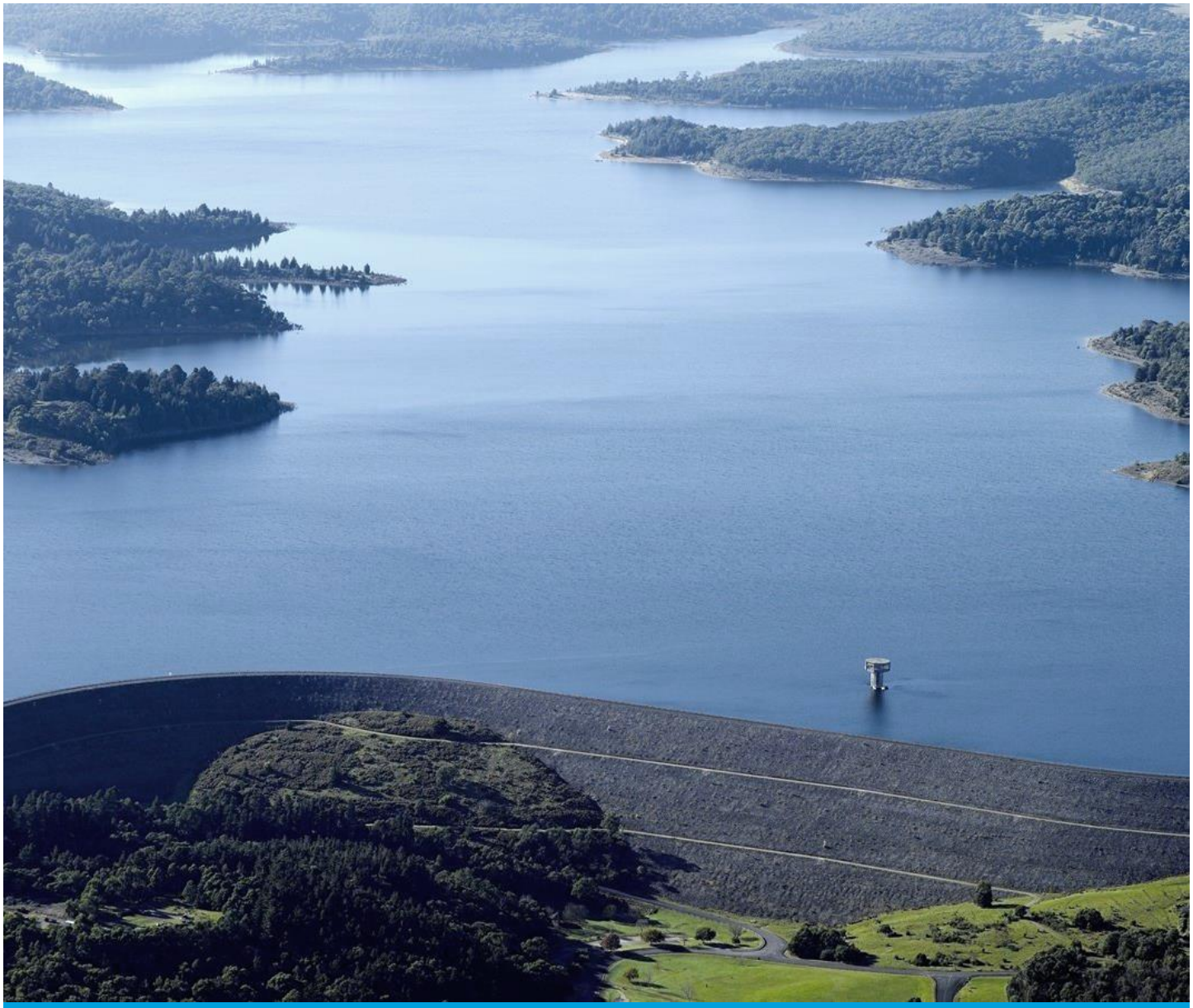

2020/21 Desalinated Water Order Advice

Technical Analysis

March 2020

VICTORIA State Government

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Purpose

1. This report provides technical analysis supporting the 2020/21 desalinated water order advice.

Context

Background

2. The Melbourne water supply system includes 10 major reservoirs and associated catchments that are used to harvest and store water, and the network of pipelines, pump stations, and tanks that are used to supply water to households and businesses across Melbourne and the surrounding region. The total system storage capacity of the 10 major reservoirs is 1,812 gigalitres[1] (GL). The Victorian Desalination Project (VDP) is connected by an 84 kilometre underground transfer pipeline to Cardinia Reservoir in the Melbourne water supply system. The VDP is operated by AquaSure, and can supply up to 150 GL/year, or around one third of current annual water demand. Bulk Entitlements to water from the VDP are owned by the retail water businesses (City West Water, South East Water and Yarra Valley Water).

3. At capacity, Melbourne's water storages hold the equivalent of around four times Melbourne's annual urban water demand. They supply water to the metropolitan water companies of City West Water, South East Water and Yarra Valley Water. Melbourne's water supply system also provides water to regional water authorities including Barwon Water, Western Water, Westernport Water, Gippsland Water and South Gippsland Water; for the environment on behalf of the Victorian Environmental Water Holder (VEWH); and from Thomson Reservoir for Southern Rural Water irrigators. During severe drought years such as 2006, storage volumes can drop by as much as 20% to maintain supplies for these needs. The capacity of the VDP means that it can only meet a proportion of water demand, and during drought periods water security is dependent on the volume of water already in storage at the start of these periods.

4. The aim of water supply system planning and operations is to maintain a buffer of water in storage, subject to pricing impacts, to be able to supply demand while rainfall and reservoir inflows vary from year to year. A sufficient storage buffer is especially critical during severe drought periods. These periods could last for more than a decade, as experienced in the 1997-2009 Millennium Drought. Thomson Reservoir, which provides around 60% of total system storage capacity, is Melbourne's drought reserve and was last full in November 1996, immediately prior to the Millennium Drought.

5. Since the VDP was completed in 2012, desalinated water has been ordered by the Victorian Government in 2016/17, 2017/18, 2018/19 and 2019/20. A total of approximately 167 GL of desalinated water has been delivered from 2017 up to 1 January 2020, with the remainder of the 2019/20 order to be delivered over the remainder of the 2019/20 period.

6. Figure 1 shows historical water storage levels since 2012.

[1] 1 gigalitre = 1 billion litres (the equivalent of around 400 Olympic swimming pools). In recent years, Melburnians have used around 450 GL of water per year.

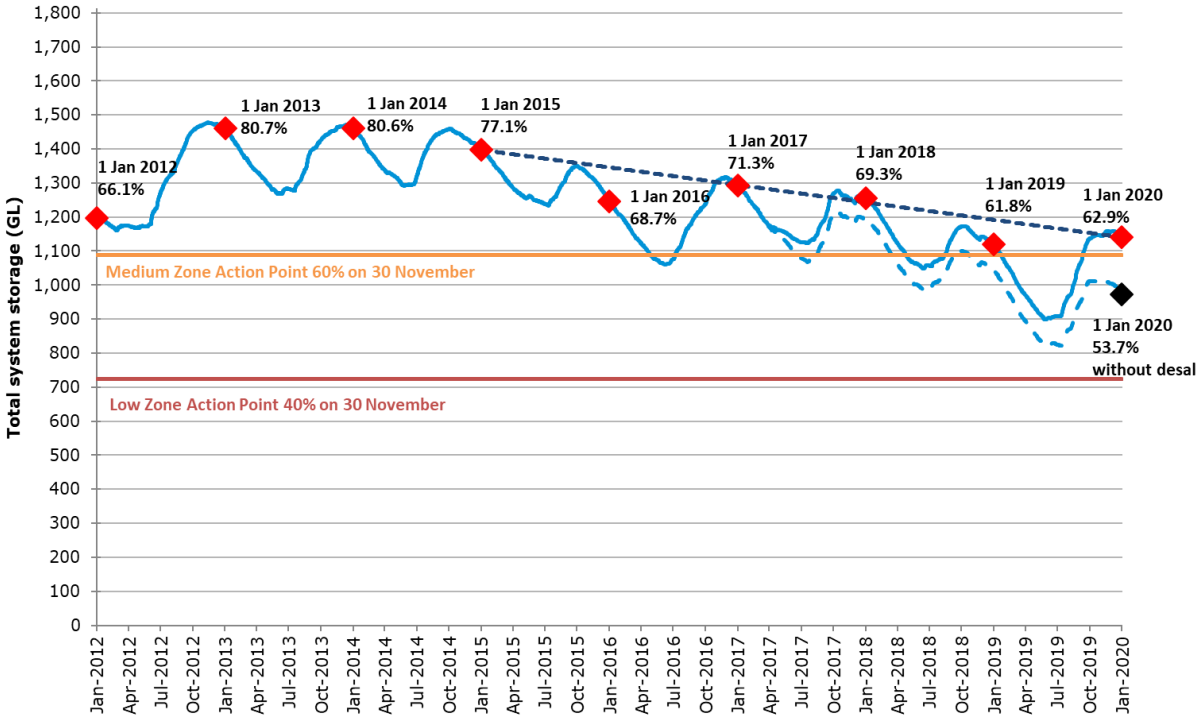

Figure 1: Historical water storage levels

7. Figure 1 shows that:

   - Melbourne's water storages were approximately 62.9% full (1,140 GL) on 1 January 2020 – slightly higher than the 61.8% at the same time in the previous year. Thomson Reservoir, Melbourne's drought reserve, held 599 GL (56.1% of its capacity) at 1 January 2020, 28 GL less than on 1 January 2019.
   - Based on 1 January storage volumes, there has been a declining trend over the last five years, with water storages falling by around 51 GL/year (or 2.8% per year of total storage capacity) on average.
   - As at 1 January 2020, the 167 GL of desalinated water delivered since 2017 had contributed the equivalent of 9.2% of current storage. Without this delivery, water storages would have fallen by around 85 GL/year on average over the last five years.

8. The declining water storage volumes and water security for the greater Melbourne area, illustrated in Figure 1, have been driven by lower streamflows and increased water demand in recent years. Over the past five years:

   - Average annual streamflows into Melbourne's four major harvesting storages (Thomson, Upper Yarra, O'Shannassy and Maroondah Reservoirs) have been approximately 404 GL/year, which is only 7% higher than average annual streamflow during the 1997-2009 Millennium Drought (376 GL/year) and is around 34% lower than the pre-1997 long-term average back to 1913 (615 GL/year), when streamflow began to be reliably recorded.
   - Population in Melbourne supplied by the three retail water businesses has grown to a total population of approximately 5 million people.
   - Average daily residential water use has increased slightly from 160 litres per person per day in 2014/15 to 162 litres per person per day in 2018/19.

- Primarily due to population growth, Melbourne's water demand has grown by approximately 12%, from 394 GL/year in 2013/14 to 442 GL/year in 2018/19.

Melbourne Water System Strategy

9. In 2017, Melbourne Water published the *Melbourne Water System Strategy*, which presents a system view of water resource management across Melbourne and the surrounding region over the following 50 years. The *Melbourne Water System Strategy* includes long-term water supply outlooks for each of the four streamflow scenarios described in the Department of Environment, Land, Water, and Planning (DELWP) *Guidelines for Assessing the Impact of Climate Change on Water Supplies in Victoria*. These long-term water supply outlooks suggest that under climate change impacts the reliable yield of the water supply system throughout an extended drought sequence will continue to decline over time, and is currently estimated to be around 525 to 575 GL/year, including the operation of the VDP at its full capacity of 150 GL/year. Without the VDP, the reliable yield of the water supply system from the surface water catchments falls below the projected 2020/21 demands for the retail and regional water businesses of around 444 GL (see paragraph 24). This highlights the increasingly important role of the VDP in the Melbourne water supply system in meeting the ongoing water needs of greater Melbourne and in managing the impacts of changing climate conditions and a growing population. Since the timing and severity of future extended drought sequences is uncertain, it is important to ensure preparedness for such an event by planning and operating the water supply system to maintain a buffer of water in storage, subject to pricing impacts.

Desalinated water order advice

10. The State of Victoria is required to place a desalinated water order with AquaSure by 1 April each year under the *Project Deed* between the two parties. Prior to this, the *Water Interface Agreement* between the Minister for Water, Melbourne Water, and the Secretary of DELWP requires Melbourne Water to provide the State of Victoria (represented by DELWP) with the following desalinated water order advice by 1 March:

    a) Its opinion of the volume of desalinated water required for the next financial year (i.e. 2020/21).

    b) Its opinion of the constrained months[2] (if any) that it considers should be subject to a constrained month cap and the proposed volume of such caps.

    c) A non-binding forecast of the quantity of desalinated water required for the next two financial years (i.e. 2021/22 and 2022/23).

11. Melbourne Water worked with the Melbourne retail water businesses (City West Water, South East Water and Yarra Valley Water), which hold the Bulk Entitlements to water from the VDP, to coordinate the process of consultation and deliver the extensive modelling and technical analysis required to support the development of the 2020/21 desalinated water order advice. Other water entitlement holders across the water grid were also consulted during the development of the 2020/21 desalinated water order advice, to ensure the advice reflected their forecast demands from the Melbourne system.

[2] Subject to conditions specified in the *Project Deed*, the State may specify the maximum volume of desalinated water which can be delivered (i.e. a constrained month cap) during the months of August, September, October and/or November.

Water Outlook zones

12. The desalinated water order advice is a key annual planning activity supporting short- and long-term water security for Melbourne and the surrounding region. The annual preparation of the advice follows from the publication of the *Water Outlook* by Melbourne Water and the retail water businesses on 1 December each year, and is linked to this process through the use of the Water Outlook zones in the preparation of the advice.

13. The retail water businesses' *Drought Preparedness Plans* specify a three-zone adaptive framework for monitoring water security based on the volume of water in Melbourne's storages on 30 November each year, as shown in Figure 2. As illustrated in Figure 1, the end of November is typically when Melbourne's water storage volumes transition from rising during the cooler, wetter months, to falling during the warmer, drier months. Notable features of the framework are:

    - A Water Outlook is published by 1 December each year by Melbourne Water and the retail water businesses to document and communicate water security status and actions needed in the short to medium term with reference to the three-zone adaptive framework.
    - Storages are managed proactively for possible future severe drought events when storage levels are in the High Zone including ensuring water is used efficiently and drought response measures are identified.
    - When storages are in the Medium Zone, actions are taken to ensure supply is available under severe and extended drought conditions for up to five years. Stages 1 and 2 of the retail water businesses' water restrictions by-laws may also be used in this zone, although water restrictions can have significant social and economic impacts, so other approaches (e.g. voluntary water efficiency programs) may be implemented if similar reductions in water use can be achieved.
    - Actions are taken to ensure water storages do not enter the Low Zone except in extreme circumstances. Stages 3 and 4 of the retail water businesses' water restriction by-laws are available to be used in such a severe event.
    - Varying water ordered from the VDP is an option in all three zones, however the amount taken is determined through detailed analysis that considers and balances the five principles and other factors (discussed below), including being in the Low and Medium Zones in the Drought Preparedness Plans.

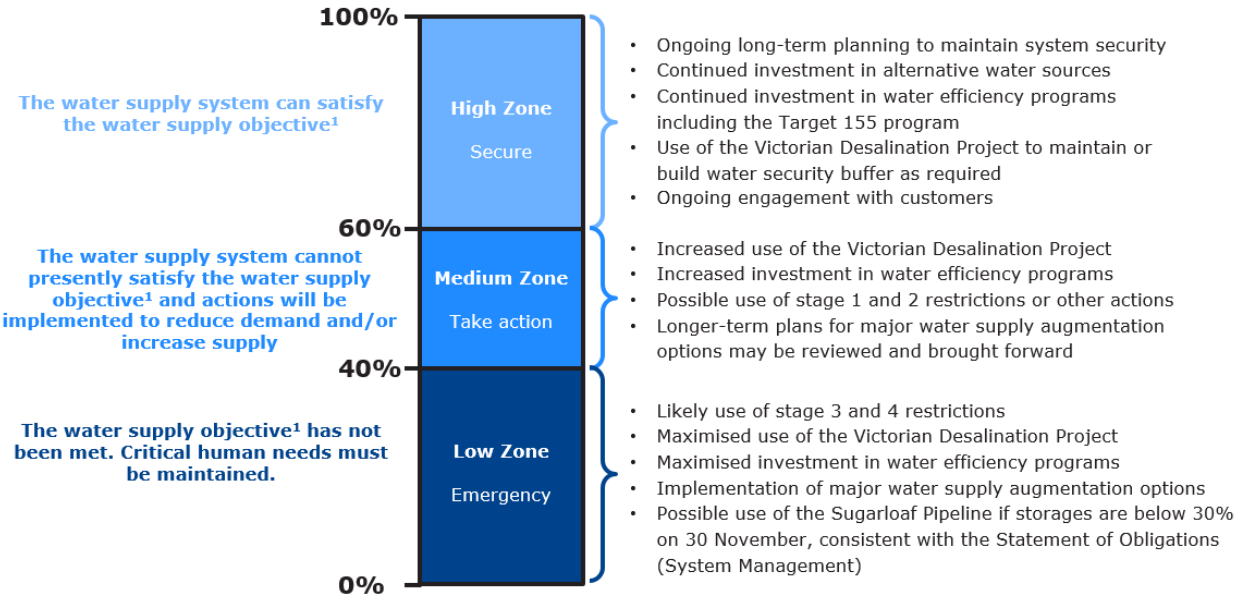

Figure 2: Melbourne's adaptive water security framework

14. In the development of the desalinated water order advice, the Water Outlook zones are used to measure potential future water security by comparing projections of future water storage levels against the three zones.

15. The retail water businesses' *Drought Preparedness Plans* are periodically reviewed to ensure a similar level of water security is maintained with growing population and changing water use, and changing streamflow conditions under climate change. The retail water businesses' current *Drought Preparedness Plans* were implemented in 2017, and will be reviewed prior to 2022 to take account of changed water demand and expected hydrological conditions. More information on the 2017 review of the *Drought Preparedness Plans* can be found in the *Melbourne Water System Strategy* and the retail water businesses' *Urban Water Strategies*.

16. The 2020 Water Outlook for Melbourne, published on 29 November 2019, noted that while storages were in the High Zone (63.9%) and therefore secure for the coming year, it was only 3.9% (approximately 70 GL) above the Medium Zone storage level, and that reducing customer demand and continued use of the VDP would improve storage recovery and minimise the risk of falling into the Medium Zone on 30 November 2020.

Principles

17. Consistent with the approach established by the water businesses and used in previous years, the 2020/21 desalinated water order advice is based around five principles. These were developed and assessed by the water businesses to balance the benefits of using the VDP in maintaining the short- and long-term security of supply to customers against the costs of placing an order and the potential for foregone water harvest[3]. Short-term water security is maintained by avoiding going into the Low Zone, and minimising the risk of going into the Medium Zone, while long-term water security is achieved by driving storage

[3] 'Foregone harvest' is defined as the modelled additional flow over dam spillways from the Melbourne water supply system and/or reduced harvest into Sugarloaf Reservoir for each modelled streamflow sequence due to the desalinated water order volumes supplied.

recovery over a number of years. The advice is based on the water businesses assessing an appropriate balance across these principles. The advice is prepared recognising that while the first year order is contractually binding, the opportunity to revisit the volume required in each of the second and third years, as part of the annual planning and ordering cycle, allows adaptation based on the storage levels and outlooks at the time. The technical assessments of different potential desalinated water order volumes for 2020/21 described later in this document take this ability to adapt subsequent order volumes into account.

18. The intent of the principles is to provide for water security for Melbourne and surrounding regions supplied from the system by avoiding storages from falling to low levels, while avoiding the potential for foregoing harvest of lower cost water from within the system in wetter years (although this can potentially provide environmental benefits for downstream waterways). In satisfying these at times competing objectives, customer impacts should be minimised. The principles are:

    - **Principle 1: Chance of storage volume falling below the Low Zone Action Point**
      Storages should remain above the Low Zone described in the retailers' Drought Preparedness Plans on 30 November 2020, 30 November 2021 and 30 November 2022 under a severe drought sequence, which is defined as the driest sequence among the modelled streamflow sequences.
    - **Principle 2: Chance of storage volume falling below the Medium Zone Action Point**
      Storages should remain above the Medium Zone described in the retailers' Drought Preparedness Plans on 30 November 2020, 30 November 2021 and 30 November 2022 under 90 per cent of modelled streamflow sequences.
    - **Principle 3: Storage Recovery**
      Storages should display a recovery trend such that the median (50th percentile) modelled total system storage levels across the modelled streamflow sequences increase in 2020/21, 2021/22 and 2022/23.
    - **Principle 4: Risk of desalinated water causing avoidable foregone harvest**
      Foregone water harvest should be less than 12.5 GL/year for at least 50% of modelled streamflow sequences, and less than 25 GL/year for at least 90% of modelled streamflow sequences in 2020/21, 2021/22 and 2022/23. 'Foregone water harvest' is defined as the modelled additional flow over dam spillways from the Melbourne water supply reservoirs and/or reduced harvest into Sugarloaf Reservoir for each modelled streamflow sequence due to the desalinated water order volumes supplied. All water may not be harvested from smaller storages and weirs in wetter years.
    - **Principle 5: Customer impacts**
      The impacts on the retailers' customers' bills should be minimised while providing an acceptable security of supply.

19. Potential desalinated water order pathways were assessed against the five principles using detailed technical analysis described later in this report.

Technical analysis inputs and assumptions

Initial water storage levels

20. Water resource modelling for the 2020/21 advice projects possible future water storage levels from those observed on 1 January 2020 (1,140 GL or 62.9%). Approximately 186 GL of the water in storage on 1 January 2020 was allocated to entitlement holders other than the retail water businesses, including the regional water businesses, the Victorian Environmental Water Holder, and Southern Rural Water. Water resource modelling supporting the desalinated water order advice considers both inflows and demands associated with all entitlement holders in the Melbourne system. The distribution of water across the 10 major storage reservoirs in the Melbourne water supply system on 1 January 2020 is shown in Table 1.

Table 1: Distribution of water across the 10 major storage reservoirs in the Melbourne water supply system on 1 January 2020

Reservoir	Capacity at full supply (ML)	Volume (ML)	% Full
Thomson	1,068,000	599,089	56.1%
Upper Yarra	200,579	89,087	44.4%
O'Shannassy	3,123	237	7.6%
Maroondah	22,179	20,105	90.6%
Sugarloaf	96,253	92,949	96.6%
Yan Yean	30,266	20,879	69.0%
Greenvale	26,839	21,780	81.2%
Silvan	40,445	35,649	88.1%
Cardinia	286,911	236,209	82.3%
Tarago	37,580	24,367	64.8%
Total	**1,812,175**	**1,140,351**	**62.9%**

21. The observed water storage levels on 1 January 2020 increased slightly (19.6 GL, or 1.1% higher) over water storage levels on 1 January 2019. During 2019, observed streamflows were approximately 4% below the average of the last 30 years, due to the drier conditions for the first half of 2019. In 2019, storages received 91 GL of the 125 GL desalinated water order for 2019/20.

Streamflow scenario

22. The technical analysis was based on modelling with the 'Post-1997 step climate change' streamflow scenario described in the 2016 *Guidelines for Assessing the Impact of Climate*

Change on Water Supplies in Victoria prepared by DELWP. The use of the 'Post-1997 step climate change' streamflow scenario is representative of streamflows observed in recent history and therefore appropriate for developing the three year desalinated water order advice. The methodology used to establish this streamflow scenario results in consideration of some drought sequences more severe than those that have occurred historically and during the Millennium Drought (1997 – 2009).

23. The 'Post-1997 step climate change' streamflow scenario uses the observed streamflows for the period July 1997 to December 2019, with the observed streamflows from January 1913 to June 1997 adjusted to match the statistical properties of the period July 1997 to June 2019. The difference between the observed historical streamflows (grey bars) and the adjusted streamflows (orange bars) are illustrated in Figure 3. In the water resource modelling, the 107 years of streamflow data, with the adjusted streamflows from 1913 to 1997, are used to create 107 streamflow replicates (also referred to as streamflow sequences), that are used to assess the performance of potential desalinated water order pathways against a range of potential streamflow conditions.

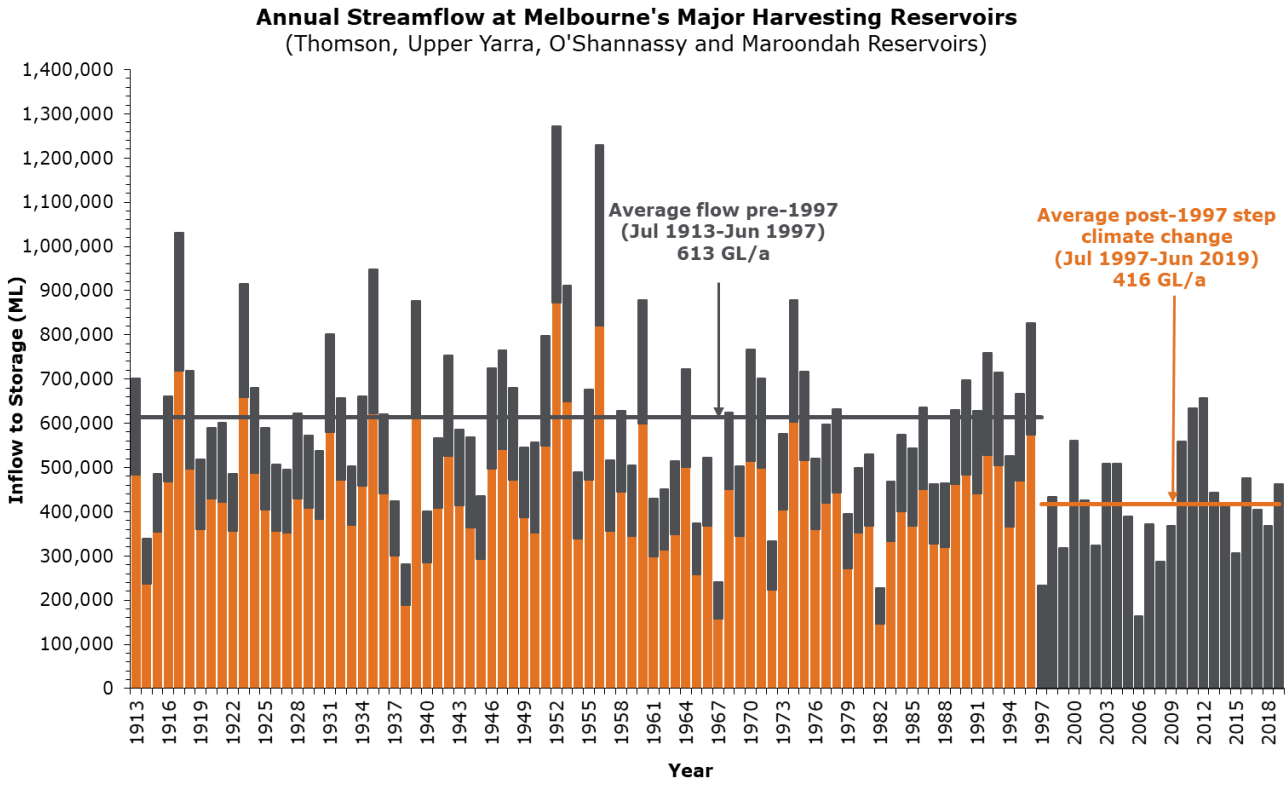

Figure 3: 'Post-1997 step climate change' streamflow scenario

Demand forecasts

24. To support the desalinated water order advice development process, the retail and regional water businesses provided demand forecasts for the next 15 years. Focusing on the first three years covered by the advice, the demand forecasts provided are outlined in Table 2. These demand forecasts assume the Target 155 program and Permanent Water Use Rules are in place. In the water resource modelling, these expected demand forecasts are adjusted in each modelled year using a climate index to reflect the potential variability in demand typically observed in warmer and drier or cooler and wetter years. The demand forecasts for the retail water businesses outlined in Table 2 reflect the impact of significant recent growth in Melbourne's population.

Table 2: Demand forecasts provided by the retail and regional water businesses

Year	Retail water businesses (GL)	Regional water businesses (GL)	Total (GL)[1]
2020/21	444	18	462
2021/22	447	17	464
2022/23	451	17	468

[1]Total calculated based on sum of retail and regional water businesses before rounding to the nearest 1 GL

25. The water demand forecasts in Table 2 do not include environmental water releases from water entitlements held by the Victorian Environmental Water Holder. For modelling purposes, it was assumed that the Victorian Environmental Water Holder would use 2019/20 planned releases and the annual allocation each year thereafter. The environmental allocations for key modelled river systems include:

    - Yarra River system: 17 GL/year
    - Thomson River system: 10 GL/year plus 3.9% of inflows to Thomson Reservoir (under the 'Post-1997 step climate change' streamflow scenario, 3.9% of inflows to Thomson Reservoir is approximately 6.8 GL/year on average).

26. The water demand forecasts in Table 2 also do not include rural irrigation water releases from water entitlements held by Southern Rural Water. For modelling purposes, it is assumed that Southern Rural Water uses their annual allocation of 6% of inflows to Thomson Reservoir each year (under the 'Post-1997 step climate change' streamflow scenario, 6% of inflows to Thomson Reservoir is approximately 10.5 GL/year on average).

Operational considerations

27. The technical analysis supporting the 2020/21 desalinated water order advice also takes into account planned asset and operational factors including:

    - **Upper Yarra Reservoir:** Modelling has included the effect of dam improvement works currently in progress, and the requirement to temporarily maintain storage volumes at around 91 GL (full supply level approximately 200 GL) during the period of the works. During the works, Upper Yarra Reservoir also has to be operated within a narrow operational band of around 9 GL. The works are planned for completion by mid-2021.
    - **Cardinia Reservoir:** The modelling includes a maximum operating volume of 263 GL (full supply level approximately 286 GL), consistent with dam management guidelines until embankment improvement works are completed. Cardinia Reservoir is required to store desalinated water delivered, but is also required to store wet season streamflows from Upper Yarra Reservoir (during the dam improvement works), as well as the upper Yarra River tributaries.
    - **Yan Yean Reservoir:** Modelling takes account of the expected timing for completion of the Yan Yean Reservoir water treatment plant upgrades in 2021.
    - **O'Shannassy Reservoir:** Current upgrades of the outlet works until June 2020 are included in the modelling.

    Other key modelling assumptions related to water supply system operations are similar to those used in previous years, including:

    - **Winneke** and **Tarago water treatment plants** planned operating capacity for 2020/21 and subsequent years thereafter was taken as 130 GL/year and 16 GL/year respectively, with output depending on water availability at these sites and others.

Cost information

28. To support water resource modelling and price modelling, DELWP provided estimates of costs associated with each of the desalinated water order volume options based on the best available information.

Technical analysis results

29. Water resource modelling was undertaken to support the 2020/21 desalinated water order advice, which provides an outlook from 1 January 2020 to 30 June 2023, covering the three financial years for which advice is required under the *Water Interface Agreement*. This modelling process considers all possible desalinated water orders that could be placed under the *Project Deed* during this three year period (including 0 GL), and identifies the desalinated water orders most likely to lead to outcomes consistent with the principles described in paragraph 18.

30. The water resources modelling separately considers each of the seven possible orders from 0 to 150 GL in the first year of the three-year desalinated water order advice. For each of these seven possible first year (2020/21) orders, Melbourne's water supply system is modelled over the next three and a half years under 107 different streamflow sequences. For each streamflow sequence, the model selects the second (2021/22) and third year (2022/23) desalinated water orders that best meet the five principles under that particular sequence.

31. The water resources modelling results are summarised in Table 3. These results reflect, for a given 2020/21 desalinated water order volume, the risks after taking into account the potential to increase or decrease desalinated water orders in 2021/22 and 2022/23 in response to observed conditions.

    Table 3 also includes results derived from price modelling undertaken by the retail water businesses, to assess the indicative impact of each potential 2020/21 order volume on a typical residential customer bill in 2020/21 based on the use of 150 kilolitres/year. The price modelling was focused on the additional costs associated with each of the various potential order volumes, and does not reflect the impact of the annual security payment. The annual impacts on typical residential customer bills are indicative only and will vary across metropolitan water business and depend on individual household use patterns. Typical residential customer bills will also be impacted by a range of other factors in addition to the costs associated with the desalinated water order.

2020/21 desalinated water order volume (GL)	Average order volume across all streamflow replicates (GL)		Principle 1			Principle 2			Principle 4						Principle 3			Principle 5		
			Percentage of streamflow replicates that fall into the Low Zone (below 40% on 30 November)			Percentage of streamflow replicates that fall into the Medium Zone (below 60% on 30 November)			10th percentile foregone harvest (90% of streamflow replicates have foregone harvest less than this volume) (GL)			50th percentile (median) foregone harvest (50% of streamflow replicates have foregone harvest less than this volume) (GL)			50th percentile (median) storage recovery (50% of streamflow replicates have greater storage recovery than this volume) (GL)			Average discounted cost of producing desalinated water over the three year outlook period ($M)	Indicative annual impact of 2020/21 order on typical residential customer bill (150 kL) ($/yr)	Average change in order volume between years across all streamflow replicates
			Principle target: 0%			Principle target: Less than 10%			Principle target: Less than 25 GL			Principle target: Less than 12.5 GL			Principle target: More than 0 GL			Principle target: Minimise impacts (magnitude and variability) on customer bills in all three years		
	Year 2	Year 3	Year 1	Year 2	Year 3	Year 1	Year 2	Year 3	Year 1	Year 2	Year 3	Year 1	Year 2	Year 3	Year 1	Year 2	Year 3	All three years	Year 1	All three years
0 GL	132	134	0	2	4	45	43	27	0	7	27	0	0	9	-54	79	67	198	-38	92
15 GL	129	131	0	2	2	43	36	25	1	8	27	0	2	9	-40	73	67	204	-34	83
50 GL	117	118	0	1	2	38	28	21	3	11	33	0	4	10	-5	58	43	202	-28	60
75 GL	105	114	0	0	0	35	24	19	5	13	35	0	5	9	19	38	39	206	-22	47
100 GL	96	104	0	0	0	29	21	15	12	16	33	0	8	8	44	25	29	211	-16	38
125 GL	79	97	0	0	0	25	19	12	18	19	33	0	9	6	69	15	20	218	-10	34
150 GL	65	85	0	0	0	17	16	11	28	24	31	1	11	6	86	9	15	225	-4	48

Table 3: Summary of assessment against the five principles for all potential 2020/21 desalinated water order volumes

32. Table 3 suggests that:

    - **Principle 1 - Avoid being in the Low Zone:** At least a 75 GL order is required in 2020/21 to ensure the assessed chance of storages falling into the Low Zone on 30 November is 0% in all three years of the advice period.
    - **Principle 2 – Minimise risk of being in the Medium Zone:** Given current storage volumes, modelling shows there are no order volumes in 2020/21 that can reduce the future chance of storages falling into the Medium Zone on 30 November below 10% in any of the three years of the advice period. A 150 GL order is required to keep the risk of storages falling into the Medium Zone below 20% in all years of the advice period, while a 125 GL order keeps the risk to 25% or less in all years of the advice period. These outcomes are due to 1 January 2020 water storage levels at the beginning of the advice modelling already being close to the Medium Zone storage volume.
    - **Principle 3 – Maximise storage recovery:** At least 75 GL is required in 2020/21 to enable at least a 50% chance of storages recovering in all three years covered by the order advice. Order volumes of 100 GL or more provide the volumes necessary to aid more rapid storage recovery and build a buffer of water in storage that can be used to manage future dry periods.
    - **Principle 4 – Minimise foregone harvest:** Orders less than 150 GL will maintain foregone water harvest within the benchmark of less than 25 GL in 2020/21 and 2021/22 for at least 90% of modelled streamflow sequences. No potential 2020/21 order volumes result in foregone water harvest less than 25 GL in 2022/23 for at least 90% of modelled streamflow sequences.
    - **Principle 5 – Minimise customers' bill impacts:** Price modelling indicates that all 2020/21 order volumes would result in a decrease in the indicative typical residential customer bills. Water resource modelling indicates that the order pathways with the lowest variation in projected desalinated order volumes across the three year order period are those with 100 GL and 125 GL in 2020/21.

33. Figure 4 illustrates projected water storage levels over the next three financial years for the 107 replicates of streamflow associated with the 'Post-1997 step climate change' streamflow scenario. Figure 4 assumes, for example, that 125 GL is ordered in 2020/21, followed by orders in 2021/22 and 2022/23 adapted for each streamflow replicate as needed to deliver outcomes consistent with the principles.

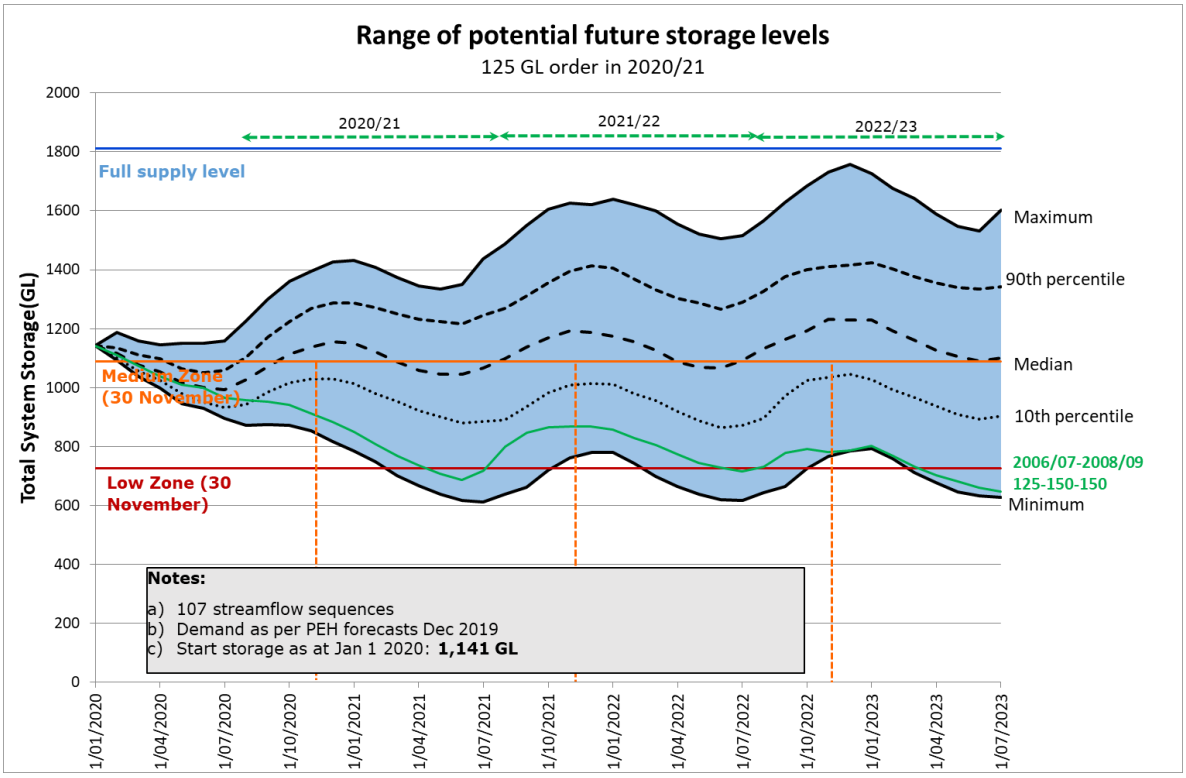

Figure 4: Modelled projection of potential future water storage levels assuming a 125 GL order in 2020/21

34. In Figure 4, the projected water storage levels if streamflows are similar to those observed in 2006/07, 2007/08 and 2008/09 (a particularly dry sequence within the Millennium Drought period) were to be repeated are highlighted in green. For this particular streamflow sequence, the modelling suggests that it could be appropriate to order 150 GL in both 2021/22 and 2022/23, although water storage levels would still fall into the Medium Zone (on 30 November) for at least the next three years.

35. Other scenarios were also modelled to test the sensitivity of the model results in terms of performance against the principles, including a scenario with higher demands, and a scenario with higher streamflows.

36. For the higher demand sensitivity scenario, retail water businesses' high demand projections were used, and the regional water businesses' demands and assumed Southern Rural Water and Victorian Environmental Water Holder usage were increased to higher scenarios as provided. Under this higher demand sensitivity scenario, results from technical analysis suggest that there are no 2020/21 order volumes that can ensure the assessed risk of storages falling into the Low Zone on 30 November is 0% in all three years of the advice period.

37. For the higher streamflow sensitivity scenario, the 'Post-1975' streamflow scenario described in the 2016 *Guidelines for Assessing the Impact of Climate Change on Water Supplies in Victoria* prepared by DELWP was used, which assumes future streamflows will reflect those that have been observed since 1975 and are some 19% higher than the 'Post-1997' scenario. Under this higher streamflow sensitivity scenario, results from technical analysis suggest that at least a 75 GL order is required in 2020/21 to ensure the assessed risk of storages falling into the Low Zone on 30 November is 0% in all three years of the advice period. In this scenario, ordering 150 GL in 2020/21 is required to reduce the risk of entering the Medium Zone on 30 November 2020 to 10%. However, for this scenario, ordering 100 GL or more would also result in 10th percentile foregone harvest increasing to more than 25 GL in all three years of the advice period.

Foregone harvest and the constrained month caps

38. With the delivery of the 2019/20 125 GL desalinated water order, 91 GL (or 73%) of the total order was delivered by 1 January 2020. A sensitivity scenario was analysed where various possible 2020/21 orders were modelled using the same delivery timing profile as the 2019/20 order. Under this delivery profile, only orders less than 75 GL will maintain foregone harvest within the benchmark of less than 25 GL in 2020/21 and 2021/22 for at least 90% of modelled streamflow sequences. For this delivery profile with a 125 GL order, the 50th percentile of climate scenarios result in a foregone harvest of 1 GL while the 90th percentile of climate scenarios (wetter years) result in a foregone harvest of 30 GL.

39. The *Project Deed* allows the State to limit the volume of desalinated water supplied in August, September, October and/or November to one twelfth of the annual water order, for an additional cost.

40. By applying a constrained month cap to the desalinated water delivery in August 2020, while also pumping from Cardinia to Silvan, orders of 125 GL or less are expected to maintain foregone harvest within the agreed acceptable criteria of less than 25 GL in 2020/21 for at least 90% of modelled streamflow sequences. A 150 GL order in wetter years does not satisfy the foregone harvest principle.

41. For an order volume of 125 GL in 2020/21, analysis suggests a benefit in applying a constrained month in August 2020.

Other considerations

Climate outlooks

42. The desalinated water order advice was informed by the Bureau of Meteorology's seasonal streamflow forecasts and ENSO Wrap-up issued during January 2020.

    - The ENSO Wrap-up (issued 21 January 2020) indicated that:
        - 'The El Niño–Southern Oscillation (ENSO) and Indian Ocean Dipole (IOD) is currently neutral.'
        - 'The Bureau's ENSO Outlook is currently INACTIVE. This means there is little or no sign of El Niño or La Niña developing in the coming months.'
        - 'When these main climate drivers are neutral, Australia's climate can be influenced by more local or short-term climate drivers.'
        - 'It should be noted that model outlooks that span the southern autumn period tend to have lower accuracy than outlooks issued at other times of the year. This means outlooks beyond May should be used with some caution.'
    - The seasonal streamflow forecasts for Melbourne's four major harvesting storages (issued mid-January 2020 and illustrated in Figure 5) generally favoured low flow for the period January to March 2020.

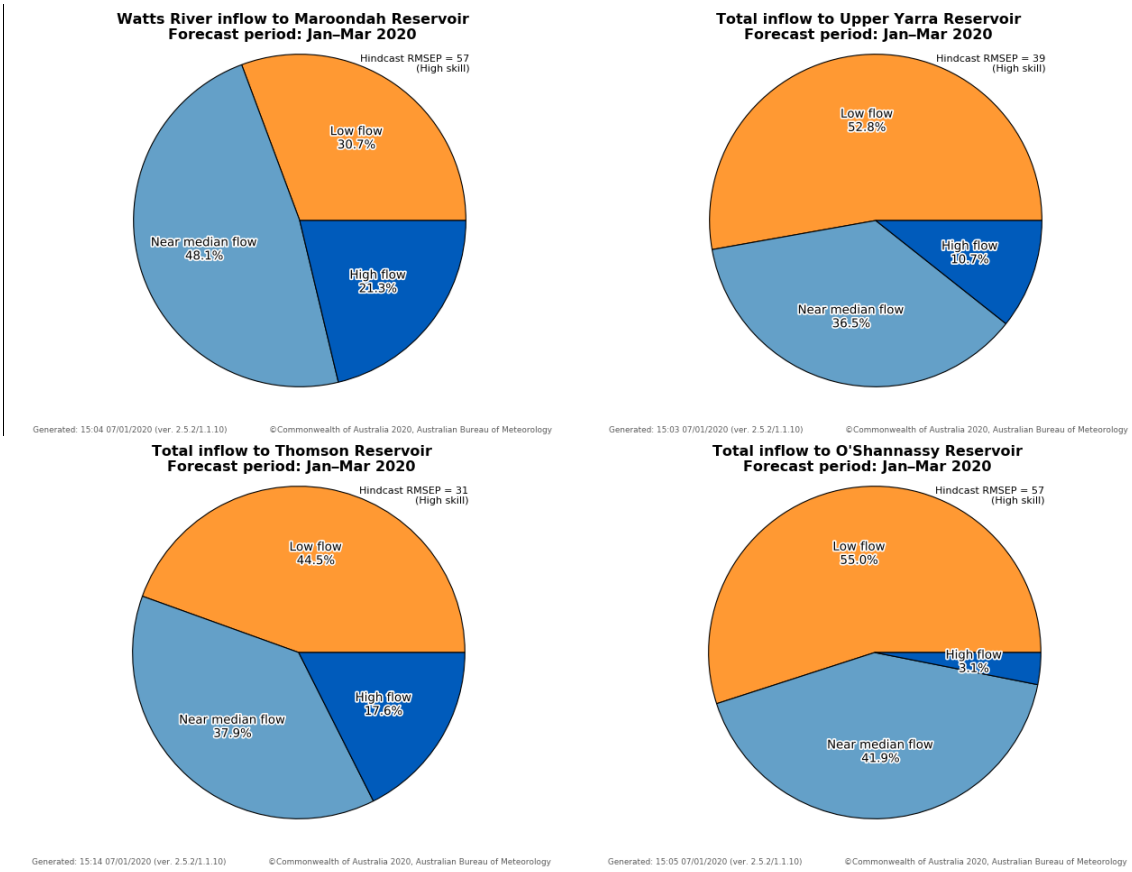

Figure 5: Seasonal streamflow forecast for Melbourne's four major harvesting storages for January to March 2020 (Source: Australian Government Bureau of Meteorology)

43. More generally, the Bureau of Meteorology climate outlooks issued on 16 January 2020 indicated for the period February to April 2020 approximately:
    - 45-50% chance of exceeding median rainfall.
    - 60-75% chance of exceeding median maximum temperature.

44. While these outlooks did not extend over the three years of the desalinated water order advice period, they highlighted that in the short term streamflow conditions were unlikely to result in storage volumes in the higher storage volume range in Figure 4.

Value of Water in Storage

45. The 2018 Melbourne University study 'The economic value of water in storage' found that:
    - Storing additional water can have important economic value as it can reduce or defer the need to augment the water supply system.
    - Additional storage can reduce the severity and impact of water restrictions, and the resulting economic and social costs.
    - It is preferable to run a desalination plant on a consistent basis to build a storage buffer, rather than as a drought response measure.

46. The severe droughts recently experienced in Northern and Eastern Victoria, and over large parts of New South Wales and Queensland, with the resulting social and economic costs, underline the importance of having a buffer in water storages, to increase water supply system resilience and reduce the economic and social impact of restrictions in the event of low storage volumes.

47. The average annual streamflow into Melbourne's four major harvesting reservoirs over the last five years is below the total annual potable water demand from the water supply system. In the medium to long term, yield is projected to continue to decrease while demand is projected to continue to increase. As a result:
    - Water storage levels will, in an average year, continue to decrease without the supply provided by the VDP.
    - Increasingly large desalinated water orders will therefore be necessary in order to maintain or recover storage levels.
    - Prior to the VDP's capacity being required to primarily supply growing base demand in future, larger orders can be used to build a storage level buffer for drought resilience.
    - Augmentation to the water supply system will become necessary as the gap between water demand and yield means that water security cannot be maintained otherwise.
    - Larger desalinated water orders made earlier will function as a buffer on storage levels, delaying the need for augmentation and increasing Melbourne's resilience to extreme climate events such as droughts.

Technical outcomes

48. To ensure water security by managing the Low and Medium Zone risks, while supporting storage recovery and a buffer against the impacts of future drought, 100 GL, 125 GL and 150 GL were part of the final consideration for the 2020/21 desalinated water order.
49. While the 150 GL option provided the best water security benefits, the risk of foregone harvest was above the agreed acceptable criteria in the principle.
50. The 100 GL option has the least risk of foregone harvest, however it would also provide the lowest expected increase in average storage volumes and hence the least water security benefits of the three options.
51. The risks of foregone harvest for an order of 125 GL are able to be managed by applying one constrained month and pumping water back from Cardinia to Silvan Reservoir, while also satisfying the principles of improving water security.
52. To best balance the need to drive storage recovery and increase the storage buffer, with managing the increased risk of foregone harvest due to current capacity constraints associated with dam improvement and safety works, a 125 GL desalinated water order for 2020/21 is most aligned with the desalination order advice principles. Thereafter, non-binding forecasts of 150 GL in 2021/22 and 150 GL in 2022/23 are recommended to improve Melbourne's water security and the resilience of the water supply system in the face of a drying climate and growing population.

Conclusion

53. Consistent with the requirements of the *Water Interface Agreement* described in paragraph 10, the following desalinated water order advice has been provided by Melbourne Water to the Victorian Government:
    a. The desalinated water order advice for 2020/21 should be 125 GL.
    b. The month of August be subjected to a constrained month cap of 10.417 GL.
    c. A non-binding forecast of the quantity of desalinated water required is 150 GL in 2021/22 and 150 GL in 2022/23 (which are both inclusive of the 15 GL minimum order volume).