Mallee Floodplain Management Strategy 2018–28

Acknowledgements

The Mallee Catchment Management Authority (CMA) acknowledges and respects Traditional Owners, Aboriginal communities and organisations. We recognise the diversity of their cultures and the deep connections they have with Victoria's lands and waters. We value partnerships with them for the health of people and country. The Mallee CMA Board, management and staff pay their respects to Elders past and present, and recognise the primacy of Traditional Owners' obligations, rights and responsibilities to use and care for their traditional lands and waters.

A Steering Committee involving key regional partners was established to oversee the development of this Floodplain Management Strategy. The committee was chaired by Nicholas Sheahan, Floodplain Manager at Mallee CMA, and had representation from: Mildura Rural City Council, Swan Hill Rural City Council, Yarriambiack Shire Council, Buloke Shire Council, Hindmarsh Shire Council, VicSES, Lower Murray Water and Grampians Wimmera Mallee Water Corporation (GWM Water). The project was also supported by the management and staff of the Mallee CMA, with technical input from many partner agencies.

The Mallee Floodplain Management Strategy was supported by the Mallee CMA, through funding from the Victorian Government.

Images

Cover images:
Upper: Tyrrell Creek flooding, 2011.
Centre: Stormwater flooding, Irymple 2011.
Lower: Murray River Flooding at Bruce's Bend, 2016.

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Preface

The Mallee Floodplain Management Strategy has been developed to help communities within the Victorian Mallee be better prepared for future floods.

By providing a single regional planning document and a high level regional work plan, this strategy will support and guide future investment priorities over the next ten years, while building on past achievements and recognising future challenges.

An extensive consultation process was undertaken to inform the Mallee Floodplain Management Strategy, with stakeholder input integral to improving the understanding of how floods behave across our region; what important infrastructure may be impacted by flooding; and flood mitigation works that could reduce risks and/or impact of flooding.

Thank you to everyone who provided comment, attended workshops and meetings, and made individual submissions throughout the development of this strategy. Your local knowledge and expertise has been invaluable.

All sectors of our community including individual land managers, industry and community based groups, along with government agencies and authorities are fundamental to the success of the Mallee Floodplain Management Strategy. It will only be through sustained and collaborative efforts that our aspirations for the region's flood management priorities can be realised.

The Mallee has a proud history of identifying and addressing key natural resource management issues through practical solutions and effective partnerships. This capacity continues to be a vital resource for the region, and one which I believe can be further enhanced through the implementation of this Mallee Floodplain Management Strategy.

Sharyon Peart
Mallee CMA Board Chair

April 2018

Our Vision

The Mallee Floodplain Management Strategy (Mallee FMS) has adapted the vision from the Victorian Floodplain Management Strategy to reflect the Victorian Mallee's long term (50-year) aspirations for flood management.

Our vision:
'*The Mallee community understands flooding and actively manages its flood risks.*'

To further define strategic directions for flood management in the Mallee region and help guide priorities for action planning, four long term (>10 years) objectives have also been established.

These objectives are:
- To support a flood resilient community;
- To reduce existing flood risks;
- To avoid future flood risks; and
- To manage residual flood risks.

The Mallee FMS also demonstrates a direct link to the Mallee Regional Catchment Strategy (2013-19) in delivering against a strategic (6 year) action of the long term objective for Mallee Waterway Assets, specifically:
- Action 1.1.2: Review, update and implement the Mallee Floodplain Management Plan

Tyrrell Creek at Culgoa.

Contents

1 Strategic Context

1.1 About the strategy

The Mallee Floodplain Management Strategy (FMS) provides a single, regional planning document for floodplain management and a high level regional work program to guide future investment priorities over the next ten years (2018-2028).

Developed in partnership with regional stakeholders, the Mallee FMS supports and focuses the coordinated effort of land managers, government agencies and the wider community; while building on past achievements and recognising future challenges.

1.1.1 Purpose and scope

The Mallee FMS will interpret and apply the policies, actions and accountabilities outlined in the Victorian Floodplain Management Strategy (VFMS) (DELWP 2016) at the regional and local levels (See Figure 1).

The VFMS was informed by the Victorian Floods Review and the Parliamentary Environment and Natural Resources Committee Inquiry into Flood Management Infrastructure of the 2010-11 floods. This state-wide strategy sets out actions and policies that will help to implement the Victorian Government's response to those inquiries. It also clarifies institutional arrangements to ensure continual improvement in all aspects of floodplain management.

The Mallee FMS is the starting point for implementing the policies, actions and accountabilities of the VFMS to manage local flood risks. The main role of the regional strategy is to help all agencies with flood emergency management functions align their priorities in the form of a rolling three year regional implementation plan.

Within this context, the Mallee FMS will deliver against:

- State-wide strategic directions for floodplain management, as detailed by the 2016 VFMS
- Regional objectives and priorities for the management of natural, cultural and productive landscapes (particularly those that relate to floodplains), as detailed by the 2013-19 Mallee Regional Catchment Strategy (RCS)[1]

To achieve this, the Mallee FMS:

- Applies a regional assessment of flood risks across the region;
- Identifies potential actions to mitigate identified flood risks;
- Documents regional priorities for the next three years and associated responsibilities, timeframes and costs in a Regional Work Plan;
- Establishes a monitoring and evaluation framework to determine the success of implementing the Strategy; and

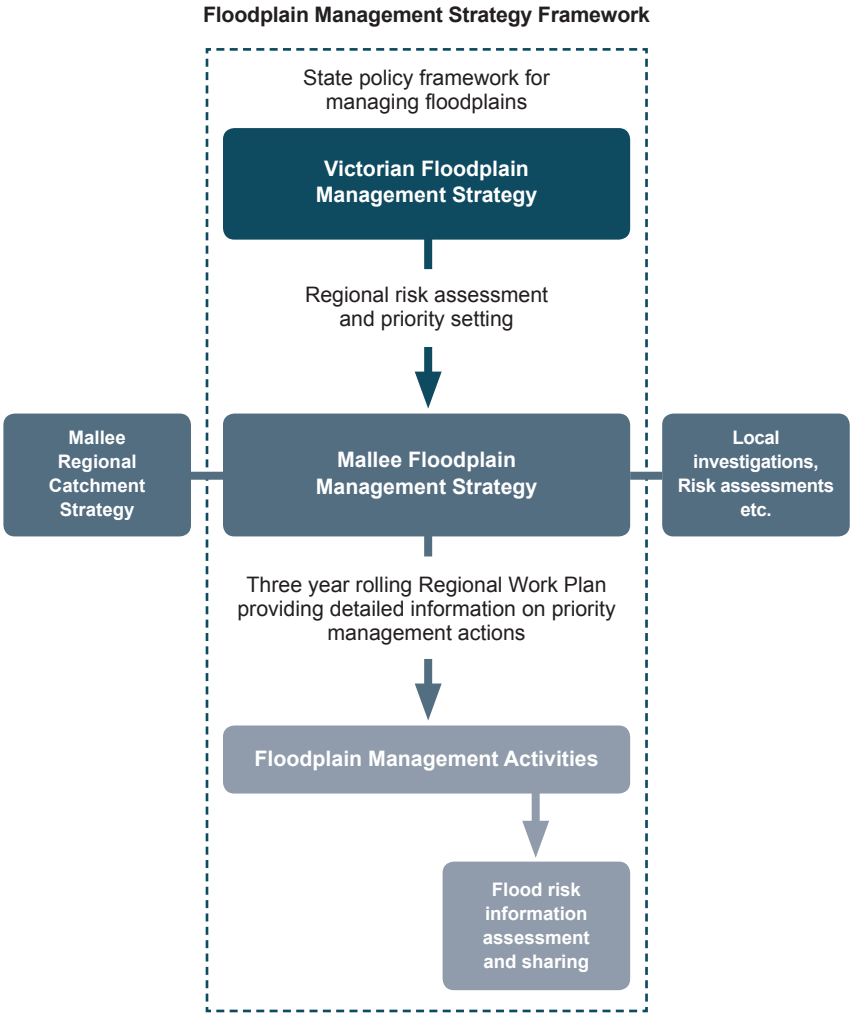

Figure 1 | Integrated Floodplain Management Planning Framework

1 The 2013-19 Mallee RCS is the primary integrated planning framework for land, water and biodiversity management in the region.

Stormwater flooding in Cardross, 2011.

- Provides the framework for collaboration with cross boundary stakeholders (regional and state) for the management of floodplains and flood events.

1.1.2 History of the Mallee Floodplain Management Strategy

This 2018-28 Mallee FMS replaces the Mallee Regional Floodplain Strategy (MRFS) as the primary document to align the priorities of agencies with flood emergency management functions.

The MRFS was prepared as a requirement of the Victorian Government and was ministerially endorsed in March 2001.

A 2017 review of the MRFS found that 36 out of 39 actions were either completed or in progress. One action is ongoing, one action was not commenced and one action was partially completed.

Major achievements included:

- Comprehensive data collection, analysis and review of:
  - Levees and culverts
  - Development impacts on floodplains
  - Flood studies
  - Major flood events (mapped and maintained in a register)
  - Floodplain data
- Cooperation and communication with stakeholders:
  - Development of a formal process for landowners and stakeholders to realign, maintain or remove levees and/or culverts
  - Development of siting and design guidelines for pump sites
  - Circulation of floodplain information to local government bodies
  - Maintenance of relationships with local government organisations through regular meetings
  - Establishment of floodplain development guidelines
  - Installation of gauge boards in critical locations to improve flood warning distribution following 2011 flooding.

Risk management practices that were undertaken in the latter stage of strategy implementation included:

- Hydraulic modelling of 2009/2011 floods at Beulah and Culgoa to better identify flood risks;
- Assessment of the Robinvale levee;
- Regional input into the Review of 2010/2011 Flood Warnings & Response (Comrie Review);
- An update of 1% Annual Expenditure Probability Mapping;
- Management of a greater level of insurance enquiries in response to the 2011 flood events;
- Community engagement; and
- Development of a flood guide in response to the 2011 floods.

All risk management practices except the update of 1% AEP Mapping were implemented in response to flood events, and were deemed appropriate and effective for the events at the time.

The 2018-28 Mallee FMS builds on the outputs and outcomes achieved in the previous MRFS, and incorporates lessons learnt from the implementation of the previous strategy, specifically in regard to:

- **Planning** – To improve risk management practices in the future, the Strategy should provide for more frequent planning discussions to be conducted by relevant agencies (including cross border agencies) to both build and maintain relationships in between natural flooding events. Learnings from flood events need to be better incorporated into procedures, and properly documented to influence future actions;
- **Knowledge** – the Strategy should continue to be based on the best available information in order to provide confidence in investment and interventions;
- **Engagement** – facilitating a high level of regional understanding and ownership of the Strategy's purpose, objectives and priorities to provide the foundation for future implementation. Providing opportunities for all key stakeholders to have input into the Mallee FMS should be a key consideration in the development phase;
- **Accountability** – the Strategy should outline clear reporting mechanisms for evaluating and communicating the region's progress against long, medium and short term targets;
- **Feasibility** – the long, medium and short term targets detailed within the Strategy need to balance the region's ambitions for improved floodplain management and what is financially, physically and socially possible;
- **Partnerships** – collaborative arrangements between government, community, land owners and industry stakeholders have been a positive and rewarding feature of regional waterway management to date. The Strategy should continue to provide specific strategic support and encouragement for such arrangements;
- **Flexibility** – the Strategy should be sufficiently flexible and adaptable throughout its delivery timeframe to respond to changing conditions and circumstances; and
- **Relevance** – Formal reviews of the Strategy (e.g. mid-term review) are required to ensure it remains relevant and up to date with the latest information regarding flood events, accountabilities and key actions.

1.2 Development of the Strategy

1.2.1 Development framework

The purpose of this regional strategy is to provide a single, regional planning document for floodplain management and a high level regional work plan to guide future investment priorities.

The development of the Mallee FMS has been led by the Mallee CMA, in partnership with stakeholders and the community.

A steering committee was established by the Mallee CMA, to guide the development of the Strategy. Membership on the steering committee included representatives from local government, Victorian State Emergency Service (VICSES), water authorities and the Mallee CMA.

Key steps in the development of the Mallee FMS included:

- Establishing and applying regional objectives to ensure that all significant risks are captured;
- Identifying both potential threats (hazards) and the causes of those threats;
- Determining levels of risk by analysing both the impacts (consequences) and the probability/ frequency (likelihood);
- Making decisions about risk types that need treatment (intolerable, tolerable, acceptable) and treatment priorities; and
- Documenting regional priorities for the next three years and associated responsibilities, timeframes and costs (Regional Work Plan).

1.2.2 Description of the approach to stakeholder engagement

The success of the Mallee FMS is dependent on meaningful and ongoing engagement with all stakeholders. Capturing the values, knowledge and aspirations of the region's individuals, groups and organisations through the Mallee FMS development phase was a fundamental component of this process.

Figure 3 provides a summary of the communication and engagement framework employed in the development of the Mallee FMS. Key engagement activities conducted under this framework included media articles, workshops, surveys, email updates, and associated information resources. Further detail on activities delivered and the stakeholders engaged throughout the Mallee FMS development phase is provided in Appendix B.

Through these activities a broad cross-section of the Mallee community provided valuable input into:

- The identification of regional and local scale flood risks and mitigation options;
- The identification of existing flood mitigation strategies under two main themes: land use planning and flood mitigation infrastructure;

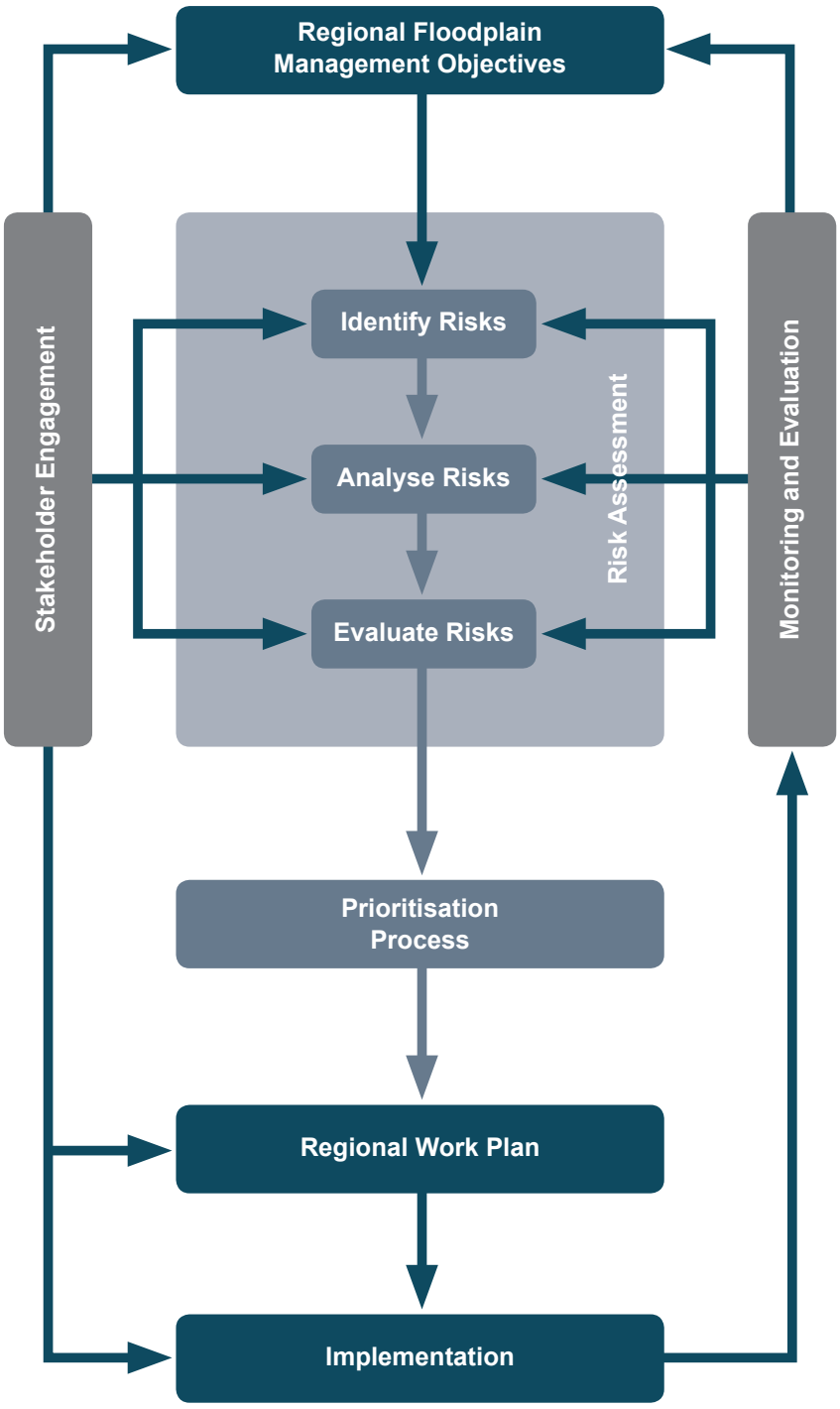

Figure 2 | Overview of the Mallee FMS development process

Flooded agriculture from stormwater, Red Cliffs, 2011.

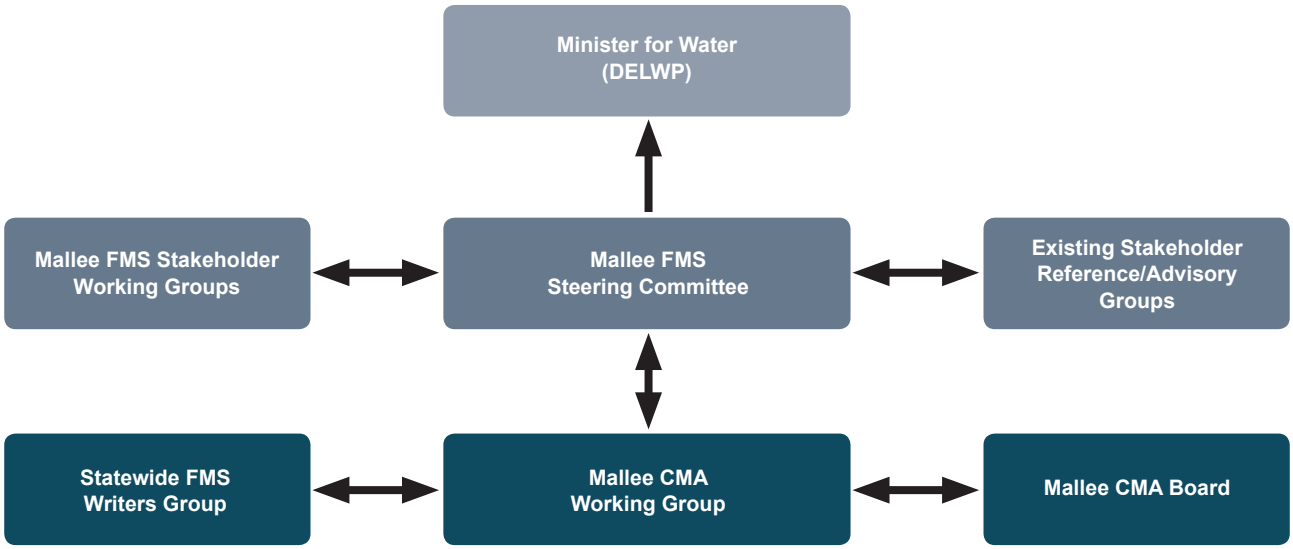

Figure 3 | Engagement mechanisms for the development of the Mallee FMS

- The prioritisation of floodplain management activities; and
- The evaluation of flood risks, including consideration of any existing service levels in place to mitigate flood risks, any gaps in service levels, the priority for consideration and the priority for action over the next three years.

A draft of the Mallee FMS was released for public comment in September 2017, with opportunities to provide feedback widely promoted. Comments were received on the draft at targeted workshops, through written submissions and personal communications (e.g. emails).

The final Mallee FMS was developed with consideration of the comments and feedback received throughout the consultation period.

Regional stakeholders will also be engaged throughout the Mallee FMS's implementation and review phases. This ongoing consultation will utilise established partnership/engagement mechanisms as outlined in Figure 3.

1.3 Description of the region

The Mallee region covers 39,939km^2, around one-fifth of Victoria. The largest catchment area in the state, it runs along the Murray River from Nyah to the South Australian border and south through vast dryland cropping areas and public reserves. The Mallee region includes the entire Mildura Rural City Council municipality, plus portions of Swan Hill Rural City Council, Buloke Shire Council, Yarriambiack Shire Council, Hindmarsh Shire Council and small sections of West Wimmera Shire and Gannawarra Shire[2].

The region is recognised nationally and internationally for the diversity and uniqueness of its natural, cultural and productive landscapes.

2 As there are no significant waterways in the small areas of the West Wimmera and Gannawarra Shires that overlap with the Mallee region, these organisations were not included in the development of this strategy.

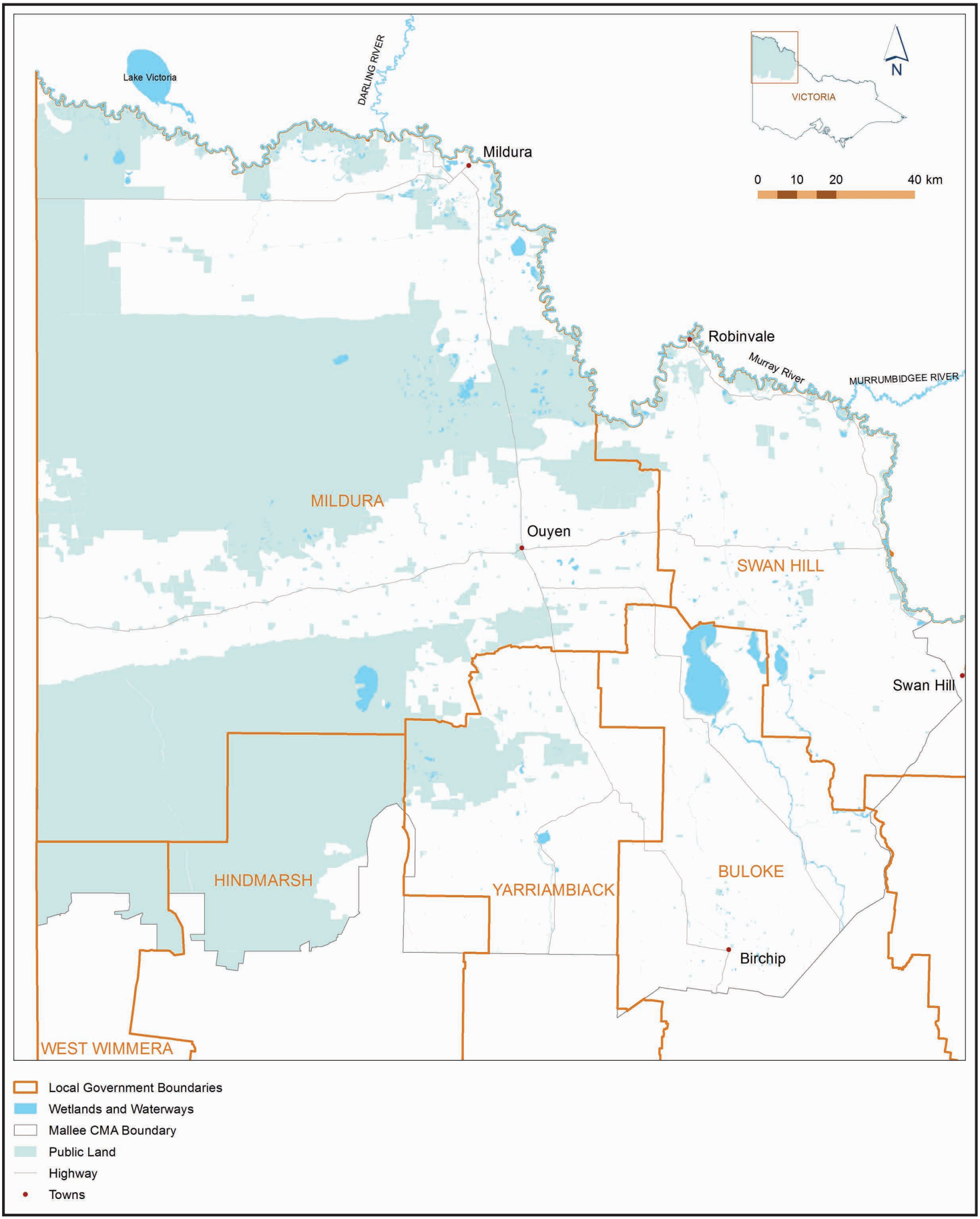

Figure 4 | The Mallee CMA region

1.3.1 Cultural heritage

The Mallee has been occupied for thousands of generations by Indigenous people with human activity dated as far back as 23,400 years ago. The region's rich and diverse Indigenous heritage has been formed through the historical and spiritual significance of sites associated with this habitation, together with the strong connection Traditional Owners continue to have with the Mallee's natural landscapes.

Given the semi-arid climate of the region, ready access to more permanent water has been a major determinant of human habitation, and as such the highest density of identified Indigenous cultural heritage sites are located around or close to areas of freshwater sources.

The Murray River and its associated waterways were important habitation areas for multiple Indigenous groups, containing many places of spiritual significance. The high number of Indigenous cultural heritage sites throughout the Murray floodplain is unique in Victoria, for both concentration and diversity. They include large numbers or burial, middens and hunting sites.

In the south, waterways were focal points for the region's Traditional Owners, with many lakes being the site for large gatherings of several social clan groups that afforded trade and cultural exchange.

1.3.2 Exposure to flooding

Flooding is a natural hazard in the Mallee region. Whether floods are caused by high rainfall, storms or inadequate drainage, they can severely disrupt communities by causing injury, loss of life, property damage, personal hardship, and disruptions to regional economies.

It is a question of when, not if, floods will occur. Fortunately, the location, the scale of effects and the probability of occurrence can be estimated with reasonable accuracy for a range of floods in the Mallee region.

Understanding flood behaviour enables us to assess the likely costs of flooding. It also enables us to assess the benefits of different options for managing the community's exposure to flood risk.

The variability of climate in the Mallee region 'presents significant external risks' (Mallee CMA 2013). Weather extremes are common, including drought, heavy frosts, hail, heat waves, high winds and flooding. The most recent flooding events include:

- the La Niña rains of 2010/11 summer which caused significant flooding and widespread damage;
- 2016 flooding in the Southern Creeks in September, which caused localised damage to crops and roads; and
- the 2016 Murray River flood event which peaked in the Mallee region in late November at the highest level recorded in over 20 years

The following figures show historic flooding along the Murray River and in the Southern Creeks in the Mallee region. See Section 5.3 for detail on flood class levels for each site. Appendix C provides further detail on the information in the following charts.

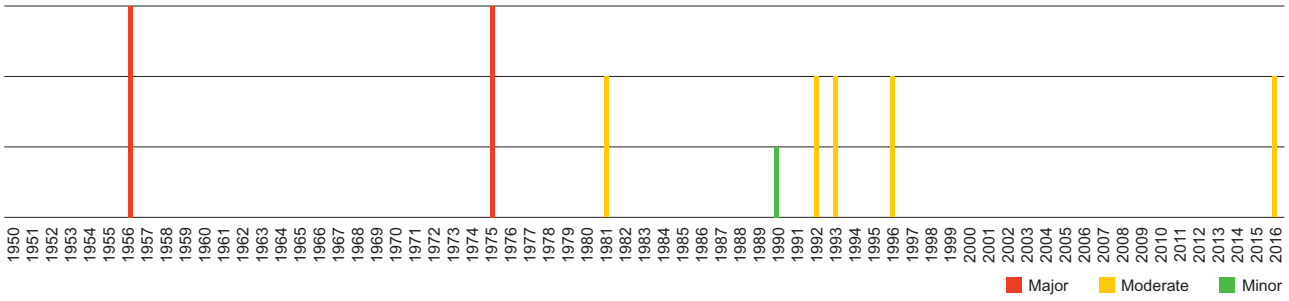

Figure 5 | Historic flooding, Murray River at Boundary Bend

The two largest recorded floods at Boundary Bend occurred in 1956, reaching a peak height of 56.63m Australian Height Datum (AHD), and 1975, reaching a peak height of 56.26m AHD.

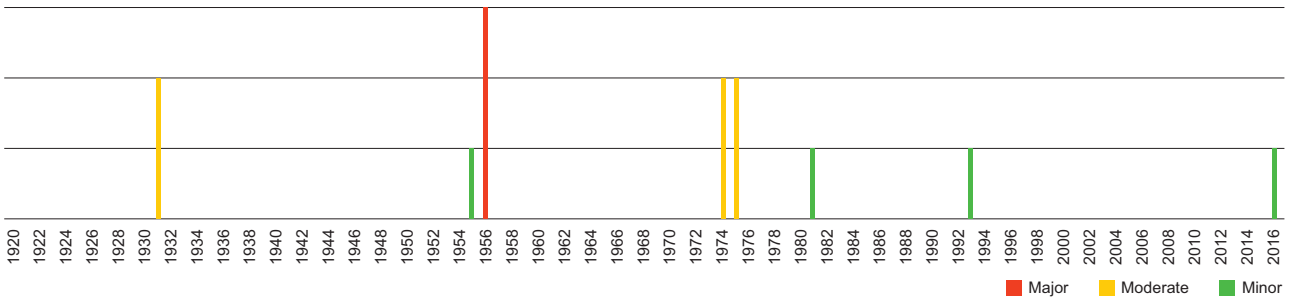

Figure 6 | Historic flooding, Murray river at Euston

The largest recorded flood at Euston occurred in 1956, reaching a peak height of 52.43m AHD.

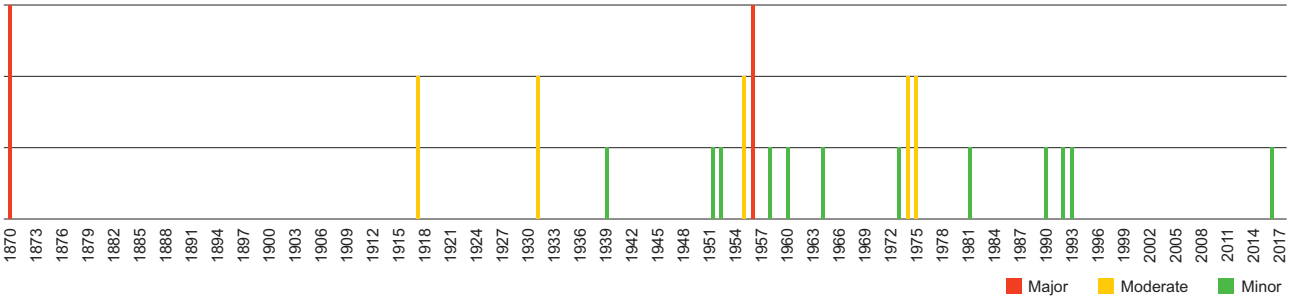

Figure 7 | Historic flooding, Murray River at Mildura

The two largest recorded floods at Mildura occurred in 1870, reaching a peak height of 39.29m AHD and in 1956, reaching a peak height of 39.26m AHD.

Figure 8 | Historic flooding, Murray River at Wentworth

The largest recorded flood at Wentworth occurred in 1956, reaching a peak height of 34.56m AHD.

Flood history in the Southern Creeks of the Mallee has limited records. As such, upstream gauges have been used to estimate flood classes, accompanied with other resources including testimonials and previous reports.

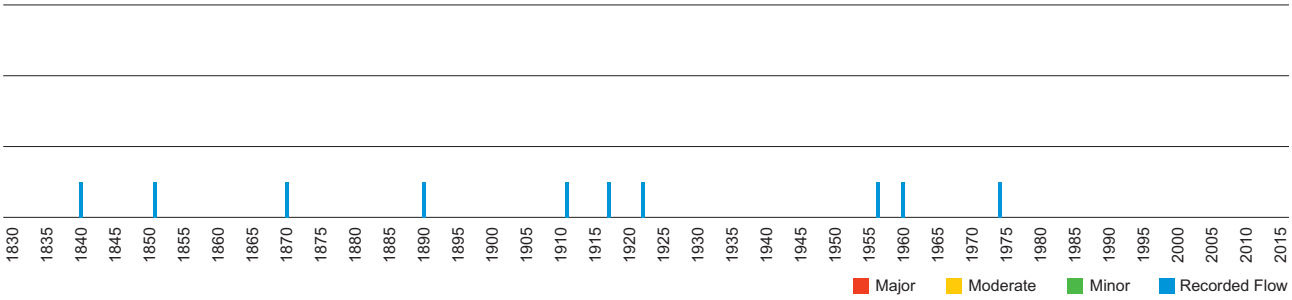

Figure 9 | Historic Flooding, Outlet Creek (southern Mallee)

For Outlet Creek to flow, Lake Albacutya must fill and overflow. This occurs irregularly, and has become less frequent since 1975. Reliable long-term data on actual inflows or water levels of Lake Albacutya does not exist. The data in the chart above has been collated from historical records based on incidental and anecdotal evidence (Cibilic & White 2010).

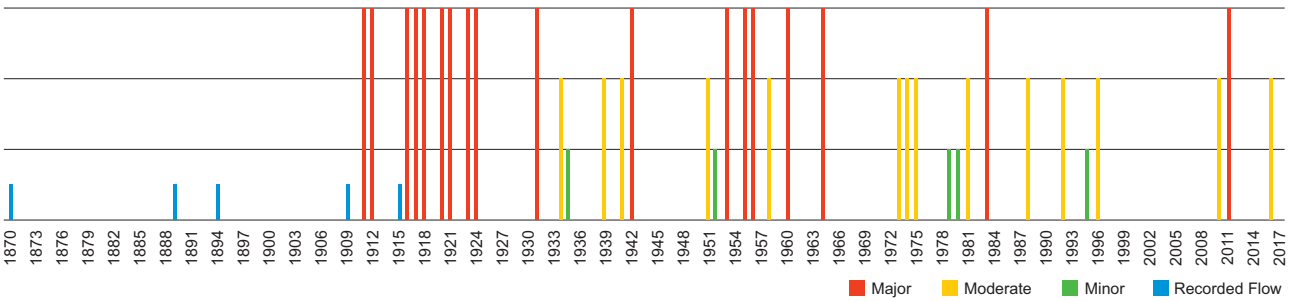

Figure 10 | Historic flooding, Yarriambiack Creek (southern Mallee)

Flooding in the Yarriambiack Creek is directly related to flooding in the Wimmera River. Flooding in the creek can also occur as a result of short duration, high intensity rain which causes localised flash flooding.

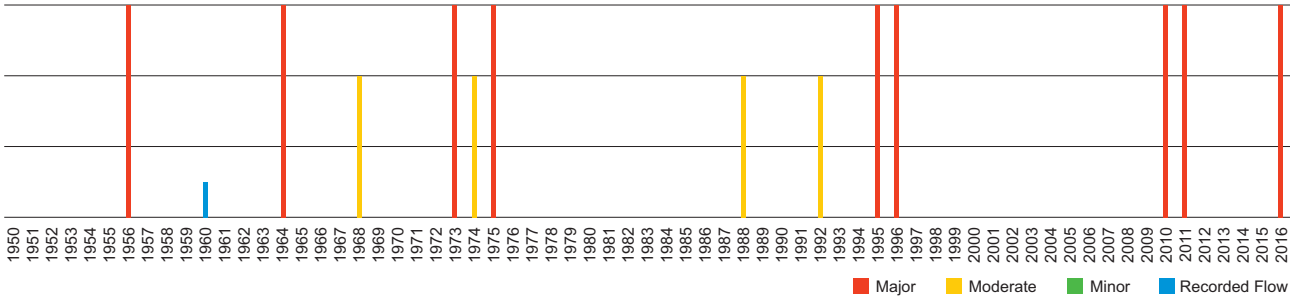

Figure 11 | Historic flooding, Tyrrell Creek (southern Mallee)

The Tyrrell Creek is ephemeral, only flowing after significant rainfall or flooding in the Avoca River. The 2011 flood event was the largest event in living memory in Culgoa.

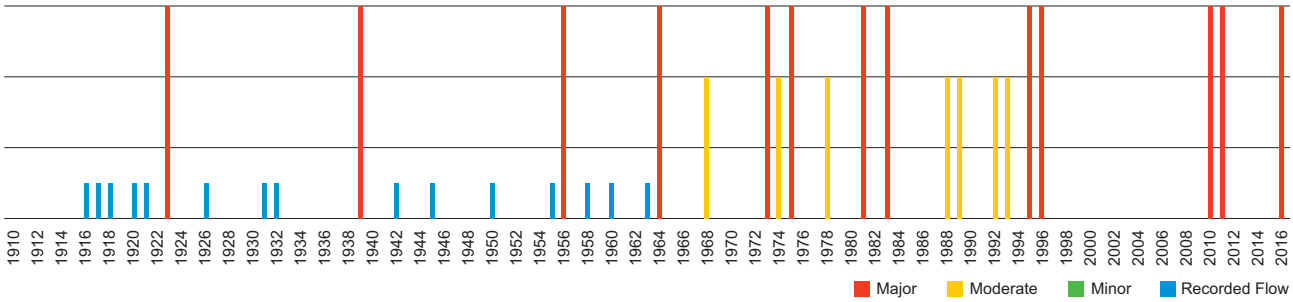

Figure 12 | Historic flooding, Lalbert Creek (southern Mallee)

Similarly to the Tyrrell Creek, the Lalbert Creek flows after significant rainfall or high flows in the Avoca River. The 2011 flood event was the first flow through the creek in around 15 years.

1.3.3 Climate change

The future climate of the Mallee region is projected to be warmer than it is today, with a higher frequency of hot days and longer durations of warm periods. Rainfall characteristics are expected to change with a shift towards more rain in the warmer months rather than during the cooler months; and increasing intensity of rainfall events. The frequency and duration of drought periods is also expected to increase and projected changes to temperature and rainfall may result in harsher bushfire seasons. These will also be accompanied by changes in other weather and climate driven variables.

There is significant spatial variation in both temperature and rainfall in the Mallee region, with the north experiencing average maximum temperatures that are around two degrees warmer than the south, and the south receiving rainfall totals higher than those in the north-east.

Recent examples of weather extremes in the Mallee include the “Millennium Drought” and the La Niña rains of 2010/11 that caused significant flooding and widespread damage. Other weather extremes can occur in relation to frost, hail, temperature and wind events.

Beulah Weir on Yarriambiack Creek provides both flood mitigation and recreational benefits.

2 Assessment of regional flood risks

2.1 Overview

Flood risk is a combination of the likelihood of a flood occurring, the consequences when it does occur and the vulnerability of those affected.

Flood risks must be quantified to be able to rank their relative seriousness. This involves being able to measure:

- the probability of flood events;
- the population exposed to flood hazard; and
- the economic damage associated with different events.

The following sections detail the approach applied in identifying and prioritising flood risks in the Mallee region.

2.2 Key issues

2.2.1 Limited ability to forecast flood impacts

The 2016 flood event along the Murray River, although only classified as a minor flood within the Mallee CMA region, was the first significant Murray River flood since Catchment Management Authorities (CMAs) were established in 1997. While there is some flood data available for the Murray River within the CMA region, it is all based around the 1956 flood event which is considered the 1% Annual Exceedance Probability (AEP) flood. Due to this limited data, predicted flood impacts along the Murray River were considerably inaccurate in some locations due to the difference between a 1% AEP and the estimated 5% event for 2016.

Similarly, contemporary modelling of various flood scenarios is required for Tyrrell and Lalbert Creeks in the southern Mallee to get a better understanding of how such events might impact on people in the future. This modelling should consider increasing intensity of certain weather events and the changing nature of the landscapes through different farming methods, changing communities and built environments (e.g. channel decommissioning).

2.2.2 Education and community engagement

It is recognised that the community has a desire for this information to be available. Ensuring the community is educated about this information is vital to ensuring people understand flood risk and take responsibility for their own protection.

There is a need for regional authorities to work together with VICSES to ensure education and engagement is coordinated and targeted to the greatest need.

Authorities will also ensure that local flood information is made available on websites so the community can access this information when needed.

2.2.3 Cross-border flood management

The 2010-11 floods brought into focus long-standing issues about the lack of integration across state borders for the management of flood mitigation infrastructure. Border communities in both Victoria and New South Wales (NSW) expressed concerns that levees on one side had aggravated flood impacts on the other. They also had concerns that neither state was doing enough to share floodwaters and flood storage capacity through the integrated operation of regulators (Victorian Floodplain Management Strategy, DELWP 2016).

Cross-border issues are complex. Efforts to resolve these issues date back to 1910, when NSW and Victoria entered a formal Interstate Levees Agreement. Centralised efforts to coordinate levee construction persisted, nominally at least, until 2008 when the Murray-Darling Basin Commission was abolished. They were not successful, partly because flood behaviour is more complex than envisaged more than a century ago (Victorian Floodplain Management Strategy, DELWP 2016).

For example, Mildura Rural City Council's submission to the "Inquiry into flood mitigation infrastructure in Victoria (2012)" raised concerns over the impact of existing levees and possible consequences from proposed levees and recommended that flood modelling should be on a "whole of floodplain basis". In the case of the Murray River, it was recommended flood modelling should include both the Victorian and NSW floodplains.

Similarly, floodplains that cross CMA boundaries should also be modelled and managed on a "whole of floodplain basis", in particular:

- Lalbert and Tyrrell Creeks – distributaries of the Avoca River originating in the North Central CMA
- Yarriambiack Creek – headwaters and upstream reaches originating in the Wimmera CMA.

2.2.4 Stormwater

The impacts of urbanisation on the natural water cycle are many and varied. The most obvious is on rainfall run-off regimes and occurs because of alterations to land surfaces. Land clearing and the construction of impervious surfaces, such as roofs and paved areas, characterise urban development. Paved surfaces serve to limit and, in most cases, prevent infiltration of rainfall and dramatically reduce the attenuation and retention of surface flows. These two outcomes result in increased surface run-off volumes, increased peak flows and

Stormwater Flooding, Irymple 2011.

reduced times to peak flow (Mildura Stormwater Quality Improvement Plan, BMT WBM Pty Ltd 2009).

When surface runoff exceeds the capacity of an urban stormwater drainage system, stormwater flooding can occur.

In general, urban stormwater flooding risks arise from the legacy of previous drainage infrastructure design and planning practices. For example, the Sunraysia Drainage Strategy (SKM 2002) identified inadequate drainage infrastructure as a "driving issue" in meeting both existing and future short and long term urban stormwater runoff needs.

While the total amount of stormwater flooding will generally be less than from riverine flooding, stormwater flooding can cause just as much damage to an individual property as riverine flooding. It is the depth and velocity of water at each property which determines how destructive the flood waters are.

2.2.5 Rural drainage

Due to the relatively flat terrain of the Mallee and the scarcity of defined rural watercourses, there is limited scope for rural surface drainage infrastructure. Runoff from roads and rural properties following rainfall events tends to pond in localised areas and infiltrate through the soil profile.

Due to this lack of infrastructure, localised flooding has been highlighted as an important issue for some areas (e.g. the Sunraysia region).

DELWP is currently developing a rural drainage strategy that will provide strategic guidance for matters relating to rural drainage. This will include consideration of clearing a stream of debris or sediment that may have multiple benefits (e.g. flood mitigation, rural drainage and waterway management) and involve the same activities and potential costs (Victorian Floodplain Management Strategy, DELWP 2016).

2.2.6 Channel decommissioning

High levels of evaporation and seepage from the Wimmera Mallee Domestic and Stock Channel System were key motivators for the regional push for a piped supply system, which led to the construction of the Northern Mallee Pipeline and the Wimmera Mallee Pipeline.

With the pipeline in operation, Grampians Wimmera Mallee (GWM) Water instigated a channel decommissioning program to eliminate large open channels from the landscape. This program was completed in 2014. However, full decommissioning remains incomplete with many smaller channels and structures still in place.

As some of the channels have been in place for longer than 80 years, it is unclear whether they mitigate or amplify flood risks.

2.2.7 Informal levees

The Mallee region has an existing ad-hoc series of largely unmaintained levees. These levees were constructed to protect various land uses including residential, agricultural, recreational and sewerage reserves. Historical records indicate that parts of the levee system have failed in recent major flood events.

In addition, during the 2010-11 flood events many new levees appeared which were not constructed to suitable standards, or in consideration of the broader floodplain context.

There were several examples of individuals protecting their own assets, but not understanding their potential liability due to the effect of their actions on others within the floodplain. For example, the concentration of flood flows by a levee system creating increased flooding for other parties.

2.2.8 Climate change

Victoria's weather and climate can change in response to a wide range of natural and human factors. Recent experience highlights the challenges posed to floodplain management by Victoria's climate. The prolonged drought from 1997 to 2009 was the worst on record. It was followed by severe floods in western and northern Victoria particularly during spring and summer in 2010-12 (Victorian Floodplain Management Strategy, DELWP 2016).

Estimates of the probability of a flood of a given magnitude occurring or being exceeded will change if the flood regime is altered. This could shift the likelihood and consequence of floods in different parts of Victoria (Victorian Floodplain Management Strategy, DELWP 2016).

These issues must be considered when assessing and treating flood risk.

2.3 Existing flood risk treatments

2.3.1 Planning scheme controls

The objectives of planning in Victoria are set out in the *Planning and Environment Act 1987* (the Act). The purpose of the Act is to establish a framework for planning the use, development and protection of land in Victoria in the present and long-term interests of all Victorians. The Act does not remove an applicant's responsibility

to apply for any authorisation or permission necessary under any other Act with respect to anything authorised by the permit. Any applicant proposing to undertake an activity must comply with any other legal obligation with respect to the proposed activity, such as those that protect Aboriginal cultural heritage under the *Aboriginal Heritage Act 2006* or restrict the removal of native vegetation.

State Planning Policy Framework

The Victorian planning policy for floodplains (Clause 13.02) provides the broad framework for the integration of flood policy and provisions into planning schemes. It brings together various strands of policy and strategic planning from all areas of government that have a bearing on floodplain management. It also aims to provide consistency in planning controls for flood affected areas of the state.

The objective of the State Planning Policy for floodplain management is to assist in the protection of:

- life, property and community infrastructure from flood hazard;
- the natural flood-carrying capacity of rivers, streams and floodways;
- the flood storage function of floodplains and waterways; and
- floodplain areas of environmental significance or of importance to river health.

The policy states that flood risk must be considered in the preparation of planning schemes and in land use decisions, so as to avoid intensifying the impact of flooding through inappropriately located uses and developments. It also states that land affected by flooding should be shown on planning scheme maps and recognises that land affected by flooding is land inundated by the 1-in-100-year flood event or as determined by the floodplain management authority.

Planning schemes

The Act provides for a single instrument of planning control for each municipality, which is referred to as the planning scheme. The planning scheme sets out the way land may be used or developed. It is a legal document, prepared and approved under the Act. It contains state and local planning policies, zones and overlays and other provisions that affect how land can be used and developed.

Each of the four local government areas in the Mallee region is covered by a planning scheme.

Planning schemes include maps that show how the land is zoned (e.g. residential, industrial or rural) and any planning controls (overlays) affecting the land. Specific zones and overlays relevant to floodplain management are described below:

- *Urban Floodway Zone (Clause 37.03 and schedule)*. This zone is applied to urban land where the primary function of the land is to carry or store floodwater. It applies to high hazard areas with high flow velocities, where impediment of flood water can cause significant changes in flood flows and adversely affect flooding in other areas.
- *Floodway Overlay (Clause 44.03 and schedule)*. This overlay is applied to urban and rural land identified as part of an active floodway, or to a high hazard area with high flow velocities, where impediment of flood water can cause significant changes in flood flows and adversely affect other areas.
- *Land Subject to Inundation Overlay (Clause 44.04 and schedule)*. This overlay applies to land in either rural or urban areas that is subject to inundation, but is not part of the primary floodway.
- *Special Building Overlay (Clause 44.05 and schedule)*. This overlay applies to urban land that is subject to overland flow resulting from stormwater flooding where the capacity of the drainage system is exceeded during heavy rainfall. This land is not part of a primary floodway from a river or stream.

Applying the Flood Provisions in Planning Schemes

The nature of the flood risk and the type of flood information available will determine how and to what extent the flood provisions are applied in the planning scheme.

The flood zone and overlay provisions ensure that the use and development of land subject to inundation is made compatible with the level of flood risk through the planning permit process.

The Mallee CMA provides advice to agencies and the public that encourages appropriate development and reduces the impacts of flooding on life, property and infrastructure. Information includes:

- General flood advice for property owners or potential property buyers. Advice may include the likelihood of flooding, or any restrictions for development on land.
- 1% AEP (the 100-year flood) level for a location.
- Likely conditions for a proposed development.
- Overlays or zoning on land and their implications with regards to flooding.

It should be noted that the flood provisions in planning schemes do not address the cause of flooding, but the way future land use and development will impact on the flooding problem or be impacted themselves by flooding. The cause needs to be dealt with by separate means. This may include other actions of council and/or the floodplain management authority, such as flood mitigation measures, that may be linked to a corporate plan or a floodplain management strategy (DELWP 2015[3]).

2.3.2 Structural flood mitigation infrastructure

A number of structural measures are used to mitigate the effects of flooding, including levees, channel modifications, bypass floodways, retention basins, dams and floodgates. Collectively, these measures are referred to as flood mitigation infrastructure (DELWP 2016).

Within the Mallee region, the majority of structural works that perform flood mitigation functions are in the form of levees.

When appropriately designed and maintained, flood mitigation infrastructure can be a useful tool in reducing or minimising existing flood risks. However, across Victoria, most flood mitigation infrastructure is not being formally managed. A 2004 audit of urban levees surrounding Mildura (Price Merrett Consulting 2004[4]) revealed ad-hoc management arrangements as the levees were originally constructed at relatively short notice of impending floods, with little consideration given to the

3 https://www.planning.vic.gov.au/__data/assets/pdf_file/0018/11538/PPN12-Applying-the-Flood-Provisions-in-Planning-Schemes_June-2015.pdf

Ring levee at Culgoa, 2011.

engineering associated with the levee, its location, alignment and longevity.

In these cases, it is assumed that the infrastructure is privately managed (or not managed at all). A likely consequence of this is that the flood mitigation infrastructure will deteriorate and may be liable to failure during a flood, providing very little, if any, protection to those areas originally intended to be protected by the levees. This may, in turn, impact on emergency management planning and land use planning.

For example, DELWP (2016) states that where there is flood mitigation infrastructure that is not being formally managed:

- the relevant municipal planning scheme must not assume that the infrastructure will provide flood protection; and
- the relevant Municipal Flood Emergency Plan must provide for the potential for sudden and complete failure of that infrastructure.

Flood mitigation infrastructure that is not currently subject to formal management arrangements will remain that way unless the relevant Local Government Area (LGA) determines that the infrastructure should be brought into formal management arrangements through a Water Management Scheme or other appropriate arrangements.

This would involve consideration of:

- the current governance arrangements;
- the costs and benefits of restoring the infrastructure (if required) to a reasonable standard of protection;
- the costs of ongoing management and maintenance;
- the costs and benefits of alternative solutions; and
- the community's willingness to pay.

Where the benefits of a particular rural levee do not meet Government investment criteria (and therefore would not be managed through a formal Water Management Scheme), there may be individuals who still see a benefit in that levee and wish to maintain it themselves. Where the levee is on private land, it will be for the beneficiaries to negotiate with landholders about management arrangements. Landholders opting to jointly manage their own scheme may request local government assistance, on terms negotiated directly between the local government and the group. DELWP will work with local governments to determine how these arrangements could work.

Where the levee is on Crown land, a new permit scheme created by legislation in 2014 means beneficiaries are able to maintain that levee themselves. Previously, if they wanted to maintain the levee they needed to seek a variety of Crown land manager approvals and, in some instances, to have approval from multiple land managers, some of whom did not have the power to give any approval at all. Under the new scheme, people will only need a single permit from their local CMA DELWP (2016).

Permit holders will be authorised to access the Crown land and maintain the levee in accordance with conditions on the permit. Permit holders will not be authorised to change the levee's original location, height and width, build a new levee or remove an old one, as this could affect third parties. CMAs and land managers, such as DELWP and Parks Victoria, will set reasonable conditions on the permit to minimise the impact of maintenance activities on Crown land values. In most instances, a person holding a Crown land levee maintenance permit will not be required to also apply for a permit under the relevant municipal planning scheme. Nonetheless, their maintenance activities must comply with other legal obligations, such as those that protect Aboriginal cultural heritage.

4 Price Merrett Consulting (2004). Mildura Rural City Council Urban Levee Audit

2.3.3 Total Flood Warning System services

The goal of flood warnings is to help flood management agencies and the members of flood-prone communities to understand the nature of developing floods so that they can take action to mitigate flood impacts. To achieve this goal, flood warning systems must be established and operated (Australian Institute for Disaster Resilience, 2009[5]).

A flood warning system is made up of a number of components which must be integrated if the system is to operate effectively. The components of a 'total flood warning system' (TFWS) are:

- Monitoring of rainfall and river flows that may lead to flooding;
- Prediction of flood severity and the time of onset of particular levels of flooding;
- Interpretation of the prediction to determine the likely flood impacts on the community;
- Construction of warning messages describing what is happening and will happen, the expected impact and what actions should be taken;
- Dissemination of warning messages;
- Response to the warnings by the agencies involved and community members; and
- Review of the warning system after flood events.

A preliminary assessment of TFWS services for at-risk locations in the Mallee region (Cawood 2017[6]) has been completed for this strategy.

2.3.4 Municipal Flood Emergency Plans

VICSES is responsible for the community education and awareness that underpins flood preparedness. This includes facilitating the preparation of Municipal Flood Emergency Plans (MFEPs) with support from the relevant LGA (DELWP 2016).

The purpose of an MFEP is to detail agreed arrangements for the planning, preparedness/ prevention, response and recovery from flood incidents within a municipality. The objective of an MFEP is to ensure a coordinated response by all agencies having responsibilities and functions in emergencies (EMV 2016[7]), including:

- Flood risk assessments, for all types of possible flood events (available flood intelligence);
- Flood monitoring data (data collection);
- Existing flood mitigation measures and their management;
- Community education and engagement;
- Flood warning and emergency information;
- Community flood guides.

In the Mallee region, the following MFEPs (and related plans) are currently available:

- Buloke Municipal Flood Emergency Plan;
- Mildura Rural City Council Municipal Flood Emergency Plan;
- Swan Hill Rural City Council Municipal Flood Emergency Plan;
- Robinvale Local Flood Guide;
- Yarriambiack Shire Council Flood Response Plan.

2.4 Regional risk assessment process

Like other natural resource management issues, there will always be more actions identified to mitigate flood impacts than resources (money, time, people) available. Additionally, the existing planning and funding cycles of delivery agencies may not align with some actions (at least in the short term). As such, a priority setting process is required to identify strategic actions that can be:

- Delivered in the short-term (over the next three years) using currently available resources; and
- Planned and delivered in the mid to long-term to maximise return on investments.

The key steps to assessing flood risk in the Mallee region involved:

1 Dividing the region into manageable sub-regions (management units);
2 Determining risk levels for each management unit (using a rapid assessment methodology); and
3 Refining the risk levels (by considering risks to community infrastructure).

2.4.1 Step 1 - management units

The Mallee region consists of several catchments (e.g. the Murray River, Tyrrell Creek, Little Yarriambiack Creek) with a varied mix of urban and rural areas with differing characteristics. It was therefore considered sensible to define smaller sub regions (or management units) to allow flood risks to be assessed in a manageable and systematic way.

For the Mallee FMS, the approach used to define management units involved:

- separating urban flooding from rural flooding;
- dividing rural flooding into practical management units where the assets at risk were comparable; and
- aligning management units to LGA boundaries.

This approach resulted in the Mallee region being divided into:

- 57 urban management units, and
- 30 rural management units.

These units are shown in Figure 13 and detailed in Appendix A: Relative risk assessment outputs.

5 https://knowledge.aidr.org.au/media/1964/manual-21-flood-warning.pdf
6 Cawood, M. 2017). Total Flood Warning System Assessment Tool. Application to the Mallee CMA area. Report to Mallee Catchment Management Authority
7 http://files.portal.em.vic.gov.au/refdocs/EMK-01.19-SERP-FloodSubplan.pdf

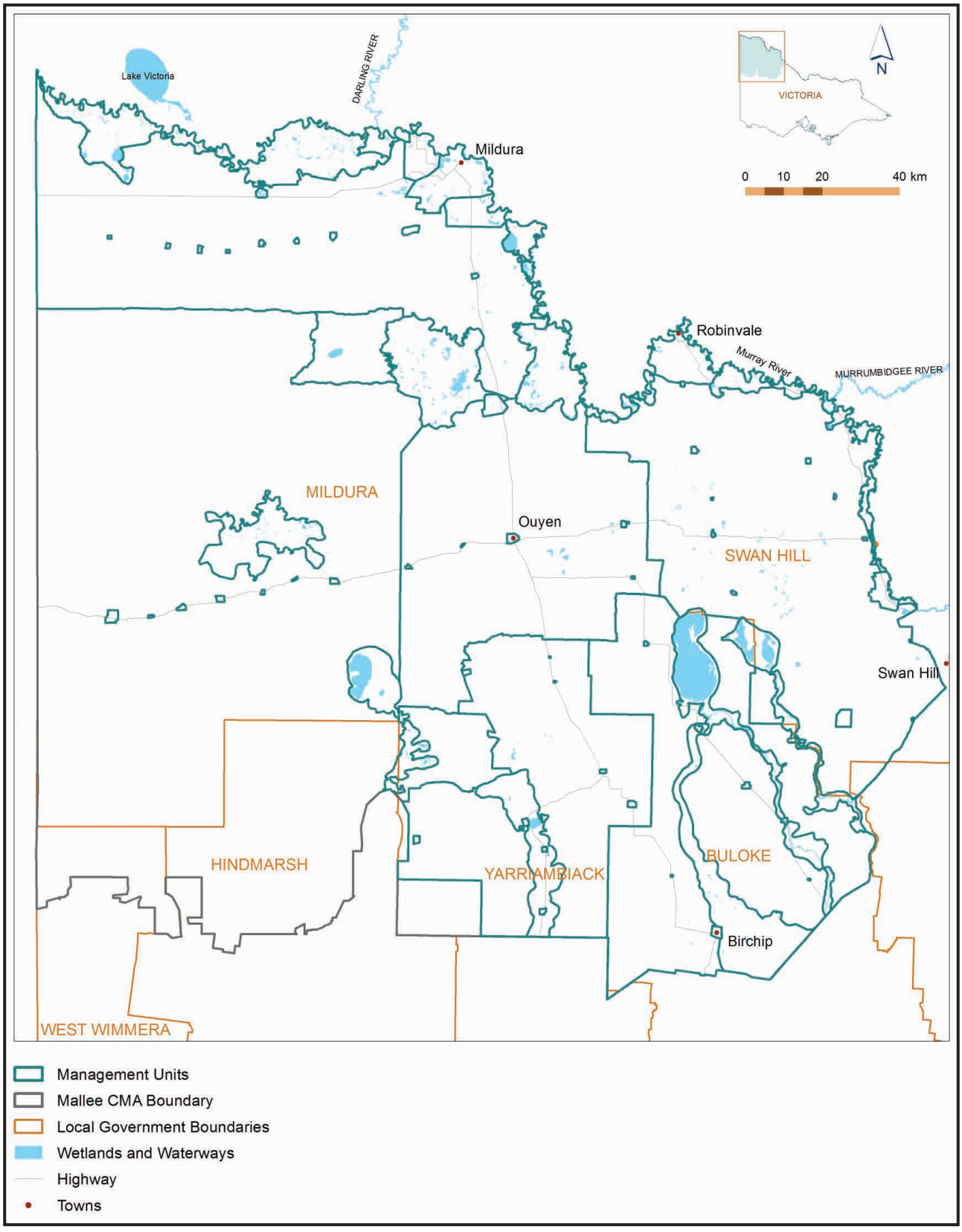

Figure 13 | This map illustrates the number and distribution of management units in the Mallee along with the various local government boundaries.

Train traversing flooded Murray River, Mildura, circa 1924. Credit: Museum Victoria

2.4.2 Step 2 - rapid risk assessment

The purpose of this step was to quantify and compare the relative flood risk (riverine and stormwater) for each management unit by applying DELWP's rapid appraisal of flood risk methodology. This methodology is 'fit for purpose' and produces a relative measure of risk associated with agriculture, property, buildings, and emergency services.

For each management unit, flood damages were assessed and presented using three risk metrics:

1. Absolute damage - Average Annual Damages (AAD). This risk metric measures the absolute size of the flood risk.
2. Town resilience - the average annual population affected (AAPA) divided by the town population. This risk metric measures the proportion of the town that is flooded.
3. Damage density - flood risk calculated as average annual damage (AAD) divided by the flood extent for the 1% AEP event. This risk metric measures the density of damage

The flood metrics were presented on a 1 to 6 scale, where 1 is low risk and 6 is extreme risk (a 0 reflects no available data).

The management units with the highest relative flood risk are presented in Tables 1 and 2. Risk assessment outputs for all management units are presented in Appendix A.

Table 1 | Urban management units identified as having significant flood risks

No.	Name	LGA
2	Beulah	Yarriambiack
8	Nullawil	Buloke
9	Culgoa	Buloke
26	Robinvale	Swan Hill
29	Wood Wood	Swan Hill
30	Piangil	Swan Hill
32	Ouyen	Mildura
42	Murrayville	Mildura
45	Red Cliffs	Mildura
46	Mildura	Mildura

Table 2 | Rural management units identified as having significant flood risks

No.	Name	LGA
62	Karadoc RWS Unit	Mildura
71	Tyrrell RWS Unit	Buloke
82	Buloke LGA Central	Buloke
83	Buloke LGA East	Buloke

2.4.3 Step 3 - risk refinement

The results from the rapid appraisal provide a relative ranking of flood risk across all management units and can be used to inform flood risk management decisions. However, it should be acknowledged that the methodology is not designed to be an absolute assessment of flood risk.

In addition to the risks identified through Step 2, a number of local risks were also considered to refine the risk levels for each management unit.

Key stakeholders from across the region were invited to participate at a workshop on 6 December 2016 to identify additional flood risks under the following categories:

- Community infrastructure. This category can be defined as infrastructure that is essential for the ongoing functioning of local communities. Such infrastructure can include premises, assets, goods or social systems. It can exist at the town scale, locality scale or possibly the whole of region scale. It is infrastructure that is relied upon by residents, businesses and industry on a day to day basis.
- At-risk populations. This category considered populations who may have additional needs before, during and after a flood (e.g. hospitals, nursing homes, disability support services, kindergartens, pre-schools).
- Areas of high-risk to life. This category considered areas where floodwaters are likely to cause a significant risk to life (e.g. floodways with high flood velocities or flood water depths).
- Other risks (e.g. areas with minimal or no flood hazard data (extent, depth, duration) or areas earmarked for new developments).

Using a series of A0 maps of the region overlaid with the 1% AEP flood extent, workshop participants located important infrastructure where either the infrastructure or its access was within this flood extent.

Including these additional risks in the risk assessment process ensured that an appropriate risk category was allocated to each management unit.

2.5 Priority risk areas

The regional risk assessment process identified 12 priority risk areas for the Mallee region. These risk areas are presented in Tables 3 to 6 (by municipality) and include the areas' location (urban or rural), flood type (riverine or stormwater) and summary of flood risks.

Road damage caused by Tyrrelll Creek flooding, Culgoa 2011.

Table 3 | Priority risk areas within the Mildura Rural City Council boundary

No.	Name	Location	Flood Type	Flood Risk
32	Ouyen	urban	stormwater	• Inadequate drainage of the Matheson St, Ritchie St, Emmett St and Mitchell St catchment area. • Flooding issue at the Mallee Deli Shop - runoff water over the kerb (front) and channel and overland flow (rear). • Inadequate drainage capacity of existing swale along Farrell Street. • Reduced flow capacity in side entry pits and box culverts under Farrell St (Calder Highway).
42	Murrayville	urban	stormwater	• Water ponding in front of shops along Mallee Highway. • Flooding of the Murrayville Hotel by runoff water from Milde Lane. Other business owners along the section of the Mallee Highway have to sandbag their back doors to avoid flooding. • Capacity of existing kerb and channel drainage along Reed Street and Sharrock Street. • Capacity and safety of grated pits and culverts under the Mallee Highway near Reed Street and the Murrayville Hotel. • Condition and capacity of formed and unformed swales and culverts used to direct runoff from the Mallee Highway to Recreation Road.
45	Red Cliffs	urban	stormwater	• Older township. • Stormwater system utilises decommissioned irrigation infrastructure (not specifically designed for stormwater management).
46	Mildura	urban	stormwater	• Council currently cleaning and inspecting existing network. • New infrastructure is required for new developments (e.g. pipes, detention basins).
46	Mildura	urban	riverine	• Limited ability to forecast flood impacts – flood information is based on the 1956 flood event.
62	Karadoc RWS Unit	rural	riverine	• Access to properties can be disrupted for up to six weeks during river flooding.

Table 4 | Priority risk areas within the Buloke Shire Council boundary

No.	Name	Location	Flood Type	Flood Risk
8	Nullawil	urban	stormwater	• Drainage improvement works required at Nullawil North Road and Bart Street. • Shire has completed preliminary design plans and quantities/estimates to resolve urban drainage issues.
9	Culgoa	urban	riverine	• Flood study completed - overflow from Avoca at Charlton. • Cannot predict flood timing and height at Culgoa.
71 72 82 83	Tyrrell RWS Unit Lalbert RWS Unit Buloke LGA Central Buloke LGA East	rural	riverine	• Existing flood study does not account for recent irrigation channel decommissioning OR the impact of informal levees (as experienced in 2010/11 flood events). • Not all flood mapping in planning scheme.

Table 5 | Priority risk areas within the Swan Hill Rural City Council boundary

No.	Name	Location	Flood Type	Flood Risk
26	Robinvale	urban	riverine	• There is a high risk from rain events due to all drainage systems being gravity leading to floodwater becoming trapped behind the current levee. • This leads to flooding in low sections of the town. • There are design concepts completed to resolve this issue.
29	Wood Wood	urban	riverine	• The likelihood of a flood event impacting Wood Wood is low but possible (with a low number of properties impacted). • Limited ability to forecast flood impacts – flood information is based on the 1956 flood event.
30	Piangil	urban	riverine	• The likelihood of a flood event impacting Piangil is very low (e.g. the river would need to be at a high level to impact the town however, if the highway was overtopped, there would be extensive damage to properties). • Limited ability to forecast flood impacts – flood information is based on the 1956 flood event.

Table 6 | Priority risk areas within the Yarriambiack Shire Council boundary

No.	Name	Location	Flood Type	Flood Risk
2	Beulah	urban	riverine	• 2007 flood study revealed floodwater from Little Yarriambiack Creek would enter township (with 4-5 houses flooded above floor level). • Prior to the 2011 flood, the shire in partnership with local landholders built a small (1ft) levee to protect houses and buildings (east bank of creek). • There is normally an 11-12 day lead time to prepare for flooding. • Flood risk is higher if flooding is from a local storm event i.e. lack of time to prepare.

Yarriambiack Creek in flood, 2011.

3 Regional Works Plan

The information from Part 2 of this strategy was used to determine priority actions for managing flood risks in the Mallee region. These particular actions were given priority because:

i. The Regional Risk Assessment identified a significant risk of flooding for the location;
ii. The existing risk treatments for the location are considered inadequate;
iii. Additional risk treatment(s) are available and achievable in the short term (e.g. the next three years); and
iv. Additional risk treatment(s) are financially, socially and environmentally feasible.

Flood risks and priority actions for the region and each municipality are summarised in the following sections. This information has been derived from a number of sources, including the relevant MFEP, flood studies, current funding applications, community engagement and discussions with local government authorities (LGAs) and VICSES.

3.1 Region-wide priority actions

3.1.1 Background

The Mallee is home to over 61,000 people. The largest centre is Mildura and its surrounds (Irymple, Merbein and Red Cliffs). Other population centres of the region include Robinvale, Ouyen, Sea Lake, Hopetoun, Murrayville and Birchip. Population growth is uneven across the region, with strong growth in urban Mildura, matched by parallel losses in smaller communities.

There are approximately 1,600 km of waterways and associated floodplains in the Mallee region including the Murray River, approximately 555 km of Murray River anabranches and tributaries, Tyrrell and Lalbert Creeks, Outlet Creek and Yarriambiack Creek.

3.1.2 Identified flood risks

Flood data and information
Flood data including hydrographic records and flood impacts in the Mallee is difficult to find and inconsistent in quality. The lack of high quality data regarding historic events presents difficulties for emergency response agencies in predicting the impact of flood events.

Existing flood studies proved valuable during the 2010/11 flood event; however, there was inconsistent coverage of the affected areas. Furthermore, any minor or major landscape changes made after the study was completed significantly reduced the accuracy of the flood mapping.

To mitigate these issues, flood studies need to be regularly reviewed and updated to reflect changes in the nature of the floodplain and to include the community to ensure they understand the principles for any flood protection works.

Detailed flood studies should utilise Geographic Information System (GIS) data including Light Detection and Radar (LiDAR) that provides data for Digital Elevation Modelling (DEM) and satellite/aerial imagery to provide predictions of possible flooding extents and flood contours to help inform flood prediction and emergency response.

Cultural heritage
Floods and floodplain management activities can present risks to Aboriginal cultural heritage. Past flood events have resulted in damage to significant sites through prolonged inundation, soil erosion, and mitigation works.

Regional flood assessments, local flood studies and flood mitigation works must take into account culturally significant places, sites and landscapes.

The Aboriginal Heritage Register is an invaluable resource, but Traditional Owners have a much broader information base about Aboriginal cultural heritage than is available to government. It is essential to consult with Traditional Owners and local Aboriginal communities in assessing and mapping flood risks.

Structural flood mitigation infrastructure
Across the Mallee region, local councils own most levees protecting townships; however, the ownership and maintenance of rural levees is ambiguous and requires government clarification and accurate flood mapping to determine their value. The Victorian Floodplain Management Strategy (2016) states that any flood mitigation infrastructure that is not being formally managed should not be recognised as being functional in Municipal Planning Schemes, and MFEPs must consider the potential for sudden and complete failure of that infrastructure.

During the 2010/11 flood events the majority of the pre-existing rural levees were found to be in poor condition and many new levees appeared which were not constructed to suitable standards, or in consideration of the broader floodplain context.

To minimise the potential of this occurring in the future there needs to be consideration of the principle that beneficiaries should bear the cost of the construction and maintenance of flood mitigation works, including public assets.

Consideration should also be given to roads and decommissioned channels to determine if they are mitigating or amplifying flood risks.

Regular updating of LiDAR would improve assessments of levee development on the floodplain by enabling modelling of their impact at a catchment scale. This data would significantly enhance the review of flood studies and ensure that alterations to flood passage are being regularly captured and analysed.

Flood warnings
Flood warnings provide communities and emergency management agencies with information about when flooding may occur, its likely impacts and what to do to reduce damages.

There are a number of gauges across the Mallee to assist with flood predictions, and modelling at various locations is based on historic readings from these sites. However, many of these gauges are old and require maintenance and updating. The 2010/11 flood events also highlighted locations where a number of additional gauges would greatly assist flood modelling and predictions.

Stream gauges have also proved to be unreliable in some cases where they malfunctioned, as flood peaks passed due to the accumulation of debris in flood waters and minimal maintenance over the 14-15 years of drought during late 1990s-early 2000s.

There is a need for old gauges to be renewed, including both AHD elevation and height from bottom of the river/stream bed. The installation of height gauges at new sites is also required to assist with flood predictions and modelling.

Strategically placed automated gauging stations that are able to provide real-time data (telemetry) to the Bureau of Meteorology (BoM), incident control centres and the community would allow for more informed and timely decision making. To ensure this capability exists during times of flood, funding and resources need to be made available on an ongoing basis to provide for maintenance and upkeep.

Land use planning
Planning scheme controls include measures such as minimum floor levels, minimum fill levels, land zoning based on flood hazard, building requirements such as material types and structural integrity, and access and egress requirements.

Land Subject to Inundation Overlay (LSIO) is the mechanism currently in place in parts of municipal areas to identify land in an area affected by a 1% AEP flood. The overlay does not only protect potential development from flood impacts, but also aims to ensure that infrastructure does not cause a rise in flood level or flow velocity. The overlay also seeks to maintain or improve river and wetland health.

The current flood mapping available in the region is based on historical information that is not accurate. The availability and incorporation of new flood data/mapping into the planning scheme is critical to managing flood risks. Inaccurate flood mapping could obstruct town growth and give a false sense of security to communities.

Other region-wide land use planning issues include:
- Negative environmental impacts (native veg removal, developments, effluent disposal etc.) on floodplains and rivers caused by inappropriate developments;
- Establishing the current floodplain uses (what land uses are located in the floodplains);
- Ensuring the right overlay and zone controls are used. There is the LSIO but also the more serious Floodway Overlay control, and for exceptional areas the Urban Flood Zone, so it is important the most suitable controls are used; and
- Including Insurance Council Australia in any mapping change proposals.

Emergency management
Currently there are significant gaps in flood intelligence information for the whole Murray River region, from Nyah to the South Australian border. No flood studies have been undertaken and these are needed to generate detailed flood intelligence that would be invaluable to guide decisions when undertaking response activities during flood events.

Specific flood studies are needed for Mildura, Red Cliffs, Robinvale and Nyah. Undertaking these studies would provide detailed flood information such as damage to buildings, flood depths, travel times, time to inundation of roads, people isolated at a range of flood magnitudes, impact to school bus routes etc.

Access to this information would greatly improve community confidence in flood response activities and enable the VICSES to better support the community.

3.1.3 Priority actions

Based on the above, the following region-wide priority actions have been identified:

Flood data and information
- Undertake a detailed Murray River flood study (including stormwater modelling, where appropriate to investigate various riverine and stormwater flooding scenarios for different flood magnitudes.
- Develop a community flood portal with an interactive reporting functionality which allows a user to search for a particular address, obtain a property report and visually identify flood information related to that address.
- Support the BoM and regional monitoring partnerships in the renewal of old gauges, including both AHD elevation and height from bottom of the waterway.
- Develop processes to share data with cross border (regional, further upstream and state) agencies.

Cultural heritage
- Work to incorporate Aboriginal cultural heritage values in emergency management planning and response activities via consultation with Aboriginal Victoria and other relevant stakeholders.
- Consult with Traditional Owners when floodplain management activities are carried out.

Structural flood mitigation infrastructure
- Undertake a LiDAR survey to identify and map all flood mitigation infrastructure (e.g. levees, channels, roads), which alters the flow of flood water within the region, with detailed assessment of infrastructure as required/where relevant.
- Investigate the positive and negative flood impacts presented by road infrastructure and decommissioned channels.
- Undertake three yearly LiDAR updates across the broader landscape at appropriate scales for future flood and storm water planning.

Murray River in flood, Robinvale, 1956.

Flood warnings

- Enhance the real-time transmission of rainfall and stream flow data from key flood monitoring sites by ensuring that data is remotely accessible by at least two telemetry pathways.
- Evaluate the potential to provide localised neighbourhood-scale flash flood warning services where there is a history of flash flooding.

Land use planning

- Complete updated flood mapping and distribute to local governments.
- Investigate opportunity to develop region-wide flood mapping.
- Develop process to streamline the ability for the CMA to provide local government bodies with latest updated flood information as it is developed.
- Identify funding opportunities to assist in costs associated with updating planning schemes.

Emergency management

- Incorporate updated flood mapping, flood intelligence and local knowledge into MFEP for all flood affected communities, incorporating new flood studies, townships, levees, surveys required etc.
- Develop catchment plans to summarise main points out of MFEPs.
- Develop pre-plans for public warnings – informing communities of impending flood.
- Undertake operational readiness training/exercises for all Local Flood Guides that incorporate MFEPs into operation responses (in Incident Control Centres), using a risk based approach to prioritise within current VICSES resources.
- Pre-develop community messaging tailored for relevant towns/ communities with known impacts for various AEPs, using a risk based approach to prioritise within current VICSES resources.
- Develop community engagement activities and/or awareness products relating to high flood risk townships and communities. This may include installing community signs, gauge boards or community led response plans.

3.2 Priority actions for Mildura Rural City Council

3.2.1 Background

Mildura Rural City Council covers an area of 22,330 square kilometres and includes the city of Mildura and the towns of Merbein, Red Cliffs, Irymple, Ouyen, Werrimull, Murrayville, Walpeup and Hattah. Agriculture in the area is comprised of a mixture of irrigated and dryland farming. Fruit and vegetable production are the most significant industries in Mildura with more than 80% of Victoria's grapes and much of Victoria's citrus fruit produced in the region. The municipality's population is approximately 53,500 and this is expected to increase by approximately 6,000 in the next 15 years (source: Victoria in Future 2016 - Population and Household Projections to 2031).

The major waterway and associated floodplain within the municipality is the Murray River, which forms the northern boundary of the municipality. Flooding from the Murray River was a severe threat at the end of the last century; however, this risk has been somewhat mitigated with the construction of levees of varying heights to 3.0m along most of the river (although this levee system is considered old and possibly unreliable).

In addition to riverine flooding, the relatively flat terrain and scarcity of defined rural watercourses results in flash flooding from rain events in some parts of the municipality.

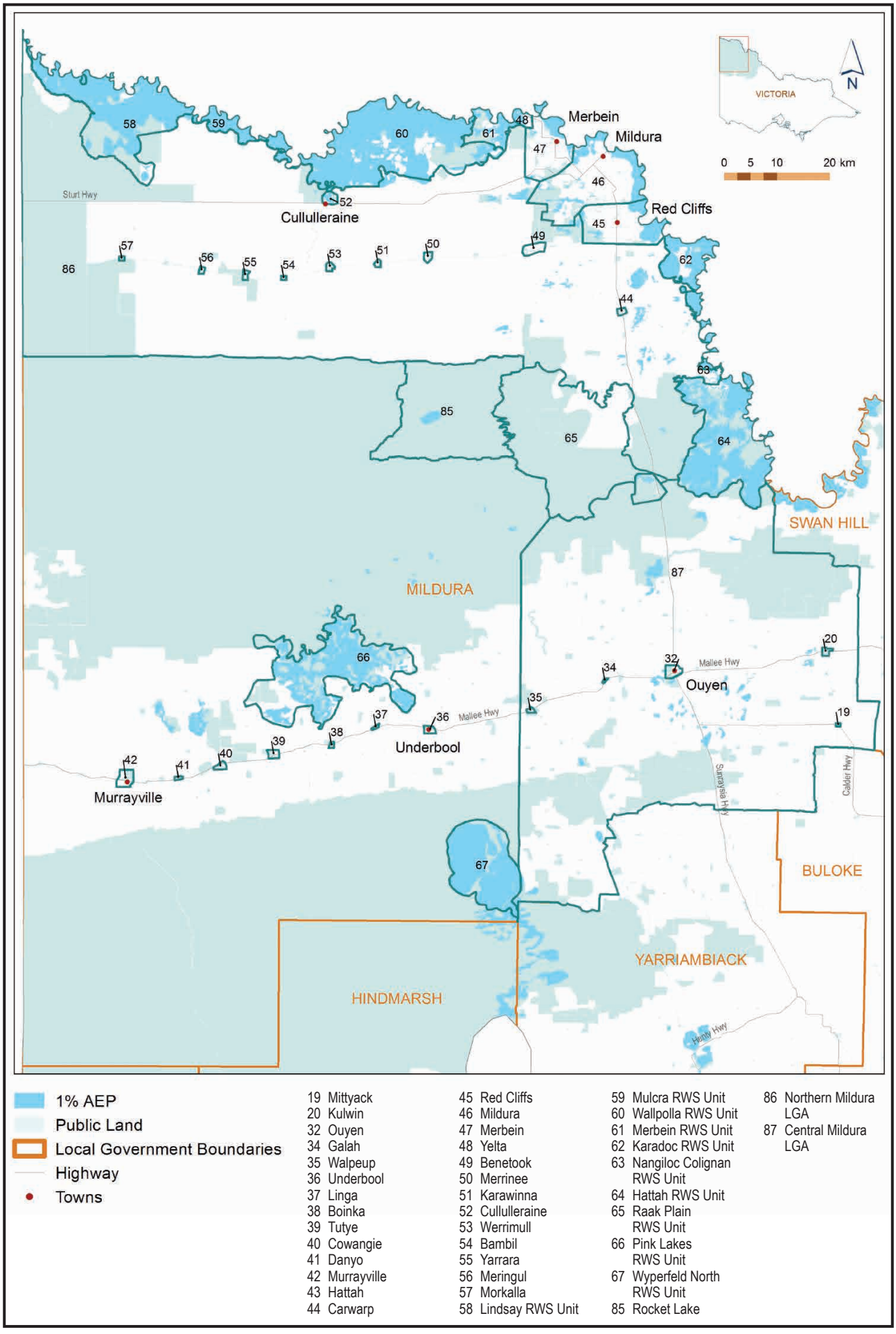

Figure 14 | Mildura Rural City Council Management Units

3.2.2 Identified flood risks

Murray River floodplain
The six largest riverine floods on record at Mildura occurred (in order of decreasing magnitude) 1870, 1956, 1917, 1931, 1975, and 1974. The 1870 flood at Mildura was above normal river level for about seven months with a flow rate of 367,000 ML/day. The second largest flood on record was observed in 1956 and was approximately 0.2m lower than the 1870 event with a flow rate of 308,000 ML/day. The two levees, one on the Victorian side and one on the New South Wales side, failed in this event and resulted in an increase to the flood extent.

The benchmark flood extent adopted for the Murray River is based on the 1956 flood event. Analysis of flood records indicates that this flood is very close to the 1% AEP event. However, without detailed modelling based on current conditions, flood levels and risks to the municipality under various flood scenarios are limited.

Stormwater/flash flooding
Short duration, high intensity rainfall (usually associated with thunderstorms) can cause flooding within the urbanised areas and some rural areas of the municipality. Blocked or capacity impaired stormwater drains can lead to overland flows and associated flooding: the drain surcharges and excess water flows above ground.

Such flood events, which are mainly confined to the summer months, do not generally create widespread flooding since they only last for a short time and affect limited areas. However, flooding from these storms occur with little warning and localised damage can be severe.

A Regional Risk Assessment identified significant stormwater risks for the following locations in the municipality:

- Mildura: Stormwater impacts through the township can be significant as the stormwater drainage system struggles to cope with the excessive flows (e.g. the February 2011 event inundated both residential and industrial areas). Council is currently undertaking an annual program of cleaning and inspecting the existing drainage network to mitigate future impacts. With the projected population increase, additional drainage infrastructure will be required for new developments (e.g. pipes, detention basins).
- Red Cliffs: This is an older township in the municipality that utilises decommissioned irrigation infrastructure (not specifically designed for stormwater management) as part of its stormwater system.
- Ouyen: Due to inadequate drainage and flow capacity of the drainage system, a number of properties, bounded by Matheson Street, Ritchie Street, Emmett Street and Mitchell Street, are impacted by flooding whenever significant rainfall events occur.
- Murrayville: A number of drainage issues have been identified within the township of Murrayville. Some of these issues can be solved through maintenance; however, there are a number of issues that require significant design work and remodelling of the existing drainage system to mitigate flood risks.

3.2.3 Priority actions

Murray River floodplain
The risk of a flood from the Murray River impacting one or more townships within the municipality is low to very low as the towns are located on high ground, well above any recorded flood levels. There are, however, some small pockets of residential and industrial development that were established after 1956 and could be subject to flooding if the existing levee bank system was breached.

In addition, access to some properties on the floodplain (e.g. Johns Way at Karadoc) can be disrupted for a number of weeks during floods.

Of potentially greater concern is a large flood event combining with an extreme rainfall event. Under this scenario, high river levels can submerge stormwater drainage outlets, restricting outflows and causing the drainage discharge to back up and flood residential and industrial developments.

Based on the above, the following priority actions have been identified for the Murray River floodplain:

- Short term:
  - Utilise the Murray River flood study to confirm likely flood levels and risks to the municipality.
  - Incorporate stormwater modelling into the Murray River flood study to investigate various riverine and stormwater flooding scenarios for different flood magnitudes.
  - Develop a flood management plan for Mildura. This plan will:
    - provide improved flood intelligence and information to enable more accurate and meaningful flood predictions; and
    - identify options to reduce the impact of future floods.
  - Formalise management responsibilities for the Murray River levees based on the flood study.
  - Investigate feasibility (cost/benefit analysis) of improving access to properties at Johns Way during flood.
- Longer term:
  - Install permanent telemetered stream gauge at Colignan.
  - Install isolation valves to prevent floodwater movement up stormwater assets (based on riverine and stormwater flooding investigation).
  - Amend the Mildura planning scheme to incorporate the Mildura Flood Management Plan.

Mildura
Depending on the location, stormwater from Mildura's residential, commercial and industrial areas is diverted either to:

- The Murray River (directly from urban drains or via Etiwanda Wetland);
- Bob Corbould Wetland;
- Lake Ranfurly; and/or
- Lake Hawthorn (via Mildura South Wetlands Drainage Scheme).

To ensure that the stormwater system is managed efficiently and effectively, the following priority actions have been identified:

- Short term:
  - Continue Council's annual program of cleaning, inspecting and renewing the existing drainage network to mitigate future impacts.
  - Implement the key stormwater actions of the Lake Hawthorn Management Plan. Lake Hawthorn is an integral part of Mildura Rural City Council's urban stormwater drainage strategy. The Lake Hawthorn Management Plan was completed in 2015 and includes an overall framework for the management of the lake.
  - Investigate tailored flash flooding warning systems.
- Longer term:
  - Upgrade drainage systems where required to enable further development and manage stormwater effectively.

- Investigate the design and installation of an extended rain gauge network at selected key sites in the Sunraysia irrigated area to better inform stormwater drainage designs and severe rain event responses. Include opportunities to develop a telemetered rain gauge network to better inform stormwater response.

Red Cliffs
Stormwater from Red Cliffs is discharged mainly into Basin 12 which is a floodplain wetland. At high levels, basin 12 discharges to the Murray River via pipeline.

To ensure that the stormwater system is managed efficiently and effectively, the following priority actions have been identified:
- Short term:
  - Investigate stormwater impacts under various design storm events (ie. where does flooding occur, to what height, for how long?)
- Longer term:
  - Develop solutions to minimise significant flood impacts based on investigation and risk modelling (e.g. construction of non-return valves to limit irrigation surcharges).
  - Investigate the design and installation of an extended rain gauge network at selected key sites in the Sunraysia irrigated area to better inform stormwater drainage designs and severe rain event responses.

Ouyen
Mildura Rural City Council has recently investigated design options to resolve key drainage issues in Ouyen along the Calder Highway near the Mallee Deli. The objective is to direct runoff water quickly and efficiently to the swale along the rail line, thereby decreasing the amount of water ponding in Farrell Street and the backyard of the Mallee Deli Shop. An increase in the outfall pipe size under the railway line to the south of Ouyen Saleyards is scheduled for completion by the end of 2017, removing an existing choke point in the current system.

Based on this investigation, the following priority actions have been identified:
- Short term:
  - investigate known drainage issues within the Ouyen township;
  - Undertake modelling and/or surveying of affected areas;
  - Produce designs to rectify or mitigate the known drainage issues;
  - Produce a drainage plan for the Ouyen township; and
  - Investigate tailored flash flooding warning systems.
- Longer term:
  - Implement priority actions.

Murrayville
Mildura Rural City Council has recently investigated design options to resolve key drainage issues in Murrayville. The objective is to direct runoff water quickly and efficiently to the north side of Recreation Road, thereby decreasing the amount of water ponding in the township and the likelihood of businesses flooding.

Based on this investigation, the following priority actions have been identified:
- Short term:
  - Investigate known drainage issues within the Murrayville township;
  - Undertake modelling and/or surveying of affected areas;
  - Produce designs to rectify or mitigate the known drainage issues;
  - Produce a drainage plan for the Murrayville township; and
  - Investigate tailored flash flooding warning systems.
- Longer term:
  - Implement priority actions.

3.3 Priority actions for Buloke Shire Council

3.3.1 Background

Buloke Shire Council covers an area of 8,004 square kilometres and includes the towns of Birchip, Charlton, Donald, Sea Lake, Wycheproof, Berriwillock, Culgoa, Nandaly, Nullawil and Watchem. The main industry is agriculture, especially grain and sheep production. The Shire's population is approximately 5,900 and this is expected to decrease by approximately 1,000 in the next 15 years (source: Victoria in Future 2016 - Population and Household Projections to 2031).

Note
Buloke Shire Council covers parts of the Mallee, Wimmera and North Central regions. The following sections only consider that part of the municipality within the Mallee region.

The major waterways and associated floodplains within the Mallee region are:
- Tyrrell Creek (an effluent stream of the Avoca River system which flows north through farmland and the township of Culgoa before terminating at Lake Tyrrell)
- Lalbert Creek (another effluent stream of the Avoca River system).
- Dunmunkle Creek
- Haddon Creek

3.3.2 Identified flood risks

The following information has been adapted from the following documents:
- Submission to the Inquiry into Flood Mitigation Infrastructure in Victoria - Submission no.95 Buloke Shire Council (2011)
- Stories of the Flood, Buloke Shire Council (2014)
- Flood Emergency Plan Buloke Shire Council (VicSES 2013).

Tyrrell Creek floodplain
Flows in Tyrrell Creek can be generated from two major sources:
- Tyrrell Creek catchment rainfall, which leads to runoff directly entering the waterway.
- Avoca River flows distributed to Tyrrell Creek at the off take point downstream of Charlton.

In flood conditions the Tyrrell Creek becomes a very wide fast-flowing water mass. The Tyrrell Creek flood of January 2011 resulted in:
- Three rural homesteads near Culgoa being severely impacted by flood waters;
- Extensive damage to road infrastructure;
- Widespread pasture damage;
- Inundation and significant crop loss. Surrounding farmland was inundated, with the November 2010 and January 2011 floods resulting in significant losses in grain quality, livestock, fencing, infrastructure and

Figure 15 | Buloke Shire Council Management Units

subsequent effects on the incomes of farming families; and
- Closure of arterial roads (e.g. Calder Highway at various locations, Sea Lake-Swan Hill Road and Sea Lake Robinvale Road) and numerous local roads.

Culgoa
Culgoa sits adjacent to the Tyrrell Creek. During floods the creek can inundate homes and rural properties on the eastern and western sides of the Calder Highway as it passes through Culgoa. The Calder Highway is also impassable during flood conditions.

The January 2011 flood peak in the Culgoa area was the highest in recorded history, resulting in an evacuation notice being served on residents on 15 January 2011. Late on Sunday 16 January 2011 some water arrived in the northern part of Culgoa and by Monday morning, 17 January 2011 twelve homes (fifty percent of the town) were inundated by flood waters with water around a further ten homes. Essential infrastructure such as health, electricity, telephone, internet/communications, water and septic sewerage services were all compromised during the flood.

Large areas of public land around Culgoa were still inundated many months after the event.

Nullawil
While Nullawil was also impacted by the January 2011 Tyrrell Creek flood with inundation of one home, the greater flood risk is from stormwater. This occurs when heavy localised rainfall exceeds the capacity of the town's stormwater drainage systems.

Lalbert Creek floodplain
The Lalbert Creek and its floodplain within the shire boundary (i.e. both banks from Glenloth to just north of Towaninny then only the west bank to Lake Lalbert and the Rural City of Swan Hill boundary) receive floodwaters from Avoca River overflows.

During small floods in the Avoca River (i.e. around the 2 or 3 year annual recurrence interval (ARI) event at Yawong Weir and peaking at around the 5 year ARI), floodwaters enter relatively well defined floodways feeding into the Tyrrell Marshes before draining into Lalbert Creek below the Wycheproof–Goshen Channel.

From here, Lalbert Creek becomes a well-defined channel and has a relatively narrow floodplain as far as Tittybong. From Tittybong to Lake Lalbert, the floodplain widens considerably.

During high flows, the Haddon Creek (an overflow) links to the Lalbert Creek with the Tyrrell Creek. This overflow has the potential to further inundate Culgoa and surrounding areas.

Levee construction along Lalbert Creek has had a major impact on the natural distribution of flood flows.

3.3.3 Priority actions

Tyrrell Creek floodplain
There are currently no stream flow gauges, specific flood warning systems or arrangements in place for the Tyrrell Creek system. The Charlton downstream gauge (located on the Avoca River upstream of the Tyrrell Creek off take) is considered a good indicator of likely downstream flooding into the Tyrrell Creek system. To ensure that the Tyrrell Creek community is adequately prepared, improved information is required regarding the likelihood and impacts of flood events in the system.

There is also a clear need to model various flood scenarios along the Tyrrell Creek to inform planning and implementation of response and recovery activities. In particular, modelling needs to consider the impact of GWM Water's channel decommissioning project and low level informal levees (as identified during the 2010/11 flood events).

This updated information then needs to be included in Buloke Shire's planning scheme and MFEP. Based on the above, the following priority actions have been identified for the Tyrrell Creek floodplain:
- Short term:
  - Review/update 2011 flood mapping. This review should include an assessment of the benefits and risks of:
    - the channel decommissioning project. Some landholders consider channel retention as an important part of future flood mitigation whereas other landholders see these channels as possible contributors to future flood scenarios; and
    - the existing informal levee bank network.
  - Risk assessment process to review flood risks of channels and levees;
  - Amend the Buloke planning scheme to incorporate the updated Tyrrell Creek Flood Study mapping.
- Longer term:
  - Install permanent telemetered stream gauge/s along Tyrrell Creek;
  - Incorporate updated Tyrrell Creek Flood Study mapping, flood intelligence and local knowledge into the Buloke MFEP; and
  - Formalise or decommission channels and levees (based on the risk assessment above).

Culgoa
In addition to the priority actions for the Tyrrell Creek floodplain, the following actions are recommended for Culgoa:
- Short term:
  - Review Culgoa flood study;
  - Develop a flood management plan for Culgoa. This plan will:
    - provide improved flood intelligence and information (to enable more accurate and meaningful flood predictions; and
    - identify options to reduce the impact of future flood.
  - investigate the establishment of TFWS and prediction services for high risk community of Culgoa.
- Longer term:
  - Amend the Buloke planning scheme to incorporate the Culgoa Flood Management Plan; and
  - Incorporate the Culgoa Flood Management Plan mapping, flood intelligence and local knowledge into the Buloke MFEP.

Nullawil
Buloke Shire has recently completed preliminary design plans and quantities/estimates to resolve these drainage issues.

Based on these design plans, the following priority actions have been identified for Nullawil:
- Short term:
  - implement drainage improvements works at Nullawil North Road and Bart Street.

Lalbert Creek floodplain
Similar to Tyrrell Creek, there is a clear need to model various flood scenarios along the Lalbert Creek to inform planning and implementation of response and recovery activities. In particular, modelling needs to

Tyrrell Creek in Flood, 2011.

consider the impact of GWM Water's channel decommissioning project and low level informal levees (as identified during the 2010/11 flood events).

This updated information then needs to be included in Buloke Shire's planning scheme and MFEP.

Based on the above, the following priority actions have been identified for Lalbert:

- Short term:
  - Review/update 2011 flood mapping. This review should include an assessment of the benefits and risks of:
    - the channel decommissioning project. Some landholders consider channel retention as an important part of future flood mitigation whereas other landholders see them as possible contributors to future flood scenarios; and
    - the existing informal levee bank network.
  - Formalise or decommission channels and levees (based on the review); and
  - Amend the Buloke planning scheme to incorporate the updated Lalbert Creek Flood Study mapping.
- Longer term:
  - incorporate updated Lalbert Creek Flood Study mapping, flood intelligence and local knowledge into the Buloke MFEP.

3.4 Priority actions for Swan Hill Rural City Council

3.4.1 Background

Swan Hill Rural City Council covers an area of 6,096 square kilometres and includes the city of Swan Hill and the towns of Lake Boga, Manangatang, Nyah, Nyah West, Piangil, Robinvale, Ultima and Woorinen South. The main industry is agriculture, including both dryland farming areas in the west and irrigated areas in the east. The municipality's population is approximately 20,500 and this is not expected to change significantly in the next 15 years (source: Victoria in Future 2016 - Population and Household Projections to 2031).

Note
Swan Hill Rural City Council covers parts of the Mallee and North Central regions. The following sections only consider that part of the municipality within the Mallee region.

The major waterways and associated floodplains within the Mallee region are:

- The Murray River (which forms the northern boundary of the municipality). The Murray River floodplain is influenced by flows from the Murray, Wakool and Murrumbidgee Rivers and includes some rural levee systems.
- The lower Lalbert Creek. This waterway carries the overflow from the Avoca River into the terminal Lake Timboram. The floodplain includes uncontrolled levees along its entire length.

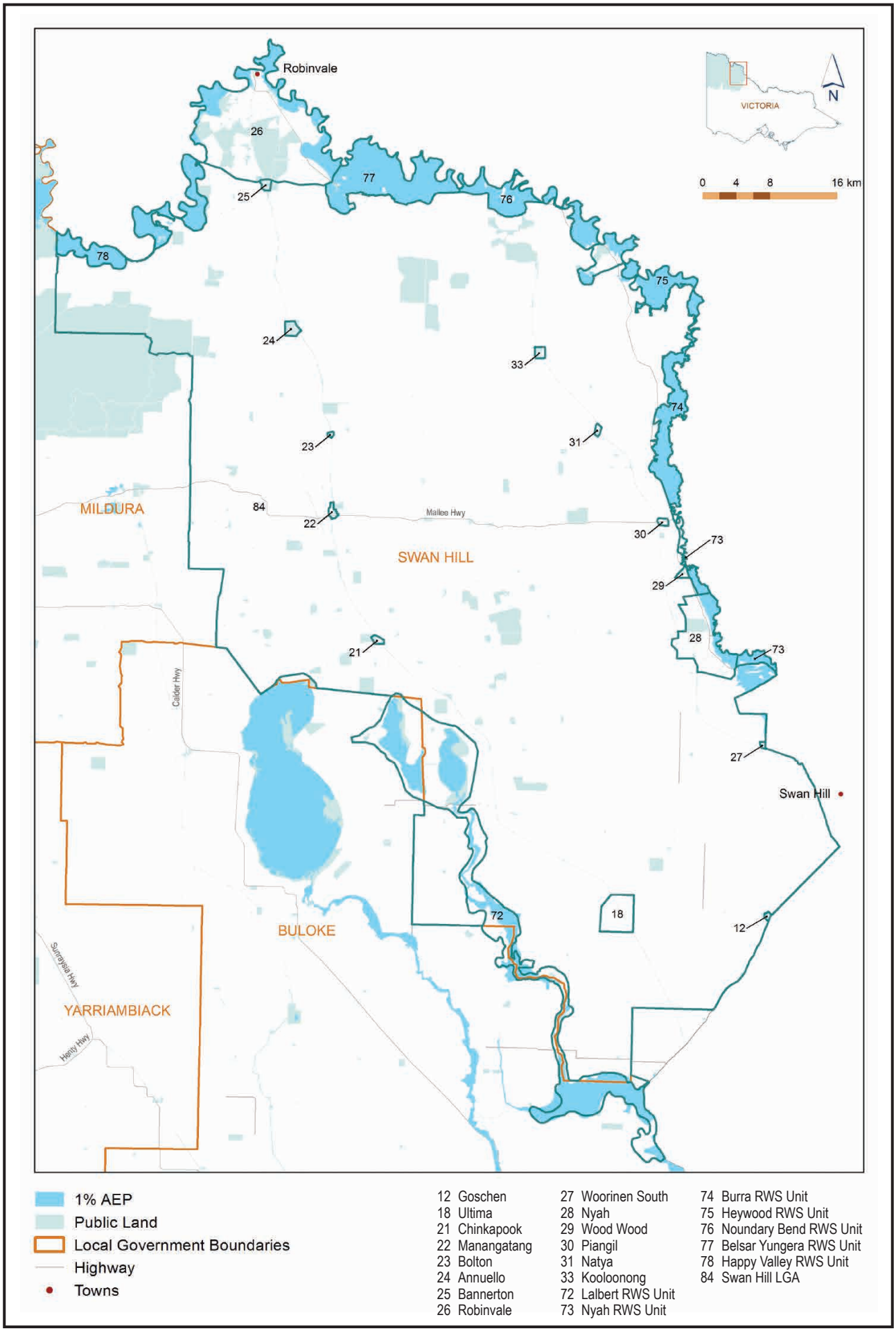

Figure 16 | Swan Hill Rural City Council Management Units

3.4.2 Identified flood risks

The following information has been adapted from Municipal Flood Emergency Plan - Swan Hill Rural City (VICSES 2014).

Murray River floodplain, Nyah Forest to the Wakool Junction
The Wakool River connects with the Murray River on the New South Wales side midway between Swan Hill and Robinvale. The area from Nyah to the junction is alternating high loamy land and outbreaks of low lying land. Properties in this area are generally large and sparsely populated. Some of this agricultural land is vulnerable, but in the main the individual levee banks and significant areas of available floodplain provide reasonable protection from floodwaters.

A number of properties located between the Murray River and the Murray Valley Highway may become isolated for >24 hours, with the following information provided as a rough guide to the general locations:
- Seven properties in the Piangil/ Wood Wood area
- Five properties in the Nyah area
- Five properties in the Vinifera area

Robinvale
Areas south of Robinvale are prone to significant outflows from the Murray, however there is no risk to homes or roads. West of Robinvale is generally high land which does not come under threat and only pumping sites need protection. The eastern section of the Robinvale township is protected by a significant but unmaintained levee bank.

The Robinvale levee extends approximately 5 kilometres and runs from Ninth Road to the south to the Murray River Bridge at Robinvale. The levee was constructed over 50 years ago with no formal maintenance program in place. It has poor compaction and is constructed out of material of varying quality. It also has a large number of irrigation and drainage pipelines passing through it. Due to its condition, it is uncertain what level of protection is currently provided by the levee.

In addition, if the river is high there may be issues of flash flooding due to urban storm water retention behind the levee system and its inability to exit the stormwater system.

Cloverdale
Cloverdale, a small village south-west of Robinvale, lies at the base of a localised depression. During typical rain events, local stormwater accumulates on Crown land to the north of Sanananda Road (the lowest point of the depression). However, in severe storms (i.e. >5% AEP), water levels rise to flood Arafura Street and the houses to the west of Arafura Street (e.g. 2011 flash flooding impacted 10-15 houses near Bogadjim Road).

Lalbert Creek floodplain
An uncontrolled levee exists along its entire length which passes through large acreage farmland. Flows are also impacted upon by extensive lignum growth which flourishes on the creek bed; this may have the effect of holding back the natural flow of the floodwaters and is not subject to any maintenance.

In larger floods concern often arises about the Ultima-Culgoa Road, and also the Sea Lake Swan Hill Road, where water will impact on the roads and these may become impassable; this is due to constrictions at the culverts where the creeks bisect the roads.

3.4.3 Priority actions

Murray River floodplain, Nyah Forest to the Wakool Junction
While the likelihood of a flood event impacting the townships of Piangil and Wood Wood is low to very low, this assessment is based on data from the 1956 flood event. If the 1% AEP is in fact higher than the 1956 flood event and resulted in the overtopping of the Murray Valley Highway, extensive damage to properties could occur, particularly at Piangil. This could also be the case if the existing levee system is not functioning as assumed.

As such, the following priority actions have been identified:
- Short term:
  - Utilise the Murray River flood study to confirm likely flood level and risk to townships;
  - Review and update local flood mapping based on study results;
- Longer term:
  - Update planning scheme maps; and
  - Incorporate updated flood study mapping, flood intelligence and local knowledge into the Swan Hill MFEP.

Robinvale
Swan Hill Rural City Council has recently submitted a funding application to upgrade the Robinvale Levee. The project seeks to:
- Remove the informal levee and reconstruct it to an acceptable standard;
- Remove pipelines through the levee and improve drainage across the levee;
- Formalise management responsibility for the levee; and
- Remove the LSIO from the land protected by the levee (the LSIO is in the Swan Hill Planning Scheme as the current informal levee is considered unreliable).

Based on the funding application, the following priority actions have been identified for Robinvale:
- Short term:
  - Complete reconstruction of the Robinvale levee. This will involve removal of the existing levee and construction of a new levee to an acceptable standard with proper section, service crossings, compaction, freeboard and crest width;
  - Formalise management responsibilities for the reconstructed Robinvale levee;
  - Update the Robinvale Flood Study to include the reconstructed Robinvale levee;
  - Amend the Swan Hill planning scheme based on the reconstructed Robinvale levee (i.e. remove the LSIO from the land protected by the levee);
  - Complete drainage study for Robinvale.
- Longer term:
  - Incorporate updated Robinvale flood study mapping, weir operating procedures, flood intelligence and local knowledge into the Swan Hill MFEP; and
  - Design and construct pump station solution to transfer stormwater from low sections of the town to the river side of the Robinvale levee.

Cloverdale
Based on its location and flash flooding history, the following priority actions have been identified for Cloverdale:
- Short term:
  - Investigate options to store and release stormwater. There is a subsurface drain owned by Lower Murray Water (LMW) but it does not have the capacity to

include significant stormwater inputs. There may be an option to install a retarding basin within the Crown land north of Sanananda Road with a low flow rate discharge to the subsurface drain when capacity is available.
- Long term:
  - Implement preferred option.

Lalbert Creek floodplain
Similar to the reach of Lalbert Creek in the Buloke Shire, there is a clear need to model various flood scenarios to inform planning and implementation of response and recovery activities. In particular, modelling needs to consider the impact of GWM Water's channel decommissioning project and low level informal levees, as identified during the 2010/11 flood events.

This updated information then needs to be included in the Swan Hill Rural City Council's planning scheme and MFEP.

Based on the above, the following priority actions have been identified for the Lalbert Creek floodplain:
- Short term:
  - Review/update 2011 flood mapping. This review should include an assessment of the benefits and risks of:
    - the channel decommissioning project; and
    - the existing informal levee bank network.
  - Formalise or decommission channels and levees (based on the review); and
  - Amend the Swan Hill planning scheme to incorporate the updated Lalbert Creek Flood Study mapping.
- Longer term:
  - Incorporate updated Lalbert Creek Flood Study mapping, flood intelligence and local knowledge into the Swan Hill MFEP.

3.5 Priority actions for Yarriambiack Shire Council

3.5.1 Background

Yarriambiack Shire Council covers an area of 7,158 square kilometres and includes the towns of Warracknabeal, Hopetoun, Murtoa, Rupanyup, Brim and Beulah. The main industry is agriculture, with the Shire described as the heartland of grain production and handling in the Wimmera and Mallee. The shire's population is approximately 6,500 people and this is expected to decrease by approximately 1,000 in the next 15 years (source: Victoria in Future 2016 - Population and Household Projections to 2031).

Note
Yarriambiack Shire Council is split between the Mallee and Wimmera regions. The following sections only consider that part of the municipality within the Mallee region.

The major waterway and associated floodplains within the Mallee region is the lower Yarriambiack Creek which flows through the township of Beulah and near the township of Hopetoun.

3.5.2 Identified flood risks

Flood behaviour in Beulah along Yarriambiack Creek is primarily influenced by upstream and downstream weir structures. Floodplain flow to the east of Henty Highway is controlled by the set of culverts under the railway track to the south to the township.

The 2007 Beulah flood study (*Warracknabeal and Beulah Flood Study, Water Technology 2007*) did not recommend any structural changes to these structures as modelling revealed minimal reductions to flood levels or extents and adverse flood related impacts due to flow re-direction east of the township.

However, during the 2011 flood the Council and local residents did construct an informal 'levee' (a line of earth pushed up by earthmoving machinery) along the eastern edge of Yarriambiack Creek. This was achieved as Beulah had sufficient warning of the flood peak.

3.5.3 Priority actions

Based on the knowledge gained from the 2011 flood, the following priority actions have been identified for Beulah:
- Short term:
  - Update the 2007 Beulah flood study (*Warracknabeal and Beulah Flood Study, Water Technology 2007*). Since the 2010/11 floods, a number of flood mitigation activities have been undertaken (e.g. increasing flood capacity under the Birchip-Rainbow-Road by replacing the old pipes with larger culverts);
  - Amend the Yarriambiack Shire Council planning scheme to incorporate the updated Beulah flood study mapping;
  - Develop formal operating procedures for the weirs upstream and downstream of Beulah; and
  - Upgrade the 'informal' flood levee (if required) based on the findings of the updated flood study.
- Longer term:
  - Install two permanent telemetered stream gauge: one south of Beulah and one south of Warracknabeal; and
  - Incorporate updated Beulah flood study mapping, weir operating procedures, flood intelligence and local knowledge into the Yarriambiack MFEP.

3.6 Regional works plan – summary

To allow ongoing reviews and prioritisation processes, the priority actions detailed in the previous sections will be captured in a three-year regional works plan, as a supporting document to the Mallee FMS. This will allow the region to review and renew our management priorities on an annual basis, and to ensure that best available information is informing the delivery of activities.

A summary of the regional works plan is presented in Table 7.

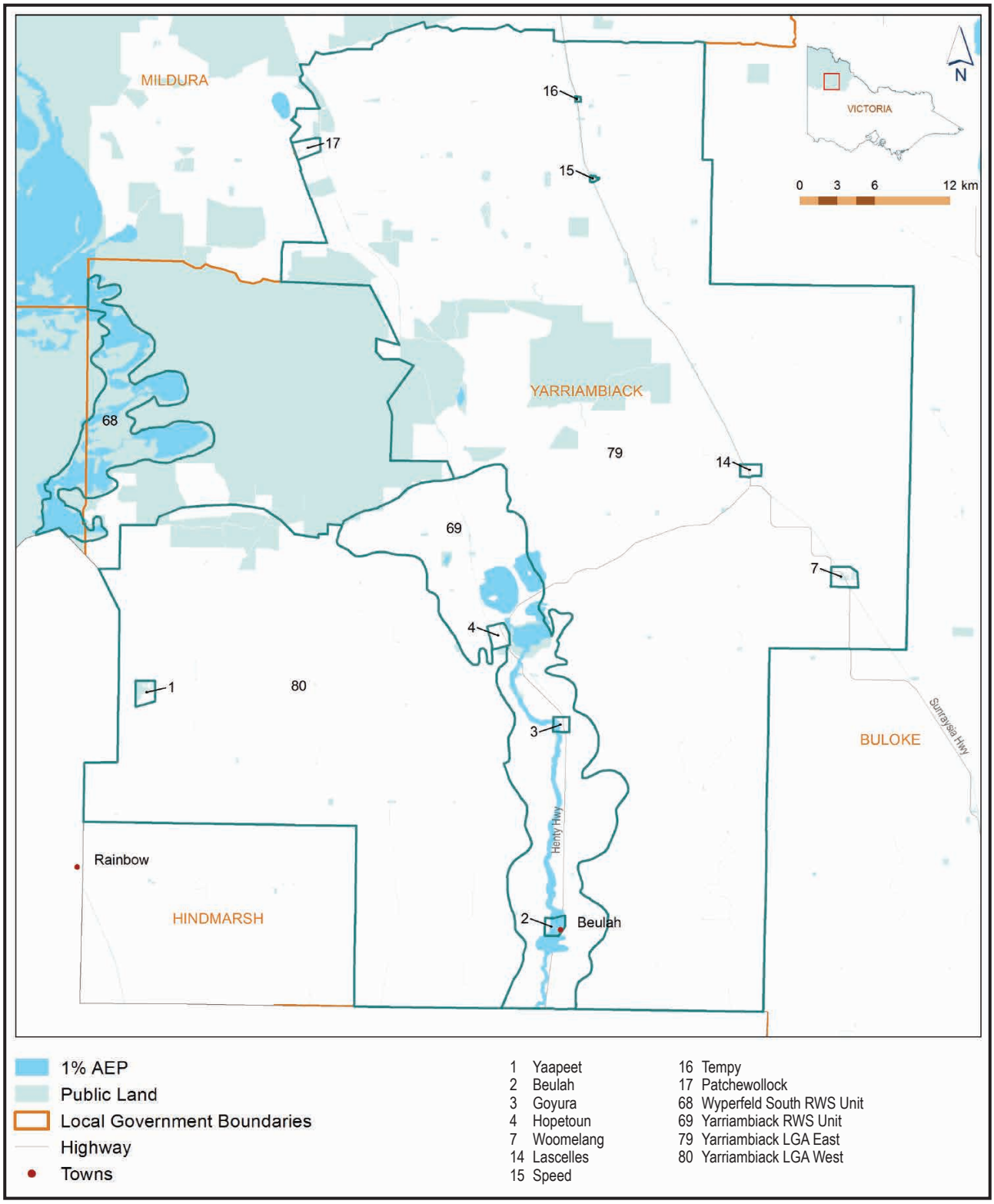

Figure 17 | Yarriambiack Shire Council Management Units

Table 7 | Regional works plan 2018-2020

Management Action		Location	Lead Agency
No.	Description		
R1	Develop a community flood portal with an interactive reporting functionality which allows a user to search for a particular address, obtain a property report and visually identify flood information related to that address.	Region-wide	MCMA
R2	Support the Bureau of Meteorology and regional monitoring partnerships in the renewal of old gauges including both AHD elevation and height from bottom of the creek.	Region-wide	DELWP
R3	Develop processes to share data with cross border (regional, further upstream and state) agencies.	Region-wide	DELWP
R4	Work to incorporate Aboriginal cultural heritage values in emergency management planning and response activities via consultation with Aboriginal Victoria and other relevant stakeholders.	Region-wide	All
R5	Consult with Traditional Owners when floodplain management activities are carried out.	As required	All
R6	Undertake a LiDAR survey to identify and map all flood mitigation infrastructure (e.g. levees, channels, roads) which alters the flow of flood water within the region, with detailed assessment of infrastructure as required/where relevant.	Region-wide	MCMA
R7	Investigate the positive and negative flood impacts presented by road infrastructure and decommissioned channels.	Region-wide	MCMA
R8	Undertake three yearly LiDAR updates across the broader landscape at appropriate scales for future flood and storm water planning.	Region-wide	MCMA
R9	Enhance the real-time transmission of rainfall and stream flow data from key flood monitoring sites by ensuring that data is remotely accessible by at least two telemetry pathways.	Region-wide	DELWP
R10	Evaluate the potential to provide localised neighbourhood-scale flash flood warning services where there is a history of flash flooding.	Region-wide	DELWP, VICSES
R11	Complete updated flood mapping and distribute to Councils.	As required	MCMA
R12	Investigate opportunity to develop region wide flood mapping.	Region-wide	MCMA
R13	Develop process to streamline the ability for the CMA to provide Councils with latest updated flood information as it is developed.	Region-wide	MCMA
R14	Identify funding opportunities to assist in costs associated with updating planning schemes.	Region-wide	MCMA
R15	Incorporate updated flood mapping, flood intelligence and local knowledge into MFEP for all flood affected communities, incorporating new flood studies, townships, levees, survey required etc.	As required	VICSES
R16	Develop catchment plans to summarise main points out of Municipal Flood Emergency Plans.	Region-wide	VICSES
R17	Develop pre-plans for public warnings – informing communities of impending flood.	Region-wide	VICSES
R18	Undertake operational readiness training/exercises for all Local Flood Guides that incorporate MFEPs into operation responses (in Incident Control Centres), using a risk based approach to prioritise within current VICSES resources.	Region-wide	VICSES
R19	Pre-develop community messaging tailored for relevant towns/communities with known impacts for various AEPs, using a risk based approach to prioritise within current VICSES resources.	As required	VICSES
R20	Develop community engagement activities and/or awareness products, relating to high flood risk townships and communities. This may include installing community signs, gauge boards or community led response plans.	As required	VICSES
M/S1	Undertake a detailed Murray River flood study (including stormwater modelling (where appropriate) to investigate various riverine and stormwater flooding scenarios for different flood magnitudes).	Murray River floodplain	MCMA
M1	Utilise the Murray River flood study to confirm likely flood levels and risks to the municipality and townships.	Mildura municipality	MRCC
M2	Incorporate stormwater modelling into the Murray flood study to investigate various riverine and stormwater flooding scenarios for different flood magnitudes.	Murray River floodplain	MRCC
M3	Develop a flood management plan for Mildura. This plan will: • provide improved flood intelligence and information to enable more accurate and meaningful flood predictions; and • identify options to reduce the impact of future floods.	Mildura	MRCC
M4	Formalise management responsibilities for the Murray River Levees (based on the Flood Study).	Murray River floodplain	DELWP
M5	Investigate feasibility (cost/benefit analysis) of improving access to properties at Johns Way during flood.	Johns Way	MRCC
M6	Continue Council's annual program of cleaning, inspecting and renewing the existing drainage network to mitigate future impacts.	Mildura	MRCC
M7	Implement the key stormwater actions of the Lake Hawthorn Management Plan.	Mildura	MRCC
M8	Investigate tailored flash flooding warning systems.	Mildura, Ouyen and Murrayville	MRCC
M9	Investigate stormwater impacts under various design storm events - where does flooding occur, to what height, for how long?	Red Cliffs	MRCC
M10	Investigate known drainage issues within the Ouyen Township.	Ouyen	MRCC

Table 7 | Regional works plan 2018-2020 *Continued...*

Management Action		Location	Lead Agency
No.	**Description**		
M11	Undertake modelling and/or surveying of affected areas.	Ouyen	MRCC
M12	Produce designs to rectify or mitigate the known drainage issues.	Ouyen	MRCC
M13	Produce a drainage plan for the Ouyen Township.	Ouyen	MRCC
M14	Investigate known drainage issues within the Murrayville Township.	Murrayville	MRCC
M15	Undertake modelling and/or surveying of affected areas.	Murrayville	MRCC
M16	Produce designs to rectify or mitigate the known drainage issues.	Murrayville	MRCC
M17	Produce a drainage plan for the Murrayville Township.	Murrayville	MRCC
B/S1	Review/update 2011 Tyrrell/Lalbert flood mapping. This review should include an assessment of the benefits and risks of: • the channel decommissioning project. Some landholders consider channel retention as an important part of future flood mitigation whereas other landholders see them as possible contributors to future flood scenarios; and • the existing informal levee bank network.	Tyrrell and Lalbert floodplains	MCMA
B1	Formalise or decommission channels and levees (based on the review).	Tyrrell and Lalbert floodplains	TBD
B2	Amend the Buloke planning scheme to incorporate the updated Tyrrell/Lalbert Creeks Flood Study mapping.	Tyrrell and Lalbert floodplains	BSC
B3	Review Culgoa flood study.	Culgoa	MCMA
B4	Develop a flood management plan for Culgoa. This plan will: • provide improved flood intelligence and information to enable more accurate and meaningful flood predictions; and • identify options to reduce the impact of future flood.	Culgoa	BSC
B5	Investigate the establishment of TFWS and prediction services for high risk community of Culgoa.	Culgoa	BSC
B6	Implement drainage improvements works at Nullawil North Road and Bart Street.	Nullawil	BSC
S1	Utilise the Murray River flood study to confirm likely flood levels and risks to the municipality and townships.	Swan Hill municipality	SHRCC
S2	Review and update local flood mapping based on study results.	Swan Hill municipality	SHRCC
S3	Complete reconstruction of the Robinvale Levee. This will involve removal of the existing levee and construction of a new levee to an acceptable standard, with proper section, service crossings, compaction, freeboard and crest width.	Robinvale	SHRCC
S4	Formalise management responsibilities for the reconstructed Robinvale Levee.	Robinvale	DELWP
S5	Update the Robinvale Flood Study to include the reconstructed Robinvale Levee.	Robinvale	MCMA
S6	Amend the Swan Hill planning scheme based on the reconstructed Robinvale Levee i.e. remove the LSIO from the land protected by the levee.	Robinvale	SHRCC
S7	Complete drainage study for Robinvale.	Robinvale	SHRCC
S8	Investigate options to store and release stormwater.	Cloverdale	SHRCC
S9	Amend the Swan Hill planning scheme to incorporate the updated Tyrrell/Lalbert Creeks Flood Study mapping.	Tyrrell and Lalbert floodplains	SHRCC
Y1	Update the 2007 Beulah flood study (Warracknabeal and Beulah Flood Study, Water Technology 2007).	Beulah	MCMA
Y2	Amend the Yarriambiack Shire Council planning scheme to incorporate the updated Beulah flood study mapping.	Beulah	YSC
Y3	Develop formal operating procedures for the weirs upstream and downstream of Beulah.	Beulah	YSC
Y4	Upgrade the 'informal' flood levee (if required) based on the findings of the updated flood study.	Beulah	YSC

3.6.1 Identifying integrated catchment management threats and opportunities

Integrated Catchment Management (ICM) is the co-ordinated involvement of agencies, stakeholders and the community in policy making, planning, and management to promote sustainable use of natural resources from a catchment wide perspective, in contrast to artificially separating land management from water management. Our Catchments Our Communities – Integrated Catchment Management in Victoria 2016-19 (Victoria State Government, 2015) recommends the following ICM approach:

- Strengthen community engagement in regional planning and priority setting.
- Clarify roles and responsibilities of key agencies.
- Strengthen coordination between key management partners.
- Improve accountability of partners implementing Regional Floodplain Management Strategies.
- Improve state and regional floodplain management reporting using a consistent set of indicators.

In order to manage floodplains in a responsible and sustainable manner, implementation of the regional works program will adopt this recommended approach and will seek to minimise the potential negative impacts (economic, social and environmental)

Pumping stormwater to restore access, Kulkyne Way 2011.

of proposed actions and where possible maximise the benefits.

Threats to floodplains

As described in Part 2, a number of actions within a catchment can have significant impacts on the flood storage and conveyance functions of floodplains. For example, levee construction can constrict the floodplain area causing afflux upstream and increased flow volumes and rates downstream. Levees can also effectively disconnect the floodplain from the waterway, reducing the retention of water in wetlands, decreasing habitat diversity, and destroying riparian vegetation.

Identification of activities and/or induced processes that create threats to floodplains is a critical step in determining appropriate management responses.

For the Mallee region, the key catchment based threats to floodplain management are:

- Residential and commercial development. Development of 'greenfield' sites on floodplains without consideration of ecological processes and ecosystem structure can impact a number of beneficial functions, including:
  - Habitat. Urbanisation often replaces natural vegetation, wetlands and depressions with streets, parking lots, houses and drains.
  - Flood storage and conveyance. Extensive filling of the floodplain, which is often related to urbanisation, removes the flood storage capacity and blocks the natural conveyance properties of floodplains, which can lead to increased flooding.
- Agriculture. Cropping and horticulture can significantly alter the floodplain landscape and consequently, limit the value of floodplain functions. For example, to increase available productive land: native vegetation may be removed, resulting in reduced habitat availability; or wetlands may be drained, resulting in reduced habitat availability, and flood storage capacity.
- River regulation (i.e. changes to natural flow regimes from dams holding back water and releases for economic use). Large reservoirs, such as Hume Dam, have had profound effects on floodplains through reductions in inundation frequency and/or extent which in turn has impacted the ecological values of floodplains.
- Climate change and severe weather. Flooding is the key natural process that creates, develops and maintains a floodplain, increases in frequency and severity of extreme flood events can impact floodplain functions, particularly soil retention (as rapid floods tend to scour rather than replenish).

Threats from floodplain management

In protecting or enhancing the lives of humans, floodplain management can lead to changes in natural processes. The main type of flood control in the Mallee region is levee construction.

Levees are constructed to protect occupied floodplain land (rural and urban) from problem flooding. The majority of what is classed as problem flooding occurs when urban development and infrastructure (such as roads) constrict the floodplain or block natural drainage lines and flow paths.

Subsequently, the location of levees is generally dictated by existing development and land use, particularly in urban areas.

Levee systems create drier conditions on the protected floodplain, which may contribute to the loss of wetlands. Levees also typically raise the water surface elevation on the river side during flood conditions, causing further inundation that can lead to soil, vegetation and habitat loss.

Opportunities

Development and implementation of this Strategy provides an opportunity to strengthen floodplain management. In particular, this includes improved stakeholder engagement in regional planning, coordination between partner agencies, and accountability of partner agencies based on the roles and responsibilities outlined in the Victorian Floodplain Management Strategy (Victoria Government, 2016).

Opportunities to strengthen floodplain management could include:

- Environmental watering, particularly where it includes inundation of the floodplain to mimic natural flow regimes;
- Road upgrades, including modification of existing bridges and/or culverts; and
- Enhancement of the ecological value of floodplains, including revegetation, and/or pest, plant and animal control

An example that demonstrates this integrated approach is the improved management of the weir pool and increased amenity and environmental outcomes of the Yarriambiack Creek at Beulah.

Opportunities to strengthen floodplain management may arise from policy changes, emerging technology, collaboration within CMAs and improved stakeholder engagement.

4 Monitoring, Evaluation and Reporting

Tyrrell Creek Flooding, 2016.

The Monitoring, Evaluation and Reporting (MER) Framework for Land, Water and Biodiversity (DSE, 2012) states that well planned MER plays an important role in supporting decision making that focuses on continuous improvement, and more specifically, that MER can provide information related to:

- Resource condition - the condition of natural resources.
- External drivers - the impact of environmental events and social changes (e.g. floods, population growth) on resource condition.
- Management - the location, impact and effectiveness of management in contributing to management outcomes and resource condition change.

A detailed MER plan will be developed upon release of the Mallee FMS. The following sections outline the MER framework for the Strategy.

4.1 MER Framework

The management of floodplains in the Mallee region is conducted within an adaptive management framework. This requires both regular review and learning from previous experience.

At its core, adaptive management involves flexible decision making that can be adjusted in the face of uncertainties as outcomes from management actions and flood events become better understood (National Research Council, 2004[8]). This allows responsible agencies and the community to alter management approaches and decisions as new knowledge is gained.

The MER plan will support the adaptive management framework for the Strategy by:

- Presenting a detailed program logic underpinning the Strategy;
- Clarifying any assumptions associated with the program logic and identifying strategies to manage potential risks;
- Identifying the key questions for evaluation and establishing processes to monitor progress;
- Clarifying the communication and reporting needs and identifying the processes required to support these needs; and
- Enabling lessons learned from monitoring and evaluation to be gathered and inform improvement.

The MER plan will be reviewed on an annual basis to ensure it remains current and relevant to informing adaptive management.

Key elements to be addressed in the MER plan are presented in the following sections.

4.1.1 Program logic

Program logic is an approach to planning that uses a diagram to demonstrate the rationale for a program and express how change is expected to occur.

The detailed program logic for the Strategy will show how each year, specific management actions will be delivered to head toward particular management outcomes measured through the attainment of Key Performance Indicator (KPI) targets. Over time (generally longer than the life of the Strategy), these management actions and outcomes collectively contribute to achieving the regional objectives.

A simplified program logic for the Strategy is shown in Figure 18 on the following page.

8 National Research Council (2004). Adaptive management for water resources planning. National Academies Press, Washington DC.

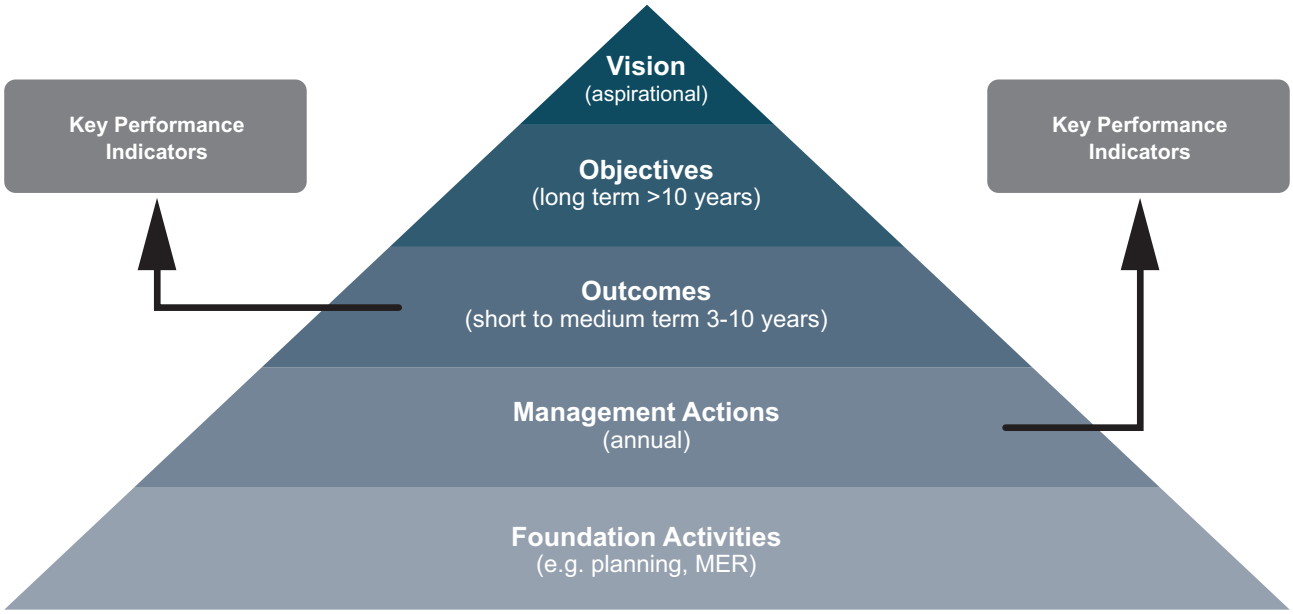

Figure 18 | Simplified program logic for the Mallee FMS.

Program logic assumptions
The program logic (Figure 18) articulates the series of events that are expected to occur over the life of the Strategy and beyond. However, within each of the levels of the logic there are a range of assumptions. During the development of the MER plan, a risk analysis of the assumptions will be undertaken to determine whether a management response is required.

4.1.2 Monitoring and evaluation

Monitoring and evaluation will be consistent with the Victorian Floodplain Management Strategy's MER framework (to be developed). This framework will include:

- Processes for monitoring, evaluating and reporting delivery of actions at the local, regional and state levels;
- A process to update the Strategy if required; and
- A three-yearly progress review of the Strategy's implementation.

Monitoring
Monitoring activities are targeted to inform evaluation and reporting on Strategy implementation. In accordance with the program logic, most monitoring activities will focus on collating data and information relating to the lower section of the program logic (i.e. from foundational activities to outcomes).

Monitoring activities also include the collection of information relating to foundational influences and externalities that impact on the Strategy implementation. Foundational influences include factors such as climatic variability, drought, flood and potential impacts of climate change. Externalities include factors such as land use change, population growth, government support, economic conditions, community expectations and landholder attitudes.

Evaluation questions
Evaluation questions will be developed to assess the effectiveness of the regional strategy and gain new knowledge and information. These questions provide the basis for evaluation design and associated monitoring processes.

Evaluation of the Strategy will include an assessment of the extent to which the outcomes have been achieved at each level of the program logic. This will be undertaken through the tracking of KPI targets for outcomes, management actions and foundational activities.

It will also address any assumptions in the program logic and provide direction and improved knowledge for subsequent planning cycles.

The evaluation questions developed for the Strategy will address the following five categories (DSE, 2012[9]):

- Impact - changes to resource condition, management activities or institutions.
- Appropriateness - addressing the needs of beneficiaries and against best practice.
- Effectiveness - achievement of desired management outputs and objectives.
- Efficiency - value or return from investment.
- Legacy - after the activity/program ends.

Evaluation process
The scale and frequency of evaluation will vary throughout the life of the Strategy, and will include an annual review cycle and more detailed reviews after three years and in the final year of the Strategy.

The annual reviews will assess progress towards the planned management activities and KPIs, and associated financials. These reviews will consider any new knowledge and information that may require changes to the planned management activities (via the risk assessment or prioritisation processes). The annual review will be led by the Mallee CMA and will align with regional investment processes.

9 DSE (2012). Monitoring, Evaluation and Reporting Framework for Land, Water and Biodiversity. Victorian Government Department of Sustainability and Environment, Melbourne.

Stormwater flooding, Dow Avenue, Red Cliffs, 2011.

The three-year review will also assess progress towards management activities and KPIs, and where possible, review progress towards management outcomes. This review may also provide new knowledge and information that may lead to an update of the Strategy to support an adaptive approach.

The final review of the Strategy will focus on capturing all of the knowledge gained during implementation, and an assessment of achievements and progress towards the management outcomes and objectives. This will ensure that there is a clear record of achievements and lessons learned, and an evidence base for updating or changing programs and management approaches in the future.

4.1.3 Reporting

Reporting is an important tool to ensure accountability for the investment of funds. Over the long-term, consistent and effective reporting provides evidence to evaluate and communicate the effectiveness of the Strategy.

Annual management reporting is a component of the annual review cycle, and includes reporting on the activities and KPIs achieved for the year and associated financials. For CMAs, this reporting is delivered through the CMA Annual Report, and annual investment reports for existing funding arrangements with the State Government.

Key stakeholders at organisational, community, regional, state and Commonwealth levels who should be kept informed of the progress of the regional strategy will be identified and appropriate communication tools developed.

Public reporting against outcome KPI targets will occur, at a minimum, at the three-year review phase and the final review. The CMA will also support reporting of management outcome targets for the VFMS at its five-year review phase.

4.1.4 Knowledge gaps and research

The MER plan will specify the key knowledge gaps identified through the development of the program logic and drafting of the evaluation questions. It will also identify the strategies to address these gaps which may involve further analysis of existing information or proposing new areas for research.

New information will be used to review and update priorities and required activities as it becomes available. For example, findings from the development or update of flood plans.

4.2 Governance and accountability

Governance and accountability for implementation of the MER Plan are essential for achieving the desired outcomes. The following sections outline the agencies that should be responsible for driving improvements in accordance with monitoring and evaluation outcomes.

4.2.1 Responsibility agencies

Responsibility for implementation of the Strategy will be shared by the Mallee CMA and its delivery partners, particularly Mildura Rural City Council, Swan Hill Rural City Council, Buloke Shire, Yarriambiack Shire and VicSES.

Accountability for implementation of specific actions from the Strategy will rest with the organisations nominated to lead the delivery of that action. The Mallee CMA will coordinate the development and implementation of the MER Plan monitoring and evaluation program.

4.2.2 Mallee Flood Committee

A committee comprising representatives of the partner agencies with primary responsibility for the management of floodplains in the region will be convened and co-ordinated by the Mallee CMA.

Each partner organisation will be responsible for developing annual implementation plans for the actions that they have lead responsibility for in the Strategy. Bi-annual meetings of the committee will seek to ensure that the responsibilities for individual management actions are clearly established, priorities and sequencing is logical, implementation is focused and coordinated, and funding opportunities are identified.

5 Reference Material

5.1 Acronyms

Acronym	Full Name
AAD	Average Annual Damage
AEP	Annual Exceedance Probability
ARI	Average Recurrence Interval
ARR	Australian Rainfall and Runoff
BCA	Building Code of Australia
BoM	Bureau of Meteorology
BSC	Buloke Shire Council
CMA	Catchment Management Authority
DELWP	Department of Environment, Land, Water and Planning
DFE	design flood event
MFMS	Mallee Floodplain Management Strategy
GWM Water	Grampians Wimmera Mallee Water
HSC	Hindmarsh Shire Council
LGA	Local Government Authority

Acronym	Full Name
LPPF	Local Planning Policy Framework
LMW	Lower Murray Water
MFEP	Municipal Flood Emergency Plan
MRCC	Mildura Rural City Council
SHRCC	Swan Hill Rural City Council
SPPF	State Planning Policy Framework
TFWS	Total Flood Warning System
VCS	Victorian Coastal Strategy
VFD	Victorian Flood Database
VFMS	Victorian Floodplain Management Strategy
VICSES	Victoria State Emergency Service
VPP	Victoria Planning Provisions
WMS	Water Management Scheme
YSC	Yarriambiack Shire Council

5.2 Glossary

Adaptation
Adjustment in response to actual or expected climate change or its effects, which moderates harm or exploits beneficial opportunities.

Annual Exceedance Probability (AEP)
The likelihood of the occurrence of a flood of a given or larger size occurring in any one year, usually expressed as a percentage. For example, if a peak flood flow of 500 m3/s has an AEP of 5%, it means that there is a 5% (one-in-20) chance of a flow of 500 m3/s or larger occurring in any one year (see also average recurrence interval, flood risk, likelihood of occurrence, probability).

Average annual damage (AAD)
Depending on its size (or severity), each flood will cause a different amount of flood damage to a flood-prone area. AAD is the average damage per year that would occur in a nominated development situation from flooding over a very long period of time. If the damage associated with various annual events is plotted against their probability of occurrence, the AAD is equal to the area under the consequence–probability curve. AAD provides a basis for comparing the economic effectiveness of different management measures (i.e. their ability to reduce the AAD).

Average Recurrence Interval (ARI)
A statistical estimate of the average number of years between floods of a given size or larger than a selected event. For example, floods with a flow as great as or greater than the 20-year ARI (5% AEP) flood event will occur, on average, once every 20 years. ARI is another way of expressing the likelihood of occurrence of a flood event (see also Annual Exceedance Probability).

Australian Rainfall and Runoff (ARR)
ARR is a national guideline for the estimation of design flood characteristics in Australia published by Engineers Australia. ARR aims to provide reliable (robust) estimates of flood risk to ensure that development does not occur in high risk areas and that infrastructure is appropriately designed. The 1987 edition is currently being revised. The revision process includes 21 research projects, which have been designed to fill knowledge gaps that have arisen since the 1987 edition was published.

Catchment
The area of land draining to a particular site. It is related to a specific location and includes the catchment of the main waterway as well as any tributary streams.

Consequence
The outcome of an event or situation affecting objectives, expressed qualitatively or quantitatively. Consequences can be adverse (e.g. death or injury to people, damage to property and disruption of the community) or beneficial.

Design flood event (DFE)
In order to identify the areas that the planning and building systems should protect new development from the risk of flood, it is necessary to decide which level of flood risk should be used. This risk is known as the design flood event.

Tyrrell Creek flooding, Culgoa 2011.

Development
Development may be defined in jurisdictional legislation or regulation. It may include erecting a building or carrying out work, including the placement of fill; the use of land, or a building or work; or the subdivision of land.

New development is intensification of use with development of a completely different nature to that associated with the former land use or zoning (e.g. the urban subdivision of an area previously used for rural purposes). New developments generally involve rezoning, and associated consents and approvals. Major extensions of existing urban services, such as roads, water supply, sewerage and electric power may also be required.

Infill development refers to the development of vacant blocks of land within an existing subdivision that are generally surrounded by developed properties and is permissible under the current zoning of the land.

Redevelopment refers to rebuilding in an existing developed area. For example, as urban areas age, it may become necessary to demolish and reconstruct buildings on a relatively large scale. Redevelopment generally does not require either rezoning or major extensions to urban services.

Greenfield development refers to building in a currently undeveloped area or development that is unrestrained by prior work.

Flash flooding
Flooding that is sudden and unexpected, often caused by sudden local or nearby heavy rainfall. It is generally not possible to issue detailed flood warnings for flash flooding. However, generalised warnings may be possible. It is often defined as flooding that peaks within six hours of the causative rain.

Flood
A natural phenomenon that occurs when water covers land that is normally dry. It may result from coastal or catchment flooding, or a combination of both (see also catchment flooding and coastal flooding).

Flood awareness
An appreciation of the likely effects of flooding, and a knowledge of the relevant flood warning, response and evacuation procedures. In communities with a high degree of flood awareness, the response to flood warnings is prompt and effective. In communities with a low degree of flood awareness, flood warnings are liable to be ignored or misunderstood, and residents are often confused about what they should do, when to evacuate, what to take with them and where it should be taken.

Flood class levels
The terms minor, moderate and major flooding are used in flood warnings to give a general indication of the types of problems expected with a flood.

Minor flooding: Causes inconvenience. Low-lying areas next to watercourses are inundated. Minor roads may be closed and low-level bridges submerged. In urban areas inundation may affect some backyards and buildings below the floor level as well as bicycle and pedestrian paths. In rural areas removal of stock and equipment may be required.

Moderate flooding: In addition to the above, the area of inundation is more substantial. Main traffic routes may be affected. Some buildings may be affected above the floor level. Evacuation of flood-affected areas may be required. In rural areas removal of stock is required.

Major flooding: In addition to the above, extensive rural areas and/or urban areas are inundated. Many buildings may be affected above the floor level. Properties and towns are likely to be isolated and major rail and traffic routes closed. Evacuation of flood-affected areas may be required. Utility services may be impacted.

Flood damage
The tangible (direct and indirect) and intangible costs (financial, opportunity costs, clean-up) of flooding. Tangible costs are quantified in monetary terms (e.g. damage to goods and possessions, loss of income or services in the flood aftermath). Intangible damages are difficult to quantify in monetary terms and include the increased levels of physical, emotional and psychological health problems suffered by flood-affected people that are attributed to a flooding episode.

Flood education
Education that raises awareness of the flood problem to help individuals understand how to manage themselves and their property in response to flood warnings and in a flood event. It invokes a state of flood readiness.

Flood emergency management
Emergency management is a range of measures to manage risks to communities and the environment. In the flood context, it may include measures to prevent, prepare for, respond to and recover from flooding.

Flood hazard
Potential loss of life, injury and economic loss caused by future flood events. The degree of hazard varies with the severity of flooding and is affected by flood behaviour (extent, depth, velocity, isolation, rate of rise of floodwaters, duration), topography and emergency management.

Flood peaks
The maximum flow occurring during a flood event past a given point in the river system (see also flow and hydrograph). The term may also refer to storm-induced flood peaks and peak ocean or peak estuarine conditions.

Flood-prone land
Land susceptible to flooding by the largest probable flood event. Flood-prone land is synonymous with the floodplain. Floodplain management plans should encompass all flood-prone land rather than being restricted to areas affected by defined flood events.

Flood proofing of buildings
A combination of measures incorporated in the design, construction and alteration of individual buildings or structures that are subject to flooding, to reduce structural damage and potentially, in some cases, reduce contents damage.

Flood readiness
An ability to react within the effective warning time (see also flood awareness and flood education).

Flood risk
The potential risk of flooding to people, their social setting, and their built and natural environment. The degree of risk varies with circumstances across the full range of floods. Flood risk is divided into three types – existing, future and residual. Existing flood risk refers to the risk a community is exposed to as a result of its location on the floodplain. Future flood risk refers to the risk that new development within a community is exposed to as a result of developing on the floodplain. Residual flood risk refers to the risk a community is exposed to after treatment measures have been implemented. For example: a town protected by a levee, the residual flood risk is the consequences of the levee being overtopped by floods larger than the design flood; for an area where flood risk is managed by land-use planning controls, the residual flood risk is the risk associated with the consequences of floods larger than the DFE on the community.

Flood severity
A qualitative indication of the 'size' of a flood and its hazard potential. Severity varies inversely with likelihood of occurrence (i.e. the greater the likelihood of occurrence, the more frequently an event will occur, but the less severe it will be). Reference is often made to major, moderate and minor flooding (see also flood class levels).

Flood study
A comprehensive technical assessment of flood behaviour. It defines the nature of flood hazard across the floodplain by providing information on the extent, depth and velocity of floodwaters, and on the distribution of flood flows. The flood study forms the basis for subsequent management studies and needs to take into account a full range of flood events up to and including the largest probable flood. Flood studies should provide new flood mapping for Planning Scheme inclusion, data and mapping for MEMPs, and a preliminary assessment into possible structural and non-structural flood mitigation measures.

Flood warning
A Total Flood Warning System (TFWS) encompasses all the elements necessary to maximise the effectiveness of the response to floods. These are data collection and prediction, interpretation, message construction, communication and response. Effective warning time refers to the time available to a flood-prone community between the communication of an official warning to prepare for imminent flooding and the loss of evacuation routes due to flooding. The effective warning time is typically used for people to move farm equipment, move stock, raise furniture, transport their possessions and self-evacuate.

Floodplain
An area of land that is subject to inundation by floods up to, and including, the largest probable flood event.

Floodplain management
The prevention activities of flood management together with related environmental activities (see also floodplain).

Flow
The rate of flow of water measured in volume per unit time, for example, megalitres per day (ML/day) or cubic metres per second (m3/sec). Flow is different from the speed or velocity of flow, which is a measure of how fast the water is moving, for example, metres per second (m/s).

Freeboard
The height above the DFE or design flood used, in consideration of local and design factors, to provide reasonable certainty that the risk exposure selected in deciding on a particular DFE or design flood is actually provided. It is a factor of safety typically used in relation to the setting of floor levels, levee crest heights and so on. Freeboard compensates for a range of factors, including wave action, localised hydraulic behaviour and levee settlement, all of which increase water levels or reduce the level of protection provided by levees. Freeboard should not be relied upon to provide protection for flood events larger than the relevant design flood event. Freeboard is included in the flood planning controls applied to developments by LGAs.

Frequency
The measure of likelihood expressed as the number of occurrences of a specified event in a given time. For example, the frequency of occurrence of a 20% Annual Exceedance Probability or five-year average recurrence interval flood event is once every five years on average (see also Annual Exceedance Probability, Average Recurrence Interval, likelihood and probability).

Hazard
A source of potential harm or a situation with a potential to cause loss.

Hydraulics
The study of water flow in waterways; in particular, the evaluation of flow parameters such as water level, extent and velocity.

Hydrology
The study of the rainfall and runoff process, including the evaluation of peak flows, flow volumes and the derivation of hydrographs for a range of floods.

Intolerable risk
A risk that, following understanding of the likelihood and consequences of flooding, is so high that it requires consideration of implementation of treatments or actions to improve understanding of, avoid, transfer or reduce the risk.

Likelihood
A qualitative description of probability and frequency (see also frequency and probability).

Likelihood of occurrence
The likelihood that a specified event will occur (see also Annual Exceedance Probability and average recurrence interval).

Local overland flooding
Inundation by local runoff on its way to a waterway, rather than overbank flow from a stream, river, estuary, lake or dam. Can be considered synonymous with stormwater flooding.

Mitigation
Permanent or temporary measures (structural and non-structural) taken in advance of a flood aimed at reducing its impacts.

Municipal Flood Emergency Plan
A sub-plan of a flood-prone municipality's Municipal Emergency Management Plan. It is a step-by-step sequence of previously agreed roles, responsibilities, functions, actions and management arrangements for the conduct of a single or series of connected emergency operations. The objective is to ensure a coordinated response by all agencies having responsibilities and functions in emergencies.

Planning Scheme zones and overlays
Planning Schemes set out the planning rules – the state and local policies, zones, overlays and provisions about specific land uses that inform planning decisions. Land use zones specify what type of development is allowed in an area (e.g. urban (residential, commercial, industrial), rural, environmental protection). Overlays specify extra conditions for developments that are allowed in a zone. For example, flooding overlays specify that developments must not affect flood flow and storage capacity of a site, must adhere to freeboard requirements, and not compromise site safety and access.

Probability
A statistical measure of the expected chance of flooding. It is the likelihood of a specific outcome, as measured by the ratio of specific outcomes to the total number of possible outcomes. Probability is expressed as a number between zero and unity, zero indicating an impossible outcome and unity an outcome that is certain. Probabilities are commonly expressed in terms of percentage. For example, the probability of 'throwing a six on a single roll of a dice is one in six, or 0.167 or 16.7% (see also Annual Exceedance Probability).

Rainfall intensity
The rate at which rain falls, typically measured in millimetres per hour (mm/h). Rainfall intensity varies throughout a storm in accordance with the temporal pattern of the storm (see also temporal pattern).

Risk analysis
Risk is usually expressed in terms of a combination of the consequences of an event and the associated likelihood of its occurrence. Flood risk is based upon the consideration of the consequences of the full range of flood events on communities and their social settings, and the natural and built environment. Risk analysis in terms of flooding is a combination of defining what threat exists (see flood risk) and what steps are taken (see risk management); (see also likelihood and consequence).

Risk management
The systematic application of management policies, procedures and practices to the tasks of identifying, analysing, assessing, treating and monitoring flood risk.

Riverine flooding
Inundation of normally dry land when water overflows the natural or artificial banks of a stream, river, estuary, lake or dam. Riverine flooding generally excludes watercourses constructed with pipes or artificial channels considered as stormwater channels.

Runoff
The amount of rainfall that drains into the surface drainage network to become stream flow; also known as rainfall excess.

Stormwater flooding
The inundation by local runoff caused by heavier than usual rainfall. It can be caused by local runoff exceeding the capacity of an urban stormwater drainage systems, flow overland on the way to waterways or by the backwater effects of mainstream flooding causing urban stormwater drainage systems to overflow (see also local overland flooding).

Vulnerability
The degree of susceptibility and resilience of a community, its social setting, and the natural and built environments to flood hazards. Vulnerability is assessed in terms of ability of the community and environment to anticipate, cope and recover from flood events. Flood awareness is an important indicator of vulnerability (see also flood awareness).

Water Management Scheme
The formal process set out in the Water Act 1989 that can be applied to a flood mitigation infrastructure development and its ongoing management. It can be based on and carried out in parallel with a floodplain management study.

Goods trucks beside floodwaters of the Murray River, Mildura, 1931. Credit: Museum Victoria

5.3 Flood Classes

Table 8 | Flood Classes for Murray Basin

Flood Type	Boundary Bend AWRC No: 414201		Euston AWRC No: 414213		Mildura AWRC No: 414210		Wentworth AWRC No: 425010	
	M	AHD	M	AHD	M	AHD	M	AHD
Minor	8.0	55.694	9.1	50.94	N/A	36	7.3	32.06
Moderate	8.5	56.194	9.8	51.64	N/A	37.5	7.9	32.66
Major	9.0	56.694	10.3	52.14	N/A	38.5	9.1	33.86

Table 9 | Flood Classes for Southern Creeks

Flood Type	Yarriambiack Creek (Jung) AWRC No: 415241		Wimmera River at Horsham (Walmer) AWRC No: 415200		Charlton Town AWRC No: 408900 Charlton Downstream AWRC No: 408212		Yawong Weir (Avoca River at Coonooer) AWRC No: 408200	
	M	AHD	M	AHD	M	AHD	M	AHD
Minor	1.8	132.67	2.8	2.3	3.5	N/A	2.3	145.019
Moderate	2.0	132.87	3.1	3.4	5.0	N/A	3.4	146.119
Major	2.1	132.97	3.6	5.0	7.0	N/A	5.0	147.719

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6 Appendices

Appendix A: Relative risk assessment outputs

Each measure of flood risk (damage density, absolute damage and town resilience) is assigned a score, where 1 is low risk and 6 is extreme risk (a 0 reflects no available data).

The overall relative risk is based on the highest score from the three measures and is presented as:

high | moderate | low | no data

In a small number of cases, the Steering Committee adjusted the relative risks based on local knowledge. These adjusted risks are indicated with an asterisk (*).

For more information on the relative risk method and its application see: Aither, 2016, Mallee CMA Regional Flood Risk Assessment, Report to the Mallee Catchment Management Authority.

Table A.1 | Risk assessment results for riverine flooding in urban areas

No.	Name	LGA	Damage density	Absolute Damage	Town resilience	Relative Risk
46	Mildura	Mildura	1.3	4.6	1.1	H
9	Culgoa	Buloke	3.4	2.9	4.6	H
30	Piangil	Swan Hill	4.5	2.5	4.5	H
26	Robinvale	Swan Hill	1.1	3.5	2.0	M
29	Wood Wood	Swan Hill	0.0	1.0	2.9	M
2	Beulah	Yarriambiack	1.8	1.2	2.5	M
47	Merbein	Mildura	1.0	1.4	1.2	L
45	Red Cliffs	Mildura	1.0	1.2	0.0	L
48	Yelta	Mildura	1.0	1.1	0.0	L
28	Nyah	Swan Hill	1.0	1.0	0.0	L
3	Goyura	Yarriambiack	1.0	1.0	0.0	L
52	Cullulleraine	Mildura	1.0	1.0	0.0	L
4	Hopetoun	Yarriambiack	1.0	1.0	0.0	L
24	Annuello	Swan Hill	0.0	0.0	0.0	no data
54	Bambill	Mildura	0.0	0.0	0.0	no data
25	Bannerton	Swan Hill	0.0	0.0	0.0	no data
49	Benetook	Mildura	0.0	0.0	0.0	no data
10	Berriwillock	Buloke	0.0	0.0	0.0	no data
5	Birchip	Buloke	0.0	0.0	0.0	no data
38	Boinka	Mildura	0.0	0.0	0.0	no data
23	Bolton	Swan Hill	0.0	0.0	0.0	no data
44	Carwarp	Mildura	0.0	0.0	0.0	no data
21	Chinkapook	Swan Hill	0.0	0.0	0.0	no data
40	Cowangie	Mildura	0.0	0.0	0.0	no data
6	Curyo	Buloke	0.0	0.0	0.0	no data
41	Danyo	Mildura	0.0	0.0	0.0	no data
34	Galah	Mildura	0.0	0.0	0.0	no data
12	Goschen	Swan Hill	0.0	0.0	0.0	no data
43	Hattah	Mildura	0.0	0.0	0.0	no data
51	Karawinna	Mildura	0.0	0.0	0.0	no data
33	Kooloonong	Swan Hill	0.0	0.0	0.0	no data
20	Kulwin	Mildura	0.0	0.0	0.0	no data
14	Lascelles	Yarriambiack	0.0	0.0	0.0	no data

Public consultation in Nyah, 2011 Flood Event.

Table A.1 | Risk assessment results for riverine flooding in urban areas *Continued...*

No.	Name	LGA	Damage density	Absolute Damage	Town resilience	Relative Risk
37	Linga	Mildura	0.0	0.0	0.0	no data
22	Manangatang	Swan Hill	0.0	0.0	0.0	no data
56	Meringul	Mildura	0.0	0.0	0.0	no data
50	Merrinee	Mildura	0.0	0.0	0.0	no data
19	Mittyack	Mildura	0.0	0.0	0.0	no data
57	Morkalla	Mildura	0.0	0.0	0.0	no data
42	Murrayville	Mildura	0.0	0.0	0.0	no data
13	Nandaly	Buloke	0.0	0.0	0.0	no data
31	Natya	Swan Hill	0.0	0.0	0.0	no data
8	Nullawil	Buloke	0.0	0.0	0.0	no data
32	Ouyen	Mildura	0.0	0.0	0.0	no data
17	Patchewollock	Yarriambiack	0.0	0.0	0.0	no data
11	Sea Lake	Buloke	0.0	0.0	0.0	no data
15	Speed	Yarriambiack	0.0	0.0	0.0	no data
16	Tempy	Yarriambiack	0.0	0.0	0.0	no data
39	Tutye	Mildura	0.0	0.0	0.0	no data
18	Ultima	Swan Hill	0.0	0.0	0.0	no data
36	Underbool	Mildura	0.0	0.0	0.0	no data
35	Walpeup	Mildura	0.0	0.0	0.0	no data
53	Werrimull	Mildura	0.0	0.0	0.0	no data
7	Woomelang	Yarriambiack	0.0	0.0	0.0	no data
27	Woorinen South	Swan Hill	0.0	0.0	0.0	no data
1	Yaapeet	Yarriambiack	0.0	0.0	0.0	no data
55	Yarrara	Mildura	0.0	0.0	0.0	no data

Table A.2 | Risk assessment results for riverine flooding in rural areas

No.	Name	LGA	Damage density	Absolute Damage	Town resilience	Relative Risk
71	Tyrrell RWS Unit	Buloke	1.0	3.5	0.0	M
62	Karadoc RWS Unit	Mildura	1.1	3.5	0.0	M
83	Buloke LGA East	Buloke	1.1	3.5	0.0	M
82	Buloke LGA Central	Buloke	1.1	2.7	0.0	M
72	Lalbert RWS Unit	Buloke	1.0	1.4	0.0	M*
84	Swan Hill LGA	Swan Hill	1.3	4.5	0.0	L*
86	Northern Mildura LGA	Mildura	1.1	3.5	0.0	L*
73	Nyah RWS Unit	Swan Hill	1.3	2.5	0.0	L*
74	Burra RWS Unit	Swan Hill	1.1	2.7	0.0	L*
60	Wallpolla RWS Unit	Mildura	1.0	2.7	0.0	L*
69	Yarriambiack RWS	Yarriambiack	1.0	1.9	0.0	L
58	Lindsay RWS Unit	Mildura	1.0	1.8	0.0	L
76	Boundary Bend RWS Unit	Swan Hill	1.0	1.6	0.0	L
63	Nangiloc Colignan RWS Unit	Mildura	1.1	1.5	0.0	L
64	Hattah RWS Unit	Mildura	1.0	1.6	0.0	L
61	Merbein RWS Unit	Mildura	1.0	1.3	0.0	L
70	Dunmunckle RWS Unit	Buloke	1.3	1.0	0.0	L
77	Belsar Yungera RWS	Swan Hill	1.0	1.3	0.0	L
75	Heywood RWS Unit	Swan Hill	1.0	1.2	0.0	L
68	Wyperfeld South RWS Unit	Yarriambiack	1.2	1.0	0.0	L
59	Mulcra RWS Unit	Mildura	1.0	1.2	0.0	L
78	Happy Valley RWS Unit	Swan Hill	1.0	1.1	0.0	L
80	Yarriambiack LGA West	Yarriambiack	1.0	1.0	0.0	L
81	Buloke LGA West	Buloke	1.0	1.0	0.0	L
66	Pink Lakes RWS Unit	Mildura	1.0	1.0	0.0	L
87	Central Mildura LGA	Swan Hill	1.0	1.0	0.0	L
65	Raak Plain RWS Unit	Mildura	0.0	0.0	0.0	no data
85	Rocket Lake	Mildura	0.0	0.0	0.0	no data
67	Wyperfeld North RWS Unit	Mildura	0.0	0.0	0.0	no data
79	Yarriambiack LGA East	Yarriambiack	0.0	0.0	0.0	no data

Table A.3 | Risk assessment results for stormwater flooding in urban areas

No.	Name	LGA	Damage density	Absolute Damage	Town resilience	Relative Risk
46	Mildura	Mildura	1.3	3.6	1.1	M
8	Nullawil	Buloke	3.4	1.1	2.7	M
45	Red Cliffs	Mildura	1.0	1.1	1.0	M*
32	Ouyen	Mildura	0.0	0.0	0.0	M*
42	Murrayville	Mildura	0.0	0.0	0.0	M*
9	Culgoa	Buloke	1.4	1.3	2.6	L*
15	Speed	Yarriambiack	2.6	1.0	2.5	L*
11	Sea Lake	Buloke	2.8	1.1	1.2	L*
49	Benetook	Mildura	3.4	1.0	0.0	L*
4	Hopetoun	Yarriambiack	1.9	1.1	1.2	L
10	Berriwillock	Buloke	1.4	1.1	1.7	L
13	Nandaly	Buloke	1.4	1.0	1.6	L
28	Nyah	Swan Hill	1.1	1.2	1.8	L
18	Ultima	Swan Hill	1.2	1.1	1.5	L
2	Beulah	Yarriambiack	1.3	1.1	1.5	L
5	Birchip	Buloke	1.3	1.2	1.3	L
14	Lascelles	Yarriambiack	1.2	1.0	1.4	L
7	Woomelang	Yarriambiack	1.3	1.0	1.3	L
27	Woorinen South	Swan Hill	1.4	1.0	1.1	L
47	Merbein	Mildura	1.0	1.1	1.0	L
12	Goschen	Swan Hill	1.0	1.0	0.0	L
3	Goyura	Yarriambiack	1.0	1.0	0.0	L
48	Yelta	Mildura	1.0	1.0	0.0	L
44	Carwarp	Mildura	1.0	1.0	0.0	L
6	Curyo	Buloke	1.0	1.0	0.0	L
21	Chinkapook	Swan Hill	1.0	1.0	0.0	L
24	Annuello	Swan Hill	0.0	0.0	0.0	no data
54	Bambill	Mildura	0.0	0.0	0.0	no data
25	Bannerton	Swan Hill	0.0	0.0	0.0	no data
38	Boinka	Mildura	0.0	0.0	0.0	no data
23	Bolton	Swan Hill	0.0	0.0	0.0	no data
40	Cowangie	Mildura	0.0	0.0	0.0	no data
52	Cullulleraine	Mildura	0.0	0.0	0.0	no data
41	Danyo	Mildura	0.0	0.0	0.0	no data
34	Galah	Mildura	0.0	0.0	0.0	no data
43	Hattah	Mildura	0.0	0.0	0.0	no data
51	Karawinna	Mildura	0.0	0.0	0.0	no data
33	Kooloonong	Swan Hill	0.0	0.0	0.0	no data
20	Kulwin	Mildura	0.0	0.0	0.0	no data
37	Linga	Mildura	0.0	0.0	0.0	no data
22	Manangatang	Swan Hill	0.0	0.0	0.0	no data
56	Meringul	Mildura	0.0	0.0	0.0	no data
50	Merrinee	Mildura	0.0	0.0	0.0	no data
19	Mittyack	Mildura	0.0	0.0	0.0	no data
57	Morkalla	Mildura	0.0	0.0	0.0	no data
31	Natya	Swan Hill	0.0	0.0	0.0	no data
17	Patchewollock	Yarriambiack	0.0	0.0	0.0	no data
30	Piangil	Swan Hill	0.0	0.0	0.0	no data
26	Robinvale	Swan Hill	0.0	0.0	0.0	no data
16	Tempy	Yarriambiack	0.0	0.0	0.0	no data
39	Tutye	Mildura	0.0	0.0	0.0	no data
36	Underbool	Mildura	0.0	0.0	0.0	no data
35	Walpeup	Mildura	0.0	0.0	0.0	no data
53	Werrimull	Mildura	0.0	0.0	0.0	no data
29	Wood Wood	Swan Hill	0.0	0.0	0.0	no data
1	Yaapeet	Yarriambiack	0.0	0.0	0.0	no data
55	Yarrara	Mildura	0.0	0.0	0.0	no data

Appendix B: Mallee FMS engagement and communications activities conducted

Overview of stakeholders 'directly' engaged to inform the development of this 2018–28 Mallee FMS.

Audience	Representation
Mallee CMA Board	Ministerially appointed community members
Mallee Floodplain Management Strategy Steering Committee	Comprised of representatives from: • Mildura Rural City Council; • Swan Hill Rural City Council • Yarriambiack Shire Council • Buloke Shire Council • Hindmarsh Shire Council • GWM Water • Lower Murray Water • VICSES • Mallee CMA
Relevant Stakeholders	Comprised of representatives from: • Balranald Shire Council • Country Fire Authority • Department of Environment, Land, Water and Planning • Department of Health and Human Services • Emergency Management Victoria • Goulburn Murray Water • Murray Darling Basin Authority • Office and Environment and Heritage (NSW) • Parks Victoria • SA Water • VicRoads • Victoria Policy • VicTrack • WaterNSW • Wentworth Shire Council
Mallee Land and Water Advisory Committee	10 Mallee community members
Mallee Aboriginal Reference Group	Aboriginal Elders Traditional Owner Representatives Mallee CMA Parks Victoria
Traditional Owner Groups and Indigenous Stakeholders	Barengi Gadjin Land Council First People of the Millewa Mallee Aboriginal Corporation
Other Interest Groups/Organisations	Mildura Rural City Council Municipal Emergency Management Planning Committee Buloke Shire Council Municipal Emergency Management Planning Committee.

Overview of communications 'indirectly' used to promote the Mallee FMS development process and to encourage feedback from all stakeholders as it was being developed.

Medium	Media	Audience
Media Articles	Local papers, social media posts	Mallee Community
Newsletter Articles	Mallee CMA E-Newsletter	Mallee Community
Surveys	Online	Mallee stakeholders and broader community
Progress updates	Emails	Mallee stakeholders and community groups
Fact Sheets	Handouts at relevant forums	Mallee stakeholders and community groups

Appendix C: Historic Flooding in the Mallee

Table 10 | Flood History of Murray River, Boundary Bend – Wentworth

Year	River	Flood Class	Comment
1870	Murray River (Mildura)	Major	
	Murray River(Wentworth	Major	
1917	Murray River (Mildura)	Moderate	
	Murray River(Wentworth	Major	
1931	Murray River (Euston)	Moderate	
	Murray River (Mildura)	Moderate	
	Murray River (Wentworth)	Major	
1939	Murray River (Mildura)	Minor	
1951	Murray River (Mildura)	Minor	
1952	Murray River (Mildura)	Minor	
1955	Murray River (Euston)	Minor	
	Murray River (Mildura)	Moderate	
1956	Murray River (Boundary Bend)	Major	
	Murray River (Euston)	Major	
	Murray River (Mildura)	Major	
	Murray River (Wentworth)	Major	
1958	Murray River (Mildura)	Minor	
1960	Murray River (Mildura)	Minor	
1964	Murray River (Mildura)	Minor	
1973	Murray River (Mildura)	Minor	
1974	Murray River (Euston)	Moderate	
	Murray River (Mildura)	Moderate	
	Murray River (Wentworth)	Major	
1975	Murray River (Boundary Bend)	Major	
	Murray River (Euston)	Moderate	
	Murray River (Mildura)	Moderate	
1981	Murray River (Boundary Bend)	Moderate	
	Murray River (Euston)	Minor	
	Murray River (Mildura)	Minor	
	Murray River (Wentworth)	Moderate	
1989	Murray River (Wentworth)	Minor	
1990	Murray River (Boundary Bend)	Minor	
	Murray River (Mildura)	Minor	
	Murray River (Wentworth)	Moderate	
1992	Murray River (Boundary Bend)	Moderate	
	Murray River (Mildura)	Minor	
	Murray River (Wentworth)	Moderate	
1993	Murray River (Boundary Bend)	Moderate	
	Murray River (Euston)	Minor	
	Murray River (Mildura)	Minor	
	Murray River (Wentworth)	Moderate	
1996	Murray River (Boundary Bend)	Moderate	
2011	Murray River (Wentworth)	Minor	
2016	Murray River (Boundary Bend)	Moderate	
	Murray River (Euston)	Minor	
	Murray River (Mildura)	Minor	
	Murray River (Wentworth)	Moderate	

Table 11 | Flood History of the Southern Creeks

Year	River/Stream	Flood Class	Comment
1830	Outlet Creek	N/A	
1851	Outlet Creek	N/A	
1870	Outlet Creek	N/A	
	Yarriambiack Creek	N/A	
1889	Yarriambiack Creek	N/A	
1890	Outlet Creek	N/A	
1894	Yarriambiack Creek	N/A	
1909	Yarriambiack Creek	N/A	
1911	Outlet Creek	N/A	
	Yarriambiack Creek	Major	Flood Height at Wimmera River, Horsham
1915	Yarriambiack Creek	N/A	
1916	Yarriambiack Creek	Major	Flood Height at Wimmera River, Horsham
	Lalbert Creek	N/A	
1917	Outlet Creek	N/A	
	Lalbert Creek	N/A	
	Yarriambiack Creek	Major	Flood Height at Wimmera River, Horsham
1918	Lalbert Creek	N/A	
	Yarriambiack Creek	Major	Flood Height at Wimmera River, Horsham
1920	Lalbert Creek	N/A	
	Yarriambiack Creek	Major	Flood Height at Wimmera River, Horsham
1921	Lalbert Creek	N/A	
	Yarriambiack Creek	Major	Flood Height at Wimmera River, Horsham
1922	Outlet Creek	N/A	
1923	Lalbert Creek	Major	Height at Charlton (James Paterson Bridge)
	Yarriambiack Creek	Major	Flood Height at Wimmera River, Horsham
1924	Yarriambiack Creek	Major	Flood Height at Wimmera River, Horsham
1926	Lalbert Creek	N/A	
1931	Lalbert Creek	N/A	
	Yarriambiack Creek	Major	Flood Height at Wimmera River, Horsham
1932	Lalbert Creek	N/A	
1934	Yarriambiack Creek	Moderate	Flood Height at Wimmera River, Horsham
1935	Yarriambiack Creek	Minor	Flood Height at Wimmera River, Horsham
1939	Lalbert Creek	Major	Height at Charlton (James Paterson Bridge)
	Yarriambiack Creek	Moderate	Flood Height at Wimmera River, Horsham
1941	Yarriambiack Creek	Moderate	Flood Height at Wimmera River, Horsham
1942	Lalbert Creek	N/A	
	Yarriambiack Creek	Major	Flood Height at Wimmera River, Horsham
1945	Lalbert Creek	N/A	
1950	Lalbert Creek	N/A	
1951	Yarriambiack Creek	Moderate	Flood Height at Wimmera River, Horsham
1952	Yarriambiack Creek	Minor	Flood Height at Wimmera River, Horsham
1953	Yarriambiack Creek	Major	Flood Height at Wimmera River, Horsham
1955	Lalbert Creek	N/A	
	Yarriambiack Creek	Major	Flood Height at Wimmera River, Horsham
1956	Outlet Creek	N/A	
	Yarriambiack Creek	Major	Flood Height at Wimmera River, Horsham
	Tyrrell Creek	Major	Height at Charlton (James Paterson Bridge)
	Lalbert Creek	Major	Height at Charlton (James Paterson Bridge)
1958	Lalbert Creek	N/A	
	Yarriambiack Creek	Moderate	Flood Height at Wimmera River, Horsham
1960	Outlet Creek	N/A	
	Tyrrell Creek	N/A	
	Lalbert Creek	N/A	
	Yarriambiack	Major	Flood Height at Wimmera River, Horsham
1963	Lalbert Creek	N/A	
1964	Tyrrell Creek	Major	Height at Charlton (James Paterson Bridge)
	Lalbert Creek	Major	Height at Charlton (James Paterson Bridge)
	Yarriambiack	Major	Flood Height at Wimmera River, Horsham
1968	Tyrrell Creek	Moderate	Flood Height at Coonooer
	Lalbert Creek	Moderate	Flood Height at Coonooer
1973	Yarriambiack Creek	Moderate	Flood Height at Wimmera River, Horsham
	Tyrrell Creek	Major	Flood Height at Charlton (James Paterson Bridge)
	Lalbert Creek	Major	Flood Height at Charlton (James Paterson Bridge)

Table 11 | Flood History of the Southern Creeks *Continued...*

Year	River/Stream	Flood Class	Comment
1974	Outlet Creek	N/A	
	Yarriambiack Creek	Moderate	Flood Height at Wimmera River, Horsham
	Tyrrell Creek	Moderate	Flood Height at Coonooer
	Lalbert Creek	Moderate	Flood Height at Coonooer
1975	Tyrrell Creek	Major	Flood Height at Charlton (James Paterson Bridge)
	Lalbert Creek	Major	Flood Height at Charlton (James Paterson Bridge)
	Yarriambiack Creek	Moderate	Flood Height at Wimmera River, Horsham
1978	Lalbert Creek	Moderate	Flood Height at Coonooer
1979	Yarriambiack Creek	Minor	Flood Height at Wimmera River, Horsham
1980	Yarriambiack Creek	Minor	Flood Height at Wimmera River, Horsham
1981	Yarriambiack Creek	Moderate	Flood Height at Wimmera River, Horsham
	Lalbert Creek	Major	Flood Height at Charlton (James Paterson Bridge)
1983	Yarriambiack Creek	Major	Flood Height at Wimmera River, Horsham
	Lalbert Creek	Major	Flood Height at Charlton (James Paterson Bridge)
1988	Yarriambiack Creek	Moderate	Flood Height at Wimmera River, Horsham
	Tyrrell Creek	Moderate	Flood Height at Coonooer
	Lalbert Creek	Moderate	Flood Height at Coonooer
1989	Lalbert Creek	Moderate	Flood Height at Coonooer
1992	Tyrrell Creek	Moderate	Flood Height at Coonooer
	Lalbert Creek	Moderate	Flood Height at Coonooer
	Yarriambiack Creek	Moderate	Flood Height at Wimmera River, Horsham
1993	Lalbert Creek	Moderate	Flood Height at Coonooer
1995	Tyrrell Creek	Major	Flood Height at Charlton (James Paterson Bridge)
	Lalbert Creek	Major	Flood Height at Charlton (James Paterson Bridge)
	Yarriambiack Creek	Minor	Flood Height at Wimmera River, Horsham
1996	Yarriambiack Creek	Moderate	Flood Height at Wimmera River, Horsham
	Tyrrell Creek	Major	Flood Height at Coonooer
	Lalbert Creek	Major	Flood Height at Coonooer
2010	Tyrrell Creek	Major	Flood Height at Charlton (James Paterson Bridge)
	Lalbert Creek	Major	Flood Height at Charlton (James Paterson Bridge)
	Yarriambiack Creek	Moderate	Flood Height at Wimmera River, Horsham
2011	Yarriambiack Creek	Major	Flood Height at Wimmera River, Horsham
	Dunmunkle Creek	N/A	
	Tyrrell Creek	Major	Flood Height at Charlton (James Paterson Bridge)
	Lalbert Creek	Major	Flood Height at Charlton (James Paterson Bridge)
2016	Tyrrell Creek	Major	Flood Height at Charlton (James Paterson Bridge)
	Lalbert Creek	Major	Flood Height at Charlton (James Paterson Bridge)
	Yarriambiack Creek	Moderate	Flood Height at Wimmera River, Horsham

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