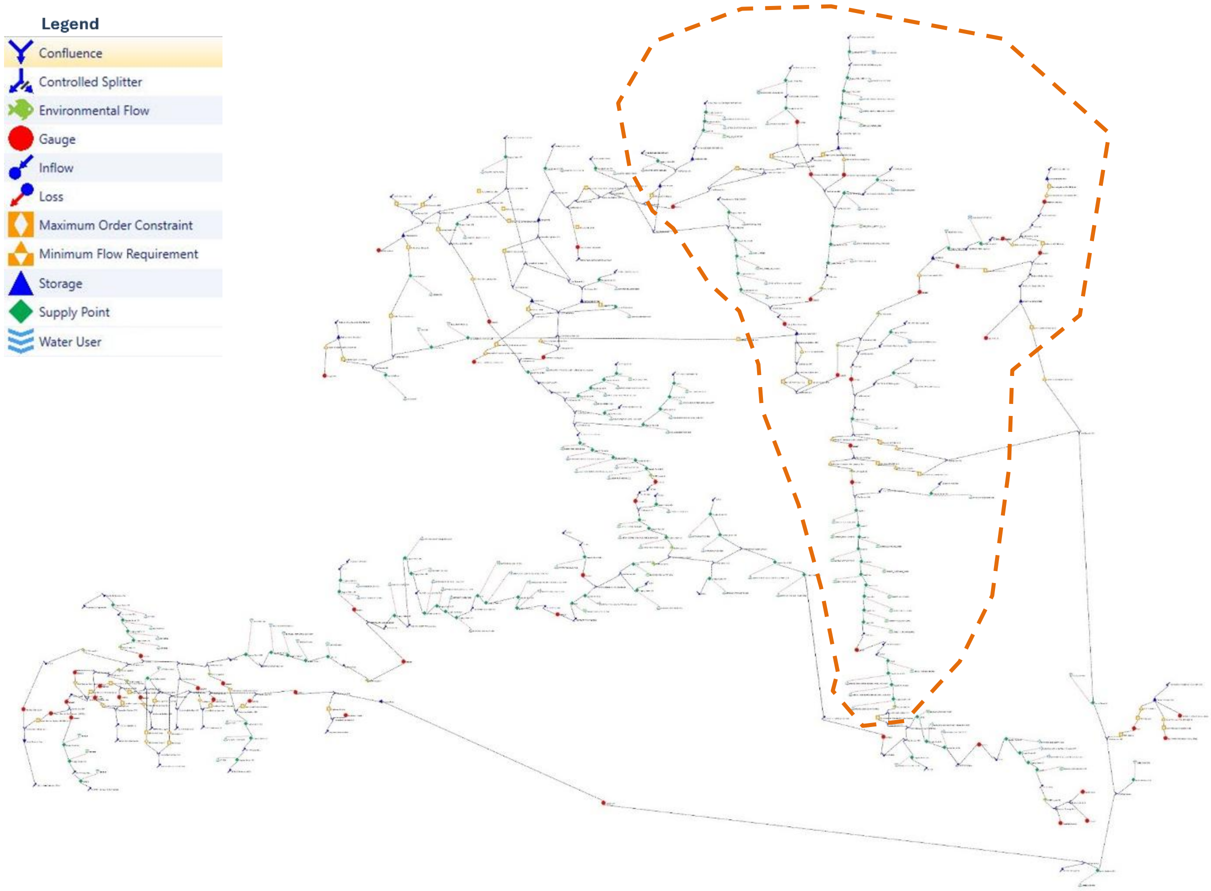

Figure 2-4 Schematic of Barwon-Moorabool Source model, with the Moorabool section enclosed within the dashed line

3. Modelling the impact of farm dams and other small water bodies on inflows

3.1 Modelling method in STEDI

The Source models for the Barwon-Moorabool and Maribyrnong systems incorporate, either explicitly or implicitly, water that is taken and used by licensed and domestic and stock (D&S) users in these systems. from the impact of farm dams due to impoundment of runoff, climate effects on storage and take from these dams in each of the major subcatchments of these systems are explicitly modelled using the Spatial Tool for Estimation of Dam Impacts (STEDI) model.

STEDI is used to explicitly model farm dam impacts in 19 subcatchments of the Maribyrnong system and 16 subcatchments of the Moorabool system. STEDI is used to model current farm dam impacts and estimate the historical impact of farm dams, which has evolved over time. These are then added back to the streamflow time series that were recorded at flow gauges.

The conceptual structure of the STEDI model is shown in Figure 3-1. The water balance for each farm dam is characterised by inflows; net evaporation: the difference between evaporation from the dam surface area and rainfall directly falling on the dam; extractions from the dam to supply demands; seepage losses and spills. Spills from upstream dams may be intercepted by dams that are further downstream. Low-flow bypasses may be installed on some or all dams in a catchment, which will divert inflows up to the flow capacity of the bypass around the dam. Low flow bypasses are currently relatively uncommon in the Maribyrnong and Moorabool catchments. Farm dams in a catchment have a cumulative impact, which affects the overall hydrograph of inflows at locations further down the catchment.

Inflows to runoff dams may be contributed by surface runoff from the upstream catchment area, capture of excess runoff from irrigated areas upstream of the dam, discharge from groundwater via springs, diversion from a nearby stream, pumping from groundwater and/or spills from upstream dams. Water that may otherwise have flowed into a farm dam may also be intercepted by features in the catchment upstream of the dam, such as natural lakes, depressions or wetlands. Gauging of inflows to individual runoff dams is rare and spatial and temporal variations in the above aspects contribute uncertainty to estimates of inflows to individual dams.

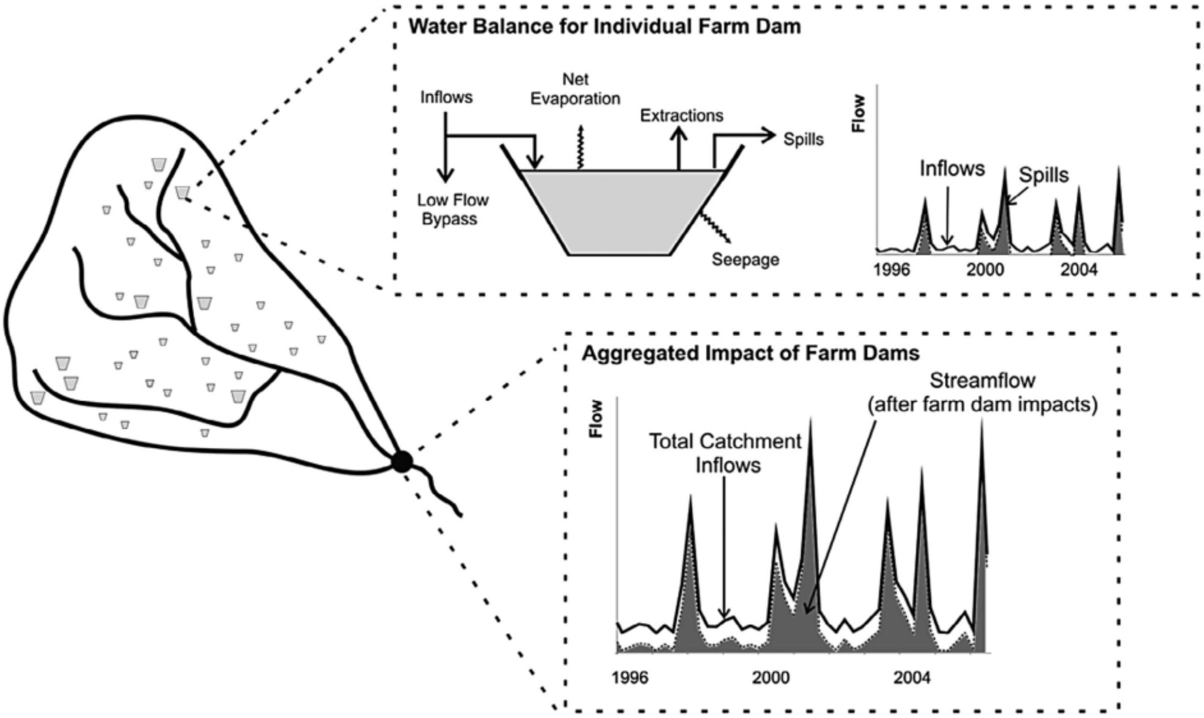

Figure 3-1 Conceptual representation of farm dam impacts in the STEDI model (from Fowler et al., 2016)

3.2 Limitations of farm dam impact modelling

The following discussion provides an overview of the main limitations and sources of uncertainty in surface water interception models for farm dams.

Identification, location classification and extent of runoff dams – Modelling runoff dam impact requires an understanding of the number, location and extent (catchment area and surface area) of runoff dams. The spatial data analysis used for this purpose is influenced by the resolution and quality of the spatial imagery and data used, the period or periods for which data is available, the method of identification, the catchment conditions at the time of data acquisition, and the quality of any regulatory or other water body data available to support identification and classification.

Historical change in the number of dams – Modelling requires assumptions to be made about which of the dams were present over the period that was concurrent with modelled or gauged streamflow data for the catchment. There is often some uncertainty about the trajectory of runoff dam development over time, and this contributes uncertainty to how the model would scale impacts from historical periods, when there may have been fewer dams and with lower aggregate storage volume, to current and forecast future numbers and storage volumes of dams.

Runoff dam inflow – Uncertainties in spatial and temporal variations of inflow to runoff dams are influenced by catchment characteristics, including soils, vegetation cover, land use, agricultural practices, hydrogeology of underlying aquifers and stream networks. Uncertainty in the estimation of inflow has been reduced, at a catchment level, by calibrating a catchment model to gauged streamflows at several locations within the Maribyrnong and Moorabool catchments. However, a component of uncertainty will remain around the inflow to each dam, due to spatial and temporal variations in surface runoff and other inflows to each dam.

Spatial and temporal variation of rainfall and evapotranspiration within a catchment – Uncertainties in spatial and temporal variations of rainfall and evapotranspiration within a catchment contribute to uncertainties in spatial and temporal variations of inflow to runoff dams

Demands and usage – Demand and usage is not metered from D&S farm dams and from almost all other small water bodies in Victoria. The typical annual volume of usage and pattern of demand, across the year, is therefore estimated as a proportion of the estimated storage volume in the STEDI model. Demand is likely to vary significantly between dams and from year to year for each dam.

Storage volume – A contributor to uncertainty in the impact of runoff dams is the uncertainty in the volumetric storage capacity of each dam, as accurate survey data is rarely available for runoff dams and their storage volumes must therefore be estimated from their surface area.

Volume stored – Uncertainty in estimating the volume stored in each farm contributes to uncertainty in usage and net evaporation losses. It will also contribute to uncertainty in the estimation of inflow if the runoff dam storage volume is used as a predictor of the area of the upstream contributing catchment.

Net evaporation – Uncertainty in net evaporation from dams is typically viewed as a relatively small component of the overall uncertainty. This is because (a) direct rainfall on the surface area of the dams counterbalances much of the evaporation losses and (b) the total surface area of all runoff dams in a catchment is a small proportion of the overall catchment area.

Seepage losses – Seepage losses from runoff dams are difficult to estimate and often ignored in models of runoff dam impacts.

Groundwater flows / Ingress – While typically assumed to be negligible due to the use of clay, plastic or geo-textile liners, inflow from groundwater can impact the overall water balance of runoff dams, i.e., the volume stored and, therefore, influences the uncertainty outlined above.

Losses and hydrologic connection: seepage rates from dams and each dam's location in the landscape can contribute significantly, in some cases, to the impact of runoff dams. It is difficult to generalise dam characteristics across a region and levels of hydrologic connection to downstream waterways may vary significantly between dams in a catchment. The modelling assumes that all of the modelled impact at each individual dam translates directly to an impact on flows in the waterway, but in many cases, particularly during dry times, the level of hydrologic connection will be significantly less than 100%.

Spatial resolution of flow regimes from Source models - Source models are focussed on assessing flow regimes and environmental water deliveries for the major streams in each system, which generally run from downstream of the major reservoirs. Spatial and temporal variations in water takes across the catchments may present different levels of risk to in-stream flows and environmental values in the tributary streams that may not be explicitly represented in the Source models.

Climate change projections - There are large variations in projected mean annual rainfall and runoff between climate change projection scenarios. The low projection scenarios show projected increases in rainfall and runoff for the Maribyrnong and Moorabool basins, whilst the high projection scenarios project decreases in runoff of up to 45% to 55% by 2065 under the high climate change projection for RCP8.5. The 2065 RCP 4.5 medium scenario provided for a reasonable assessment of the sensitivity of how the influence of farm dams might be modulated by projected climate change.

Changes in catchment response after the Millennium drought –. In some catchments, runoff decreased more than expected for the given amount of rainfall during and after the Millennium Drought, as shown in Figure 3-2. The reductions in runoff generation are widespread across central and Western Victoria and are observed in unimpacted catchments where flow conditions are not impacted by farm dam growth, changes in land use, extractions or other flow regulation. About one-third of the Victorian catchments studied are still in this drought-like state, including catchments in the upper Maribyrnong and other catchments in the vicinity of this study.

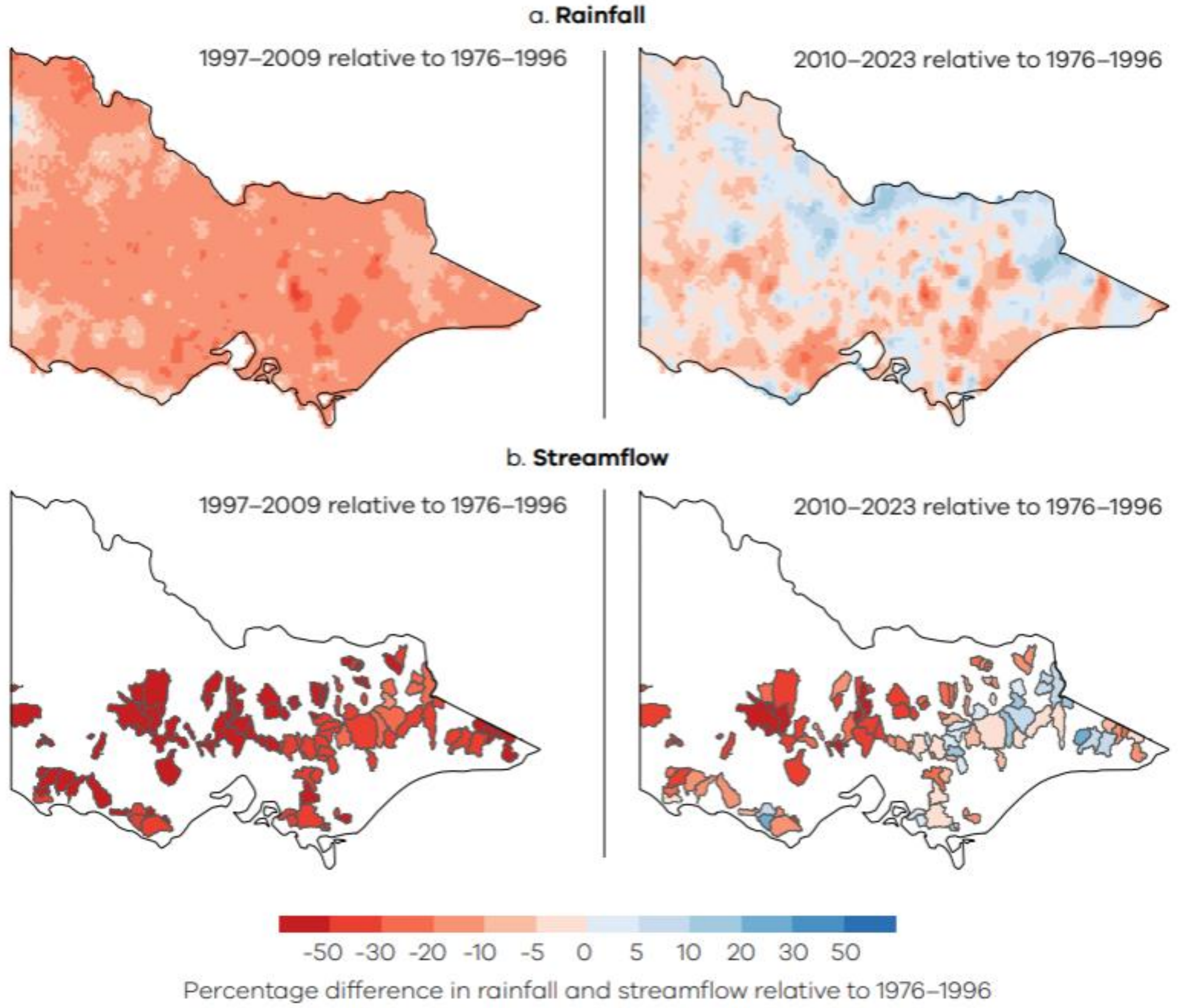

Figure 3-2 Percentage change in observed mean rainfall (a) and mean streamflow (b) in 1997–2009 during the Millennium Drought (left column) and in 2010–2023 after the drought (right column) relative to 1976–96 (pre-drought). Blue colours represent increased rainfall and streamflow, while red colours represent a reduction. (Source: CSIRO)

3.3 Improvement of previous STEDI models in the Maribyrnong and Moorabool basins

STEDI models use data on the maximum surface area of water bodies in the catchment captured from aerial photography or satellite imagery, to estimate the maximum storage volume of each farm dam. There are uncertainties in estimating the volume of each water body and in being sure about which water bodies are farm dams and which are other water bodies, such as natural wetlands or wastewater treatment ponds. The STEDI models also make assumptions about the volume of demand that is extracted from each farm dam for use in each year (normally as a function of each dam's estimated storage volume), the catchment area upstream of each farm dam (which influences the volume of inflow that each dam captures), rainfall on and evaporation from the surface area of each dam and the spatial connectivity of dam impacts in each subcatchment.

The existing Maribyrnong and Moorabool Source models available to inform this current study previously included STEDI models to represent the impact of small catchment dams on inflows in each subcatchment. That is, there are 19 existing STEDI models for catchments in the Maribyrnong system and 16 existing STEDI models for subcatchments in the Moorabool system. All of these models were “level 1” STEDI models, which made relatively simple assumptions about the spatial arrangement and catchment areas of each individual farm dam. The previous level 1 STEDI models ignored the spatial connectivity of farm dams in each subcatchment (i.e. ignoring the fact that dams are often in chains along a gully, where one farm dam may fill and then water spilling from that dam, along with local inflows, would be captured by dams that are further downstream along the chain) and that the local catchment area draining to each farm dam is a simple linear function of the storage volume of the dam (i.e. the upstream catchment area for each dam is not known; instead it is assumed that farm dams with larger volumes collect runoff from a larger upstream area).

For this study level 2 STEDI models were set up for every subcatchment in the Maribyrnong and Moorabool basin. These level 2 STEDI models explicitly represented the catchment draining to every water body in the catchment. The level 2 STEDI models demand factor assumptions by water body type are shown in Table 3-1. Note that all water bodies lose water via evaporation but gain water via direct rainfall on their surface. The previous level 1 STEDI models also assumed that the mean annual usage from each D&S farm dam was 50% of the estimated dam storage volume and that mean annual usage from each irrigation farm dam was 84% of the estimated dam storage volume.

Table 3-1 Demand factors for water bodies in level 2 STEDI models

Water body type	Ratio of mean annual demand to storage volume
Licensed irrigation dams	0.84
Domestic and stock unlicensed dams	0.5
Quarry pits	0
Natural pools and wetlands	0
Aesthetic lakes	0
Wastewater treatment lagoons	0 (and no external catchment inflows or overflows)

3.4 Data on farm dams and water bodies

The key Victorian statewide data source is the *Farm Dams Boundaries* data set[1]. Although it is dated 2019, the mapping for the Maribyrnong and Moorabool catchments was completed using imagery captured in 2009 -2010. The attributes of the dataset were updated in 2018 to improve interpretation and usability. The data set includes licensed and unlicensed dams, mapped via manual interpretation with polygon boundaries to represent the extent of each dam when full. Attribution includes a flag for farm dams and runoff dams, date of source aerial imagery and licensing status, surface area and calculated volume (where the volume is estimated by applying the equation from Fowler et al., 2016).

To identify changes in farm dams (decommissioned & newly established) post-2009, Digital Earth Australia (DEA) Water Observation From Space (WOFS) data set was utilised. Dams that consistently

[1] State Government of Victoria, Department of Energy, Environment and Climate Action. Farm Dam Boundaries

lacked water in recent observations were flagged for potential removal. Additional water bodies appearing in the dataset after 2009 were identified, as these could be newly constructed water bodies or water bodies that were missed when the DELWP (2012) dataset was compiled. Each identified change was subjected to review through comparing historical and recent aerial imagery. The volume of these newly constructed dams was estimated using the same methodology as that used in the stakeholder provided datasets (Fowler *et al.*, 2016).

Based on the metadata, the WOFS data was collected on 31 December 2023 and published on 7 March 2024 Geoscience Australia DEA data hub. The currency of the satellite imagery from Google Earth covering the study area as:

- **Maribyrnong Catchment –** captured between September 2023 to February 2024.
- **Moorabool Catchment –** captured between January and February 2024.

Stakeholder provided farm dam information was incorporated into this study. Cross-checking with the recent satellite imagery was performed to confirm the existence and current status of the farm dams reported by stakeholders. Collectively, these additions significantly enhanced the comprehensiveness of this study, ensuring that developments after the publication of the DELWP (2012) dataset were accurately captured. The updated dataset provided a more contemporary foundation for analysing the impact of farm dams on water resources within the catchments.

There was no way to reliably link the data on the Victorian Water Register on irrigation licenses or farm dam notifications to the spatial data sets on water bodies. Considering this limitation, the field on each water body called FEAT_TYPE in the DELWP (2012) farm dams data was used to assess the type of each water body. For the purposes of this project, it was assumed that:

- Water bodies in the DELWP (2012) data set were irrigation dams if they had FEAT_TYPE values of rural licensed storage or rural irrigation.
- Water bodies in the DELWP (2012) data set were D&S dams if they had FEAT_TYPE values of rural storage.
- All remaining water bodies (FEAT_TYPE values of town rural storage or industrial storage) were visually inspected in satellite imagery to determine their likely type.
- If a water body in the updated 2025 data set replaces a water body from the DELWP (2012) data set, the updated water body (normally a change in surface area) takes on the same designation as it had in the DELWP (2012) data set.
- Three licensed dams in the Maribyrnong 2025 data set were identified from historical imagery as having been in place and having the same surface area prior to 2009. Smaller farm dams in the DELWP (2012) data set that intersected with those dams, which were most likely under-estimated in surface area and volume as they were near empty during the drought in 2009, were replaced by the licensed dams with the extent and volume identified in 2025.

4. Modelling scenarios

The Source and STEDI models in the Barwon-Moorabool and Maribyrnong systems have been calibrated to recorded streamflow and climate data over the historical period of record.

In accordance with the *Guidelines for assessing the impact of climate change on water availability in Victoria* (Department of Environment Land Water and Planning, 2020), the representation of current conditions uses data on inflows and climate for the full historical period, but with data recorded prior to 1975 adjusted to be statistically equivalent to data from the post-1975 period.

The scenarios modelled for this project were as follows:

- **2009 / 2010 level of development scenario:** updating the farm dam impacts in the baseline scenario models with farm dam impacts derived using the upgraded Level 2 STEDI models and water body inputs from the DELWP (2012) data set.
- **Unimpacted by farm dams scenario:** current Source models (from Baseline scenario) but with all farm dam impacts set to zero.
- **2025 level of development scenario:** updating the farm dam impacts from the 2009/2010 level of development scenario with farm dam impacts derived from the Level 2 STEDI models with current (2025) spatial data on water bodies.
- **2025 level of development with projected climate change scenario:** as for the previous scenario (using current spatial data on water bodies) but with all climate and inflow data re-scaled to represent the 2065 RCP 4.5 Medium sensitivity climate change projections (see Table 4-1).

Table 4-1 Projected changes in mean annual rainfall and inflows for 2065 Representative Concentration Pathway 4.5 W/m^2 (RCP 4.5) Medium climate change sensitivity scenario, relative to mid-point of post-1975 period (DELWP, 2020)

Projection	Maribyrnong mean annual rainfall	Moorabool mean annual rainfall	Maribyrnong mean annual streamflow	Moorabool mean annual streamflow
2065 RCP4.5Medium	-3.3%	-3.2%	-9.7%	-7.1%

All model scenarios included the same assumptions for current large dams and water infrastructure, current licensed entitlements and demands and current operational and environmental flow rules.

5. Number and storage volume of farm dams

5.1 Maribyrnong catchment

Table 5-1 lists the total number of water bodies, by type, in the Maribyrnong catchment for the 2009 and 2025 level of development. Domestic and stock farm dams constitute by far the largest proportion of water bodies in the Maribyrnong catchment. There was an increase of 2% in the total number of domestic and stock farm dams in the Maribyrnong between 2009 and 2025.

Table 5-1 Number of water bodies in the Maribyrnong catchment by type for 2009 and 2025 level of development

Type of water body	2009 Level of farm dam development	2025 Level of farm dam development	Change between 2009 and 2025	% Change between 2009 and 2025
Domestic and stock farm dam	6,775	6,932	157	2%
Licensed irrigation farm dam	107	109	2	2%
Golf course irrigation dam	7	7	0	0%
Subtotal: Rural farm dams	**6,889**	**7,048**	**159**	**2%**
Quarry pit	17	15	-2	-12%
Natural lakes and wetlands	58	57	-1	-2%
Public aesthetic lakes and other water bodies	16	13	-3	-19%
Wastewater treatment plant and recycled water plant lagoons	2	2	0	0%
Total: water bodies modelled in STEDI	**6,982**	**7,135**	**153**	**2%**

The storage capacity (V in ML), of each water body was estimated from their surface area (S in m²) from the equation provided in (Fowler *et al.*, 2016):

$$V = 0.00001042\ S^{1.3213}$$

Storage volumes were calculated for each subcatchment in the Maribyrnong for the 2009 and 2025 levels of development by calculating the volumes for each water body that was present in the spatial data at that time and then aggregating the total volumes by subcatchment. Table 5-2 shows the total storage volume of farm dams for the 2009 and 2025 levels of development in the Maribyrnong catchment. The storage volume of domestic and stock and licensed irrigation farm dams and irrigation lakes on golf courses increased by 6% over the 16-year period. The estimated storage volume of rural farm dams increased by 6%, which was considerably larger than the 2% increase in the number of rural farm dams. This difference was due to the enlargement of the surface area of existing farm dams, which increased the estimated total storage volume.

There were also changes over the 2009 to 2025 period in the numbers and volumes of other water bodies, which include quarry pits, natural lakes and wetlands and aesthetic lakes on public land, such as parks. Whilst these other water bodies are represented in the STEDI models (see Section 6), their numbers and volumes are considerably lower than rural farm dams and it is the rural farm dams that have the largest influence on changes in impact on streamflow.

Table 5-2 Storage volume of water bodies in the Maribyrnong catchment by type for 2009 and 2025 level of development

Type of water body	2009 Level of farm dam development (ML)	2025 Level of farm dam development (ML)	Change between 2009 and 2025 (ML)	% Change between 2009 and 2025
Domestic and stock farm dam	11,731	12,448	717	6%
Licensed irrigation farm dam	1,480	1,592	112	8%
Golf course irrigation dam	26	47	21	79%
Subtotal: Rural farm dams	**13,238**	**14,088**	**850**	**6%**
Quarry pit	27	60	32	118%
Natural lakes and wetlands	221	221	0	0%
Public aesthetic lakes and other water bodies	155	156	1	1%

There is considerable spatial variation in the numbers, volume and estimated impact of farm dams across the Maribyrnong basin.

Figure 5-1 shows that most of the increase in storage volume between 2009 and 2025 occurred in 2 of the 21 subcatchments in the Maribyrnong basin, albeit that those are 2 of the larger subcatchments by area.

5.2 Moorabool catchment

Table 5-3 shows that the number of farm dams has increased in the Moorabool catchment by 4% between 2010 and 2025. Domestic and stock farm dams constitute by far the largest proportion of water bodies in the Moorabool catchment.

Table 5-3 Number of water bodies in the Moorabool catchment by type for 2010 and 2025 level of development

Type of water body	2010 Level of farm dam development	2025 Level of farm dam development	Change between 2010 and 2025	% Change between 2010 and 2025
Domestic and stock farm dam	5,749	5,996	247	4%
Licensed irrigation farm dam	294	298	4	1%
Golf course irrigation dam	0	0	0	0%
Subtotal: Rural farm dams	**6,043**	**6,294**	**251**	**4%**
Quarry pit	33	60	27	82%
Natural lakes and wetlands	19	18	-1	-5%
Public aesthetic lakes and other water bodies	15	16	1	7%
Wastewater treatment plant and recycled water plant lagoons	11	11	0	0%
Total: water bodies modelled in STEDI	**6,121**	**6,399**	**278**	**5%**
Dams operated by water corporations	8	8	0	0%

The storage capacity (V in ML), of each water body was estimated from their surface area (S in m²) from the equation provided in (Fowler *et al.*, 2016):

$$V = 0.00001042\ S^{1.3213}$$

Storage volumes were calculated for each subcatchment in the Maribyrnong for the 2009 and 2025 levels of development by calculating the volumes for each water body that was present in the spatial data at that time and then aggregating the total volumes by subcatchment.

Table 5-4 shows that the total storage volume of farm dams has increased in the Moorabool catchment by 20% between 2010 and 2025. There was an increase over this period in domestic and stock dams and licensed irrigation farm dams. The estimated storage volume of rural farm dams increased by 20%, which was considerably larger than the 4% increase in the number of rural farm dams. This difference was due to the enlargement of the surface area of existing farm dams, which increased the estimated total storage volume.

There were also changes over the 2010 to 2025 period in the numbers and volumes of other water bodies, which include quarry pits, natural lakes and wetlands and aesthetic lakes on public land, such as parks. Whilst these other water bodies are represented in the STEDI models (see Section 6), their numbers and volumes are considerably lower than rural farm dams and it is the rural farm dams that have the largest influence on changes in estimated impact on streamflow.

Table 5-4 Storage volume of water bodies in the Moorabool catchment by type for 2010 and 2025 level of development

Type of water body	2010 Level of farm dam development (ML)	2025 Level of farm dam development (ML)	Change between 2010 and 2025 (ML)	% Change between 2010 and 2025
Domestic and stock farm dam	14,880	18,059	3,179	21%
Licensed irrigation farm dam	2,177	2,458	282	13%
Golf course irrigation dam	0	0	0	0%
Subtotal: Rural farm dams	**17,057**	**20,517**	**3,460**	**20%**
Quarry pit	40	372	331	824%
Natural lakes and wetlands	93	86	-7	-8%
Public aesthetic lakes and other water bodies	4	26	22	518%

Spatial variation in the numbers, volume and estimated impact of farm dams across the Moorabool basin is considerable and probably more marked than spatial variation in these characteristics across the Maribyrnong basin.

Figure 5-2 shows that most of the increase in storage volume between 2010 and 2025 occurred in 2 of the 16 subcatchments in the Moorabool basin, albeit that those are 2 of the larger subcatchments by area (the Lal Lal Creek subcatchment and the mid-Moorabool River between Morrisons and She Oaks Diversion Weir).

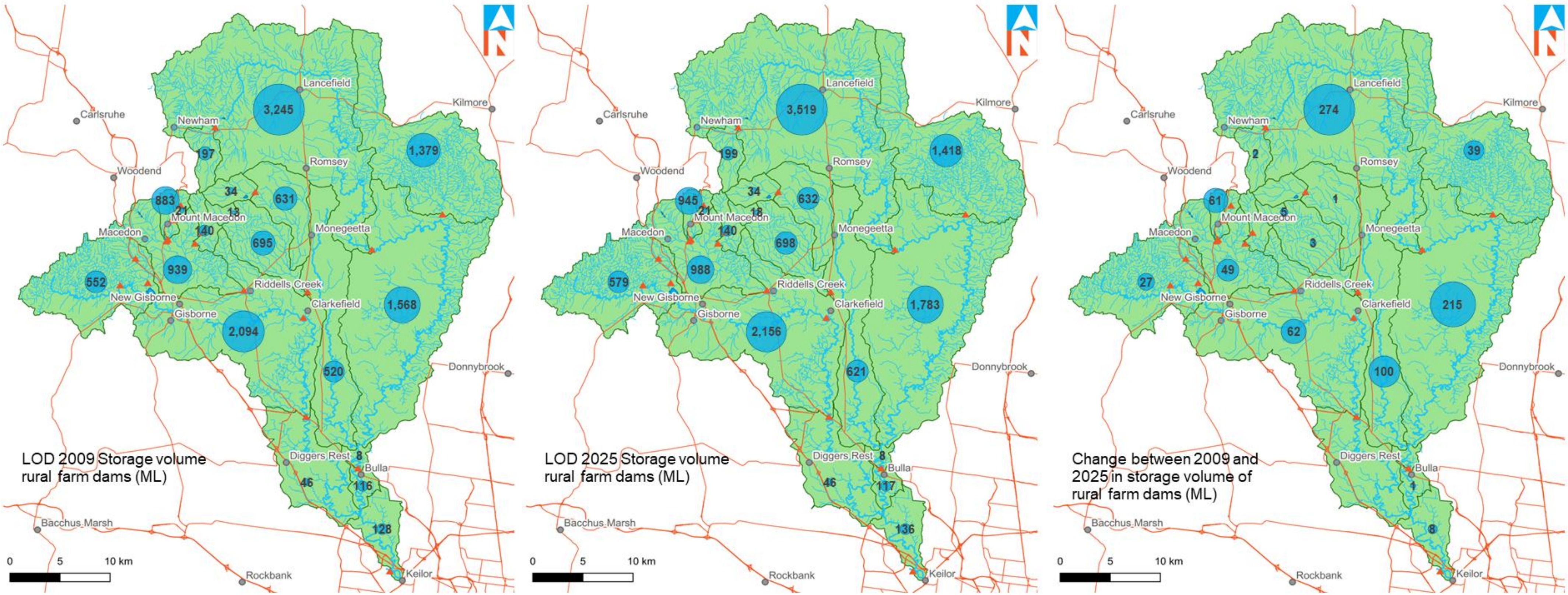

Figure 5-1 Storage volume of farm dams in subcatchments of the Maribyrnong: (left) 2010 farm dams; (centre) 2025 farm dams; (right) change in storage volume between 2010 and 2025 level of development

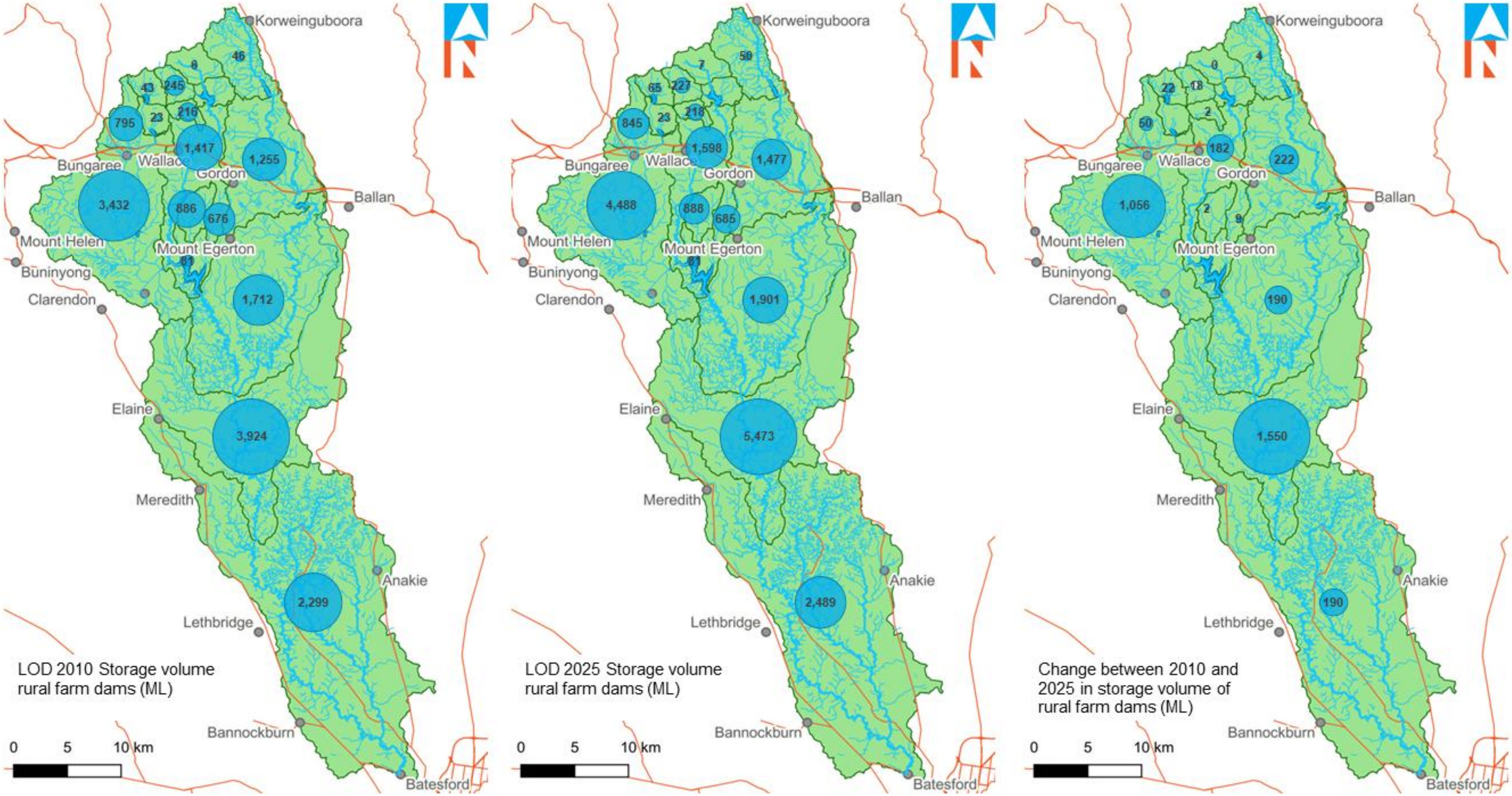

Figure 5-2 Storage volume of farm dams in subcatchments of the Moorabool: (left) 2010 farm dams; (centre) 2025 farm dams; (right) change in storage volume between 2010 and 2025 level of development

6. Estimated impact of farm dams on streamflow

There is spatial variation in the number, volume and density (ML/km²) of farm dams and other water bodies across both the Maribyrnong and Moorabool catchments. There are also spatial variations in generation of runoff across the Maribyrnong and Moorabool catchments, and these spatial variations in runoff generation and farm dam arrangement interact to produce spatial variations in the estimated impact of farm dams on streamflow. The estimated impact of farm dams also varies from year to year, in accordance with year to year variations in rainfall, evapotranspiration and runoff across each of the catchments. Uncertainties in modelling of farm dam impacts are discussed further in Section 3.2.

This section presents results for the Maribyrnong and then the Moorabool basins. Results were produced from the STEDI models for each of the subcatchments in each basin, with runs undertaken for the 2009/2010 and 2025 level of farm dam development scenarios and for a 2025 level of farm dam development with projected climate change to 2065 scenario. For each catchment, results are addressed firstly for temporal (year to year variations) in estimated farm dam impact, then for spatial variations in estimated farm dam impact and finally a summary of overall estimated farm dam impact is provided.

6.1 Temporal variation in estimated farm dam impact across the Maribyrnong

Figure 6-1 and Figure 6-2 show an annual time series of the estimated impact of water bodies on inflows in the Maribyrnong catchment for the 2009 and 2025 level of development scenarios, respectively. In both scenarios, quarries, natural water bodies and public recreational aesthetic lakes make minimal contribution to the overall impact of small water bodies. In both the 2009 and 2025 level of development scenarios, most of the estimated impact is due to domestic and stock dams, with a smaller contribution from licensed farm dams.

Figure 6-1 and Figure 6-2 also demonstrate the considerable year to year variability in the estimated impact of farm dams on flows in the Maribyrnong catchment. For example, estimated farm dam impacts in the water year starting July 2010 were the largest of any year that was modelled, as farm dams refilled during this wet La Niña year that followed the Millennium Drought (1997-2009). The estimated farm dam impacts were low in the 2001, 2002, 2005, 2006, 2007, 2008 and 2009 water years which were all dry years in the Millennium Drought. Inflows to many farm dams were low during these years, so many dams would have been at or near empty and this would have reduced their overall impact.

The volume of farm dams is larger for the 2025 than the 2009 level of farm dam development scenario, which increases the volume of impact in each year, which can be seen by comparing the orange with the blue lines in Figure 6-3.

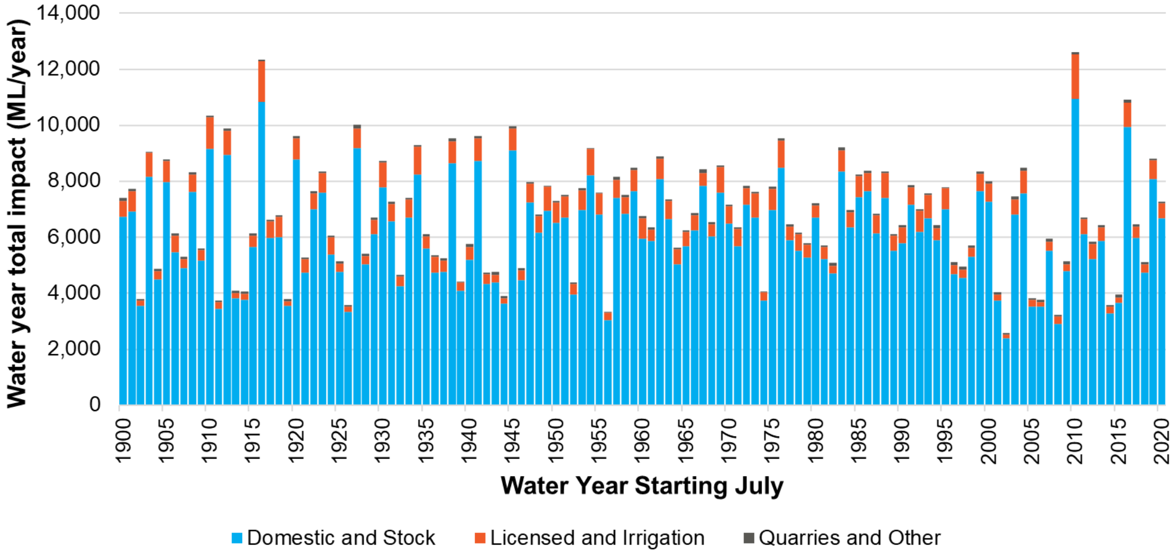

Figure 6-1 Annual estimated impact of farm dams and other small water bodies in the Maribyrnong catchment for 2009 level of farm dam development (DELWP 2012 data set)

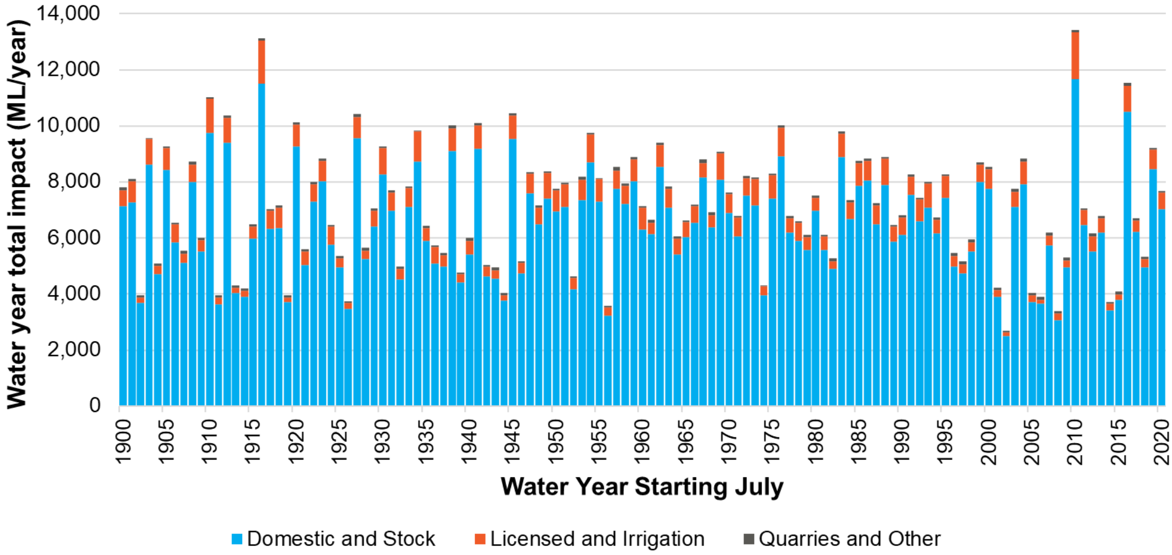

Figure 6-2 Annual estimated impact of farm dams and other small water bodies in the Maribyrnong catchment for 2025 level of farm dam development (updated data set)

With projected climate change, the total estimated impact of farm dams in the Maribyrnong is projected to further increase, as demonstrated by the grey line sitting above the orange line in Figure 6-3. The estimated impact of the current (2025) farm dams will therefore increase on the whole across the Maribyrnong catchment due to the projected influence of climate change, as farm dams capture a larger proportion of flow, even if there is no change in the number or volume of farm dams from the current level of development. This is demonstrated in Figure 6-4, which shows that farm dams have a much greater impact, as a proportion of total inflows, in dry years than average and wet years. Farm dams at 2009 or 2025 levels of development would have had an impact exceeding 20% of inflows in drought years during the 1940’s, 1982/83 and most of the Millennium Drought (2001-2004 and 2006-2010 water years).

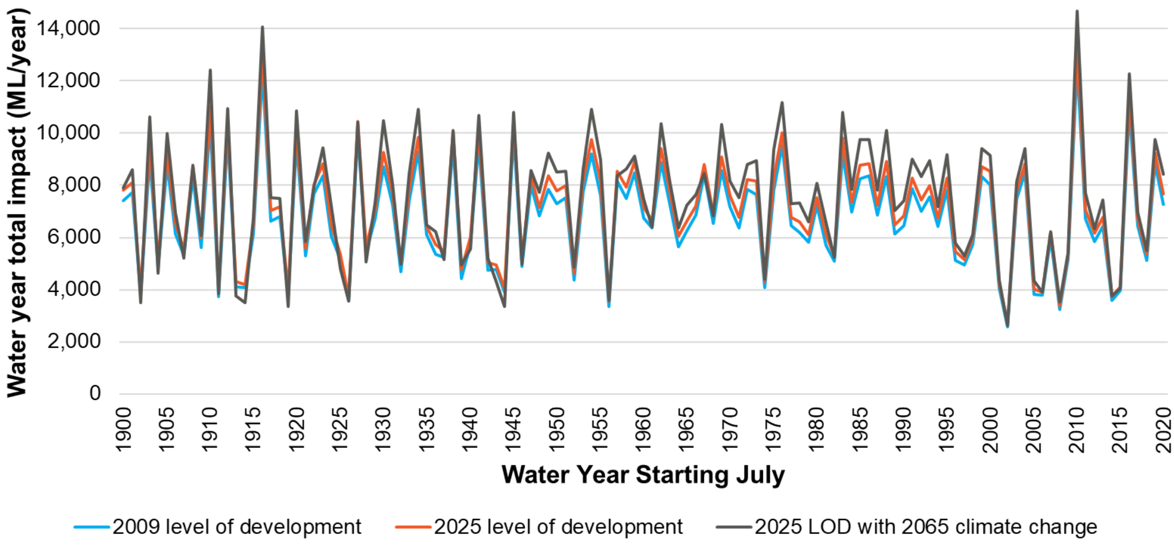

Figure 6-3 Comparison of annual estimated impact of farm dams in the Maribyrnong catchment between 2009 and 2025 levels of development and 2025 level of development with climate change projection for 2065 Medium RCP 4.5

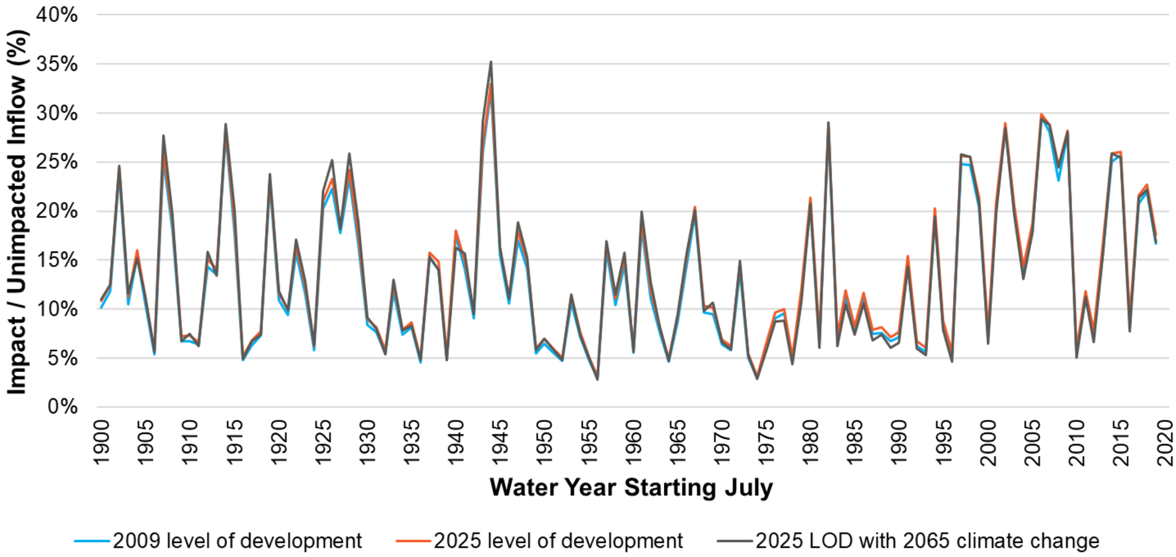

Figure 6-4 Annual estimated impact of farm dams in the Maribyrnong catchment as a proportion of unimpacted annual inflow, showing comparisons between 2009 and 2025 levels of development and 2025 level of development with climate change projection for 2065 Medium RCP 4.5

6.2 Seasonal variation in farm dam estimated impact across the Maribyrnong

Results from the STEDI model were analysed to calculate the change in outflow across each catchment due to modelled farm dam impacts for the summer/autumn (December to May) and winter/spring (June to November) seasons, as a proportion of inflows had there been no farm dams. Comparing Figure 6-5 with Figure 6-6, it can be seen that for all scenarios farm dams have a greater impact as a proportion of inflow during summer and autumn than they do during winter and spring. Inflows to farm dams are lower during summer and autumn, on average, than winter and spring, which means that farm dams are more likely to have available airspace to capture inflows during summer and autumn. As was the case with annual impacts, proportional impacts at a seasonal level are larger during dry seasons and years than in seasons and years that are average or wet.

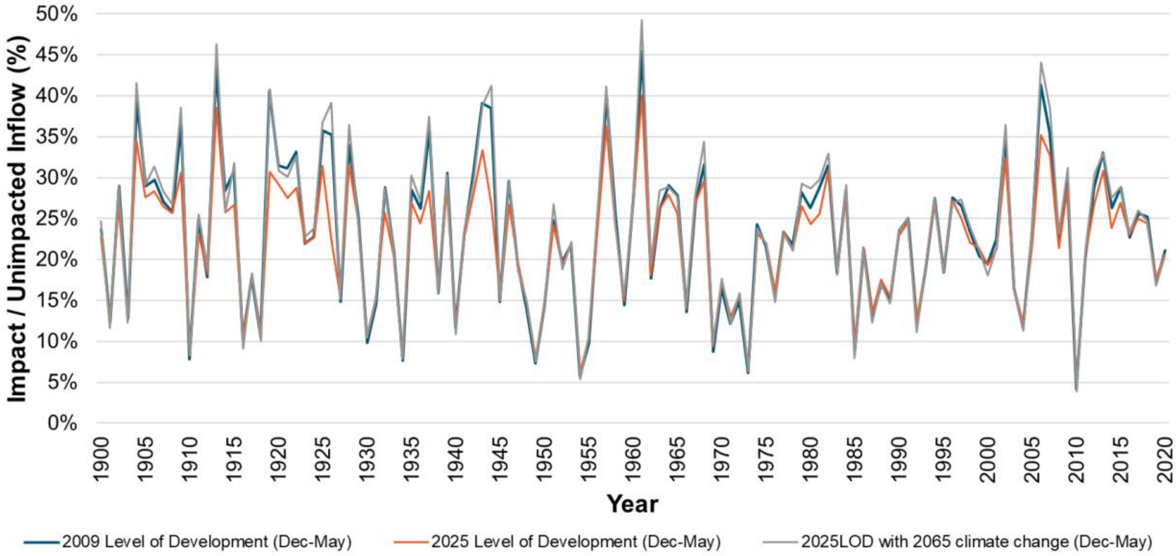

Figure 6-5 Summer and autumn estimated impact of farm dams in the Maribyrnong catchment as a proportion of unimpacted seasonal inflow, showing comparisons between 2009 and 2025 levels of development and 2025 level of development with climate change projection for 2065 Medium RCP 4.5

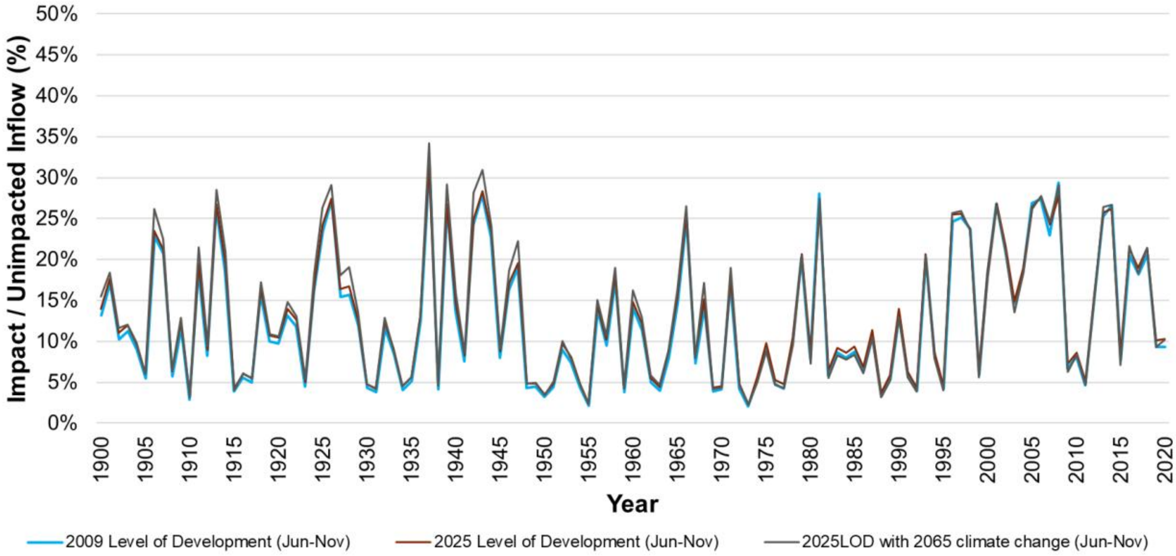

Figure 6-6 Winter and spring estimated impact of farm dams in the Maribyrnong catchment as a proportion of unimpacted seasonal inflow, showing comparisons between 2009 and 2025 levels of development and 2025 level of development with climate change projection for 2065 Medium RCP 4.5

6.3 Spatial variation in farm dam estimated impact across the Maribyrnong

Figure 6-7 shows the mean annual estimated impact by subcatchment area for the 2009, 2025 and 2065 with projected climate change scenarios. The largest mean annual estimated impacts by volume generally occur in the largest subcatchments.

Figure 6-8 shows the mean annual estimated impact divided by the area of each subcatchment, which allows more useful comparison of spatial variations in farm dam impact across the Maribyrnong catchment. The pattern of spatial variation in estimated impact is similar between the three scenarios, but the estimated impact generally increases between the 2009 and 2025 levels of development, and then increase again with the 2065 climate change projection. For the 2025 level of development, mean annual estimated impacts are between 6.9 and 8.1 ML/year/km² in the Deep and Garden Hut Creek upstream of Bolinda, Boyd Creek, Main Creek, Bolinda Creek and Riddells Creek subcatchments. Mean annual estimated impacts are generally less than 4.5 ML/year/km² in the remaining subcatchments (i.e. upstream of Rosslynne Reservoir, Emu Creek, Jacksons Creek, Deep Creek downstream of Bolinda and Boyd Creek and the Maribyrnong River).

Figure 6-9 shows the spatial variation in mean annual estimated impact as a percentage of the mean annual inflow in each subcatchment of the Maribyrnong. The same catchments that have a large mean annual impact per unit catchment area (Deep and Garden Hut Creek upstream of Bolinda, Boyd Creek, Main Creek, Bolinda Creek and Riddells Creek) also have farm dam impacts of between 10% and 20% of inflows for the 2025 level of development case. Farm dam impacts are less than 10% of inflows across most of the remaining subcatchments of the Maribyrnong. Figure 6-9 shows that percentage impacts increase between the 2009 and 2025 levels of development and are projected to increase again with climate change for the 2065 medium RCP 4.5 projection.

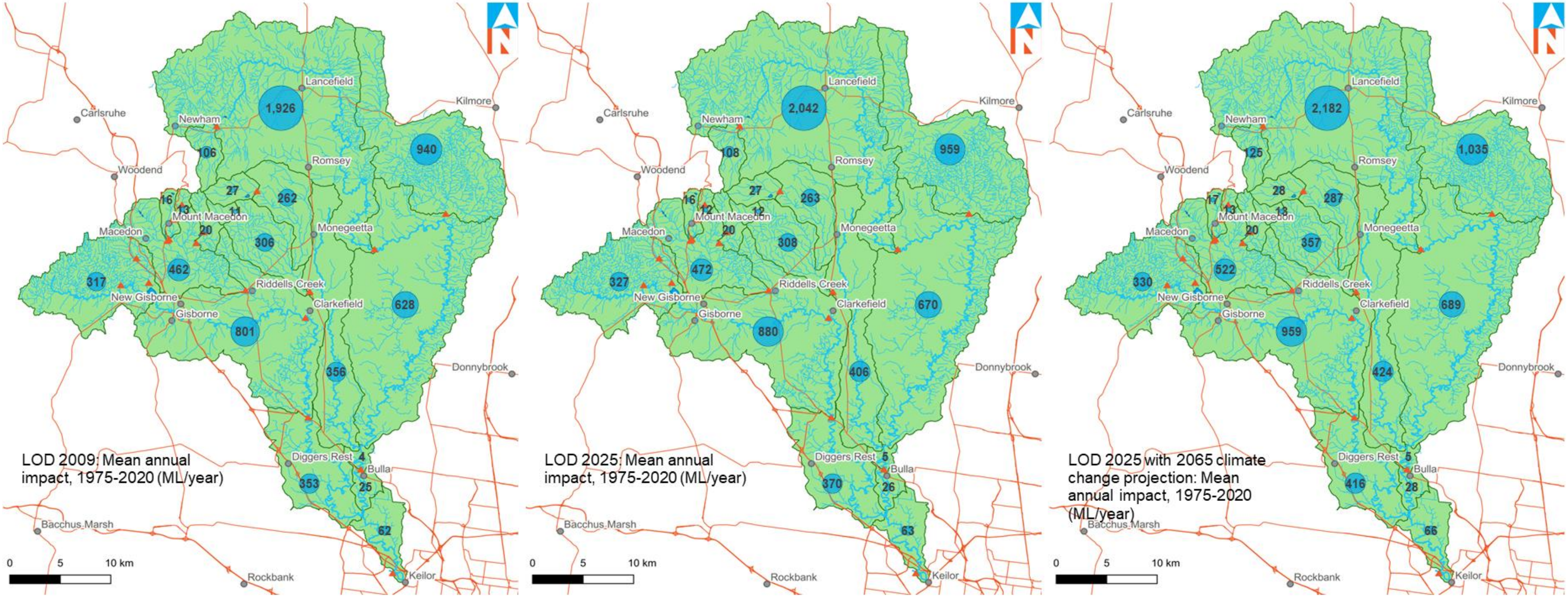

Figure 6-7 Mean annual estimated impact of farm dams in subcatchments of the Maribyrnong (all assessed across 1975-2020 period): (left) 2009 farm dams; (centre) 2025 farm dams; (right) 2025 farm dams with projected climate change for 2065 medium RCP4.5 projection

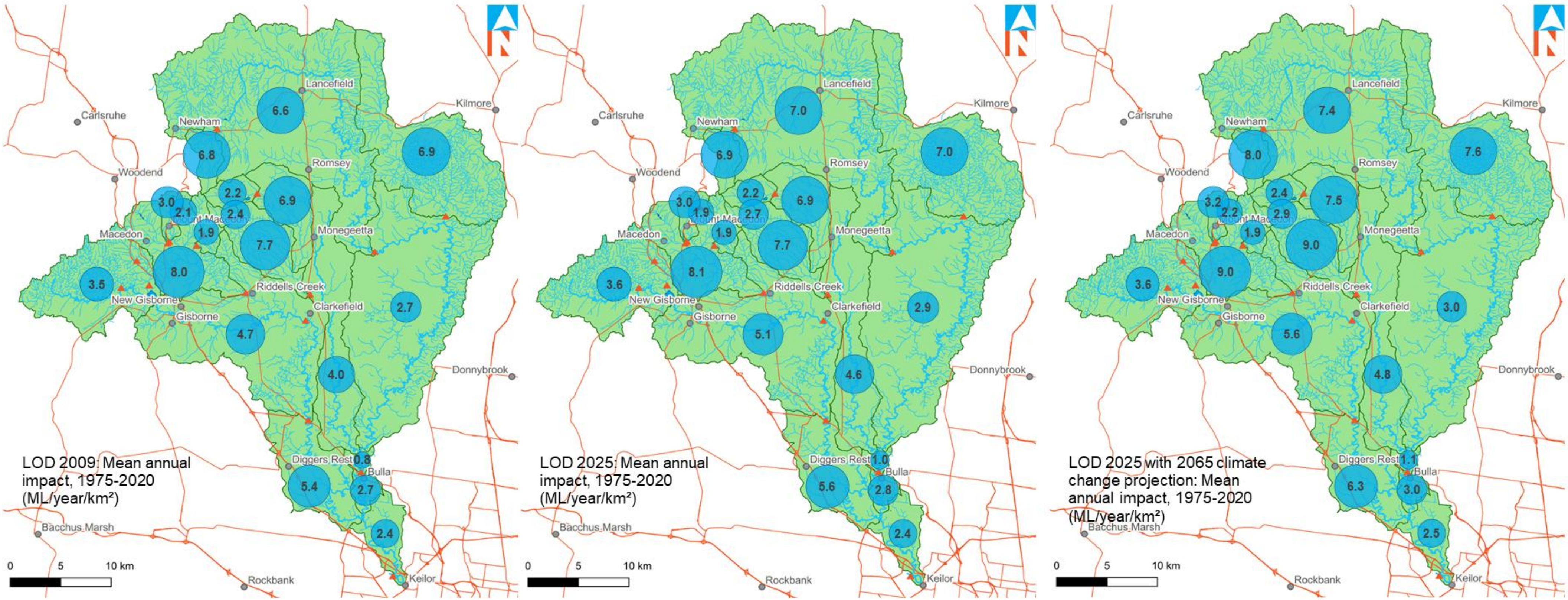

Figure 6-8 Mean annual estimated impact of farm dams per unit area in subcatchments of the Maribyrnong (all assessed across 1975-2020 period): (left) 2009 farm dams; (centre) 2025 farm dams; (right) 2025 farm dams with projected climate change for 2065 medium RCP4.5 projection

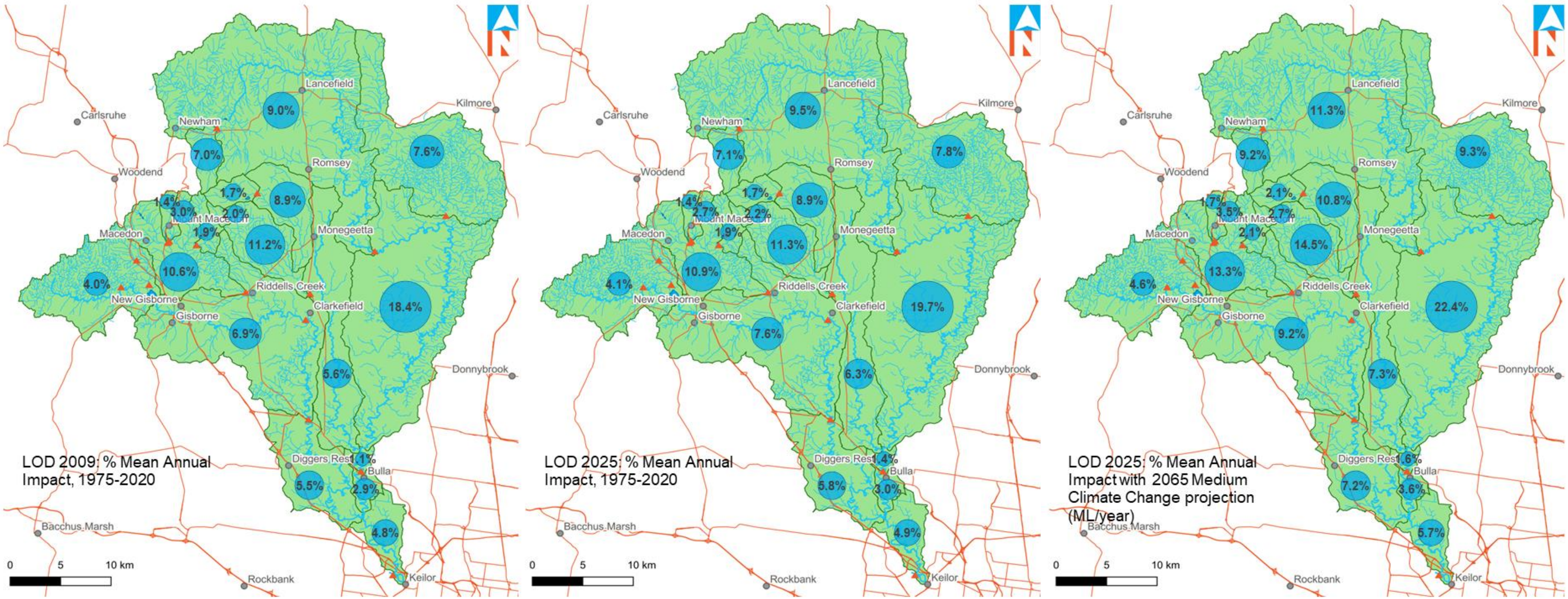

Figure 6-9 Mean annual estimated impact of farm dams as a proportion of no farm dams inflow in subcatchments of the Maribyrnong (all assessed across 1975-2020 period): (left) 2009 farm dams; (centre) 2025 farm dams; (right) 2025 farm dams with projected climate change for 2065 medium RCP4.5 projection

6.4 Temporal variation in farm dam estimated impact in the Moorabool

Figure 6-10 and Figure 6-11 show an annual time series of the estimated impact of water bodies in the Moorabool catchment for the 2010 and 2025 level of development scenarios, respectively. In both scenarios, quarries, natural water bodies and public recreational aesthetic lakes make minimal contribution to the overall impact of small water bodies. In both the 2010 and 2025 level of development scenarios, most of the estimated impact is due to domestic and stock dams, with a smaller contribution in total from licensed farm dams.

Figure 6-10 and Figure 6-11 also demonstrate the considerable year to year variability in the estimated impact of farm dams on flows in the Moorabool catchment. For example, farm dam impacts in the water year starting July 2010 were the largest of any year that was modelled, as farm dams refilled during this wet La Niña year that followed the Millennium Drought (1997-2009). The total volume of estimated farm dam impact was low in the 2001, 2002, 2005, 2006, 2007, 2008 and 2009 water years, which were all dry years in the Millennium Drought. Inflows to many farm dams were low during these years, so many dams would have been at or near empty and this would have reduced their overall impact.

The volume of farm dams is larger for the 2025 than the 2010 level of farm dam development scenario, which increases the volume of impact in each year, which can be seen by comparing the orange with the blue lines in Figure 6-12.

The combined estimated impact of projected climate change and farm dams in the Moorabool catchment is somewhat more complicated than it is in the Maribyrnong catchment. As will be discussed below, some subcatchments in the Moorabool already have a very high density of farm dam development. When the existing number and volume of farm dams is high, the reduction in inflows projected with climate change reduces the total impact of those farm dams in dry years, as the dams run dry more often. Projected impact under dryer climate conditions will be less due to the reduction in overall water availability, but will make up a greater portion of the total volume.

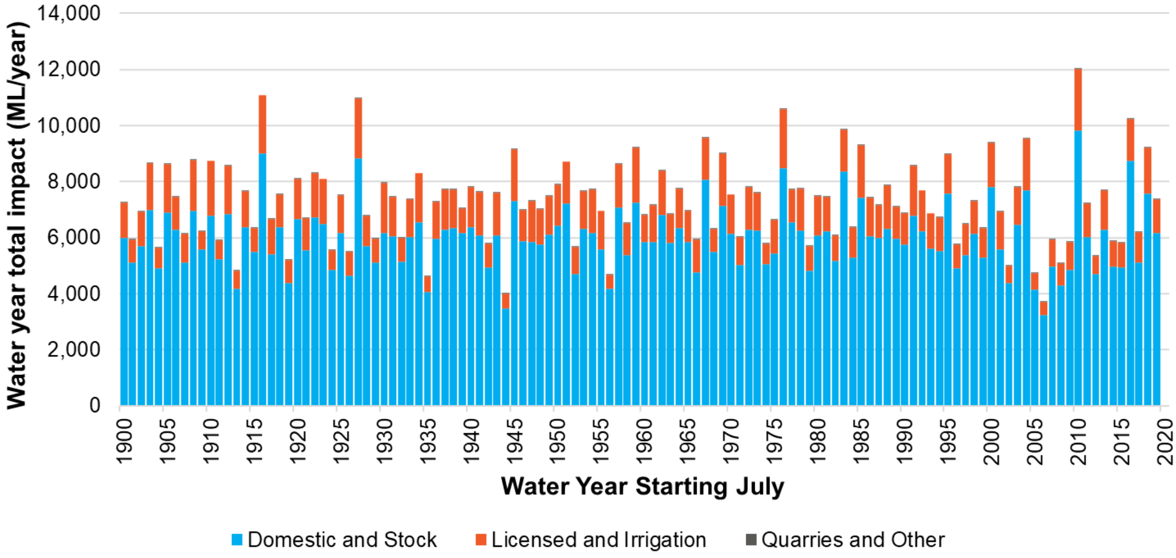

Figure 6-10 Annual estimated impact of farm dams and other small water bodies in the Moorabool catchment for 2010 level of farm dam development (DELWP 2012 data set)

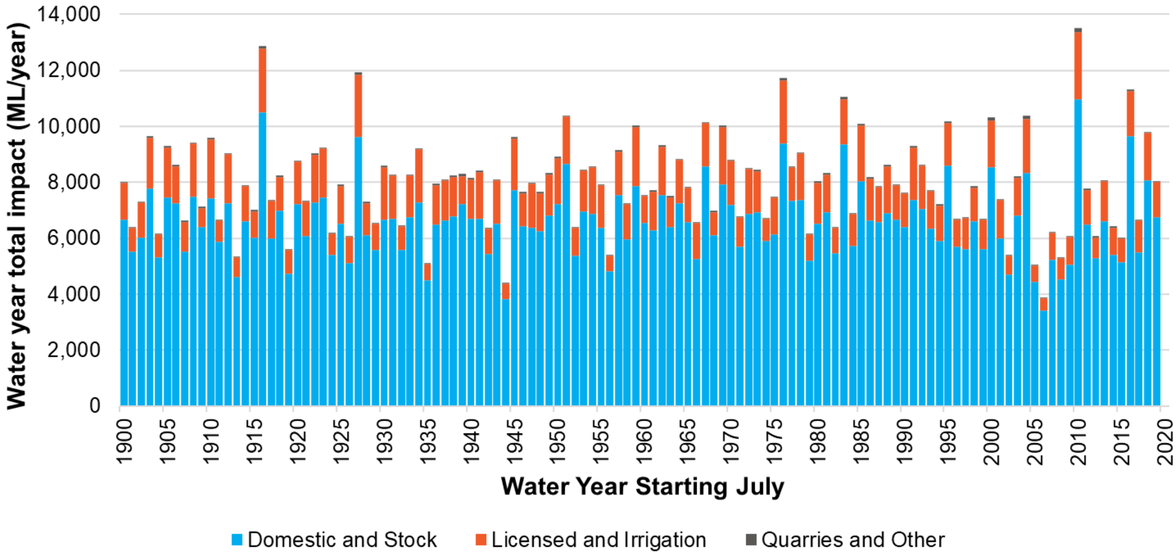

Figure 6-11 Annual estimated impact of farm dams and other small water bodies in the Moorabool catchment for 2025 level of farm dam development (updated data set)

With projected climate change, the total estimated impact of farm dams in the Moorabool is projected to further increase, as demonstrated by the grey line sitting above the orange line in Figure 6-12. Figure 6-13 shows that farm dams have a much greater impact, as a proportion of total inflows, in dry years than average and wet years. Farm dams at 2009 or 2025 levels of development would have had an impact exceeding 20% of inflows in drought years of 1914/15, 1982/83, 2015/16 and most of the Millennium Drought (1997-2000, 2002-2004 and 2006-2010 water years).

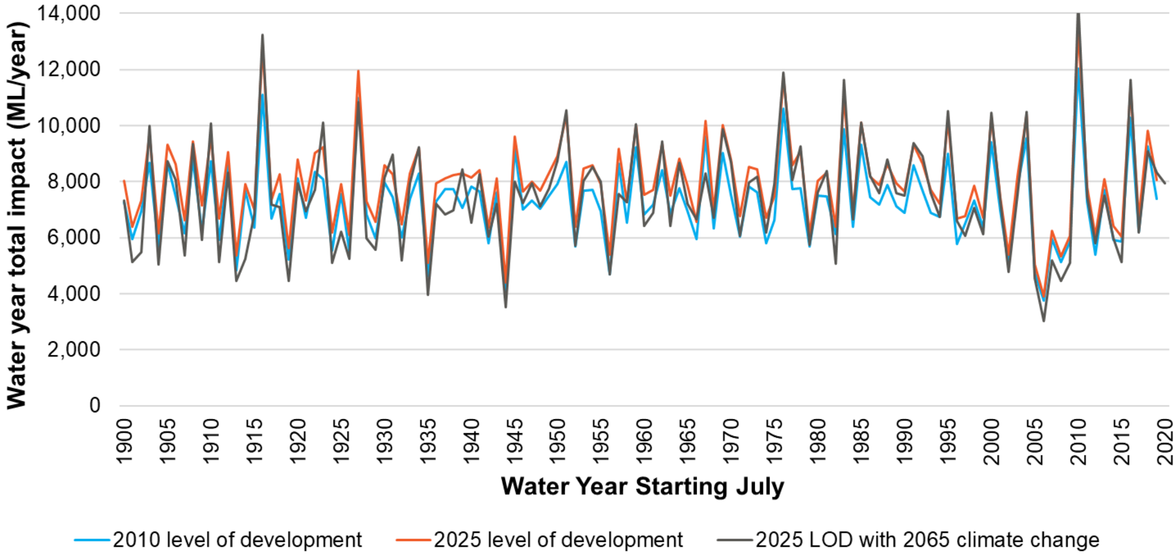

Figure 6-12 Comparison of annual estimated impact of farm dams in the Moorabool catchment between 2010 and 2025 levels of development and 2025 level of development with climate change projection for 2065 Medium RCP 4.5

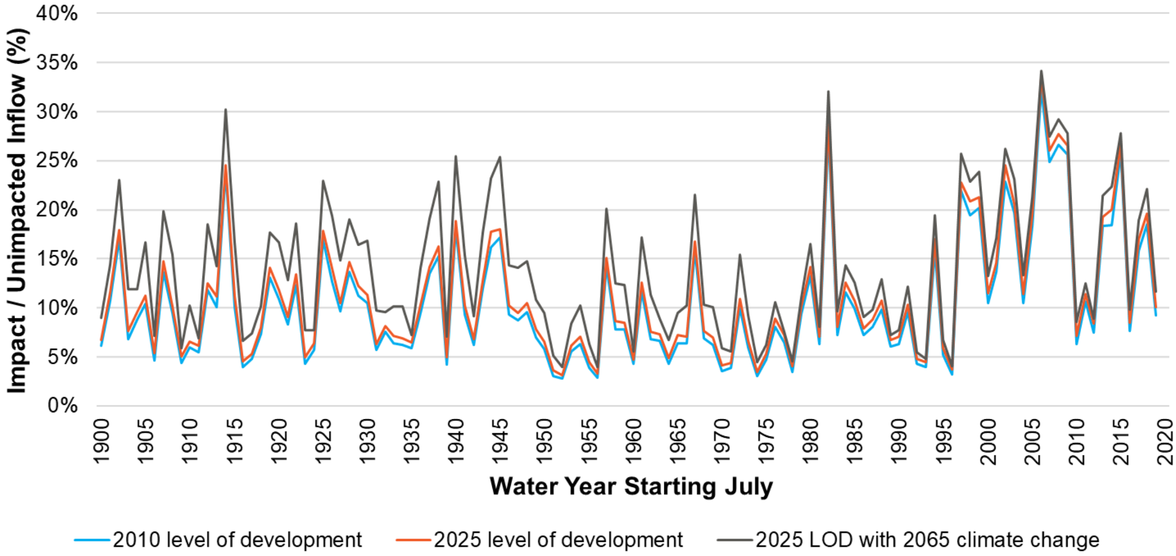

Figure 6-13 Annual estimated impact of farm dams in the Moorabool catchment as a proportion of unimpacted annual inflow, showing comparisons between 2010 and 2025 levels of development and 2025 level of development with climate change projection for 2065 Medium RCP 4.5

6.5 Seasonal variation in farm dam estimated impact across the Moorabool

Results from the STEDI model were analysed to calculate the change in outflow across each catchment due to modelled farm dam impacts for the summer/autumn (December to May) and winter/spring (June to November) seasons, as a proportion of inflows had there been no farm dams. Comparing Figure 6-14 with Figure 6-15, it can be seen that for all scenarios farm dams have a greater impact as a proportion of inflow during summer and autumn than they do during winter and Spring. Inflows to farm dams are lower during summer and autumn, on average, than winter and spring, which means that farm dams are more likely to have available airspace to capture inflows during summer and autumn. As was the case with annual impacts, proportional impacts at a seasonal level are larger during dry seasons and years than in seasons and years that are average or wet.

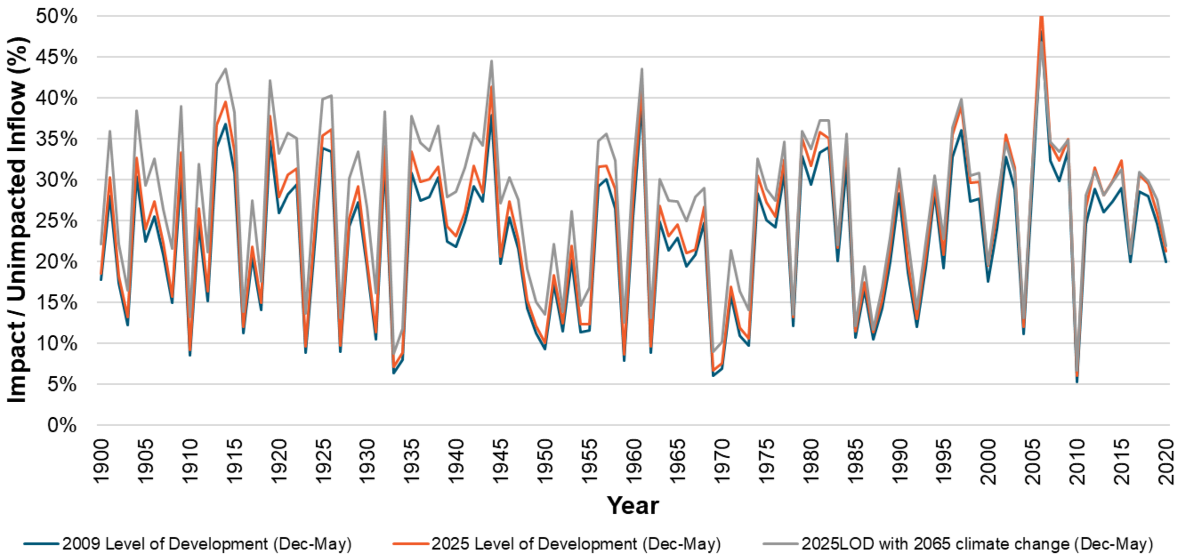

Figure 6-14 Summer and autumn estimated impact of farm dams in the Moorabool catchment as a proportion of unimpacted seasonal inflow, showing comparisons between 2010 and 2025 levels of development and 2025 level of development with climate change projection for 2065 Medium RCP 4.5

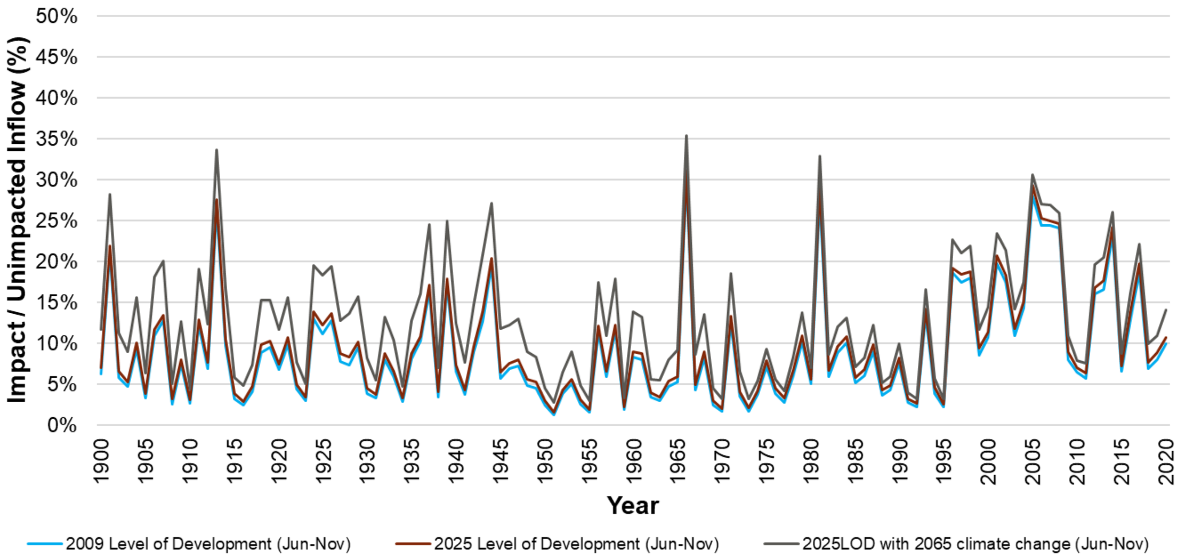

Figure 6-15 Winter and spring estimated impact of farm dams in the Moorabool catchment as a proportion of unimpacted seasonal inflow, showing comparisons between 2010 and 2025 levels of development and 2025 level of development with climate change projection for 2065 Medium RCP 4.5

6.6 Spatial variation in farm dam estimated impact across the Moorabool

Figure 6-16 shows the mean annual estimated impact by subcatchment area for the 2010, 2025 and 2065 with projected climate change scenarios in the Moorabool catchment. The largest mean annual estimated impacts by volume generally occur in the largest subcatchments.

Two subcatchments of the Moorabool, Black Creek and Woollen Creek, already have some of the highest densities of farm dam development and mean annual impact in Victoria. Figure 6-17 shows that the estimated takes in these two subcatchments were 37.8 ML/yr/km² for Black Creek and 42.7 ML/yr/km² for Woollen Creek under the 2025 level of development scenario, which were both slightly larger than for the 2010 level of development. Estimated farm dam impacts also exceeded 12 ML/year/km² in 6 other subcatchments of the Moorabool: Whiskey Creek (23.96 ML/year/km² in 2025 level of development), Devils Creek (14.1 ML/year/km²), Moorabool River West Branch between Moorabool Reservoir and Lal Lal Reservoir (14.7 ML/year/km²), Geddes Creek upstream of White Swan Channel (23.1 ML/year/km²), Lal Lal Creek (12.6 ML/year/km² in 2025 level of development) and the Geddes Creek upstream of White Swan Channel (23.1 ML/year/km²).

Figure 6-18 shows that there are several subcatchments in the north of the basin where estimated farm dam impacts were less than 2% of mean annual inflows for 2010 and 2025 levels of development and impacts are projected to remain below 2% with projected climate change. Climate change is projected to increase the estimated impact of farm dams to more than 10% of mean annual inflows in several subcatchments, with the mean annual impact projected to reach almost 40% in the Black Creek subcatchment and more than 50% in the Woollen Creek catchment. Whilst there has been minimal growth in the volume of farm dams between 2010 and 2025 in both subcatchments (see Figure 5-2), climate change will reduce inflows which will substantially increase the estimated impact due to the existing farm dams. In the subcatchments with the largest increases in total farm dam volume between 2010 and 2025 the combined estimated impact of farm dam growth (2010 to 2025) and projected climate change to 2065 will increase farm dam impacts from 9.7% to 12.6% of inflows in the Lal Lal Creek subcatchment and from 11.8% to 16% of inflows in the mid-Moorabool River between Morrisons and She Oaks Diversion Weir.

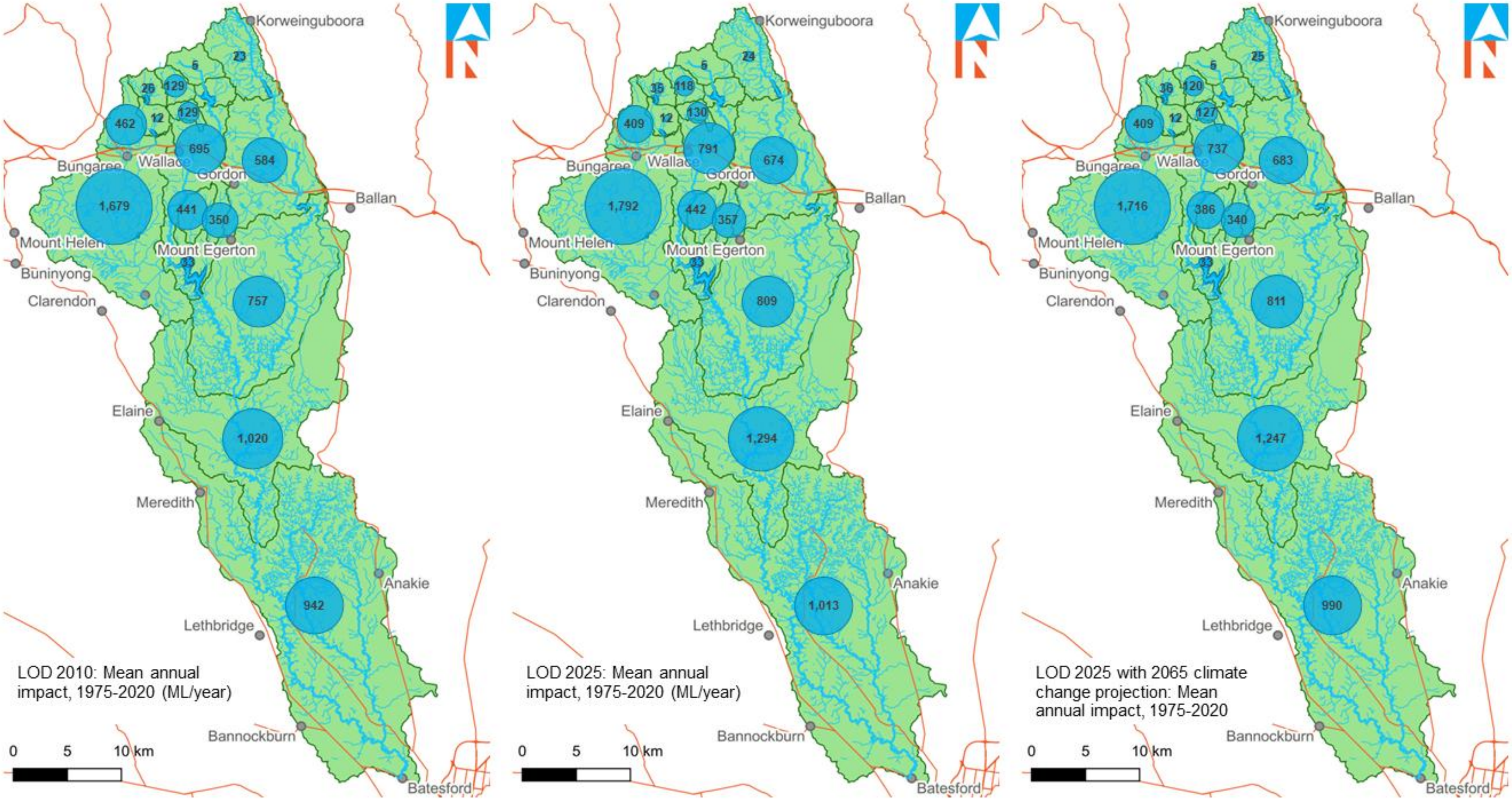

Figure 6-16 Mean annual estimated impact of farm dams in subcatchments of the Moorabool (all assessed across 1975-2020 period): (left) 2010 farm dams; (centre) 2025 farm dams; (right) 2025 farm dams with projected climate change for 2065 medium RCP4.5 projection

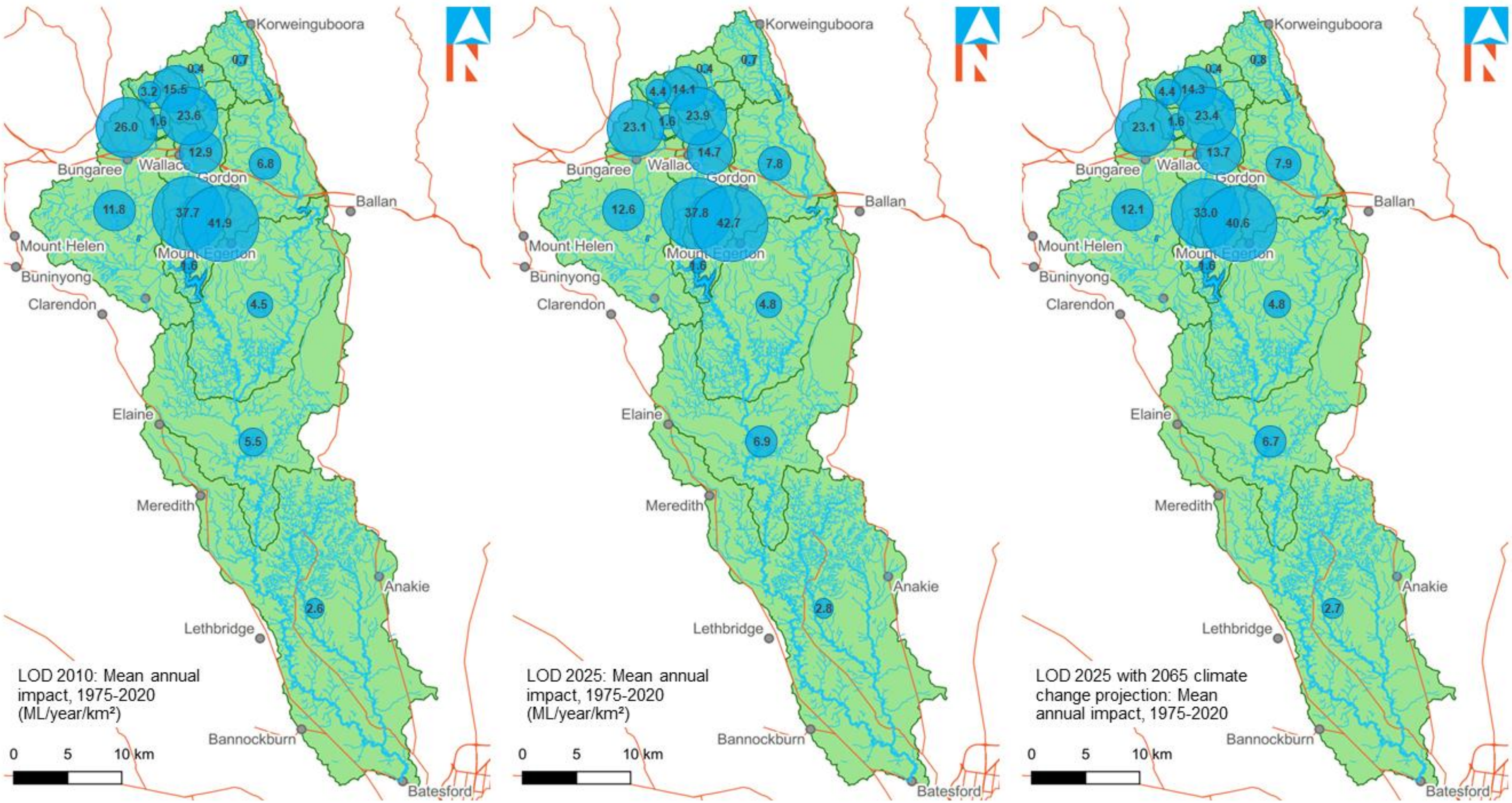

Figure 6-17 Mean annual estimated impact of farm dams per unit area in subcatchments of the Moorabool (all assessed across 1975-2020 period): (left) 2010 farm dams; (centre) 2025 farm dams; (right) 2025 farm dams with projected climate change for 2065 medium RCP4.5 projection

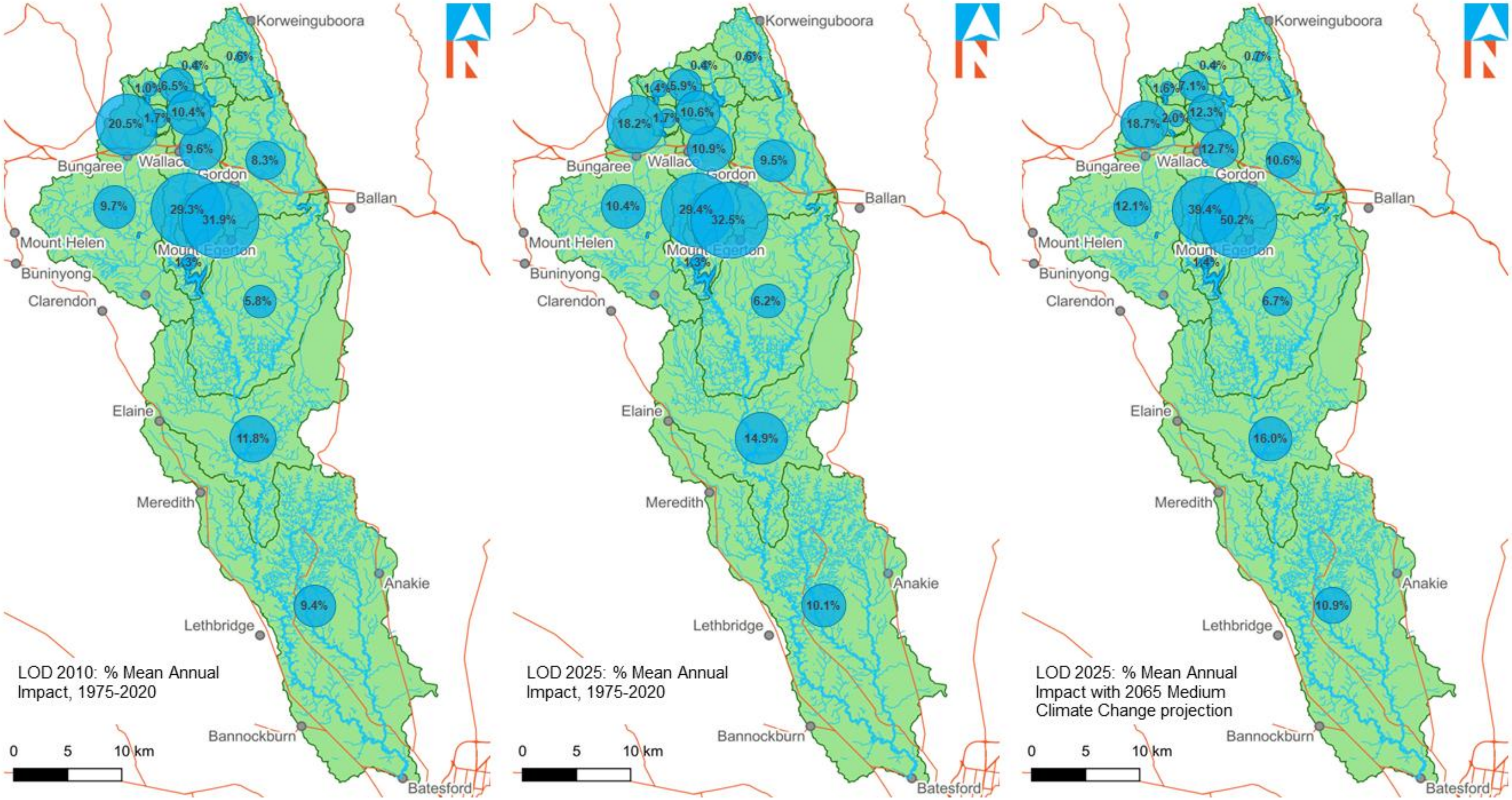

Figure 6-18 Mean annual estimated impact of farm dams as a proportion of no farm dams inflow in subcatchments of the Moorabool (all assessed across 1975-2020 period): (left) 2010 farm dams; (centre) 2025 farm dams; (right) 2025 farm dams with projected climate change for 2065 medium RCP4.5 projection

6.7 Indicative impacts of on and off waterway dams

6.7.1 Method and limitations

An indicative analysis was undertaken of the volumes and mean annual impacts of on- and off-waterway dams in each catchment. Water bodies were intersected with the VicMap hydro spatial layer line and polygon features. Any water bodies that intersected with or touched any part of a line or polygon feature in the VicMap hydro spatial layer were designated as potential on-waterway dams, whilst all other dams were designated as potential off-waterway dams. STEDI model results for farm dam impacts in each subcatchment were separated into on- and off-waterway dam impacts, using the reporting groups feature in STEDI.

There are several important limitations with this analysis:

- The VicMap hydro spatial layer of waterways are for topographic mapping only and they have not been assessed against the criteria specified in the *Water Act* (Victoria, 1989).
- The resolution of the DEM used to define catchment boundaries of each water body is relatively coarse, as it is defined from 10 m vertical interval contour data and a DEM of improved precision and accuracy (ideally captured by LiDAR) would identify different stream lines, catchment boundaries and connectivity of the stream and water body network.
- Licensed irrigation farm dams were separated from domestic and stock dams, based on designation in DELWP (2012) data set but this attribute is not updated regularly to be consistent with changes in the Water Register.

Figure 6-19 shows a sample area that illustrates these limitations. Yellow ellipse A shows a dam designated as off-waterway because it does not intersect with a VicMap hydro stream line. However, there is a VicMap hydro stream line that ends just upstream of (i.e. to the south of) the farm dam. Ellipse B shows that the VicMap hydro stream line ends downstream of (i.e. to the south of) several farm dams that were therefore designated as off-waterway. However, satellite imagery shows that streams probably should continue further to the north, which could possibly make these dams on-waterway dams. Ellipse C shows an on-waterway dam (intersecting with the VicMap hydro stream layer) that also appears to be on-waterway in the satellite imagery. However, the catchment area of this dam appears to be considerably under-estimated, due to limitations in the accuracy of the DEM. Limitations in accurately defining catchment areas affect the ability of the STEDI model, which takes catchment areas and the topology of dams as inputs, to accurately calculate impacts on flows.

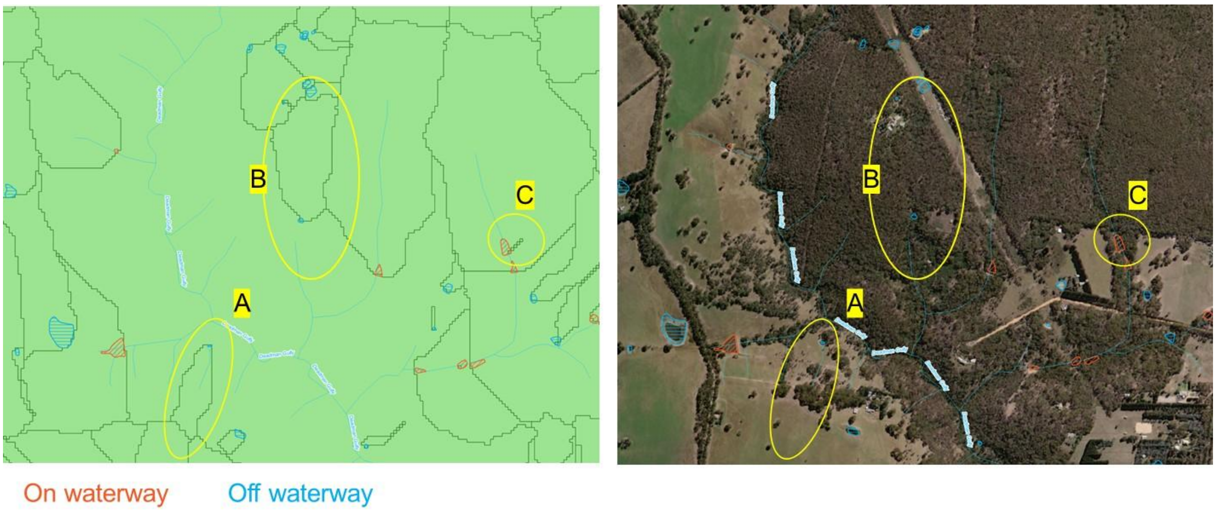

Figure 6-19 Sample area illustrating some of the limitations in accurately identifying catchment areas of farm dams and other water bodies and identifying farm dams that are on or off waterway. Both images show the same area, with the left panel showing catchments of each water body delineated from the DEM and the right panel showing Bing imagery.

6.7.2 On and off waterway dam volumes and impacts in the Maribyrnong

Indicative estimates of storage volumes of on- and off-waterway farm dams for 2009 and 2025 levels of development in the Maribyrnong catchment are provided in Table 6-1. Indicative estimates of mean annual impacts for those farm dams are shown in Table 6-2. Limitations with assessing dam types and upstream catchment areas (see Section 6.7.1) should be noted when considering these tables.

Table 6-1 Indicative estimates of on and off waterway farm dam volumes by type in the Maribyrnong

Type of dam	2009 level of development (ML)	2025 level of development (ML)	Change between 2009 and 2025 (ML)	% Change between 2009 and 2025
On waterway D&S farm dams	6,174	6,559	386	6%
Off waterway D&S farm dams	5,557	5,889	332	6%
On waterway licensed dams	1,274	1,294	20	2%
Off waterway licensed dams	232	345	113	49%
Total rural farm dams	13,238	14,088	850	6%

Table 6-2 Indicative estimates of mean annual impact of on and off waterway farm dams by type in the Maribyrnong

Type of dam	2009 level of development (ML)	2025 level of development (ML)	Change between 2009 and 2025 (ML)	% Change between 2009 and 2025
On waterway D&S farm dams	3,859	4,086	227	6%
Off waterway D&S farm dams	2,148	2,242	94	4%
On waterway licensed dams	454	470	16	3%
Off waterway licensed dams	98	109	12	12%
Total rural farm dams	6,559	6,907	348	5%

6.7.3 On and off waterway dam volumes and impacts in the Moorabool

Indicative estimates of storage volumes of on- and off-waterway farm dams for 2009 and 2025 levels of development in the Moorabool catchment are provided in Table 6-3. Indicative estimates of mean annual impacts for those farm dams are shown in Table 6-4. The small decline in mean annual impact of on-waterway licensed dams between 2010 and 2025 levels of development is probably a consequence of growth in the volume of upstream dams that impact an increased proportion of inflows. Limitations with assessing dam types and upstream catchment areas (see Section 6.7.1) should be noted when considering these tables.

Table 6-3 Indicative estimates of on and off waterway farm dam volumes by type in the Moorabool

Type of dam	2010 level of development (ML)	2025 level of development (ML)	Change between 2010 and 2025 (ML)	% Change between 2010 and 2025
On waterway D&S farm dams	8,954	11,323	2,369	26%
Off waterway D&S farm dams	5,926	6,736	810	14%
On waterway licensed dams	1,144	1,273	129	11%
Off waterway licensed dams	1,033	1,186	153	15%
Total rural farm dams	17,057	20,517	3,460	20%

Table 6-4 Indicative estimates of mean annual impact of on and off waterway farm dams by type in the Moorabool

Type of dam	2010 level of development (ML)	2025 level of development (ML)	Change between 2010 and 2025 (ML)	% Change between 2010 and 2025
On waterway D&S farm dams	3,586	3,976	391	11%
Off waterway D&S farm dams	2,361	2,523	161	7%
On waterway licensed dams	707	695	-12	-2%
Off waterway licensed dams	518	595	77	15%
Total rural farm dams	7,172	7,788	616	9%

6.8 Comparisons of growth rates with previous investigations

Table 6-5 shows that there was an annual growth rate in the number of farm dams of 0.1%/year in the Maribyrnong catchment (2009-2025) and 0.3%/year in the Moorabool catchment (2010-2025). The total storage volume of farm dams increase at a rate of 0.4%/year in the Maribyrnong and 1.2%/year in the Moorabool over the last 15 to 16 years. The mean annual impact of farm dams increased by 0.3%/year in the Maribyrnong and 0.5%/year in the Moorabool over the same period.

HARC and ERM (2020) and Jordan et al. (2018) analysed growth rates in the number and storage volume of farm dams, by analysing spatial data from rectangular tiles spread across Victoria, representing about 1% of the privately owned land area of the state. For this area, HARC and ERM (2020) found that the mean annual growth rate in farm dam volumes across sampled area of the state was 0.3%/year between July 2010 and June 2015 and that the 90% confidence interval band (5th to 95th percentiles) for this growth rate was 0.2 to 0.5%/year. HARC and ERM (2020) identified that, “It is possible that growth rates may increase again if there were another severe drought, or policy changes influenced the construction or removal of farm dams." The annual growth rate of 0.4%/year in the Maribyrnong catchment for 2009-2025 was consistent with the range of statewide estimates from HARC (2017) (0.2 to 0.5%/year) for 2010-2015. The annual growth rate in storage volume in the Moorabool (1.2%/year for 2010-2025) was higher than the statewide average growth rate identified by HARC (2017) for 2010-2015. Growth rates in the Moorabool catchment may have been faster than the statewide average because of long-term reductions in streamflow in the western part of Victoria during and after the Millennium drought and recent dry conditions (over 2024-2025), which may have encouraged landholders to expand farm dam capacity as a source of water. Growth rates in farm dam storage volumes may also be larger in the Maribyrnong and Moorabool catchments than the statewide average, as both catchments are within commuting-distance of Melbourne, resulting in subdivision for lifestyle-driven rural residential development hence increasing farm dam numbers and volumes.

Even though annual growth rates in storage volumes of farm dams may have been greater in the Maribyrnong and Moorabool catchments than the HARC and ERM (2020) statewide average, annual growth rates in the mean annual impact of farm dams in the Maribyrnong and Moorabool catchments (0.3 and 0.5%/year, respectively) were consistent with the 0.2 to 0.5%/year range for growth rate in dam storage volume from HARC and ERM (2020).

Table 6-5 Growth rate comparisons

Statistic	Maribyrnong catchment (HARC, 2025)	Moorabool catchment (HARC, 2025)	Victoria statewide estimate (HARC and ERM, 2020)
Period assessed	2009-2025	2010-2025	2010-2015
Annual growth rate in number of farm dams	0.1%/year	0.3%/year	0.4%/year (90% confidence interval: 0.3 to 0.5%/year)
Annual growth rate in storage volume of farm dams	0.4%/year	1.2%/year	0.3%/year (90% confidence interval: 0.2 to 0.5%/year)
Annual growth rate in mean annual impact of farm dams	0.3%/year	0.5%/year	Not assessed

7. Summary of farm dam volumes and estimated impacts

7.1 Summary of estimated farm dam impacts in the Maribyrnong

Table 7-1 summarises the statistics of farm dam numbers, volume and estimated mean annual impact across the Maribyrnong catchment between 2009 and 2025 levels of development. There has been a 2% increase in the number of rural farm dams between 2009 and 2025, with the current number of farm dams at just over 7,000 dams. Over that 16-year period, there was a 6% increase in the estimated total storage volume of those rural farm dams, with the current total storage volume currently at just over 14,000 ML. The estimated mean annual impact of those farm dams has increased by 5% between the 2009 and 2025 levels of development. Whilst some farm dams have increased in storage volume over the 16-year period, the overall estimated impact of those farm dams is limited by inflows. A farm dam may increase in storage volume but the impact of that dam may only increase in very wet years, when there are sufficient inflows to fill the dam. Increasing storage volumes in some farm dams within a catchment may also decrease spills and inflows to other farm dams that are downstream of them and constrain the increase in mean annual impact at the subcatchment level.

Table 7-1 Comparisons of number, storage volume and estimated mean annual impact of farm dams in the Maribyrnong catchment between 2009 and 2025 level of development

Statistic	2009 Level of farm dam development	2025 Level of farm dam development	Change between 2009 and 2025	% Change between 2009 and 2025
Number of rural farm dams	6,889	7,048	159	2%
Storage volume of rural farm dams (ML)	13,238	14,088	850	6%
Estimated mean annual impact of farm dams (ML/year)	6,559	6,907	348	5%
Mean annual impact as proportion of unimpacted inflows	7.6%	8.0%	0.4 percentage points	5%

The increase in the number and volume of farm dams between 2009 and 2025 level of development has increased the mean annual impact across the Maribyrnong catchment from 7.6% to 8.0% of mean annual inflows (see Table 7-1 and Table 7-2). Even without any further change in farm dams, with climate change mean annual farm dam impacts are projected to increase by about a further 500 ML by 2065, to 9.5% of mean annual inflows (see Table 7-2).

Table 7-2 Comparisons of estimated mean annual impact of farm dams in the Maribyrnong catchment between 2009 and 2025 level of development and 2025 level of development with projected climate change

Statistic	2009 Level of farm dam development	2025 Level of farm dam development	2025 Level of farm dam development with projected climate change (2065 Medium RCP 4.5)	Change due to projected climate change
Estimated mean annual impact of farm dams (ML/year)	6,559	6,907	7,407	500
Mean annual impact as proportion of unimpacted inflows	7.6%	8.0%	9.5%	19%

7.2 Summary of estimated farm dam impacts in the Moorabool

Table 7-3 summarises the statistics of farm dam numbers, volume and estimated mean annual impact across the Moorabool catchment between 2010 and 2025 levels of development. There are almost 6,300 rural farm dams in the Moorabool basin (as at 2025), an increase in number of 4% since the 2010 level of development. The total storage capacity of rural farm dams has increased in the Moorabool basin by 20% since 2010 and is now approximately 20,500 ML. The estimated mean annual impact of those farm dams has increased by 9% between the 2010 and 2025 levels of development. Whilst some farm dams have increased in storage volume over the 15 year period, the overall estimated impact of those farm dams is limited by overall inflows, particularly in dry years and in parts of the catchment with already high densities of farm dam development. At the 2025 level of farm dam development, the estimated impact is currently 9.6% of mean annual inflows.

Table 7-3 Comparisons of number, storage volume and estimated mean annual impact of farm dams in the Moorabool catchment between 2010 and 2025 level of development

Statistic	2010 Level of farm dam development	2025 Level of farm dam development	Change between 2010 and 2025	% Change between 2010 and 2025
Number of rural farm dams	6,043	6,294	251	4%
Storage volume of rural farm dams (ML)	17,057	20,517	3,460	20%
Estimated mean annual impact of farm dams (ML/year)	7,172	7,788	616	9%
Mean annual impact as proportion of unimpacted inflows	8.8%	9.6%	0.8 percentage points	9%

Table 7-4 shows that the overall density of farm dams and projected reductions in inflow under climate change are such that the estimated volume of mean annual impact is projected to reduce slightly by 2065 due to reductions in runoff volume. However, the impact is projected to increase from 9.6% to 10.6% of mean annual inflows under the 2065 medium RCP 4.5 climate change projection because the total volume of inflows are projected to decline in the Moorabool catchment.

Table 7-4 Comparisons of estimated mean annual impact of farm dams in the Moorabool catchment between 2010 and 2025 level of development and 2025 level of development with projected climate change

Statistic	2010 Level of farm dam development	2025 Level of farm dam development	2025 Level of farm dam development with projected climate change (2065 Medium RCP 4.5)	Change due to projected climate change
Estimated mean annual impact of farm dams (ML/year)	7,172	7,788	7,412	-376
Mean annual impact as proportion of unimpacted inflows	8.8%	9.6%	10.6%	11%

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