Melbourne Water Submission to the Maribyrnong River Flood Review

Melbourne Water

Enhancing Life and Liveability

Foreword

The flooding of the lower reaches of the Maribyrnong River in October 2022 was one of the most significant in the history of our city. The ongoing impacts on our local communities have been lasting and painful.

These events highlighted how damaging and disruptive urban flooding can be, and in the aftermath of these devastating events there have been a range of questions which the community has raised.

A core focus of our work as the floodplain manager, both within and outside of this independent review, is to ensure we have a clear picture of the October 2022 event developed over the coming months through the review to enable effective actions.

We are listening to the views and the needs of the community, including through our ongoing on-ground engagement and are committed to implementing any learnings and improvements that may come from this feedback.

Over the past year, Australians have seen cascading flood events across the country, from Lismore to Echuca. We know that climate change and urbanisation will increase the frequency and severity of urban flooding.

There is an opportunity to re-set the way that we manage urban flooding, mirroring the approach taken with other natural disasters such as bushfires.

We are progressively incorporating the projected impacts of climate change into our modelling but there is more that can be done to ready our city for a more flood resilient future.

This will take a range of approaches including ensuring planning and development controls consider increased flood risks from climate change, increased flood preparedness, alongside other engineering solutions to local flooding issues. This will set up Melbourne to be better prepared for more volatile climate events.

Melbourne Water looks forward to partnering with the community, state government, local councils and emergency management services on this challenge, for a growing and flood resilient Melbourne.

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Executive summary

The Maribyrnong flood was the third highest flood on record for that site. Melbourne Water has heard through community forums, stakeholder discussions and direct communication just how significant this event was to those impacted.

The Independent Review process has provided an opportunity to further understand the Maribyrnong flood event in October 2022 from multiple perspectives, and hear directly from the communities, businesses and organisations that were impacted. The feedback we have heard so far will contribute to improving how we prepare for and manage flood risk.

Whilst the outcomes of the review will be invaluable, we are already taking action to embed the insights from the 2022 event into how we deliver our services. This includes:

- Using the data from this event to update the Maribyrnong River flood models: Modelling depends on historic data, the 2022 event offers valuable information to improve our models.
- Continuing our work to revise our flood modelling in light of climate change projections: We know that climate change will change flood patterns. We are progressively embedding climate projections into our modelling.
- Considering how flood modelling resourcing for riverine environments can be uplifted: Flood modelling is complex and takes time, to improve our flood information we will need to look at how we resource this work.
- Reviewing the rating tables for the Maribyrnong and the rest of our network to identify and address where there may be other similar risks.
- Deepening our partnership with other agencies with associated responsibilities for floodplain management to build stronger community awareness and preparedness for flood events: While there are many ways that the community access flood information about their properties it is clear that there is more that can be done.

Whilst a lot of work has happened to review the flood event since October 2022 there are still some outstanding questions which we are further investigating, these include the:

- Impact of the operation of the river gauge network on flood forecasting
- Performance of the mitigation works to counter for the impact of the Flemington flood wall as designed
- Rivervue development - this includes the planning permit for Rivervue, which was granted in 2006 and the amendment to the Land Subject to Inundation Overlay (LSIO) as it applied to the Rivervue site in 2016

We will provide updated information to the Independent Review Panel as it becomes available on these investigations.

The flood event

The October 2022 flood event occurred in the Maribyrnong catchment region after four days of above average rainfall in an already saturated catchment. The resulting river flows exceeded the capacity of the river channel and evolved into a major flood. Floodwater inundated over 500 homes, businesses and assets in the Maribyrnong catchment.

Melbourne Water’s review of the 2022 flood event shows this was the third highest flood event on record for this area. It was assessed as a 2 in 100 probability of a flood event of that magnitude occurring.

However, no two flood events are ever the same. The location and intensity of the rainfall, the conditions of the catchment it falls onto, and changes in urban development mean that every flood event is unique. In the lead up to the October 2022 flood event, the Maribyrnong catchment was already saturated due to high and sustained rainfall throughout September and early October. This meant that the runoff levels were high.

Melbourne Water's role and actions in responding to flood events

Melbourne Water is one of several agencies that have a role to play in responding to flood events. Melbourne Water's role is to undertake modelling about anticipated flood levels based on rainfall forecasts and actual river height measurements. Other agencies are responsible for providing the rainfall forecasts that Melbourne Water relies upon and for disseminating alerts to the public informed by the results of the modelling undertaken.

Ahead of and during a flood event, Melbourne Water uses flood models to estimate the likelihood and extent of flooding. Melbourne Water prepares flood warnings and sends them to the Bureau of Meteorology (BoM), who then issue them to the community and VicSES (Victorian State Emergency Services).

If a flood of moderate level or greater is predicted, this will activate the Melbourne Water Flood Response Plan, triggering Melbourne Water to stand up an incident response team and the VicSES to establish an incident room. As part of the response to a major flood warning, Melbourne Water provides an update to the flood warning every six hours.

During the October 2022 flood event conditions changed rapidly. BoM issued an initial flood watch on 11 October following consultation with Melbourne Water. On 13 October at 8.15 Melbourne Water prepared and sent to BoM the first 'major' flood warning for the Maribyrnong, focusing on the upper Maribyrnong catchment.

In the afternoon of 13 October BOM advised Melbourne Water of revised rainfall forecast. At 2.24pm Melbourne Water prepared and sent to BoM a moderate flood warning for the lower Maribyrnong.

On 14 October at approximately 12.30am, Melbourne Water identified that the actual height in the Maribyrnong River exceeded the levels that models had predicted. Melbourne Water revised its projections in light of the real time data and contacted BoM and VicSES to upgrade the flood warning to 'exceeding major' at 2.16am (re-running models can take 30-90 minutes to run and a further 20- 45 minutes to process the information). This new warning was issued by BoM at 2.27am on 14 October.

Melbourne Water's role and actions in preparing for flood events

As a flood plain manager for the Port Phillip and Westernport region, Melbourne Water undertakes flood modelling to identify land that could be affected by a flood with a 1% chance of occurring in any year.

Planning authorities use this information is to make decisions about land use planning, including the application of flood overlays. The modelling undertaken during a flood event builds on the modelling undertaken for planning purposes.

Melbourne Water also acts as a determining referral authority for planning permits in areas subject to a flood overlay.

Flemington Wall

The land on which Flemington Racecourse is located is subject to a flood overlay. For the Flemington Wall, the Minister for Planning referred that application to Melbourne Water as a determining referral authority.

In this capacity, Melbourne Water rigorously assessed flood modelling relating to the Flemington Wall and engaged with a series of experts. Melbourne Water ultimately advised the Minister for Planning that it did not object to the grant of a permit subject to compensatory mitigation works being completed. These works were designed to negate any increased flood risk.

Melbourne Water is continuing to undertake complex modelling as part of this investigation to understand whether the compensatory mitigation measures performed as expected in the October 2022 flood event, and whether the Flemington Wall had any impact on the extent or duration of the flood event.

Looking to the future

Melbourne Water is aware of questions in relation to the Rivervue development. While broader planning matters are outside of the Terms of Reference for this Review, Melbourne Water is committed to investigating this matter. This includes the planning permit for Rivervue which was granted in 2006 and the amendment to the Land Subject to Inundation Overlay (LSIO) as it applied to the Rivervue site in 2016.

We have already learnt a lot from the October 2022 flood event and will continue to learn throughout the review process and beyond. We are keen to continue the discussion about flooding risks with the community, industry experts, local councils and the Victorian and Commonwealth governments to improve our collective ability to prevent and respond to floods.

Melbourne Water is committed to sharing learnings and improvements to our work with the community and other partners to manage flooding. Climate change and increased urbanisation across Greater Melbourne make this more important than ever.

Context

Melbourne Water is established as a statutory corporation under the *Water Act 1989*, which sets out the corporation's core functions, powers and duties. Under the Act, Melbourne Water has a broad range of functions in relation to its waterway management district, including floodplain management functions.

In performing its statutory functions, Melbourne Water is required to have regard to the sustainable management principles set out in the Act and to act as efficiently as possible consistent with commercial practice.

Melbourne Water's charges for its services, including floodplain management, are regulated by the Essential Services Commission (ESC). We are required to make a price submission to the ESC every five years which includes our forecast expenditure and revenue.

In preparing its price submission, Melbourne Water makes tradeoffs between customer affordability, willingess to pay and level of service. This is regulated by the Essential Services Commission. The impact is that trade-offs are made between priorities for the services that Melbourne Water provides.

- Flooding is a natural hazard and there is no single solution to managing flood risk. Melbourne Water has many programs that seek to reduce the impact of flooding to the community.
- Flood mitigation works are structural measures used to mitigate the effects of flooding such as levees, floodways and retention basins.
- Flood warning systems provide communities and emergency management agencies with information about when flooding may occur, its likely severity and what to do to minimise consequences.
- Land use planning is recognised as being the best means of avoiding future flooding problems. Through careful planning, flood risks to life, property and community infrastructure can be minimised and the environmental significance of our floodplains protected.
- Partnering with the community to build awareness and preparedness also another key way of minimising flood risk.

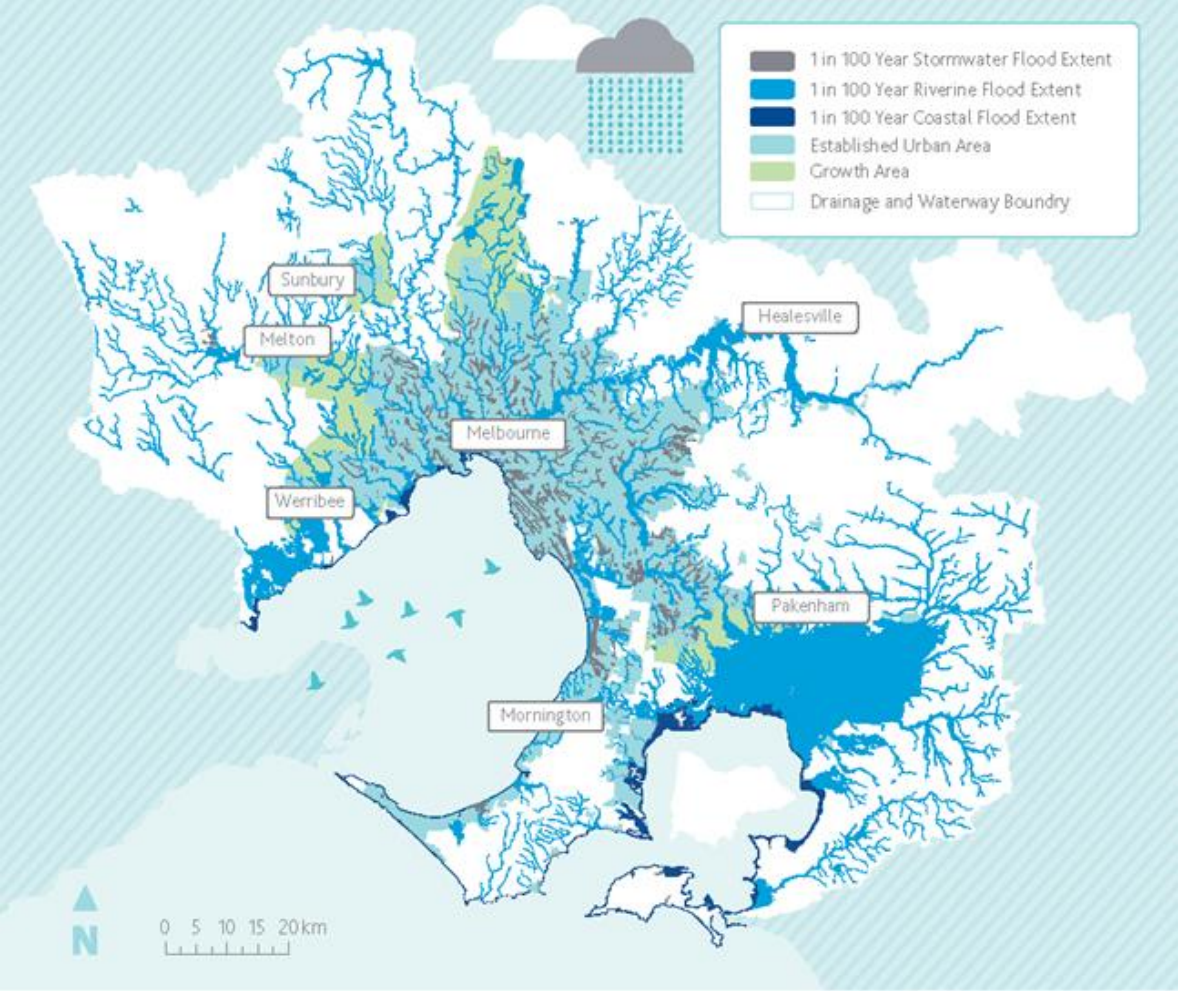
The objective of floodplain management is to ensure that communities, businesses and government agencies are made aware of the potential for flooding and are equipped to actively take steps to minimise the consequences to life, property, community wellbeing and the economy.

In any given year, it is estimated there are over 200,000 properties across the Melbourne region that have at least a 1% chance of flooding from both riverine and urban flooding[1]. The average cost of damage caused by flooding in the region is estimated at $735.5 million annually[2].

Climate change is increasing the risk of flooding in the region. By 2100, it is estimated the annual average damages caused by floods will increase to $1.6 billion[3].

[1] Melbourne Water (2021) *Flood Management Strategy Port Phillip and Westernport 2021-2031*
[2] Jacobs (2020), *Melbourne's Flood Risk: Assessment of Annual Average Damage,* Report prepared for Melbourne Water, 30 October 2020
[3] Ibid

The extent of riverine and urban flooding risk across the Greater Melbourne area is shown in Figure 1. This highlights the areas of our region that have a 1% chance of being flooded in any year.



This diagram shows Melbourne Water flood mapping for areas with a 1% chance of flooding in any given year.
(It does not include flood mapping by other authorities).

Figure 1: Mapped flooding risk in Port Phillip and Westernport

The *Victorian Floodplain Management Strategy (2016)* notes that there are some areas that can be protected from flooding, but it is not always feasible to do so. In built up urban areas there is limited room to build mitigation works for riverine flooding. In considering mitigation works affordability to our community also needs to be considered. In addition, building infrastructure to protect one part of a floodplain can increase flood impacts elsewhere on the floodplain and this also needs to be taken into consideration.

The *Port Phillip and Westernport Flood Management Strategy* was updated in 2021, in collaboration with the 50 agencies with flood management roles within the region. This strategy was purposefully co-designed to ensure it is relevant and representative of a collective approach to flood management across all the agencies involved. Since it was released, 35 agencies have endorsed the strategy.

One of the most efficient ways to manage future flooding is to through the design of any new developments on the floodplain to minimise the risk flooding to occupants. This is the most efficient use of community resources and funds.

Other critical components to minimising risk of damage and injury from flooding are education and flood warnings. Community education about flood risk and what to do if there is a flood event allows the people to be well-prepared. We know that flood preparedness can reduce the impacts of flooding by up to 80%. Preparedness can improve safety, reduce the impact of emergencies on homes and communities and enable faster recovery[4].

The role that Melbourne Water plays in State-wide floodplain management, as a floodplain manager, and in collaboration with local councils, statutory authorities and Government bodies, is set out in the *Victorian Floodplain Management Strategy* (Department of Environment, Land, Water and Planning, 2016) (*VFMS*).

The VFMS sets the direction for floodplain management in Victoria and prescribes a series of actions to be implemented at the State, regional, and local level to achieve this.

One of the key actions for Melbourne Water under the VFMS was the development of the *Flood Management Strategy for Port Phillip and Westernport 2021-2031* (Melbourne Water, 2021). This strategy sets out long term vision for flood management in the region and sets the 10-year outcomes for flood management in Port Phillip and Westernport (for which Melbourne Water is also the catchment management authority).

Maribyrnong Catchment

- The October 2022 flood event occurred in the Maribyrnong catchment region. The catchment includes the 41 kilometre long Maribyrnong River – the second major river in the Port Phillip and Westernport Region – which begins on the southern slopes of the Great Dividing Range, in the Cobaw Ranges.
- People of the Woi wurrung language group were the original occupants of this land and their descendants place enormous cultural and spiritual significance on the region's land and waters.
- The Maribyrnong River catchment is large. Deep Creek and Jacksons Creek are the two main tributaries for the Maribyrnong River.
- Much of the Maribyrnong floodplain is zoned for public park and recreation use, with some zoned for residential use.
- The October 2022 flood was the third largest on records dating back to the late 1800s. The 1974 flood was the fourth largest.

The catchment for the Maribyrnong River is 1,409.33 km^2. All rainfall in the region flows into the Maribyrnong – including from tributaries and urban drains. It is wide in the upstream areas, and then narrows downstream from Sunbury.

The floodplain extent in the lower catchment is narrow at Keilor and gradually widens to 800 metres at Maribyrnong (see Map 1 below). Deep Creek and Jacksons Creek, the two main tributaries flow into the Maribyrnong River above Sunbury. These creeks have the biggest impact on downstream flows.

The upper catchment is north of Keilor. This approximately aligns with the Urban Growth Boundary but also includes the satellite urban growth area of Sunbury. The lower catchment is south of Keilor and within the Urban Growth Boundary.

About 10 per cent of the catchment retains its natural vegetation, 80 per cent is used for agriculture and 10 per cent is urban (confined to greater Melbourne and larger

[4] Flood (ses.vic.gov.au)

townships). Population modelling shows that the Maribyrnong catchment will increase from some 600,000 people to over 800,000 in the next 20 years. This will require an additional 5000 dwellings per year.

Flooding and land use planning

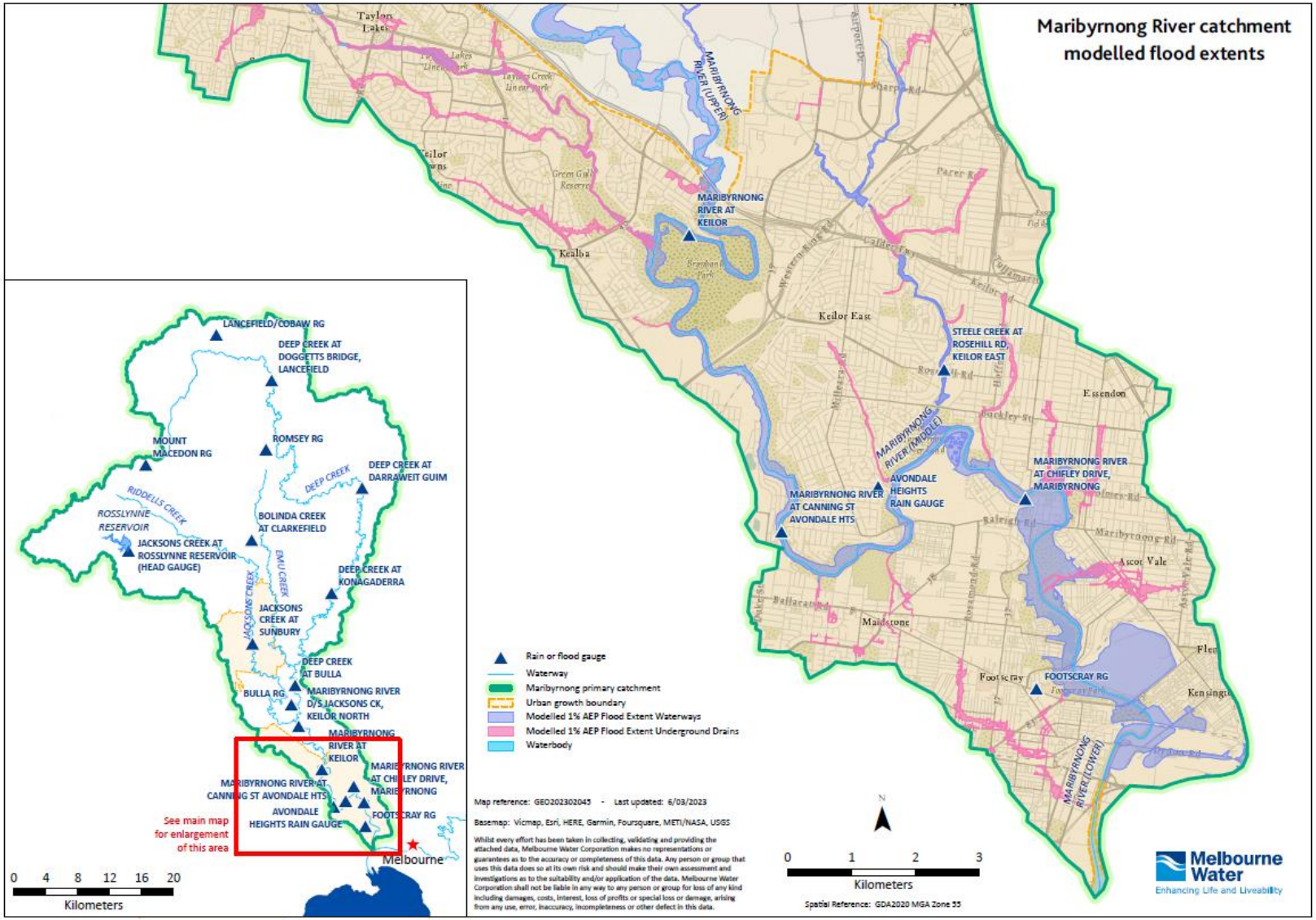
In 2003, Melbourne Water commissioned detailed modelling of the Maribyrnong River. The flood modelling and mapping identified land that could be affected by flooding from a 1% AEP flood event. This information was then included in the relevant council planning schemes as a Land Subject to Inundation Overlay (LSIO).

In terms of land use planning zones, much of the Maribyrnong floodplain is zoned for Public Park and Recreation use. This means that much of the floodplain is available for public use, whilst protecting its primary function as a floodplain. There is some land zoned for residential use in Sunshine North, Avondale Heights, Maribyrnong and Ascot Vale. Development in these zones is subject to conditions to help manage flood risk to people and property. The Commonwealth Government also owns some land which was historically zoned for defence purposes.

The October 2022 flood event in the lower catchment was the third largest flood on record, dating back to the late 1800s. For comparison, the 1974 flood was the fourth largest. The highest and second highest floods occurred when records were not what they are today. Table 1 below provides an overview of historical floods in the Lower Maribyrnong.

Table 1: Historical floods in the Lower Maribyrnong

Rank	Year	Month	Peak Height at Maribyrnong (mAHD)
1	1906	Sept	4.5
2	1916	Sept	4.26
3	2022	Oct	4.22
4	1974	May	4.2
5	1871	Sept	3.86
6	1891	July	3.32
7	1993	Sept	3.31
8	1954	Dec	2.98
9	1924	Aug	2.98
10	1983	Oct	2.85
11	1954	Nov	2.83



Map 1: Maribyrnong River catchment modelled flood extents

Flood Event

- At Keilor and Lower Maribyrnong the October 2022 flood event was slightly less than a 2% AEP. This means that each year there is less than a 2 in 100 probability of a flood event of that magnitude occurring.
- At Darrweit Guim in Deep Creek the October 2022 flood event was close to 1% AEP (a flood event with a 1 in 100 probability in each year). The river levels were the highest ever recorded at 7.22 metres.
- People from over five hundred residences were required to evacuate as a result of the flooding in the Lower Maribyrnong.
- While rainfall in the urban area had a relatively small impact, there were record breaking levels of rainfall in Deep Creek, one of the two major tributaries.
- The catchment was highly saturated on the day of the event due to previous rainfall across the catchment in September and early October. This led to higher than usual levels of runoff.

No two flood events are ever the same. The location of the rainfall, the conditions of the catchment it falls onto, and changes in the development within the catchment will mean that every flood is unique.

The impact of a flood will also vary within a catchment. If rainfall is concentrated in one part of the catchment, that tributary may experience worse flooding than other sections of the catchment.

The Maribyrnong River catchment experienced a rainfall event that lasted for four days, commencing Wednesday October 12, and concluding on Saturday October 16. During this time, the catchment experienced 164 mm rainfall at Lancefield North, and 141.8 mm at Mount Macedon.

On 14 October 2022 the Lower Maribyrnong breached its banks. Residents had to evacuate as more than 500 homes were flooded. We have heard from affected communities the significant impact of this event.

How big were these floods?

Deep Creek is the largest tributary of the Maribyrnong River. In this event it received the largest amount of rainfall in the catchment. During the flood event, all four gauges along Deep Creek recorded the highest river heights on record.

At Darraweit Guim gauge, the highest river level recorded was 7.22 metres, exceeding the major flood level for this site. The historic flow rate data for this gauge on Deep Creek shows that this flooding event had a 1% chance of being exceeded in any given year at this location (or a 1% AEP) (Jacobs 2023). This is based on data dating back to 1975.

The Maribyrnong River at Keilor recorded a water level of 8.64 metres. This water level exceeds the major flood level. Based on an analysis of historic flow data the flood event at Keilor has less than a 2% chance of occurring in any year (or less than 2% AEP) (Jacobs 2023).

The Maribyrnong River at the Maribyrnong flow gauge recorded a water level of 4.22 metres. This water level exceeds the major flood level. This water levels appears to be the third highest flood at this gauge on record, sitting slightly higher than the 1974 flood. It is difficult to compare this event directly with previous events due to development in the catchment and uncertainties in historic methods used to record flood levels and flows.

It is important to note that estimates of event sizes are reliant on analysing historic data. We know that climate change is increasing the intensity of rainfall events, which is making it harder to use historic records to determine the likelihood of future flood events.

How fast did the river levels rise?

The river levels rose rapidly during the October 2022 flood event. The Maribyrnong River at Keilor (Figure 21) rose from the minor flood level of 3.5 metres to the major flood level of 6.1 metres in just under four hours. It continued to rise further to 7.42 metres within the next five hours.

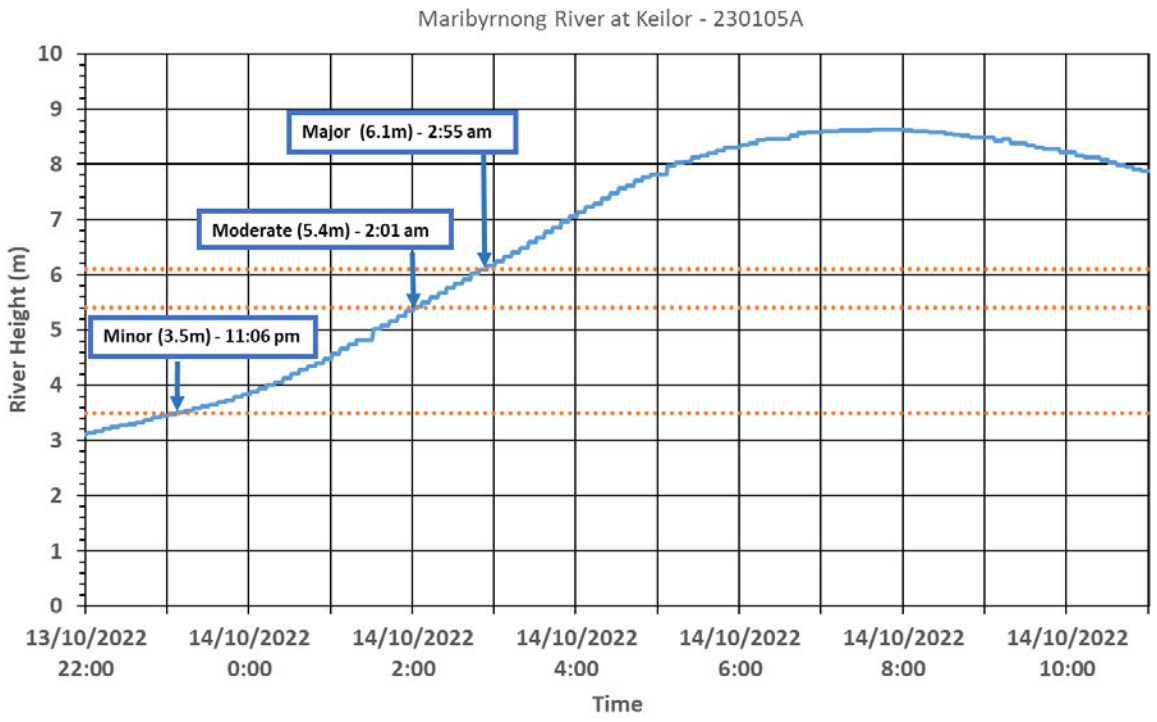


Figure 1 Observed river levels Maribyrnong River at Keilor

The Maribyrnong River at Maribyrnong (Figure 2) rose even faster from the minor flood level of 1.7 metres to the major flood level of 2.9 metres in just over two hours.

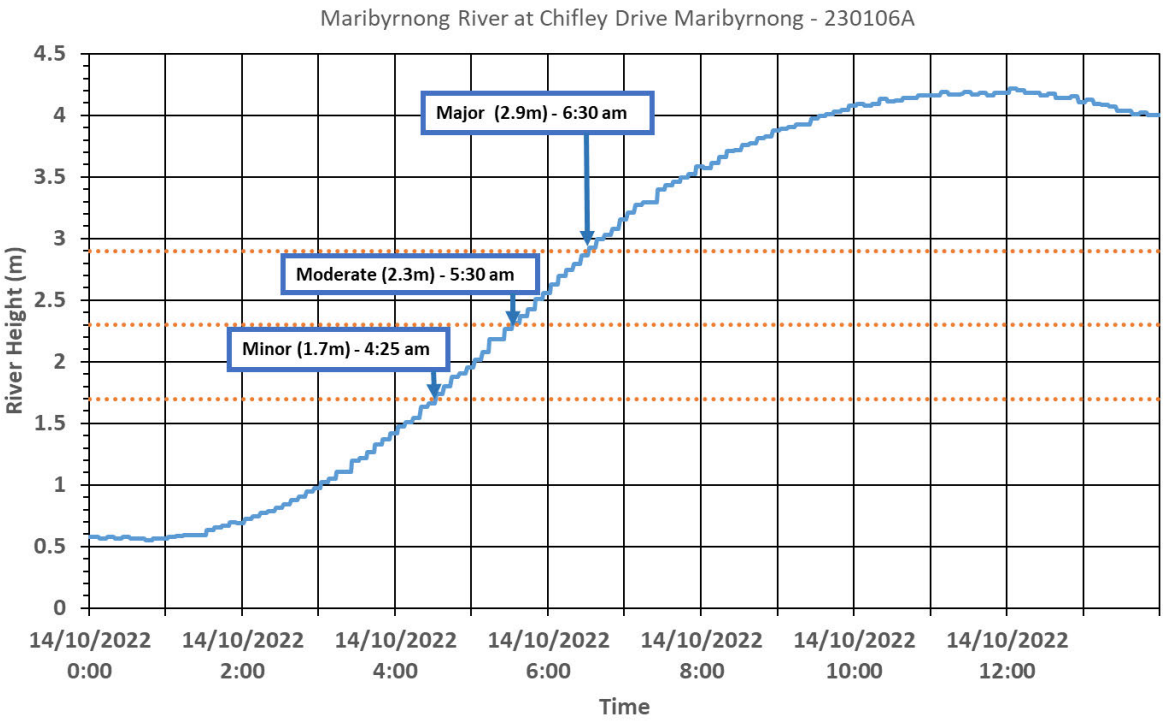


Figure 2 Observed river levels Maribyrnong River at Maribyrnong

How did this much rainfall cause a major flood?

The amount of rainfall that enters a waterway varies from one rainfall event to another. The amount of water held in the soil affects how much what proportion of the rainfall that hits the ground runs straight into the waterways. The soil and vegetation act like sponges for the rainfall. A dry sponge can absorb more water, a wet sponge cannot. For this reason, identical rainfall events can lead to different amounts of water entering the waterways.

By 12 October 2022, the Maribyrnong catchment had already received large volumes of rainfall in the preceding weeks. September 2022 rainfalls in the catchment ranged from 49 mm at Melbourne Airport in the lower Maribyrnong catchment to 116 mm at Lancefield in the upper catchment. This is 64% above average at Lancefield (Jacobs 2023). At the start of October, prior to the storm event, a further 44.8 mm had fallen at Lancefield, and 50 mm at Melbourne Airport (Jacobs, 2023). This means that by the time of the storm event, the capacity of the soil and vegetation in the Maribyrnong catchment to absorb additional rainfall was very low.

The runoff generated by the rain falling on already wet ground entered waterways that were already flowing at a relatively high level. Analyses of the streamflow data at the Maribyrnong River at Keilor show that on the first day of the rainfall (i.e before the flood occurred) the rate of flow was in the highest 4% of river flows since 1990 (Jacobs 2023).

This means that the above average rainfall on an already wet catchment created larger than normal volumes of runoff. The resultant river flows exceeded the capacity of the river channel and activated the floodplain, flooding homes, businesses and assets that are located on the floodplain.

What was the impact of the spill from Rosslynne Reservoir?

Rosslynne Reservoir is part of Southern Rural Water's network and supplies the townships of Sunbury and Gisborne as well as providing irrigation water to river diverters. During the October 2022 event Rosslynne Reservoir spilled as it is designed to do.

In Jacksons Creek, while Rosslynne Reservoir was spilling, the river level peaked just below 'minor flood level'. This water flowed into the Maribyrnong River and increased the volume of water eventually flowing through the Lower Maribyrnong during the flood event.

Melbourne Water considers the volume of water that this spill contributed to the flood peak in the Lower Maribyrnong to be small in the context of the flood event. This is because Jacksons Creek peaked below minor flood level and is the lesser of the two tributaries to the Maribyrnong River.

Melbourne Water's role and actions in responding to flood events

- Melbourne Water is one of a number of agencies responsible for responding to flood events.
- Under the State Emergency Management Plan, we are the flood prediction agency for the Melbourne Metropolitan catchments.
- During a flood event we provide modelling to predict the risk and extent of potential floods to the Bureau of Meteorology (BoM), so BoM can communicate warnings to the public.

Overview of flood response arrangements

In Victoria, Emergency Management Victoria (EMV) supports the Emergency Management Commissioner (EMC) to lead and coordinate emergency preparedness, response and recovery for events such as floods.

Under the *Emergency Management Act 2013* (Vic), the EMC must arrange for the preparation of the State Emergency Management Plan (SEMP) to provide for an integrated and coordinated approach.

The SEMP outlines the roles and responsibilities of various agencies for the mitigation of, response to and recovery from emergencies. Under the SEMP and the *State Emergency Plan, Flood Sub-plan*, the BoM acts as the flood prediction agency for Victorian catchments with the exception of the Melbourne Metropolitan catchments, In these areas Melbourne Water is the prediction agency. The Melbourne Metropolitan catchments include Yarra, Maribyrnong, Westernport, Dandenong Creek, Werribee, Diamond Creek, Merry Creek, Kororoit Creek and Plenty River.

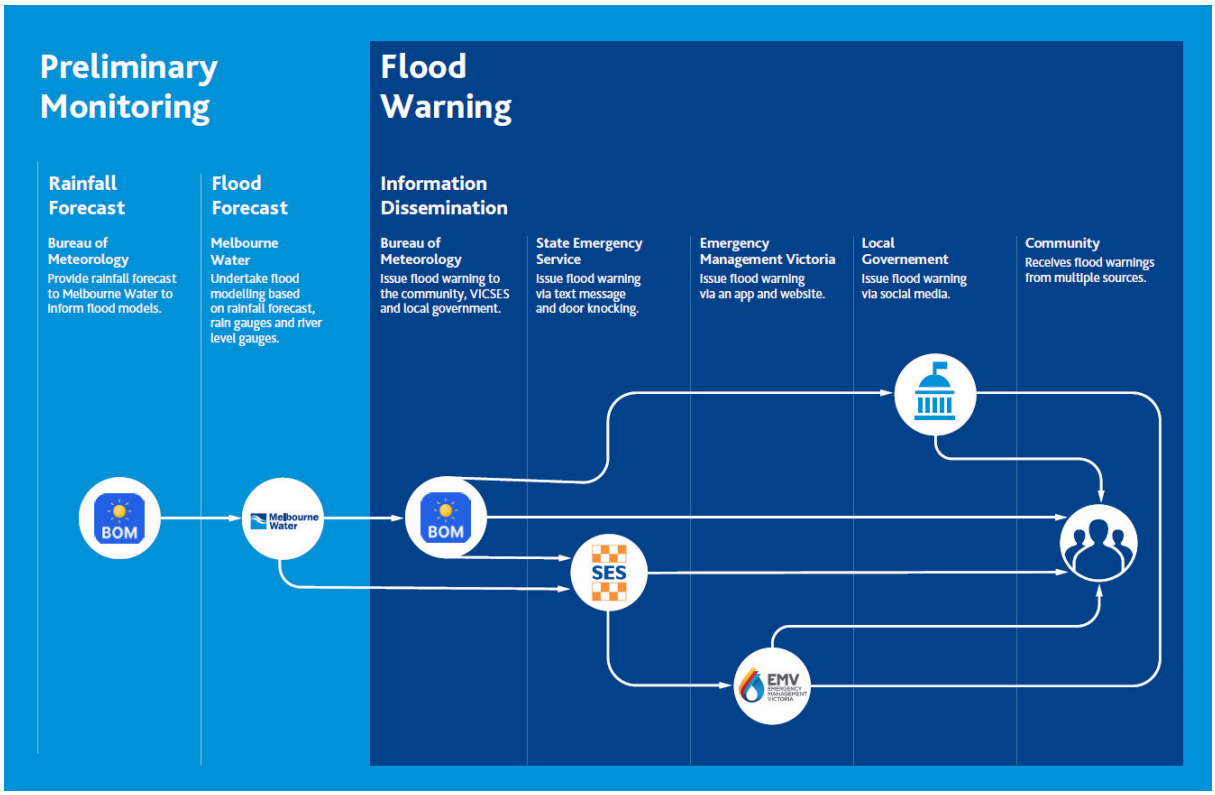
As the flood prediction agency for Melbourne Metropolitan catchments, Melbourne Water's role is to undertake modelling about anticipated flood levels based on rainfall forecasts (supplied by the BoM) and river height measurements. Ahead of and during an event, we use flood models to estimate the likelihood and extent of potential flooding. For these catchments Melbourne Water prepares flood warnings and sends them to the BoM, which then issues them to the community and VicSES.

During a heavy rainfall event, Melbourne Water resources a 24/7 flood warning roster, and is in regular contact with the BoM to ensure that up-to-date rainfall forecasts are included in the flood forecast modelling.

If a flood of moderate level or greater is predicted, Melbourne Water Flood Response Plan is activated. This means that Melbourne Water stands up an incident response team and the VicSES to establish an incident. As part of the response to a major flood warning, Melbourne Water provides an update of the flood warning every six hours to BoM. This reverts to daily once the flood declines to moderate flood level.

Flood watches are a heads up to the community about potential flood risks. They are issued 24 hours prior to rainfall occurring. Flood warnings generally follow a flood watch, after rainfall has commenced. These flood warnings are broadcast by other agencies in a number of different ways, including through the Vic Emergency system and by the BoM through their website.

Figure 3: Roles in providing warnings to the community



How do flood forecast models work?

Melbourne Water has invested in the development of a Flood Integrated Decision Support System (FIDSS) to deliver the flood forecasting service. This system uses:

- Rainfall forecasts provided to Melbourne Water by the BoM.
- Real time river level data from our network of river level gauges.
- A flood model that brings together a rainfall runoff model (how much of the rain will flow into the river) and a runoff routing model (where will that water flow to and how quickly). Melbourne Water calibrates these models based on historic events.

Melbourne Water runs its flood forecast models throughout a flood event. When a 'minor' or 'moderate' flood is predicted, model runs are updated every 24 hours. When a 'major' flood has been forecast model runs are updated every 6 hours. The six-hour cadence reflects the 'rain to flood' times set out in the SEMP. Additional model runs may be completed if real time river level data is deviating from the forecast levels. Details on each of the flood levels is outlined further below. Model runs take 30-90 minutes with a further 20-45 minutes required to process the information.

How are rainfall forecasts used in the flood forecasting?

The BoM provides one or more rainfall forecasts to Melbourne Water. The forecasts are classified based on the likelihood of the forecast rainfall occurring. BoM advises Melbourne Water which rainfall forecasts represent the "most likely" and "credible alternative" (a higher rainfall scenario, which is less likely to occur than the "most likely"

scenario) rainfall scenarios. Melbourne Water runs the flood forecast system using these rainfall scenarios.

The accuracy of climate and weather forecasts varies with the lead time, size of the region of interest and the climate variable being forecast (e.g rain or thunderstorm).

Over the four days leading up to 14 of October, the rainfall forecast changed a number of times. This is not unusual, rainfall forecasts become more accurate closer to the time of the rainfall. As rainfall forecasts change, the flood forecasts that use these updated rainfall forecasts will also change.

How is river level gauge information used in flood forecasting?

Melbourne Water maintains an extensive network of rainfall and river level gauges across the region, 21 of which are in the Maribyrnong catchment. Eleven river level gauges measure the height of the water in the river at different locations.

A rating curve is used to convert the height of water into an estimated flow rate. This rating curve is unique to each site as the shape of a river channel is different at every location. The rating curve is based on historic information including the depth, flow and stream cross section at each location. This uses leading technology called Acoustic Doppler Current Profilers.

River level gauges that are part of the flood forecasting network send updated river level information to Melbourne Water every time there is a change in river level. Flood forecasts use this real time information as an input into the flood forecasting system and flood models.

On 11 October 2022, Melbourne Water extended the rating table for the Keilor gauge ahead of the expected rainfall. We did this because when we modelled the worst-case flood scenario based on the expected rainfall, the rating table did not extend high enough for the flood forecasting model.

Extending the rating table is common in catchments where there are limited records of previous flood events or where there has not been a large-scale flood. This is because rating tables are based on historic data. In situations such as this, where there is no available historic data at the high end of a rating table it is industry best practice to extend the rating table.

The flood gauging network for the Maribyrnong catchment was introduced following the 1974 flood event. There has not been a similar magnitude flood event between then and 2022.

On 14 October at approximately 12.30am, Melbourne Water identified that the actual height at the Keilor gauge exceeded the levels that models had predicted. Melbourne Water revised its projections in light of the real time data and contacted BoM and VicSES to upgrade the flood warning to ‘exceeding major’. Re-running the model takes between 30-90 minutes with a further 20 –45 minutes to interpret the data. This new warning was prepared by Melbourne Water and sent to BoM at 2.16am, and issued by BoM at 2.27am on 14 October.

How is our flood forecast information used?

Throughout a flood event, Melbourne Water’s flood forecasts are used to generate a range of notifications and warnings. Melbourne Water provides flood forecasts to BoM for

the purpose of flood watches and warnings. Melbourne Water provides flood scenarios to VicSES to help inform their planning.

Flood Scenario Catchment Outlooks for Greater Melbourne Metro Area

Melbourne Water produces Flood Scenario Catchment Outlooks for the Greater Melbourne Metro Area. These are supplied daily to VicSES to support their planning for the upcoming flood events.

Melbourne Water provides estimated flood peak levels and timings. This information is used to inform communications materials for the community including "watch and act" advice and evacuations. It also informs VicSES deployments and resourcing.

Flood Watches (pre rainfall event)

A flood watch is an alert that there is the potential for flooding within the region. It is not a warning for imminent flooding. If flooding is predicted, a Flood watch will be issued 24 hours prior to forecast rainfall occurring.

Flood watches are updated at least daily and finalised once the risk of flooding has passed or all areas are covered by flood warnings.

Melbourne Water discusses the need to issue a flood watch for the Melbourne Metropolitan region with the BoM. This discussion is informed by the flood forecasting that Melbourne Water undertakes, based on the BoM rainfall forecasts.

Flood warnings

Melbourne Water's flood forecasts are used to inform flood warnings when it is more certain that flooding may occur. This is often when rain has started to fall. Flood warnings are more targeted and are issued for specific catchments and sub-catchments. Flood warnings will generally include specific predictions of the severity of expected flooding at specific locations.

Flood warnings are communicated within the Melbourne region using classifications that align with the BoM's National Arrangements for Flood Forecasting and Warning[5]. These classifications are:

> **Minor** - 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** - 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** - 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

Melbourne Water understands that these flood warnings are broadcast in a number of different ways, including through the Vic Emergency system and by the BoM through their website.

[5] National Arrangements for Flood Forecasting and Warning v4 2018 (Sample (bom.gov.au))

What actions did Melbourne Water take during the October 2022 event?

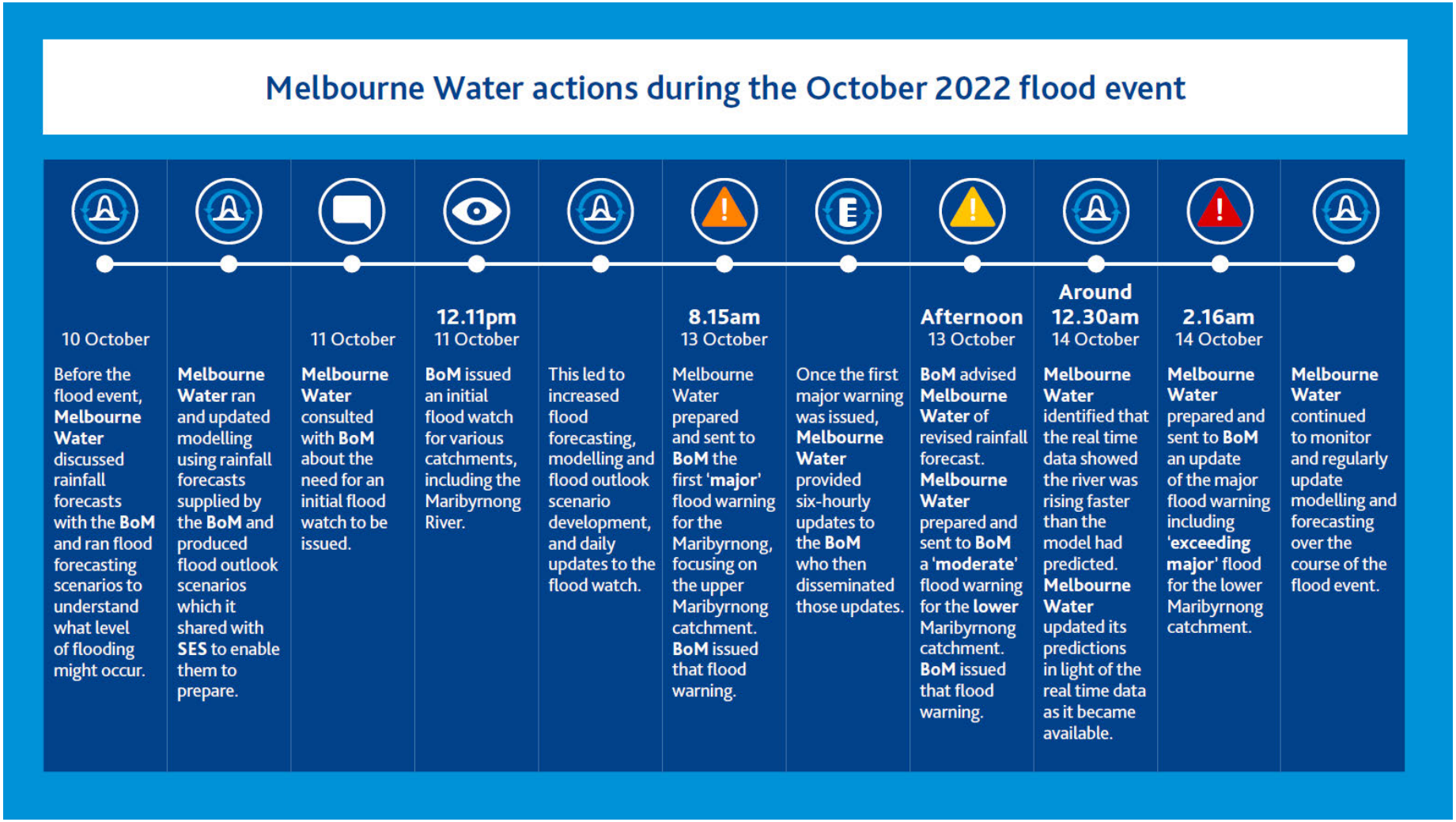
During the October 2022 flood event, conditions shifted rapidly. The rain forecasts changed as did the actual river heights and flow measurements. This meant that the likelihood, level and extent of expected flooding also changed, as did the severity of warnings.

In conjunction with other responsible agencies, Melbourne Water undertook extensive activities to forecast, monitor and respond to the October 2022 event. A high-level chronology of key developments is below. Before the flood event on 10 October 2022, Melbourne Water discussed rainfall forecasts with the BoM and ran flood forecasting scenarios to understand what level of flooding might occur.

Timeline before and during the October 2022 event

- Melbourne Water ran and updated modelling using rainfall forecasts supplied by the BoM and produced flood outlook scenarios which we shared with SES to enable them to prepare.
- Melbourne Water consulted with BoM about the need for an initial flood watch to be issued.
- At 12.11pm on 11 October, BoM issued an initial flood watch for various catchments, including the Maribyrnong River.
- This led to increased flood forecasting, modelling and flood outlook scenario development, and daily updates to the flood watch.
- At 8.15am on 13 October, Melbourne Water prepared and sent to BoM the first 'major' flood warning for the Maribyrnong, focusing on the upper Maribyrnong catchment. BoM issued that flood warning.
- Once the first major warning was issued, Melbourne Water provided six-hourly updates to the BoM who then disseminated those updates.
- In the afternoon of 13 October 2022 the rainfall forecasts were revised. At 2.24pm on 13 October, Melbourne Water prepared and sent to BoM a 'moderate' flood warning for the lower Maribyrnong catchment based on this data. BoM issued that flood warning.
- Around 12.30am on 14 October, Melbourne Water identified that the real time data showed the river was rising faster than the model had predicted. Melbourne Water updated its predictions in light of the real time data as it became available. Model runs take 30 – 90 minutes with a further 20-45 minutes required to process the outputs.
- At 2.16am on 14 October, Melbourne Water prepared and sent to BoM an update of the major flood warning including exceeding major flood for the lower Maribyrnong catchment. This new warning was issued by BoM at 2.27am.
- Melbourne Water continued to monitor and regularly update modelling and forecasting over the course of the flood event.

Figure 4: Timeline of events before and during the October 2022 flood event



Melbourne Water's role and actions in preparing for flood events

- Melbourne Water is one of several agencies responsible for floodplain management.
- Under the Water Act 1989, we are the floodplain manager for the Maribyrnong catchment.
- In preparing for flood events, we are responsible for flood modelling and mapping for the 1% AEP flood risk.
- Local councils use this information in strategic planning, including amending flood overlays through planning scheme amendments.
- Under the Planning and Environment Act, we are a referral authority for planning permits in areas subject to a flood overlay and are required to consider and either not object (with or without conditions) or object to the permit.
- The Maribyrnong River was modelled and mapped in 2003.
- Once we obtain all the learnings from this flood event, including the outcomes of the Independent Review process, we will update the model.

Responsibilities under the Water Act 1989

The floodplain management function is carried out by Catchment Management Authorities (CMAs) in regional Victoria and Melbourne Water in the Port Phillip and Westernport catchments. Local government has a significant role to play in the administration of land use planning arrangements and accountability for flood mitigation at the local level.

Under Division 4 of Part 10 of the Water Act 1989, as the floodplain manager, Melbourne Water's functions include:

- finding out how far floodwaters are likely to extend and how high they are likely to rise;
- declaring flood levels, flood fringe areas and building lines (relevantly, the Water Act empowers Melbourne Water to issue such declarations in the Government Gazette);
- controlling developments that have occurred or may be proposed for land adjoining waterways;
- developing and implementing plans or schemes and taking action necessary to minimise flooding and flood damage; and
- providing advice about flooding and controls on development to the community, local councils and the Secretary to the Department of Energy, Environment and Climate Action.

Melbourne Water's floodplain management roles includes the preparation of site specific flood level certificates and setting out the estimated flood level for properties based upon a flood event that has a probability of occurrence of 1% in any one year.

Melbourne Water must also ensure that information about any flood levels, flood fringe areas, building lines and areas of land declared liable to flooding (or to be floodway areas) is readily available to the public.

Maribyrnong floodplain modelling

To generate flood maps, flood models need to be built and tested. The most recent flood modelling for the Lower Maribyrnong River was commissioned by Melbourne Water in 2003.

Flood models are generally composed of a hydrological model, to estimate the flows reaching a river or drainage system, and a hydraulic model for the movement of water through the river or drainage systems.

In Australia, the Australian Rainfall and Runoff Guidelines are developed with the support of the Australian government to support the provision of reliable and robust estimates of flood risk[6]. Melbourne Water adopts the approaches outlined in these guidelines when undertaking flood modelling.

Hydrological modelling

A key element of any hydrological model is checking that it is a good representation of the real-life system it represents. Where possible, models are calibrated to real life data and flood events.

The 2003 model of the Maribyrnong catchment uses work completed in 1986 by the Melbourne Metropolitan Board of Works as the starting point of the hydrological modelling. It is common practice for updated flood models to build from data sets used in previous models.

The 1986 work is a calibration of peak flows, using a method known as Flood Frequency Analysis (FFA). FFA uses observed and recorded flood levels to identify the probability of flood peaks. The FFA method used in 1986 is still valid today with a full chapter devoted to the subject in the Australian Rainfall and Runoff Guidelines (2019). It is the preferred method for calibration in the Guidelines, combined with peer review by the profession.

Hydraulic modelling

The modelling software used was the Hydraulic Engineering Centre's River Analysis System (HEC-RAS), created by the United Stated Army Corps of Engineers. HEC-RAS is still used across the industry today in updated versions.

The hydraulic model involved three stages:

- Calibration to test existing modelling assumptions: This was run as a one dimensional (1D), steady-state Hec-Ras model.
- Unsteady state model: This one-dimensional model was included to consider floodplain storage effects.
- Determining design flood levels: The third stage model was created and run to take what has been learnt from the previous twostages to determine the design flood levels.

Key inputs and processes for the hydraulic modelling is terrain data (the shape of the catchment including roughness and topographical data), hydrological modelling, calibration or validation and peer review by industry.

The Maribyrnong hydraulic model used the best available information including bathometry, terrain data, survey and photogrammetry. This captured changes to terrain

[6] Geosciences Australia website. Date accessed 06/03/2023

data that had occurred since the 1986 model and was calibrated to observed flood levels.

Peer review

A peer review was completed by an independent expert. It found that that the study was carried out thoroughly and that the results stemming from the study were accurate, within the noted limitations of the calibration data.

How accurately did the model predict the extent of flooding?

Melbourne Water has flood mapping extents for a large number of our catchments. The event that has most complete coverage across our region is the 1% AEP. For the Maribyrnong River we have flood mapping available for the 1% AEP event and, at the Maribyrnong township only, we also have mapping for the 2% AEP event. In the township area where both extents are available, the changes in flow between the 1% and 2% AEP event result in limited change in flood extent.

The 2022 flood event has been assessed as being slightly rarer than the flood which has a 2% chance of occurring in any given year. This means it lies between the 1% and 2% AEP event. Given this and the limited change in extent between the events, it is considered appropriate to make comparisons between the 2022 event and the 1% AEP flood mapping.

Melbourne Water has used a number of data sets to compare the October 2022 flood event to the flood mapping. These include aerial imagery, satellite imagery, survey data and impact assessments from Fire Rescue Victoria. These datasets indicate that, apart from specific localised areas, the extent of flooding experienced in the 2022 flood event is close to what was modelled.

In addition to Melbourne Water's own internal review we commissioned engineering firm Jacobs to undertake post event analysis to assess the magnitude of the event. This included looking at rainfall and flow gauges and assessing information immediately available after the event against modelled data.

Jacobs used freely available modelling data sourced from DELWP (now DEECA) in 2022 which is a different data set to the one data we hold on our systems and use for decision making purposes. Melbourne Water is undertaking further analysis to understand any discrepancies.

How often is riverine modelling updated?

There is no regulated industry standard that sets out the frequency for updating flood models. The process of creating a model is long and resource intensive. Melbourne Water (and the wider specialist industry) has finite resources for updating flood modelling across the whole Melbourne region. Our flood modelling program is prioritised on the need for completing areas not currently modelled and mapped.

The riverine environment is typically more stable than urban drainage systems. This means that there is a need to update the flood mapping associated with urban drainage systems on a more regular basis than riverine environments. In addition, modelling and mapping of the major riverine network is complex with the most recent projects (Lower Yarra and Dandenong Creek) taking three years to complete.

Since 2003, the biggest changes in flood modelling techniques occurred in 2016 with the release of the updated Australian Rainfall and Runoff guidelines (ARR). This update took advantage of the significant advancements in computer technology, techniques and understanding of rainfall-runoff processes since the previous version (1987). It

introduced changes to then current practice. A new version of the ARR was released in 2019 following feedback from industry and practitioners.

Following the release of the 2019 ARR (ARR19), Melbourne Water worked with our stakeholders to incorporate these changes into our 5-year rolling flood mapping program. We are concurrently incorporating along with the 2100 climate change projections (see Future Challenges section). Our current program represents a substantial uplift on the previous one established in 2016.

It is common practice to use the real data on river heights and flow rates from flood events to update models. This allows for the models to be calibrated with more accuracy. We will use the information collected from the October 2022 flood event to update the model for the lower catchment.

Responsibilities under the Planning and Environment Act 1987

In addition to its Water Act functions, Melbourne Water also has a role to play in Victoria's planning framework. This role is governed by the Planning and Environment Act and planning schemes.

Land use and development in Victoria is largely regulated by planning schemes. Each municipality in Victoria is subject to a planning scheme, which is a statutory document that sets out the objectives, policies, and planning controls governing land use and development in the municipality to which it applies.

Planning controls

The key planning controls mediating land use and development are 'zones' and 'overlays':

Zones: All land in Victoria is divided into zones, and the planning scheme sets out the land uses associated with each zone, including whether a permit is required for a particular land use or development.

'Overlays': In contrast, not all land is subject to an overlay. This is a secondary control, which applies to certain areas that have a special characteristic – and therefore require additional protection.

Relevantly for the purpose of this Review, there are various planning 'zones' and 'overlays' that apply to land subject to flooding. These are, in summary:

Urban floodway zone: this is applied to areas that have the greatest risk and frequency of being affected by flooding. Land uses prohibited in this area include residential, commercial, and indoor recreation uses;

Special building overlay: this overlay is generally applied to land prone to overland flooding and is, in many cases, applied to address flooding associated with urban drainage systems (which are largely owned and maintained by local councils);

Land Subject to Inundation Overlay: this overlay is generally applied to land affected by flooding associated with open drainage systems (which are typically owned and maintained by Melbourne Water) and waterways (such as the Maribyrnong River); and

Floodway Overlay: this overlay is generally applied to land that has been identified as carrying active flood flows associated with waterways and open drainage systems.

Together these are referred to as **Flood Controls**.

Planning scheme amendments

Under the PE Act, a planning scheme amendment must be prepared by the 'planning authority' – this is typically the local council although it can sometimes be the Minister for Planning.

Any person or body (including Melbourne Water), can request that the planning authority prepare a planning scheme amendment. Though not required by statute to do so, Melbourne Water has (consistent with Action 13b of the VFMS) worked with local councils to prepare a large number of joint planning scheme amendments seeking to protect buildings and infrastructure from flood risk by imposing suitable overlays on land identified as liable to flooding. In some instances, these planning scheme amendments are informed by updated flood studies carried out jointly by Melbourne Water and local councils.

Development Services Schemes

Separately, but relatedly, Melbourne Water has also relied on its Water Act powers (including the ability to develop and implement schemes, and require contributions for works undertaken as part of its functions), to develop and implement drainage schemes for certain catchments. Historically, these powers were used to fund catchment-wide drainage service schemes in Melbourne's greenfield development areas.

Planning permits

Under the *Planning and Environment Act (1987)* (PE Act), when a planning scheme requires a permit to be obtained for a particular use or development of land, or to subdivide the land, the application for the permit must be made to the responsible authority – typically the local council but in some instances the Minister for Planning (Responsible Authority).

Under the PE Act and the VPPs Melbourne Water can also play a role in the assessment of such applications (in addition to its strategic role in the planning system detailed above) if, under the Victorian Planning Provisions (VPPs), it is identified as a 'referral authority' for such applications.

Melbourne Water is a 'determining referral authority' for:

- all applications to use or develop or subdivide land within Melbourne Water's waterway management district that are subject to flood controls by virtue of its role as floodplain manager; and
- Subject to limited exceptions, applications to subdivide land within Melbourne Water's waterway management district (regardless of whether they are subject to Flood Controls), by virtue of its role as a drainage authority.

Under the PE Act and the VPPs, this means that the Responsible Authority must refer any such use, development or subdivision planning application received by them to Melbourne Water. Melbourne Water must, in turn, consider the application, and then advise the Responsible Authority, whether:

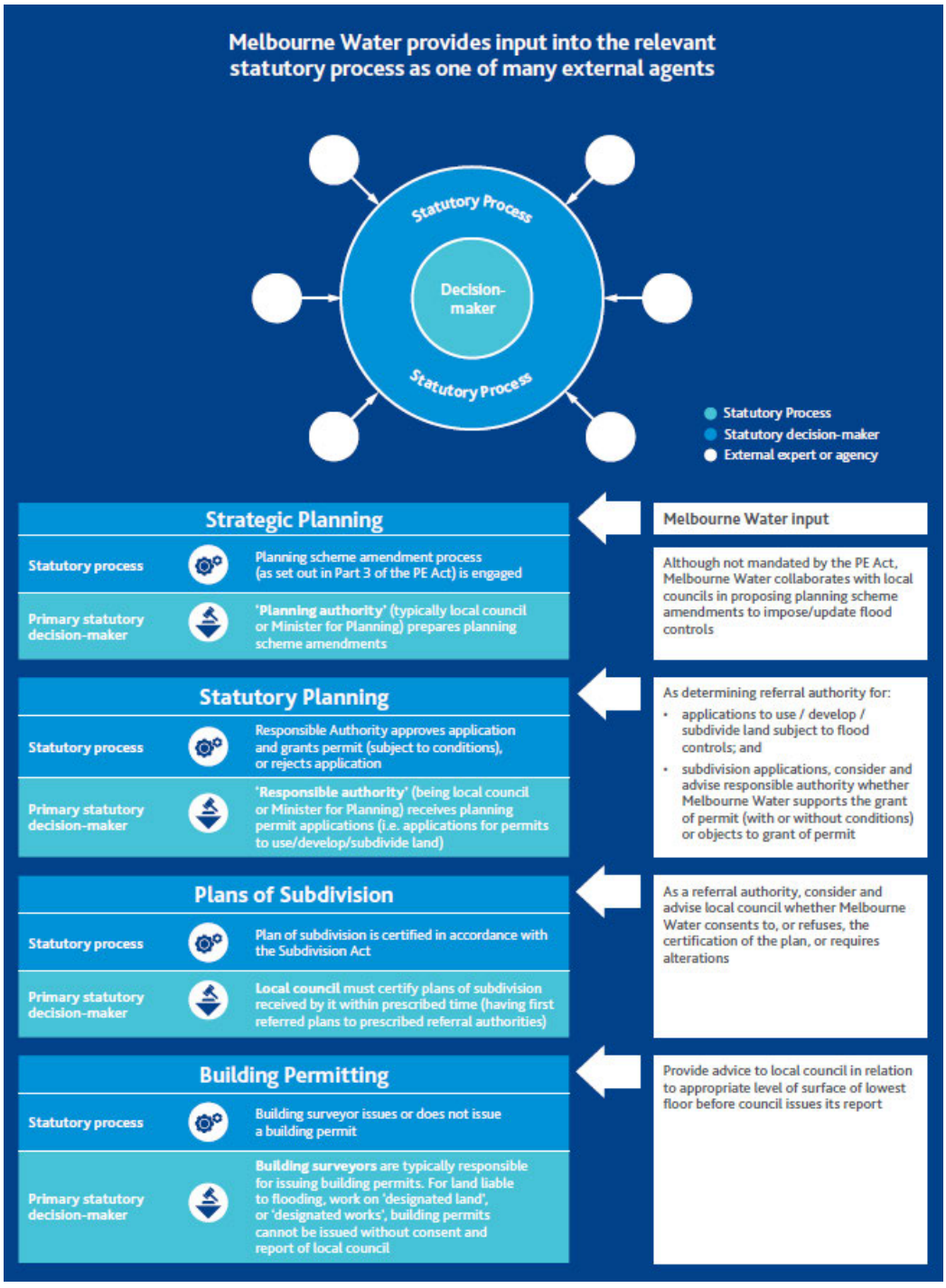
1. it does not object to the granting of the permit – in which case it is open to the Responsible Authority to decide either to reject the permit application or to grant it on any grounds the Minister thought fit;
2. it does not object to the granting of the permit if the permit is subject to specified conditions – in which case it is open to the Responsible Authority to decide either to reject the permit application or to grant it on any grounds the Responsible

Authority thinks fit. If the Responsible Authority does decide to grant the permit, then it must impose the conditions specified by Melbourne Water; or

3. it objects to the permit (specifying the grounds for its objection) – in which case the Responsible Authority is required to reject the application.

In addition to its role under the planning regime, Melbourne Water has a limited, consultative role under the building permit regime. In certain circumstances, as prescribed by the Building Regulations, relevant municipal councils are required to consult with (but are not required to seek the approval of) Melbourne Water before consenting to a building permit application.

Figure 5: Melbourne Water's role in the planning system



In assessing a planning application Melbourne Water must take into account the objectives of the PE Act and the relevant requirements of the applicable planning scheme.

In addition, any decision Melbourne Water makes must be consistent with, and not beyond the scope of, its powers and functions under the Water Act. Melbourne Water must ensure that any decision it makes with respect to a planning application, including any conditions it requires, is within its ambit of expertise.

Assessing planning applications

The objectives of the PE Act include, relevantly for Melbourne Water's floodplain management role:

- providing for the protection of natural and man-made resources;
- securing a pleasant, efficient and safe working, living and recreational environment for Victorians;
- protecting public utilities and other assets, and enabling the orderly provision of and coordination of public utilities and other facilities for the benefit of the community; and
- facilitating development in accordance with the above objectives.

With respect to the planning scheme, Melbourne Water is required to consider:

- the specific requirements of the applicable planning controls (including any specified technical, strategic and policy documents introduced into the planning controls via incorporated and background documents);
- the applicable provisions of the Planning Policy Framework, which, having regard to Melbourne Water's flood management role, include clauses 13.01-1S (Natural hazards and climate change) and 13.03-1S (Floodplain management); and
- any applicable decision guidelines specified in the planning scheme, which can be both general and specific in nature.

Melbourne Water assesses applications against relevant policy guidelines and documents, including (but not limited to):

- the-now Department of Transport and Planning's Guide to Development in Flood Prone Areas (DELWP, 2019);
- Planning for Sea Level Rise Guidelines (Melbourne Water, 2017); and
- any applicable adaption action plan prepared under the Climate Change Act 2017 (Vic) (Climate Change Act), e.g. the Water Cycle Adaptation Action Plan 2022-2026 (DELWP, 2022), which identifies climate change risks and priority adaptation actions across the water cycle system (being the system involving the collection, storage, treatment, delivery and supply of water, as well as services for managing wastewater, drainage and flooding).

Consideration of such policy guidelines and documents is expressly called up by the Planning Policy Framework – see for example, clause 13.01 (Climate Change Impacts) and clause 13.03 (Floodplain) of the VPPs).

Flemington Wall

- Melbourne Water, after detailed consideration of flood modelling and consultation with a variety of experts, did not object to a permit being granted to construct the wall provided certain conditions were met.
- Based on the modelling, those conditions would result in the Flemington Wall having no (or indeed a positive) effect on flood levels in the Maribyrnong catchment.
- The permit was granted, including the conditions requested by Melbourne Water. The decision of the Minister was upheld following a referral to the Governor in Council.
- We are continuing to investigate whether the compensatory mitigation measures performed as expected in the October 2022 flood event and whether, in fact, the Flemington Wall had any impact on the extent or duration of the flood event.
- That investigation requires complex modelling to be undertaken, which takes significant time to prepare.

The land on which the Flemington Racecourse is situated is within the Melbourne Planning Scheme and is subject to a Land Subject to Inundation Overlay (LSIO). Under the PE Act, to construct the flood wall the Victorian Racing Club (VRC) was required to submit a permit application to the Responsible Authority. The Melbourne Planning Scheme provides that the Responsible Authority for the Flemington Racecourse is the Minister for Planning.

The Minister was required to provide a copy of the permit application to relevant 'Referral Authorities' (pursuant to the PE Act as it was in force at the time). Because the Flemington Racecourse is subject to an LSIO, under the Act Melbourne Water was a Referral Authority for the permit application.

Under the Act, Melbourne Water, as a Referral Authority, was required to consider the application and inform the Minister either:

- that it did not object to the granting of the permit and if so, what, if any, conditions it required; or
- that it objected to the granting of the permit, and if so, on what grounds.

Permit Application for the Flemington Racecourse Flood Wall

On 25 February 2003, the VRC applied to the Minister for a planning permit (Permit 2003/86) to enable the construction of the Flemington Wall.

Melbourne Water undertook a detailed process to consider the permit application and supporting materials. The application was supported by modelling performed for VRC by Gutteridge Hasking & Davey (GHD). That modelling was conducted in accordance with industry standards at the time and concluded that provided certain mitigation works were performed, the Flemington Flood Wall and associated mitigation works would have no effect (more than fully offset) on flood levels in the surrounding areas.

This modelling was peer reviewed by an independent expert in hydraulic engineering and modelling, [redacted]. Melbourne Water did not object to the permit, subject to those mitigation works being performed.

Melbourne Water independently reviewed the GHD modelling and critically examined and tested the methodology before ultimately accepting its conclusions. In addition, the Cities of Moonee Valley, Maribyrnong and Melbourne engaged external consultants (Water Technology and WBM Oceanics) to review the GHD modelling and there was extensive consultation between experts about it.

During the permit application process objecting parties had the opportunity to put forward submissions and technical reports, which were considered and evaluated.

On 5 February 2004, the Minister granted the permit. The Melbourne City Council, Maribyrnong City Council, Moonee Valley City Council and Maribyrnong Residents Association sought a review of that decision in the Victorian Civil Administrative Tribunal.

On 3 August 2004, that application was determined by the Lieutenant Governor (acting in place of the Governor) under clause 58(2)(a) and clause 61(1)(b) of the *Victorian Civil and Administrative Tribunal Act 1998* and the Minister was directed to issue the permit.

Melbourne Water understands that the mitigation works were designed and constructed in accordance with the required permit conditions. This means that that, based on the modelling available at the time, the mitigation works should have offset any impact of the Flemington Wall on the extend and duration of the October 2022 flood event.

To assess whether the Flemington Wall did, in fact, have any impact on the extent and duration of the October 2022 flood event and, if so, whether that impact was, offset by the mitigation works constructed for that purpose, a complex hydraulic and hydrologic model would need to be completed. This modelling takes time and has not been possible in the period available for submissions to this Review. It is usual for modelling of this kind to take at least 12 months to complete. Melbourne Water is continuing to investigate these matters. We will provide updated information to the Independent Review Panel as it becomes available.

Future challenges

Climate change risk

- Climate change is increasing riverine flood risk.
- It makes flood modelling more difficult because it makes historical information less reliable for modelers.
- While modelling can be updated after major flood events, it is not possible to accurately predict future flooding outcomes under all potential climate change scenarios.
- Melbourne Water has been progressively including climate change impacts in its flood modelling since 2009.
- Melbourne Water is committed to a process of updating, on a rolling basis, all flood modelling within its region to incorporate climate change impacts.

Climate change is increasing flood risk. A warmer atmosphere can hold more water. For every one degree of warming, the atmosphere can hold an extra 7% of moisture. More moisture means that rainfall can come in shorter and more intense downpours. This will lead to more flooding, as a greater amount of rain falls in a shorter timeframe.[7]

Climate change projections are indicating with high confidence that extreme rainfall events in greater Melbourne will become more intense through the next century but are likely to be very variable in space and time[8]. This is making it harder to rely on historic data to predict future floods. Given this known future impact, it is no longer adequate to use past rainfall events as an indicator of the potential future events.

Climate change projections (increased rainfall intensity) have been made by the Intergovernmental Panel on Climate Change (IPCC) and advice on how to incorporate these is contained in the ARR19 Guidelines (industry guidelines for flood modelling). Melbourne Water follows these guidelines when incorporating climate change impacts in flood modelling.

The forecasted impact of climate change will vary over time, as conditions evolve. This means that the change in rainfall intensity that is modelled will also very in the future. Melbourne Water works with the best available information at the time when running the models.

Relevant Legislative Instruments

In addition to the legislative and policy instruments noted in other parts of this submission, Melbourne Water also takes into account the Climate Change Act (to the extent applicable), when exercising its functions.

There are a number of provisions in the Planning Policy Framework of the VPPs, which require consideration of climate change impacts when assessing land use and development applications.

This means that when assessing planning permit applications in its role as a referral authority, Melbourne Water is required to consider climate change impacts pursuant to

[7] Barlow, Mathew (2021) *The water cycle is intensifying as the climate warms, IPCC report warns – that means more intense storms and flooding,* published in The Conversation 9 August 2021
[8] DELWP and CSIRO (2019), *Greater Melbourne Climate Change Projections 2019,* Victorian Climate Projections 2019

the applicable provisions of the Planning Policy Framework, which include clause 13.01-1S (Natural hazards and climate change).

This clause includes an objective to minimise the impacts of natural hazards and adapt to the impacts of climate change through risk-based planning.

Melbourne Water has been including climate change impacts in its flood modelling since 2009. Melbourne Water uses information from the ARR Data Hub to calculate rainfall intensities for climate change based on the high emissions , this is currently an increase of 18.5% for 2100. This scenario is based on the high emission Representative Concentration Pathway 8.5 scenario from the IPCC report. The use of this scenario is supported by the Australian Rainfall and Runoff Guidelines 2019.

Community flood literacy

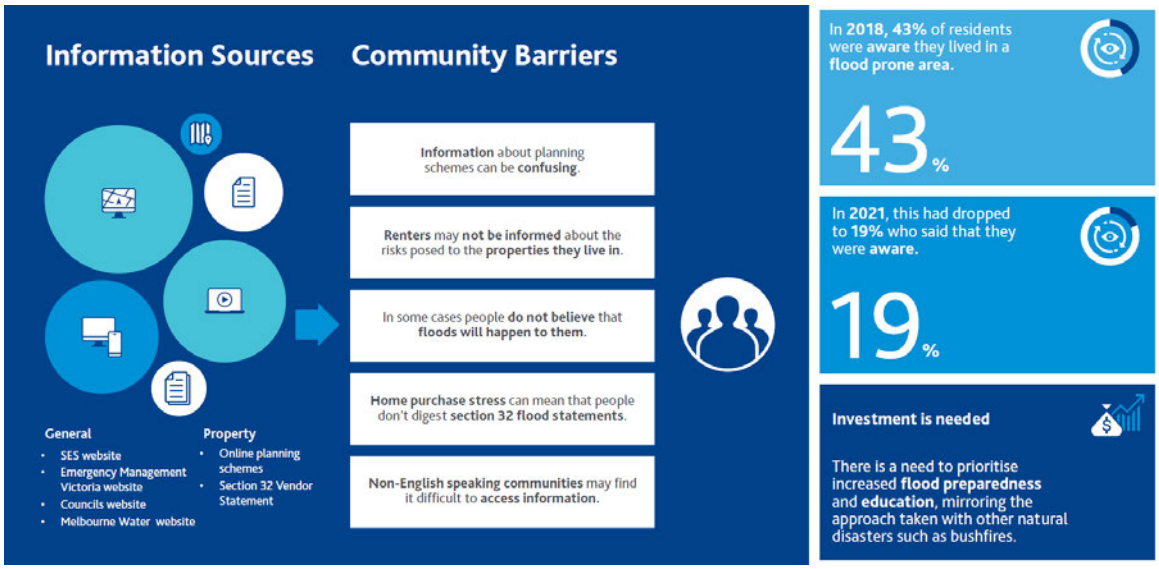
- The 2022 floods across Victoria have raised awareness of flood risk and the damage that can be caused.
- Receiving a flood warning is a stressful experience and more can be done to support a greater collective understanding of the unpredictability of flood events, local levels of risk and what to do in response to flood warnings.
- Melbourne Water is keen to work collaboratively with all the parties involved in flood management and work with community on flood literacy, taking into consideration more vulnerable groups in the community.

There is an opportunity for the many agencies involved in flood management to work collaboratively to build community awareness of flood risk and resilience to flood events.

Presently, the risk of flood is not widely understood by the community in Melbourne. A survey conducted in 2018 by Melbourne Water and VicSES found only 44% of households in flood prone areas were aware of their flood risk and only 34% were prepared for flooding[9]. This means that when a flood does occur, the impacted community are not always well prepared to take action to protect themselves and their property. This is highlighted in Figure 6 over the page.

[9] Flood Risk Awareness Progress Report, 2018 Bastion Latitude

Figure 6: Community access to information



The flood risk profile of a city is less quantifiable under conditions of changing rainfall patterns due to climate change. This can have unintended consequences such as creating a sense of complacency that can cause communities to be less prepared[10].

The recent floods across Victoria and in the Maribyrnong catchment have further highlighted that this is a real issue. More information is needed to help the community understand the risks of flooding before, during and after flood events.

There is the potential for large benefits from investments to improve community resilience to natural disasters, such as flooding[11]. Community resilience measures are predicted to significantly reduce the increasing costs of flooding. Investments in community resilience can be effective in lowering economic and social damage costs, particularly if investments are maintained over a number of years[12].

Developing community resilience will be important as climate change brings bigger and more frequent floods. Consideration should be given to:

- what information homeowners, renters, businesses and other vulnerable people in the community have access to;
- whether that is sufficient; and
- when and how that information is provided.

We can learn from Victoria's experience with improving our ability to be more prepared for bushfires. A key challenge to building community resilience is the reach of the engagement and ensuring that there is on-going engagement to reinforce key messages.

Effective community awareness programs, including the current flood information tools, must adequately communicate flood risk in an accessible way to *all* residents and

[10] Di Baldassarre Get al.2018Hess opinions: an interdisciplinary research agenda to explore the unintended consequences of structural flood protection. *Hydrol. Earth Syst. Sci.* **22**, 5629–5637.
[11] Special report Update to the economic costs of natural disasters in Australia.pdf (australianbusinessroundtable.com.au)
[12] Australian Business Roundtable for Disaster Resilience & Safer Communities (ABR) commissioned report: Building Resilience in Our States and Territories (2017)

businesses, including the elderly, and non-English speaking community members, and simplify technical flood terminology. There is no one-size-fits-all approach: Victorian communities are diverse, speaking more than 260 languages and dialects[13]. This is an important area of further work and support.

[13] Community Resilience Strategy Renewal 2019–22 (ses.vic.gov.au)

Glossary

1% AEP Flood Level	The 1% AEP flood level is defined as the flood level which has an annual exceedance probability of 1% in any given year. The older terminology is Average Recurrence Interval (ARI). The Victorian Flood Guidelines and Sea Level Rise Guidelines use the 1% AEP as a reference standard.
Annual Exceedance Probability	Likelihood of occurrence of a flood of a certain size occuring in any given year usually expressed as a percentage, e.g. 1% Annual Exceedance Probability flood.
Antecedence conditions	The capacity of the land, soil and vegetation in the catchment to absorb further rainfall. When the capacity is exceeded, the rain becomes runoff and moves downhill to low lying areas of land, including waterways and rivers.
Catchment	The region from which all rainfall flows, other than that removed by evaporation, into waterways and then to the sea. A catchment can be defined at many different levels such as the whole river basin (e.g. the Yarra catchment) or at a very local level (e.g. individual drains).
Flood	The covering of normally dry land by water. Defined by the insurance industry as water that has escaped or been released from the normal confines of either a lake, river, creek or other natural watercourse (whether or not it has been altered or modified), or any reservoir, canal, or dam, or drainage system.
Flood awareness	Appreciation of the likely effects of flooding, and a knowledge of the relevant flood warning, response and evacuation procedures.
Flood flows	The rate of flow of water measured in volume per unit time; for example, cubic metres per second (m3 /s). 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)
Flood Integrated Decision Support System	Is a modelling tool used to monitor flood events and provide flood level advice to the BoM and SES.
Flood mitigation	Permanent or temporary measures (structural and non-structural) aimed at reducing the impact of flood. Could include planning controls, infrastructure or activities on waterways.
Flood plain	An area of land that is subject to inundation by floods up to, and including, the largest probable flood event. Areas of land may be adjacent to a creek, river, estuary, lake, dam or artificial channel. Floodplains are often valued for their ecological properties
Flood risk	The potential risk of flooding to people, their social setting and their built and natural environment. The degree of risk varies with the circumstances across a range of flood events, not just the 1% AEP flood.
Flood resilience	Ability to plan for flooding as a natural and inevitable disturbance; act to mitigate risks and respond to flood events; and recognise the changing context presented by climate change and population growth while

	enabling the achievement of safety, liveability and sustainability goals within the region.
Lower catchment	Areas of the Maribyrnong catchment which are south of Keilor. This approximately aligns with areas within the Urban Growth Boundary but does not include the satellite urban growth area of Sunbury.
Major flooding	In addition to the moderate flooding, 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.
Minor flooding	Causes inconvenience. Low-lying areas next to water courses 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 minor flooding, 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.
Planning overlay	Planning control applied to land that requires a specific design treatment e.g. flooding, bushfire, heritage.
Planning scheme	A legislative document which regulates the use and development of land through planning provisions to achieve objectives and policies.
Planning zone	Prescribes land use and development requirements for a specific area.
Probable Maximum Flood	The largest flood that could conceivably occur at a location. Estimated from the greatest depth of precipitation meteorologically possible for that location, coupled with the worst flood-producing catchment conditions.
Riverine flooding	Occurs when excessive rainfall over an extended period of time causes a river or designated waterway to exceed its capacity resulting in the river water flooding on to adjacent land.
Upper catchment	Areas of the Maribyrnong catchment which are north of Keilor. This approximately aligns with areas outside the Urban Growth Boundary but also includes the satellite urban growth area of Sunbury.
Urban flooding	Occurs when excessive rainfall and/or excessive runoff due to hard surfaces over an extended period of time causes an urban drainage system to exceed its capacity resulting in flooding on to adjacent land.