

ISSUES PAPER

**Review of water and sewerage services
demand forecasting methodology**

Report 10 of 2021, May 2021



The Independent Competition and Regulatory Commission is a Territory authority established under the *Independent Competition and Regulatory Commission Act 1997* (the ICRC Act). We are constituted under the ICRC Act by one or more standing commissioners and any associated commissioners appointed for particular purposes. Commissioners are statutory appointments. Joe Dimasi is the current Senior Commissioner who constitutes the commission and takes direct responsibility for delivery of the outcomes of the commission.

We have responsibility for a broad range of regulatory and utility administrative matters. We are responsible under the ICRC Act for regulating and advising government about pricing and other matters for monopoly, near-monopoly and ministerially declared regulated industries, and providing advice on competitive neutrality complaints and government-regulated activities. We also have responsibility for arbitrating infrastructure access disputes under the ICRC Act.

We are responsible for managing the utility licence framework in the ACT, established under the *Utilities Act 2000* (Utilities Act). We are responsible for the licensing determination process, monitoring licensees' compliance with their legislative and licence obligations and determination of utility industry codes.

Our objectives are set out in section 7 and 19L of the ICRC Act and section 3 of the Utilities Act. In discharging our objectives and functions, we provide independent robust analysis and advice.

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Correspondence or other inquiries may be directed to the commission at the following address:

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We may be contacted at the above address, or by telephone on (02) 6205 0799. Our website is at www.icrc.act.gov.au and our email address is icrc@act.gov.au.

How to make a submission

This issues paper provides an opportunity for stakeholders to provide feedback and evidence to inform the development of the draft report. It will also ensure that relevant information and views are made public and brought to the commission's attention.

Submissions on the issues paper close on **Friday 25 June 2021**.

Submissions may be mailed to the commission at:

Independent Competition and Regulatory Commission
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Civic Square ACT 2608

Alternatively, submissions may be emailed to the commission at icrc@act.gov.au. The commission encourages stakeholders to make submissions in either Microsoft Word format or PDF (OCR readable text format – that is, they should be direct conversions from the word-processing program, rather than scanned copies in which the text cannot be searched).

For submissions received from individuals, all personal details (for example, home and email addresses, and telephone and fax numbers) will be removed for privacy reasons before the submissions are published on the website.

We are guided by the principles of openness, transparency, consistency, and accountability. Public consultation is a crucial element of our processes. Our preference is that all submissions are treated as public and are published on our website unless the author of the submission indicates clearly that all or part of the submission is confidential and not to be made available publicly. Where confidential material is claimed, we prefer that it is provided as a separate document and clearly marked 'In Confidence'. We will assess the author's claim and discuss appropriate steps to ensure that confidential material is protected while maintaining the principles of openness, transparency, consistency and accountability.

We can be contacted at the above address, by telephone on (02) 6205 0799 or through our website at www.icrc.act.gov.au.

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1. What is this review about?

We are reviewing the methods used to forecast demand for water and sewerage services in the Australian Capital Territory (ACT). Good demand forecasts are important because they help us to set prices that allow Icon Water to recover only prudent and efficient costs. Good demand forecasts help Icon Water plan its operations and investment program to meet demand. They also help us estimate the cost of providing services, including assessing the prudence and efficiency of Icon Water's proposed expenditure during our price investigations.

We review our regulatory models and forecasting methods regularly to confirm that they remain appropriate and to ensure they reflect relevant developments in the regulated industry, technology, and consumer preferences and behaviours. We also consider current modelling and forecasting approaches adopted by other regulators to ensure our methods are based on good regulatory practice. And we check for new and improved data sources to make sure we use the best available information and data in our models and forecasts. This review is part of our broader strategy to make sure our modelling and forecasting methods remain fit for purpose.

This review is an opportunity for industry, consumer, environmental, community and other stakeholders to tell us if our demand forecasting methods are fit for purpose or if there could be scope to improve our approach. Stakeholder feedback is important for ensuring we consider all relevant information and views.

If we decide our forecasting methods or data sources can be improved, we will make the improvements in our next price investigation to set regulated water and sewerage services prices for the regulatory period beginning on 1 July 2023.

1.1 Background to the review

We are the Australian Capital Territory's (ACT) independent economic regulator. We regulate prices, access to infrastructure services and other matters in relation to regulated industries in the ACT. We also have functions under the *Utilities Act 2000* (Utilities Act) for licensing electricity, natural gas, water and sewerage utility services, and making industry codes.

Icon Water is the monopoly provider of water and sewerage services in the ACT. We set the maximum prices Icon Water can charge for the supply of water and sewerage services, and the guaranteed service levels for water and sewerage services in the Consumer Protection Code (ICRC 2020a), made under the Utilities Act.

We undertake price investigations under Part 3 of the ICRC Act, and issue price directions under Part 4 of the ICRC Act. The 2018 Price Direction sets out our methodology for setting the maximum prices that Icon Water can charge for water and sewerage services from 1 July 2018 to 30 June 2023.

We decided to review our demand forecasting methods in our 2018 water and sewerage services price investigation. We saw value in checking that our methods are still fit for purpose, and we are using the best available data sources, or if there is scope to improve our forecasting methods or data sources. During our

2018 price investigation, we found the medium-term demand forecasts were highly sensitive to minor updates to the data used in the models. We also noted that future changes in the climate, water policies and population growth in the ACT could potentially cause historical trends to become less accurate for use in our forecasting model. We concluded it was important to check our methods and data inputs.

We believe it is important to review our methods regularly and invite stakeholders to comment on new evidence or analytical techniques that may improve our models. This way we can ensure our methods remain up-to-date and reflect new evidence and analysis.

1.2 Importance of demand forecasts

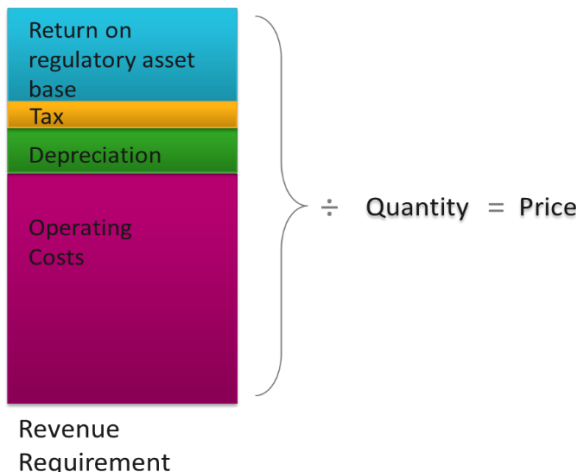
Demand forecasts are an important input for setting prices

We use demand forecasts to set maximum prices for water and sewerage services so Icon Water can recover its costs of providing those services.

We use a ‘building block’ methodology to determine the prudent and efficient costs that Icon Water can recover from its customers in a regulatory period. Under the building block model, the revenue that Icon Water can earn for a regulatory period is the sum of the operating expenditure, a contribution to the cost of capital investments made over time, and allowances for forecast tax paid by the business.

This total allowed revenue is then divided by the forecast demand for each service, which includes estimates of future water usage and expected number of water and sewerage service connections, to derive a price for each service (illustrated in figure 1.1). That is, Icon Water’s costs are spread over the demand to set the prices.

Figure 1.1 Simplified building block methodology



We need detailed forecasts for water and sewerage services demand to set prices for individual services

We need forecasts of demand for water and sewerage services to help estimate the unit cost of providing these services (for example, the cost per kL of water). We also use demand forecasts to calculate prices that will allow Icon Water to earn enough revenue given its costs:

- Icon Water earns revenue from water sales via a supply charge (per day) and a two-tier usage charge that depends on the amount of water used by a customer. Therefore, we need forecasts of customer numbers and water usage to determine prices that will allow Icon Water to earn enough revenue to recover its costs.
- Icon Water earns revenue from sewerage services via fixed supply charges. There is a fixed supply charge for residential customers and non-residential customers. There is also an additional fixed charge that applies to non-residential customers with more than two flushable fixtures. We need forecasts of sewerage installations to determine prices that will allow Icon Water to recover its costs.
- The cost of sewerage services depends on sewerage volumes. Therefore, we need an estimate of sewerage volumes to understand the costs faced by Icon Water.

Good demand forecasts ensure only prudent and efficient costs are included in setting prices

Demand forecasts help us to assess the prudence and efficiency of Icon Water's proposed expenditure during our price investigations. Icon Water's cost of providing the services depends on the demand. For example, Icon Water's infrastructure needs to be large enough to meet demand but not too large so that unnecessary costs are incurred. Good demand forecasts can help us assess whether Icon Water's capital investment program and forecast operating costs are prudent and efficient. This helps us ensure that consumers pay for only those costs that are necessary to meet their demand for services.

Good demand forecasts also help Icon Water plan its operations to meet demand. For example, they improve Icon Water's information base for its investment decisions. This helps Icon Water ensure that it incurs only those costs needed to meet demand for water and sewerage services, that is, prudent and efficient costs.

Good demand forecasts ensure consumers pay reasonable prices and Icon Water recovers its costs

Most of Icon Water's costs are fixed. We use demand forecasts to allocate these fixed costs across the water and sewerage services that are supplied to consumers. We then add the costs that are directly related to providing services (known as variable costs). Together these costs are recovered through prices.

If demand forecasts in a regulatory period are significantly different from actual demand, prices will not reflect Icon Water's assessed costs. If the demand forecasts are too low, the prices that we set will be too high. This means the consumers' bills will be higher than what they should be for Icon Water to recover its costs. If the demand forecasts are too high, the prices that we set will be too low and Icon Water will not recover its prudent and efficient costs. This could affect Icon Water's financial sustainability and its ability to keep providing water and sewerage services.

Our objective is to choose the methods that give forecasts that are likely to be closer to actual demand, so the effects of inaccurate demand forecasts on consumers and Icon Water are minimised.

1.3 Scope of the review

In this review, we will determine the water and sewerage services forecasting methods to be used in the next water price investigation, which is likely to start in late 2021.

We intend to review the current forecasting methods based on a set of assessment criteria (described in section 1.6). We will consider pros and cons of alternative forecasting approaches compared to the current approach. We will determine appropriate forecasting methods based on the assessment criteria.

We intend to review the methods for five demand components we need to determine maximum water and sewerage prices in the ACT. The five demand components are:

1. Total water releases by dams

We use the forecast volume of water releases in each year to estimate the billed water sales in the ACT (discussed below) and to estimate the annual Water Abstraction Charge paid by Icon Water to the ACT Government.

2. Billed water sales at Tier 1 and Tier 2

Icon Water sells water at two price tiers. Tier 1 rate applies to water usage up to 50kL per quarter and Tier 2 rate applies to water usage above that amount. We forecast the water sales for these two tiers separately.

3. Total number of water service connections

We forecast the total number of water service connections each year to estimate Icon Water's revenue from water supply charges in each year.

4. Total number of sewerage services consumers

We forecast the total number of sewerage service connections each year to estimate Icon Water's revenue from sewerage supply charges in each year.

5. The number of additional billable fixtures

A flushable fixture is either a toilet, urinal or other fixture with a flushing cistern or flush valve. For non-residential customers with more than two flushable fixtures, we forecast the total number of additional fixtures that attract a separate fee. We use this forecast to estimate Icon Water's revenue from supply charges for these fixtures.

More information about the methods used to forecast these components are in chapters 2 and 3.

1.4 Purpose of this issues paper

There are two reasons for this issues paper. The first is to inform stakeholders that we are undertaking a review of our water and sewerage services demand forecasting methods. The second is to describe our current demand forecasting methods and seek stakeholder input on how to improve the forecasting methods.

1.5 Our role and objectives

Under the ICRC Act, we have the following objectives as set out in sections 7 and 19L of the ICRC Act (box 1.1).

Box 1.1 Sections 7 and 19L: Commission objectives

Section 7:

- (a) to promote effective competition in the interests of consumers;
- (b) to facilitate an appropriate balance between efficiency and environmental and social considerations;
- (c) to ensure non-discriminatory access to monopoly and near-monopoly infrastructure.

Section 19L:

To promote the efficient investment in, and efficient operation and use of regulated services for the long-term interests of consumers in relation to the price, quality, safety, reliability and security of the service.

When making a price direction, in addition to the terms of reference and legislative objectives, we need to consider the provisions set out in section 20(2) of the ICRC Act (box 1.2).

Box 1.2 Section 20(2): Commission's considerations

- (a) the protection of consumers from abuses of monopoly power in terms of prices, pricing policies (including policies relating to the level or structure of prices for services) and standard of regulated services; and
- (b) standards of quality, reliability and safety of the regulated services; and
- (c) the need for greater efficiency in the provision of regulated services to reduce costs to consumers and taxpayers; and
- (d) an appropriate rate of return on any investment in the regulated industry; and
- (e) the cost of providing the regulated services; and
- (f) the principles of ecologically sustainable development mentioned in subsection (5);
- (g) the social impacts of the decision; and
- (h) considerations of demand management and least cost planning; and
- (i) the borrowing, capital and cash flow requirements of people providing regulated services and the need to renew or increase relevant assets in the regulated industry; and
- (j) the effect on general price inflation over the medium term; and
- (k) any arrangements that a person providing regulated services has entered into for the exercise of its functions by some other person; and
- (l) any arrangements that a person providing regulated services has entered into for the exercise of its functions by some other person.

1.6 Our proposed approach to this review

Assessment criteria for the review

We are proposing to use a set of criteria to assess our demand forecasting methods.

Having a set of assessment criteria will promote consistency in decision making when assessing different models. In developing the assessment criteria, we considered the pricing principles in our final report on regulated water and sewerage services prices for 2018-23 (ICRC 2018). These pricing principles are reproduced in appendix 1 for ease of reference. We developed these pricing principles during our tariff structure review 2016-17 (ICRC 2017a).

The assessment criteria that we are proposing to use in this review are:

1. **Economic logic, transparency and replicability.** This means that the model should be based on well-established theory, assumptions used in the model should be clearly documented and can be tested, modelling should be based on well-established statistical methods, and stakeholders should reasonably understand the processes involved and be able to replicate the results.
2. **Predictive ability.** This is to review how accurate the model is in predicting actual outcomes.
3. **Flexibility.** The model's ability to accommodate changing circumstances such as change in climate and water policies.
4. **Regulatory stability.** The forecasting methodology needs to be relatively stable over time to give stakeholders certainty. The methods should only be updated where there is sufficient evidence that the change would increase the accuracy of the predictions.
5. **Simplicity.** The methods should be simple for consumers to understand and straightforward for the utility service provider to implement.

We are seeking feedback on:

1. Do stakeholders have any comments on the assessment criteria proposed by us?

We consider that these criteria will address our legislative objectives and the matters that we are required to consider under section 20(2) of the ICRC Act. The allowable revenue we determine, based on the forecast demand, must promote efficient investment in, and the efficient operation and use of, regulated services for the long-term interests of consumers.

These criteria promote confidence in our forecasting methodology among the regulated business, consumers, investors and other stakeholders.

The criteria ensure that stakeholders can replicate our models. They ensure that Icon Water can earn sufficient revenue to cover its costs, earn an appropriate rate of return on its investments, and is encouraged to spend on prudent and efficient investments. Regulatory stability will promote efficient investment in, and use of, the relevant services because it gives investors the confidence to make investments in long-lived water assets.

Timeline

We will conduct public consultation during this review. Releasing this issues paper is the first step of our consultation. We invite stakeholders to provide submissions to the issues paper by 25 June 2021.

We plan to hold a workshop in mid-June to discuss the issues for this review with stakeholders.

We will then release a draft report on our draft findings and any changes we propose to make to our demand forecasting methods. We will consider written submissions and comments made during the workshop in preparing the draft report. We will also invite stakeholders to provide feedback on our draft report.

We may hold a second workshop after releasing the draft report to allow stakeholders to ask questions and provide feedback on any changes we propose to make to our demand forecasting methods.

Releasing the final report is the final step of our public engagement for this review. We will consider stakeholder feedback on our draft report in preparing the final report.

Table 1.1 **Key dates for the review**

Task	Date
Release of issues paper	28 May 2021
Workshop I	Mid June 2021
Submissions on issues paper close	25 June 2021
Draft report	Late August 2021
Workshop II (tbc)	Mid September 2021
Submissions on draft report close	Early October 2021
Final report	Late October 2021

Technical advice on forecasting methods

We have engaged the consultancy firm Marsden and Jacob Associates to provide expert technical advice for this review. In the first stage, the consultant has developed advice on the pros and cons of alternative forecasting approaches compared to the current approach. In the second stage, the consultant will develop advice on how we could improve the forecasting approach.

1.7 Structure of the issues paper

The structure of the remainder of this issues paper is as follows:

- Chapter 2 discusses our current method of forecasting water demand.
- Chapter 3 discusses the methods we use to forecast water sales at Tier 1 and Tier 2 prices, total number of water consumers, total number of sewerage service consumers, and the number of additional billable fixtures and their limitations.

- Chapter 4 contains a consolidated list of questions.
- Appendix 1 sets out the pricing principles we considered when developing the assessment criteria for the review.
- Appendix 2 sets out technical details related to the current demand forecasting models.
- Appendix 3 is the consultant's advice on the demand forecasting modelling approach.
- Appendix 4 contains information on the approaches used in other jurisdictions to forecast water demand.

2. Water demand forecasting model

This chapter describes the current model used to forecast total water demand and the issues we propose to examine in this review.

As explained in chapter 1, we use the forecast volume of water releases in each year to estimate billed water sales in the ACT. This is because dam releases are a good indicator of billed consumption. We also use it to forecast Icon Water's operating and capital costs.

Section 2.1 describes the current forecasting approach, with related technical details in appendix 2. Section 2.2 outlines the issues on which we are seeking advice from our consultant. Section 2.3 sets out our initial view on the current forecasting model. Section 2.4 discusses the areas where we can potentially improve the model.

2.1 Current forecasting approach

The current model was used to forecast total water releases from Icon Water's four dams (Corin Dam, Bendora Dam, Cotter Dam and Googong Dam) for the 2018-23 regulatory period.

Icon Water sells water released from the dams to consumers in the ACT. Icon Water also makes bulk water sales to Queanbeyan.

We use dam releases as a measure of total water demand which includes water used by Icon Water's customers and 'non-revenue' water. Non-revenue water includes water leakages, water lost due to theft, and unaccounted water due to metering errors. Icon Water does not earn revenue from non-revenue water. Icon Water incurs costs (such as water treatment costs and capital costs) on water it sells to customers as well as on non-revenue water.

ARIMA model

The model we currently use to forecast dam releases is a multivariate Autoregressive Integrated Moving Average (ARIMA) model. ARIMA models are used for forecasting variables that are measured over time, like dam releases. It is an approach that looks at relationships between data over time and makes a forecast assuming these relationships hold in the future. The ARIMA approach allows us to adjust these relationships if we believe historical data will no longer be a useful predictor on its own.

The model uses climate related data such as rainfall, temperature and evaporation as well as water customer numbers. Rainfall data is used because water demand changes with the amount of rainfall, with less demand for water on rainy days. Temperature data is used because water demand changes with temperature, with more demand on hot days. The model uses evaporation data because data analysis by Icon Water suggested that higher evaporation is related to higher water demand. Appendix 2 has details on the data inputs used in the model. We have published the full dataset we used in our model on our website (ICRC 2017b).

Forecasting process

The model forecasts daily dam releases for four separate future climate scenarios (driest, dry, medium and wet). The different climate scenarios have different rainfall and evaporation assumptions. We take the average of the forecasts for these four climate scenarios and aggregate them over the regulatory period to obtain the total dam release forecast.

We take the average forecast from four different climate scenarios because it is not possible to accurately predict which scenario will reflect the actual climate conditions.

Further details about the ARIMA model are in appendix 2.

2.2 Our independent consultant is advising on the modelling approach

We have engaged a consultant (Marsden Jacobs Associates) to give us specialist advice in two stages. In stage 1, the consultant compared alternative forecasting approaches to the ARIMA approach and assessed whether there could be significant net benefits from moving to an alternative forecasting approach. The consultant's advice is that the ARIMA approach is appropriate and fit for purpose.

The consultant found that the ARIMA approach provides regulatory stability, is simple to understand, and is a method that is replicable and transparent. The consultant also found that the ARIMA approach has a reasonable level of predictive ability.

The consultant's report is in appendix 3.

In stage 2, the consultant will advise on how to improve the current forecasting model including providing advice on:

- the explanatory variables to use in the model, and the form of the model
- how to ensure the model can appropriately account for changes in climate, policy, and demographics
- any steps needed to ensure the model and parameters are statistically sound
- how to implement changes, including advice on data sources and any adjustments that would be needed.

2.3 We are seeking views on whether to retain the ARIMA model

We first proposed using the ARIMA model in 2015 because we found the ARIMA model produced the most reliable forecasts (ICRC 2015). In our 2018 water and sewerage services price investigation, we adopted Icon Water's proposed ARIMA model, which was a variant of the model we had proposed in 2015. We found that Icon Water's ARIMA model provided greater forecast accuracy than the model used by the Industry Panel (ICRC 2018).

To help stakeholders consider whether we should retain the ARIMA model, we have done a preliminary assessment of the model against the assessment criteria we are proposing to use in this review (section 1.6).

Criterion 1: Economic logic, transparency and replicability

Our preliminary assessment is that the ARIMA model is a transparent and replicable method. It is based on well-established statistical processes and is a widely used forecasting approach. The assumptions used in the ARIMA model are clearly documented and modelling can be done using well-established procedures.

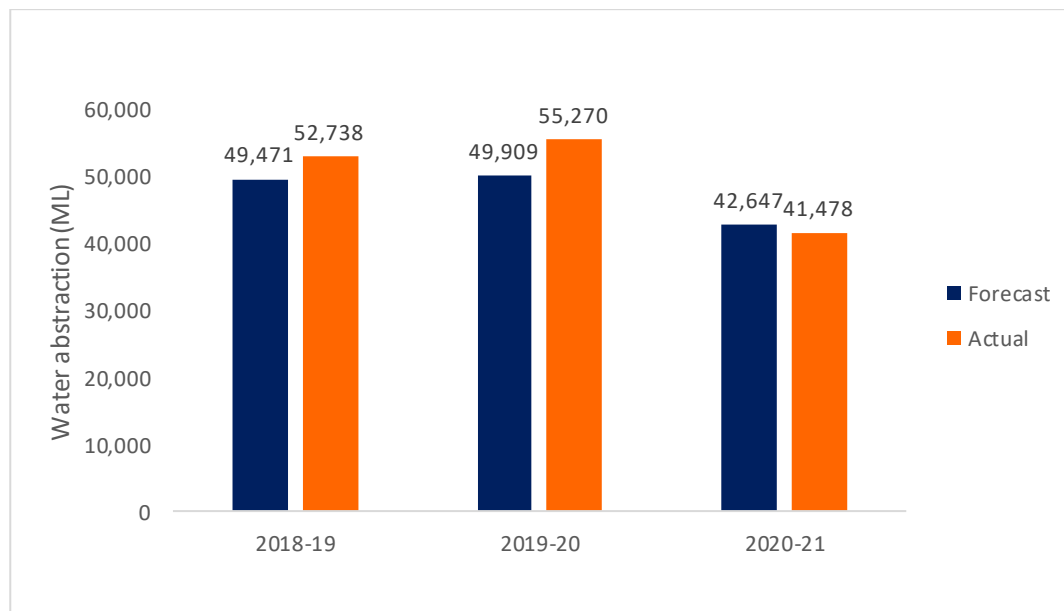
We assessed forecasting models used in other jurisdictions. There is no single well-accepted forecasting model. Different forecasting methods are used in other jurisdictions. For example, Sydney Water uses a panel data model while Hunter Water and Melbourne Water use end-use modelling. Appendix 4 summarises forecasting methods used in other jurisdictions.

Criterion 2: Predictive ability

The evidence available to us indicates that the ARIMA model provides reliable forecasts. We have compared the dam release forecasts from the model made in 2018 with actual volumes for the past 3 years. We found the model has reasonable predictive ability because the forecasts were no more than 5% different to the actual volumes, based on cumulative data to date.

Figure 2.1 shows the forecast and actual dam releases for the current regulatory period to date. For the first two years, the actual dam release was more than forecast because drier than average conditions resulted in higher demand than forecast by the model. In the current year to date, the actual dam release is below the forecast because wetter than average conditions have meant demand is less than forecast.

Figure 2.1 Water releases from Icon Water's four dams: actual vs forecasts



Source: Data from Icon Water

Note: The 2020-21 actual and forecast figures are until 28 April 2021

In chapter 3, we compare the forecasts of billed water sales with the actual data. Those forecasts are based on the outcomes from the ARIMA model. We found that the forecasts have been reasonably accurate (see figures 3.1 and 3.2).

Criterion 3: Flexibility

Flexibility refers to the model's ability to accommodate changing circumstances such as change in climate and water policies. The current ARIMA model has some flexibility. It can account for short-term fluctuations in weather conditions and step changes in water demand. Our consultant's view is that the current model can also be modified to account for the impact of climate changes on water demand, which take a long time to manifest. However, our consultant has identified that the current ARIMA model is not flexible to account for the impact of household-specific factors, such as water efficiency programs. We intend to explore whether changes are needed to improve the model's flexibility.

Criterion 4: Regulatory stability

Retaining the ARIMA model would provide regulatory stability because we currently use ARIMA model to forecast water demand. Our consultant looked at alternative models and concluded that on balance it may be better to retain the ARIMA mode. This is because the benefits of moving from an ARIMA model to another approach was outweighed by the costs due to regulatory instability and increased complexity of implementing the other approaches.

Criterion 5: Simplicity

Our preliminary view is that the ARIMA model is simple for consumers to understand and straightforward for the utility service provider to implement. The data on bulk water dam releases, rainfall and temperature that are required to implement the model are readily available. The method can be implemented using well-established methodologies using standard statistical software, including free to use software.

Our preliminary assessment based on the evidence we have considered suggests that the ARIMA model largely meets our assessment criteria. We are seeking stakeholder views on our preliminary assessment and whether we should consider alternative forecasting models.

We are seeking feedback on:

2. Do you consider the ARIMA model remains appropriate, considering the assessment criterion in chapter 1, any other factors you think are relevant, and the available evidence? If you consider an alternative model would be better, please describe the model and explain why it would be better than the ARIMA model.

2.4 We are seeking views on how the ARIMA model could be improved

As discussed in section 2.3, the current ARIMA model has considerable strengths, including high-level of predictive ability. If we decide to retain the ARIMA model, we will consider whether we can make improvements to the variables included in the model and the relationships between them¹ and to the data

¹ In technical terms, the variables included in the model and the relationships between them are the model specification. The variables are the factors that have a significant influence on the demand for water and sewerage services.

we use to measure the variables included in the model. We are seeking views on what potential improvements could be made.

Based on our preliminary assessment of the model, we propose to consider how the model currently incorporates water policy changes, climate change, demographic changes, and changes in consumer behaviour and the data used to measure these variables. For example, our consultant noted that changing the frequency of data used in the model (from daily data to monthly data) could improve the model's ability to account for climate change (appendix 3). Furthermore, the current model predicts the future customer numbers using past growth trends. However, there may be potential to use population forecasts from the ACT government (ACT Government 2019) to forecast future customer numbers.

Sustainable diversion limit

The ACT is in the Murrumbidgee River catchment, which feeds into the Murray–Darling River system. Federal and state Murray–Darling Basin water ministers have committed to introduce sustainable diversion limits by 2024 as a major change in water management policy. Sustainable diversion limits will limit how much water, on average, can be used in the Murray–Darling Basin by towns and communities, farmers, and industries, to keep the rivers and environment healthy.

The ACT has obligations under the Murray–Darling Basin Agreement and Murray–Darling Basin Plan to support sustainable diversion limits (EPSDD 2019).

When implemented, this policy could limit the amount of water released by Icon Water's dams. As our current model is based on dam releases data, this policy could have a direct impact on how we forecast water demand.

The current ARIMA model does not explicitly account for potential policy changes in water extraction limits, such as sustainable diversion limits. In this review, we will consider whether our current model is flexible enough to account for such policy changes. We will also consider whether any changes could be made to improve the flexibility of the model.

We are seeking feedback on:

3. How should future policy changes like sustainable development limits be incorporated in our forecasting model? Are any changes needed to improve how we incorporate such policy changes in our forecasting?

Climate change

Climate change has direct effects on water demand. Climate change impacts weather and changes in weather and rainfall are key factors influencing water demand. For example, changes in the frequency and severity of drought are likely to have significant effects on water demand.

The current model uses data and scenarios developed by the South Eastern Australian Climate Initiative (SEACI), which accounts for a small increase in temperature each year and potential changes in rainfall and evaporation. More information on climate data used in the model and how they are incorporated into the current model is in appendix 2.

We intend to examine whether the scenarios developed by SEACI account for potential larger changes in climate, such as an increase in the frequency of extreme weather events, or if there are other data sources available that account for those changes. We will also examine whether the model is flexible to account for a range of possible climate change scenarios.

We are seeking feedback on:

4. Is our demand forecasting model flexible enough to incorporate potentially larger changes in the climate and resulting weather and rainfall patterns?
5. Do stakeholders have any suggestions on other more suitable climate change data sources we could use in the model?

Stability of model outputs

In our 2018-23 water price investigation, we found the demand forecasts changed significantly when Icon Water added 11 months of data from April 2017 to February 2018 for their revised pricing proposal. The forecast water releases increased by 1.3 per cent to 1.5 per cent in each year over the 2018-23 regulatory period, a cumulative increase of 10 per cent by the end of the 5-year regulatory period.

This indicates that the demand forecasts produced by the current ARIMA model are sensitive to minor updates to the data used in the model. This may reflect the weighting of recent observations and absence of leading indicators. High sensitivity of the model outputs to small changes in data inputs can increase the risks associated with data timing and selection, and reduce the reliability of the model outputs. We intend to test whether there is a weakness in the model that results in unstable outputs and, if so, how the model can be improved to improve its stability.

We are seeking feedback on:

6. Do stakeholders have any suggestions on whether changes are needed to improve the stability of our demand forecasting model?

Demographic changes

The current water demand forecasting model uses forecast customer numbers as an input. Future customer numbers are estimated based on the past growth trend in the customer numbers, provided by Icon Water. More details about how this input is estimated is in chapter 3.

In this review, we will consider whether the past trend in customer numbers is still a good indicator of future demographic changes. The COVID-19 pandemic and closure of international borders, for example, might have changed population growth patterns in the ACT on a sustained basis. Border closures may slow future population growth in the ACT if there are lower numbers of new immigrants or international students. However, this may be offset if the pandemic causes an increase in migration to regional Australia and the ACT. We would like to explore the possibility of using population forecasts from the ACT Government in the model (ACT Government 2020).

Demographic change may also relate to changes in average age of the population and family structure. These changes may result in changes in the mix of housing types (for example, the proportion of freestanding houses and apartments) that will could have direct effects on water demand. A family living in

a detached house with a backyard is likely to consume more water than the same sized family living in an apartment. An increase in the average age of the ACT community, coupled with a move to downsizing, could lead to a greater share of apartments or townhouses with small outdoor areas, which tend to use less water for outdoor uses. We intend to examine whether the current model is flexible enough to account for step changes in the trend of demographic changes. We will also examine whether the model adequately accounts for demographic changes.

We are seeking feedback on:

7. Is the past trend in customer numbers likely to still be an appropriate indicator of future demographic changes? Do stakeholders have any suggestions on other data sources that may be more suitable to represent forecast demographic changes in the ACT?
8. Is the forecasting model flexible enough to account for step changes in the trend of demographic changes? If not, how could we improve our forecasting approach to account for potential demographic changes?

Changes in consumer behaviour

The current model does not explicitly account for changes in consumer behaviour that could have a medium to long term impact on water demand. Such behavioural changes can include the use of more water efficient appliances, replacement of traditional gardens with low water-use gardens, installation of more water efficient garden watering systems and recycling systems, and changes in commercial practices that reduce water usage per customer.

During the millennium drought, many consumers changed their behaviour in response to water restrictions and higher water prices. If these behavioural changes are sustained, water demand per customer may not return to previous levels when rainfall is higher. The relationships between rainfall and demand may no longer be the same as it was in the past.

We will consider how we could better incorporate these sorts of behavioural changes in our forecasting. Hunter Water, for example, uses annual sales data for individual appliances as an input to its water demand forecasting model to account for changes in water efficiency. More information about Hunter Water's demand forecasting model is in appendix 4.

The current model may not adequately account for structural changes across different customer segments where there is a significant change in past trends. For example, new properties often have smaller outdoor areas than traditional properties. Therefore, water consumers in new properties may be less sensitive to weather conditions and water prices than consumers in properties with large gardens. The current model does not use data on different customer segments. We will consider whether the predictive ability of the model could be improved by using data on different customer segments.

We are seeking feedback on:

9. How could we improve the way we incorporate changes on consumer behaviour into our demand forecasting model? What sort of data could we use to measure behavioural changes in the use of water?

3. Other demand forecasts

This chapter discusses how these water and sewerage demand components are forecast and the issues we propose to consider in this review.

- billed water sales at Tier 1 and Tier 2
- sewage volumes
- total number of water and sewerage services consumers and the number of billable fixtures.

3.1 Current approach

These demand components are forecast using methods that involve looking at their historical trends and examining their relationship with other factors. Our initial view is that these methods remain appropriate to use in the next price investigation but we are seeking stakeholder feedback before reaching our draft decision.

3.1.1 Billed water sales at Tier 1 and Tier 2

We need to forecast the annual volumes of water sold at Tier 1 and Tier 2 prices to estimate Icon Water's annual revenue from water sales. Tier 1 price applies to water consumption up to 50 kL per quarter per water connection and Tier 2 price applies to consumption thereafter.

A three-step process is followed to forecast water sales at Tier 1 and Tier 2.

1. Daily dam releases are forecast using the ARIMA model explained in chapter 2 and they are aggregated into annual dam releases.
2. We then forecast what portion of annual dam releases would be sold to ACT consumers. This is because Icon Water uses a portion of dam releases to sell bulk water to Queanbeyan city council and a portion of dam releases is non-revenue water.² We look at the historical portions of dam releases sold to ACT consumers to forecast the future portions. We multiply these forecast portions with the forecast dam releases to forecast the annual volume of ACT water sales.
3. Then we split the annual ACT water sales forecasts into Tier 1 and Tier 2. We first forecast Tier 1 sales using the method discussed below. Tier 2 sales are the difference between total ACT water sales and Tier 1 sales forecasts.

² Please see chapter 2 for a description of non-revenue water.

Forecasting Tier 1 water sales

Tier 1 water sales are estimated as follows.

First, we estimate the relationship between the observed proportion of Tier 1 sales and the average amount of water consumed by each customer each year. Box 3.1 explains how this relationship is estimated.

This relationship and the forecast average water consumption per customer are then used to forecast the proportion of Tier 1 sales for a regulatory period. The forecast average water consumption per customer is calculated by dividing the forecast ACT water sales by the forecast customer numbers. As discussed in chapter 2, in this review, we will consider whether and how we can improve our method of forecasting customer numbers, given that there may be potential changes in population growth trends.

Finally, we multiply the forecast proportion of Tier 1 sales and total ACT water sales to obtain the volume of Tier 1 sales.

Box 3.1 Equation used to forecast Tier 1 water sales

We used annual data from 2009-10 to 2015-16 to estimate the historical relationship between Tier 1 sales and per customer water consumption. We modelled this relationship and identified the best equation based on following criteria.

- the best fit between observed and modelled values
- statistical significance of the estimated coefficients
- ability of the equation to forecast sensible values

The equation we chose based on the above criteria is: $y = 98.41 - 13.50.e^{4.38x}$

where:

- y is Tier 1 proportion of total ACT water sales
- x is the average annual ACT water consumption per customer

Demand risk

As discussed in chapter 1, we set the regulated water prices based on forecast water sales. Icon Water sells water at the regulated prices to earn revenue.

However, if actual demand is different to forecast demand, the actual revenue earned by Icon Water will be higher or lower than the allowable revenue. We call this demand risk. We have a mechanism in place to manage this demand risk (box 3.2).

Box 3.2 The 'deadband' mechanism shares demand risk between Icon Water and water customers

Our mechanism to manage demand risk allows an adjustment at the end of the regulatory period if we find that Icon Water's actual revenue from ACT water sales over the regulatory period is materially different from the allowable revenue. We use a materiality threshold (known as the 'deadband') of 6%. That means if in a regulatory period Icon Water over-recovers or under-recovers its allowed revenue by more than 6%, we will make an adjustment to Icon Water's allowable revenue in the following regulatory period.

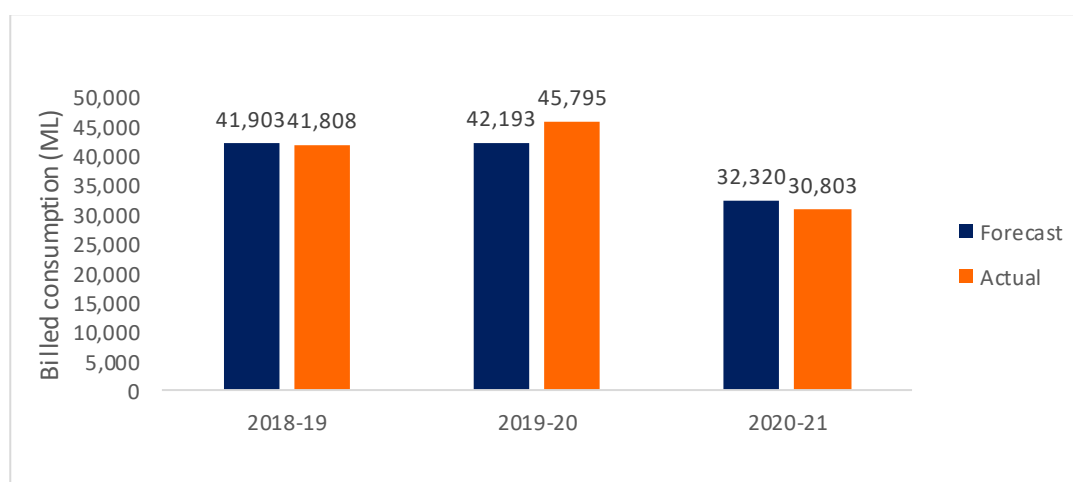
Our end of period adjustment means Icon Water can recover material under recoveries from customers and must return material over recoveries to customers during the following regulatory period. Under this approach, Icon Water bears the demand risk up to the level of the 6 per cent and consumers bear the risk beyond 6 per cent. We reviewed the deadband during our review of incentive mechanisms in relation to water and sewerage services and found that it results in an appropriate allocation of demand risk between Icon Water and its customers (ICRC 2020b).

Comparison of forecast demand and actual demand

We have compared total forecast billed consumption we estimated in our 2018 water price investigation with actual consumption in the past 3 years and found that the forecasts have been reasonably accurate. Figure 3.1 shows the forecast and actual billed consumption for the current regulatory period, to date. The actual billed consumption (cumulative data to date) is within 2% of the forecasts.

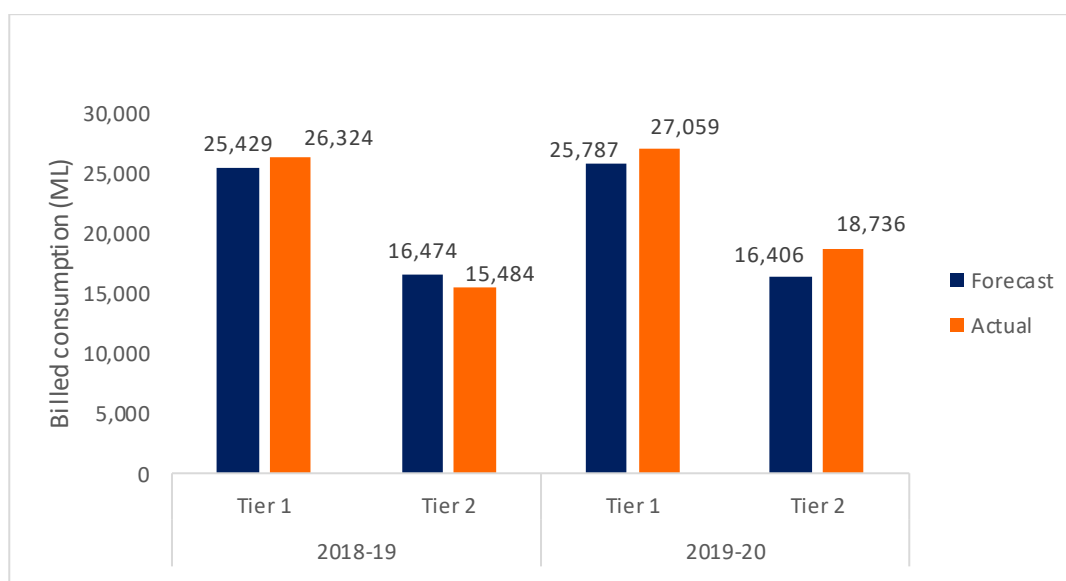
We also looked at the Tier 1 and Tier 2 categories of water consumption (figure 3.2) and found that the forecasts are within around 4% of the actual consumption based on cumulative data for the first two years of the regulatory period.

Figure 3.1 Total billed consumption: actual vs forecasts



Source: Data from Icon Water

Note: The 2020-21 actual and forecast figures are up to March 2021.

Figure 3.2 Billed consumption (Tier 1 and Tier 2 sales)

Source: Data from Icon Water

3.1.2 Sewage volumes

We need forecasts of sewage volumes to estimate sewage treatment costs. Currently sewage volumes is forecast using a range of potential scenarios that are based on average sewage volume per user, weather conditions, seasonal impact, and rates of sewage flow into the sewerage system. The average of those scenario forecasts is used to forecast sewage volumes for the regulatory period.

We will review this method of forecasting sewage volumes.

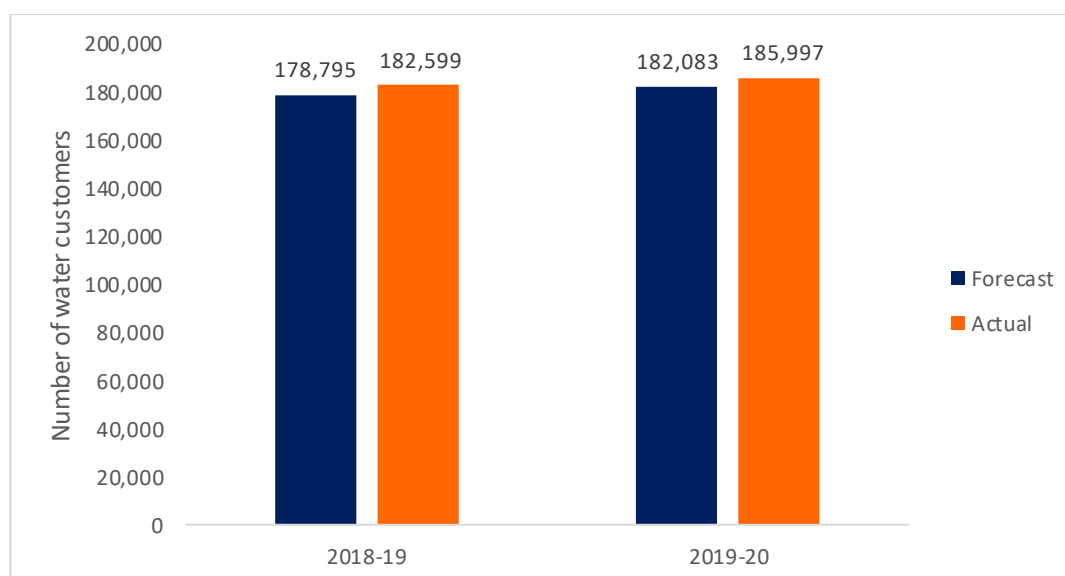
3.1.3 Water and sewerage installations and billable fixtures

We need forecasts of water installations and sewerage installations to set the supply charges for water customers and sewerage customers. Forecasts of billable (flushable) fixtures are used to determine sewerage services supply charges for non-residential consumers.

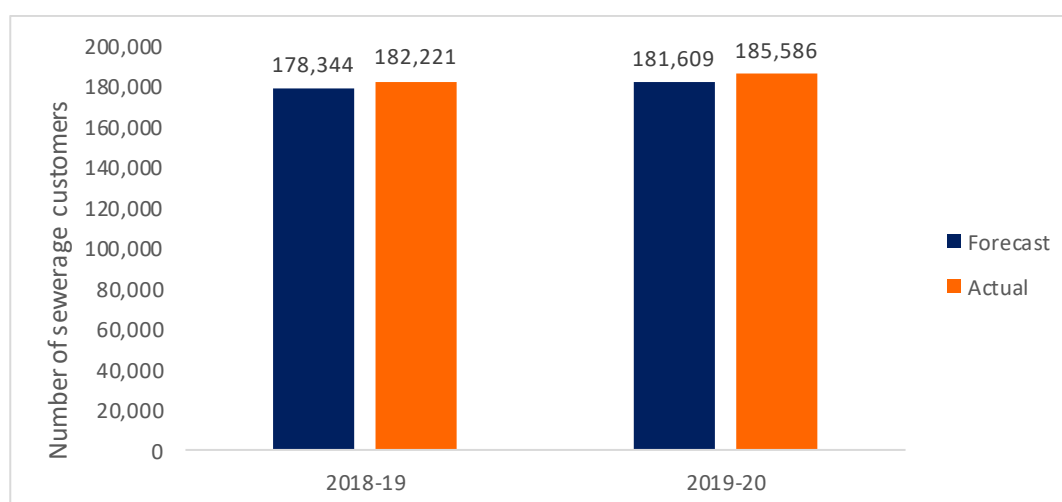
Forecasts of water and sewerage installations and billable fixtures were made based on the observed annual growth rates for those services over the 2013-14 to 2017-18 period. Specifically, the observed annual growth rates of water installations, sewerage installations, and billable fixtures were 1.84 per cent, 1.83 per cent, and 1.55 per cent, respectively. These annual growth rates were applied to 2017-18 actual values to obtain forecasts for the regulatory period.

The forecast values for these services are available in appendix 2.

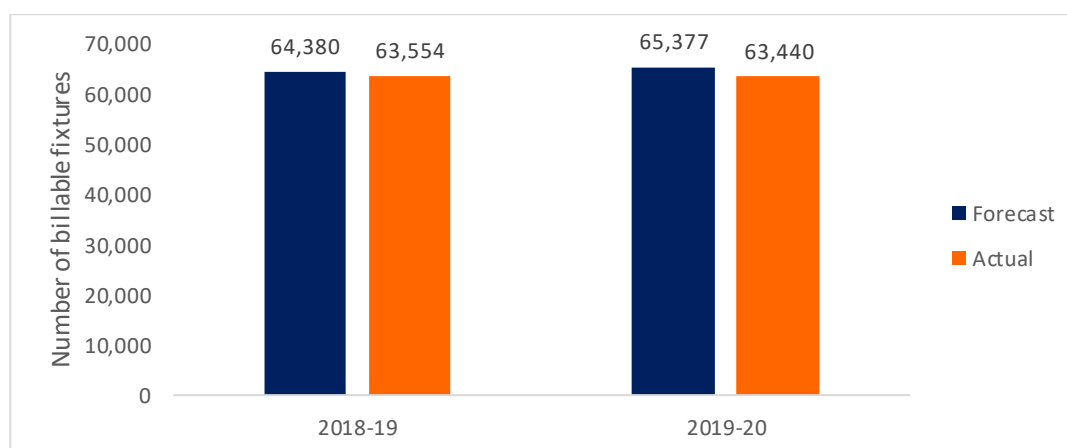
We compared the forecasts made in 2018 with actual values for 2018-19 and 2019-20 and found that the forecast values for water customer numbers (figure 3.3), sewerage customer numbers (figure 3.4), and billable fixtures (figure 3.5) are within 2% of the actual values. This indicates that the forecasting method has shown a high degree of accuracy to date.

Figure 3.3 Water customer numbers: actuals and forecasts

Source: Data from Icon Water

Figure 3.4 Sewerage customer numbers: actuals and forecasts

Source: Data from Icon Water

Figure 3.5 Billable fixtures: actuals and forecasts

Source: Data from Icon Water

3.2 Proposed issues for review

We are inviting stakeholders to provide feedback on whether any improvements can be made to the way these components are forecast.

We are seeking feedback on:

10. Are our current methods for forecasting billed water sales at Tier 1 and Tier 2, total number of water consumers, total number of sewerage service consumers and the number of additional billable fixtures still appropriate? If not, do you have suggestions to improve the methods used to forecast these variables?

4. Consolidated list of questions

The preceding chapters identified a number of questions on which we are seeking feedback. The list is consolidated in this chapter.

This list is not exhaustive, and submissions may address other issues that relate to the review. Submissions do not need to address all the questions set out by the Commission.

1. Do stakeholders have any comments on the assessment criteria proposed by us?
2. Do you consider the ARIMA model remains appropriate, considering the assessment criterion in chapter 1, any other factors you think are relevant, and the available evidence? If you consider an alternative model would be better, please describe the model and explain why it would be better than the ARIMA model.
3. How should future policy changes like sustainable development limits be incorporated in our forecasting model? Are any changes needed to improve how we incorporate such policy changes in our forecasting?
4. Is our demand forecasting model flexible enough to incorporate potentially larger changes in the climate and resulting weather and rainfall patterns?
5. Do stakeholders have any suggestions on other more suitable climate change data sources we could use in the model?
6. Do stakeholders have any suggestions on whether changes are needed to improve the stability of our demand forecasting model?
7. Is the past trend in customer numbers likely to still be an appropriate indicator of future demographic changes? Do stakeholders have any suggestions on other data sources that may be more suitable to represent forecast demographic changes in the ACT?
8. Is the forecasting model flexible enough to account for step changes in the trend of demographic changes? If not, how could we improve our forecasting approach to account for potential demographic changes?
9. How could we improve the way we incorporate changes on consumer behaviour into our demand forecasting model? What sort of data could we use to measure behavioural changes in the use of water?
10. Are our current methods for forecasting billed water sales at Tier 1 and Tier 2, total number of water consumers, total number of sewerage service consumers and the number of additional billable fixtures still appropriate? If not, do you have suggestions to improve the methods used to forecast these variables?

Appendix 1: Our pricing principles

Table A1.1 Regulatory objectives and pricing principles for water and sewerage services tariffs

Category	Aspect	Detail
Objective	Overarching interpretation	<p>To promote efficient investment in, and efficient operation and use of, regulated services for the long-term interests of consumers in relation to the price, quality, safety, reliability and security of the service.</p> <p>The various aspects of economic efficiency are given emphasis but with the ultimate objective being the long-term interests of consumers. 'Economic efficiency' when properly defined encompasses environmental objectives. Consumer interests must take account of equity and other social impacts, as required by the ICRC Act.</p> <p>Economic efficiency considerations related to pricing are a starting point but need to be balanced with environmental and social considerations.</p>
Pricing principle	1. Economic efficiency in use	<p>Regulated prices should promote the economically efficient use of Icon Water's water and sewerage services infrastructure and should also encourage economically efficient use of the water resource itself.</p> <p>This includes having regard to uneconomic bypass where water supply is sourced from a higher cost alternative.</p>
	2. Economic efficiency for investment and operation	<p>Regulated prices and supporting regulatory arrangements should facilitate the efficient recovery of the prudent and efficient costs of investment and operation. The finance recovery aspect of this principle is often described as ensuring revenue adequacy or financial viability.</p> <p>Costs also need to be efficient, which is primarily dealt with by auditing and incentive-sharing mechanisms.</p>
	3. Environmental considerations	<p>Regulated prices and complementary mechanisms should ensure that environmental objectives are effectively accounted for.</p>
	4. Community impact – gradual adjustment	<p>Any change to prices or other regulatory arrangements that will have substantial consumer impacts should be phased in over a transition period to allow reasonable time for consumers to adjust to the change.</p>

	5. Community impact – fair outcomes for low-income households	Adverse impacts on households with low incomes need to be limited or moderated by phasing and other compensating mechanisms or limits on changes to regulated prices or other regulatory arrangements.
	6. Regulatory governance – simplicity	Regulated prices and their form should be simple for consumers to understand and straightforward for the utility to implement.
	7. Regulatory governance – transparency	Regulated prices should be set using a transparent methodology and be subject to public consultation and scrutiny.

Appendix 2: Technical details of the current model

ARIMA model

The specification of our model is seasonal (weekly) ARIMA (2,0,1) (2,0,1)[7] model with lag values of a set of explanatory variables. The lag values of the variables were selected using the Akaike Information Criteria (AIC), which is a widely used statistical measure to select lag values of statistical models.

Specifically, our model forecasts daily dam releases using below variables. Abbreviations for each variable are in parentheses.

- Dam release data for the previous two days (ar1 and ar2)
- Forecast error of dam releases for the previous day (ma1)
- Dam release data for seven days prior and 14 days prior (sar1 and sar2)
- Forecast error of dam releases seven days prior (sma1)
- Maximum temperature for the latest day that data is available, one day prior, and 12 days prior (Temp0, Temp1 and Temp12)
- Maximum temperature squared data for the latest day that data is available, 1 day prior, 5 days prior and 12 days prior (Temp0sq, Temp1sq, Temp5sq, Temp12sq)
- Square root of maximum temperature data for 1 day prior (Temp1sqrt)
- Rainfall data for the latest day that data is available and 1 day prior (Rain0 and Rain1)
- Square root of rainfall data for the latest day that data is available, 1 day prior, 3 days prior, 6 days prior, 7 days prior and 8 day prior (Rain0sqrt, Rain1sqrt, Rain3sqrt, Rain6sqrt, Rain7sqrt and Rain8sqrt)
- Evaporation data for the latest day that data is available and for the previous four days (Evap0, Evap1, Evap2, Evap3, and Evap4)
- Evaporation squared data for the latest day that data is available, 1 day prior and 5 days prior (Evap0sq, Evap1sq, Evap5sq)
- Sum of daily temperature data in the previous seven days (CumTemp)
- Sum of daily rainfall data in the previous seven days (CumRain)
- Sum of daily rainfall data multiplied by daily evaporation data in the previous seven days (CumX)
- Dummy variables for Sunday until Friday (dumDM1 - dumDM6)
- Dummy variable for December (dumDec)
- Dummy variable for summer (December to February) (dumSum).
- Water customer numbers (Cust)
- Fourier seasonal term (S1-365 and C1-365), calculated using the below formula:

$$y_t = a + \sum_{k=1}^K \left[\alpha \sin\left(\frac{2\pi kt}{m}\right) + \beta \cos\left(\frac{2\pi kt}{m}\right) \right] + N_t$$

where:

- N_t represents all the other variables in the forecasting model, including the ARIMA error term
- We used $k=1$ as it minimised the AIC.

The estimated coefficients of our model are available in table 3.1.

Table A2.1 Estimated coefficients of the forecasting model

Variables	Coefficient	p-value	Sig	Variables	Coefficient	p-value	Sig
ar1	1.28	0.00	***	Rain8sqrt	-0.38	0.00	***
ar2	-0.33	0.00	***	Evap0	1.16	0.00	***
ma1	-0.75	0.00	***	Evap1	1.04	0.00	***
sar1	0.91	0.00	***	Evap2	1.16	0.00	***
sar2	-0.03	0.15	not sig	Evap3	0.88	0.00	***
sma1	-0.72	0.00	***	Evap4	0.45	0.00	***
intercept	25.30	0.37	not sig	Evap0sq	0.10	0.00	***
Temp0	-0.64	0.00	***	Evap1sq	0.07	0.02	**
Temp1	-7.11	0.00	***	Evap5sq	0.05	0.00	***
Temp12	-0.47	0.00	***	CumX	-0.02	0.00	***
Temp0sq	0.03	0.00	***	CumTemp	-0.08	0.00	***
Temp1sq	0.11	0.00	***	CumRain	0.14	0.00	***
Temp5sq	0.01	0.00	***	dumDM1	6.28	0.00	***
Temp12sq	0.01	0.00	***	dumDM2	12.35	0.00	***
Temp1sqrt	32.38	0.00	***	dumDM3	6.77	0.00	***
Rain0	0.50	0.00	***	dumDM4	5.63	0.00	***
Rain1	0.52	0.00	***	dumDM5	4.72	0.00	***
Rain0sqrt	-3.48	0.00	***	dumDM6	4.84	0.00	***
Rain1sqrt	-3.96	0.00	***	dumDec	4.16	0.01	***
Rain3sqrt	-0.48	0.00	***	dumSum	-2.53	0.11	not sig
Rain6sqrt	0.26	0.03	**	Cust	0.00	0.05	**
Rain7sqrt	-0.50	0.00	***	S1-365	-1.87	0.32	not sig
AIC	27,513			C1-365	-5.21	0.03	**

Climate scenarios and data used in the model

Reference climate scenario

Our four climate scenarios are based on a reference climate scenario. We developed the reference climate scenario as follows.

First, we divided the time period between July 1965 and March 2017 into 45 overlapping 6.5-year time periods. We chose 6.5 years as the length of each period because during the 2018 price investigation we forecast dam releases for 6.5 years until June 2023.³

Then we developed our reference climate scenario using the average data for the 45 time periods. That means our reference climate scenario has daily data for the maximum temperature, rainfall and evaporation for a 6.5-year time period.

Future climate scenarios

We adjusted the daily maximum temperature, rainfall and evaporation in the reference climate scenario to develop four assumed future climate scenarios.

We developed the four future climate scenarios by

- forecasting daily maximum temperature for the 6.5-year period based on historical trend and
- adjusting the rainfall and evaporation in our reference climate scenario based on data from South Eastern Australian Climate Initiative (SEACI 2012).

Forecasting future daily temperature

We estimated the trend in daily maximum temperature using daily data from June 1965 to March 2017. According to our modelling, daily maximum temperature has had an increasing trend of 0.0001 degrees of Celsius per day (table 3.2). We assumed this trend will continue over the 6.5-year period until June 2023. We adjusted the maximum daily temperature in our reference climate scenario to reflect this trend over the 6.5-year period until June 2023.

Table A2.2 Temperature against time regression results, 1965 to 2017

	Coefficient	Standard error	t-value	p-value	Significance
intercept	19.0514	0.1003	190.0082	0.0000	***
time	0.0001	0.0000	11.2046	0.0000	***

³ We did our forecast in early 2017 which is around 1.5 years earlier than the start of the five-year regulatory period of July 2018 to July 2023.

Forecasting rainfall and evaporation

Our assumed future climate scenarios are based on four climate scenarios from the 15 global climate scenarios developed by the SEACI.

- dry – the second driest SEACI scenario
- driest – the driest SEACI scenario
- medium – the median SEACI scenario
- wet – the second wettest SEACI scenario

Each climate scenario has different daily rainfall and evaporation. Table 3.3 has SEACI data for percentage change in rain and evaporation by season for an increase in global warming by one degree of Celsius. SEACI data is based on climate modelling. We adjusted daily rainfall and evaporation in our reference climate scenario using data in table 3.3 and the maximum temperature (forecast above) to obtain climate data for the four assumed climate scenarios.

Table A2.3 Percentage changes in rainfall and evaporation by season

	Driest		Dry		Medium		Wet	
	Rain	Evap	Rain	Evap	Rain	Evap	Rain	Evap
Winter	-18.41%	4.70%	-8.24%	1.83%	-8.17%	1.83%	1.99%	5.23%
Spring	-26.83%	0.78%	-15.35%	2.30%	-7.81%	2.30%	-2.50%	3.48%
Summer	-6.07%	4.15%	-4.60%	2.81%	-1.53%	2.81%	8.50%	2.56%
Autumn	-6.56%	7.39%	-3.93%	4.15%	5.90%	4.15%	5.78%	3.27%

Forecast of water installation numbers

We need a forecast of water installation numbers to forecast dam releases using our model. We forecast water installation numbers based on historical trend. Specifically, we estimated the growth rate in water installation numbers from 2013-14 to 2017-18, which was 1.84 per cent per year, and assumed that trend will continue until 2023. Table 3.4 has our forecasts of water installation numbers.

Table A2.4 Forecast water installations

Year	Water installations
2017-18	175,566
2018-19	178,795
2019-20	182,083
2020-21	185,432
2021-22	188,842
2022-23	192,315

Forecasts of dam releases

We fed the data on forecasts of climate variables and water installation numbers into our model to forecast dam releases. Table 3.5 has our dam release forecasts until 2023.

Table A2.5 Dam release forecasts until 2023, by climate scenario (ML)

Scenario	2017-18	2018-19	2019-20	2020-21	2021-22	2022-23
Driest	48,627	48,983	49,317	49,638	50,105	50,553
Dry	48,499	48,856	49,191	49,511	49,979	50,427
Medium	48,443	48,800	49,135	49,455	49,922	50,371
Wet	48,380	48,736	49,070	49,390	49,858	50,307
Average	48,487	48,844	49,178	49,498	49,966	50,415

Data used in the model

Daily dam releases

This is the variable we forecast using the model. Icon Water releases water from its dams to meet demand from ACT and Queanbeyan customers. The model uses daily data on dam releases measured in megalitres (ML) in our model. This data was sourced from Icon Water. In the last price investigation, the forecasts were made using daily data from 13 July 2006 to 31 March 2017.

Daily maximum temperature

The model uses daily data on the maximum temperature at Canberra Airport, measured in Celsius. Temperature data was sourced from the Bureau of Meteorology, which reports weather data for Canberra based on the weather conditions at Canberra Airport weather station. Temperature data is used in the model because daily water demand changes with temperature, with hot days having more demand.

Cumulative seven days temperature

Cumulative seven days temperature for each day is calculated by adding the daily maximum temperature data in the preceding seven days. Cumulative temperature data capture the effects of having a hot or cold 'period' on water demand.

Daily rainfall

The model uses daily rainfall data at Canberra Airport, measured in millimetres. Daily rainfall data was used because water demand changes with the amount of rainfall, with rainy days having less demand for water. Rainfall data was sourced from the Bureau of Meteorology.

Cumulative seven days rain

Cumulative seven days rain for each day was calculated by adding the daily rainfall data in the preceding seven days. This data series captures the effects of having a period of rain (or lack of it) on water demand.

Daily evaporation

The model uses daily evaporation data for Burrinjuck Dam, measured in millimetres, reported by the Bureau of Meteorology. The model used evaporation data because our data analysis suggested higher evaporation is related to higher water demand. The Bureau of Meteorology measures evaporation as the amount of water which evaporates from a specific standardized open space. The model uses data for Burrinjuck Dam because data for Canberra Airport weather station (like for other climate variables) was not available for a sufficient time period.

Cumulative rain and evaporation interaction

Daily 'cumulative rain and evaporation interaction' was calculated by multiplying the seven days cumulative rainfall by seven days cumulative evaporation. This interaction measures the effect of rainfall on water demand at different levels of evaporation.

Daily dummy variables

The model has dummy variables for the days in the week. Dummy variables represent the effect of each day on the water demand. For example, water demand in the weekend may be different to the water demand on a middle of the week.

December dummy variable

The model has a dummy variable for December to capture the effect of that month on water demand. Water demand in December is higher than other months in the ACT, likely due to high temperatures and summer holidays.

Summer dummy variables

The model has a dummy variable for summer season (December to February) to capture the effect of hot summer season on water demand.

Water customer numbers

The model has the number of Icon Water's water customers, as measured by the number of water connections, at the end of each day. Water customer numbers have been included because growing customer numbers and resulting increase in water demand represent the growth in the ACT population. Data for customer numbers was sourced from Icon Water.

A Fourier seasonal term

Adding a Fourier seasonal term to a forecasting model is a statistical technique used to incorporate annual regular and predictable changes in water demand to the forecasting model. Accuracy of forecasts can be improved by incorporating regular and predictable changes to the model. Data for a Fourier term is created using a mathematical formula.

Appendix 3: Consultant's advice

economics
public policy
markets
strategy

MARSDEN JACOB ASSOCIATES

Water demand forecasting methodology review – Stage 1

Final report

19 May 2021

A Marsden Jacob Report

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Executive Summary

This assessment of alternative approaches to demand forecasting of water usage, will be used to inform the ICRC's review of Icon Water's approach to water demand forecasting for the 2023-28 regulatory period.

The purpose of this review is to assess whether the current approach used by Icon Water to forecast water demand for revenue forecasts is fit for purpose and adheres to best practice, while considering whether other alternatives may be more appropriate.

In this stage 1 report we have undertaken an assessment of four alternative approaches to demand forecasting, including:

- Auto Regressive Integrated Moving Average (ARIMAX) – the current approach adopted by Icon Water
- Panel Data modelling
- End-use modelling (EUM)
- Historical average approach.

In this report we have examined each of the four approaches against a key assessment criteria. Key headline findings from our assessment of the four demand forecasting approaches include:

- **An ARIMAX methodology is transparent and reproducible, and is suitable for producing medium to long-term forecasts, provided that the time frequency of the data analysed matches sufficiently the interval at which forecasts need to be generated.** However, the approach is not flexible for forecasting the impact of demographic trends, water efficiency programs and policy changes, such as prices, on specific customer segments.
- **A panel data approach has high predictive ability and is more flexible than approaches that rely on bulk water data (time series) as it can account for climate, demographic and policy changes.** However, a panel data approach is more complex and does result in a material change in the forecasting methodology from the status quo.
- **An End-use methodology (EUM) is flexible in terms of running various scenarios by changing key input assumptions particularly related to changes in appliance efficiency and end-use water demand.** However, the assumptions behind EUM are not easily testable. Additionally, it does not meet the predictive ability criteria on the basis that it is difficult to identify causes for discrepancies between forecast and actual water consumption and whether individual inputs are being correctly forecasted.
- **An historical average approach is simple to implement, however it does not meet the predictive ability criteria, as it would not take into account future changes in climate and policy initiatives.** It would also not be flexible as it does not use past data to estimate the impact of specific drivers of water consumption, such as prices, weather conditions and water restrictions.

The ARIMA approach is the only method which meets the regulatory stability criteria, as all alternative approaches would require a material change in methodology from the current approach.

A summary traffic light report of our assessment is included below. We note that while there are pros and cons to each of the demand forecasting methodologies assessed, the ARIMAX and panel data approaches do rate better against the assessment criteria.

While there would be benefits in Icon Water moving from an ARIMAX approach to a panel data approach, through an increase in the level of flexibility and potentially predictive ability, there would also be costs associated with increased complexity in implementation and regulatory instability resulting from a change in approach. For this reason, it may be more pertinent at this stage to identify ways to improve on the existing ARIMAX approach, instead of moving to a different approach to demand forecasting. We will explore this in more detail in stage 2 of our assessment.

Table 6: Demand forecasting approaches: traffic light assessment

Assessment Criteria	ARIMAX	Panel Data modelling	End-use modelling	Historical average approach
Transparency and reproducibility				
Predictive ability				
Flexibility				
Simplicity				
Regulatory stability				

	Meets the assessment criteria
	Partially meets the assessment criteria
	Does not meet the assessment criteria

1. Introduction

Marsden Jacob Associates has been engaged by the Independent Competition and Regulatory Commission (ICRC) to review Icon Water's demand forecasting methodology in preparation for the 2023-28 regulatory period.

1.1 Context

The ICRC decided in its 2018 determination for water and sewerage services prices for Icon Water to review its demand forecasting model before the next price investigation. Icon Water currently uses an Auto-Regressive Integrated Moving Average (ARIMA) demand forecasting model to forecast bulk water and total sales for each upcoming regulatory period.

The ICRC 2018 regulatory determination noted that the ARIMA model for demand forecasting did not account for changes in climate, policy, and demographic projections. This was identified as a potential weakness in the forecasting model by the ICRC.

The ICRC determination also noted that the medium-term demand forecasts were highly sensitive to minor updates to the data used in the model. The ICRC has noted that this may reflect the weighting of recent observations and absence of leading indicators in the model. This has also been identified as a potential weakness in the forecasting model and may result in under or over forecasting of Icon Water's water sales revenue, which can impact both Icon Water and its customers.

1.2 Review Objectives

Given the above context, the purpose of this review is to assess whether the current ARIMA approach to forecasting water demand is appropriate and fit for purpose, considering other approaches that could be used. It is to also advice on whether there would be significant benefits from moving to an alternative forecasting approach. Recommendations from this our assessment will inform the ICRC's review of Icon Water's demand forecasting methodology for the next price investigation to commence in late 2021.

The first stage of our review includes an assessment of alternative options against key assessment criteria. The next sections of our stage 1 report include:

- Section 2 provides a description of the selected demand forecasting approaches for assessment
- Section 3 outlines a set of assessment criteria we have used to assess and compare forecasting methodologies
- Sections 4-7 provide our review of the alternative demand forecasting methodologies against the assessment criteria.

2. Demand forecasting approaches for assessment

In agreement with the ICRC, we have selected four alternative approaches to demand forecasting to undertake further assessment on.

The following table provides an outline of the four approaches to demand forecasting we have assessed in this report.

Table 7: Approaches to demand forecasting for assessment

Demand forecasting approaches	Description
Auto Regressive Integrated Moving Average with exogenous predictors (ARIMAX)	ARIMAX is a class of models that explains the variation of a given time series in terms of its own past behaviour, unobserved shocks, as well as exogenous predictors (leading indicators). ARIMAX is a popular approach for time series forecasting. The ARIMAX approach is currently used by Icon Water.
Panel Data modelling	A panel is a data set that follows the same individuals (e.g. households, businesses, etc.) over time. That is, panels provide repeated observations for the same individual agents over different periods of time. Thus, panel data analysis takes advantage of information provided by the sampling variation both across individual agents as well as over time.
End-use modelling (EUM)	EUM estimates water usage by 'end use' customer distribution points. Individual end uses are then aggregated to produce demand forecasts for each customer segment, and ultimately, a prediction of total water demand.
Historical average approach	A widely employed technique for forecasting demand is to establish a base level of historic usage, and then project demand going forward based on estimates of customer or population growth.

3. Assessment criteria

To provide a framework for assessment and comparison between the current ARIMAX model and other demand forecasting methodologies we have developed a set of assessment criteria.

This section outlines the assessment criteria and the basis for selecting them. The following outlines the assessment criteria we have used for assessing the alternative demand forecasting approaches:

1. Transparency and reproducibility
2. Predictive ability
3. Flexibility
4. Simplicity
5. Regulatory stability

The basis for adopting each assessment criteria is outlined below.

3.1 Transparency and reproducibility

Transparency and reproducibility refer to the extent to which:

- the assumptions underpinning the model can be documented and tested
- modelling can be guided based on well-established methods for statistical evaluation
- the processes involved and various steps undertaken can be readily understood by a third party
- the results are reproducible.

3.2 Predictive ability

This criterion refers to the extent to which a method is adequate for:

- producing water usage forecasts for the five-year regulatory period
- informing revenue and pricing projections
- estimating the impact of weather conditions, well as climate change adaptation
- generating forecasts that are close enough to the actual outcomes.

Since accuracy of the forecasts can only be checked ex post, this criterion focuses upon (i) the ability of the model to modify its forecasts in order to account for structural change in water consumption behaviour; (ii) whether accuracy of the forecasts can be assessed using objective and well-established measures; and (iii) how readily can one assess the accuracy of the forecasts.

An inability to account for structural change in water consumption increases estimation uncertainty and compromises the extent to which in-sample fit of the data is informative about out-of-sample performance for a given model. In other words, a model that is capable of accounting for structural changes in water usage behaviour, to the extent that such changes are material, may have greater predictive ability.

3.3 Flexibility

Flexibility refers to the ability of the model to:

- identify specific drivers of water demand, such as prices, demographics, customer segmentation, policies targeting specific sectors etc
- inform other business functions. Examples include the ability to identify the impact of water efficiency programs, or the linkages between potable and recycled water.

3.4 Simplicity

Simplicity reflects:

- the costs related to upfront development of the method, as well as on-going costs
- whether the method requires extensive data collection, such as consumption data, economic and demographic factors, weather data, etc
- whether the data required is readily available, e.g. through public sources or already collected in billing systems
- whether modelling can be conducted in-house or requires input from external consultants
- the time required to update forecasts, not including any data collection issues.

3.5 Regulatory stability

It is desirable that statistical methodologies adopted for regulatory purposes and policy making, satisfy some continuity, meaning that the basic building blocks of statistical analysis remain stable over time. Stability may be associated with higher levels of transparency, in that the longer the method is used, the easier it is to understand it, replicate and scrutinise it.

A different methodology may be adopted where there is sufficient evidence that such a major change would increase the accuracy of the predictions.

4. Assessment of the ARIMAX methodology

ARIMAX is a class of models that aims to explain the variation of a given time series in terms of its own past behaviour, a function of unobserved shocks, as well as a set of exogenous predictors (leading indicators).

ARIMAX consists of an autoregressive (AR) component (that captures past own behaviour), a moving average (MA) component (that allows for unobserved shocks), and a traditional regression component (that incorporates the impact of exogenous predictors, such as weather conditions). ARIMAX is a popular approach for time series forecasting in general. When it comes to water consumption, time series analysis and forecasting typically relies on aggregate (bulk) water usage data. Icon Water makes use of an ARIMAX model to analyse daily observations of bulk water usage (dam releases).

An ARIMAX model can be expressed as follows:

$$= \sum_{\tau=1}^P \alpha_{\tau} y_{t-\tau} + \beta x_t + \sum_{s=1}^Q \theta_s \varepsilon_{t-s}; t = 1, \dots, T,$$

where y_t denotes the observation on the dependent variable (say, bulk water usage) at time period t , $y_{t-\tau}$ denotes past water usage at time period $t - \tau$, $\tau = 1, \dots, P$, x_t is an exogenous predictor, such as weather, and ε_{t-s} is the unobserved shock (error) of the model at time period $t - s$, $s = 1, \dots, Q$. Lags of exogenous predictors are also straightforward to accommodate.

The next section outlines our review of the ARIMAX approach against each of the assessment criteria. We summarise our findings in the table below.

Table 8: Assessment of the ARIMAX Methodology: headline findings

Criteria	Comment
Transparency and reproducibility	ARIMAX approach is transparent and reproducible.
Predictive ability	ARIMAX approach is suitable for producing medium to long-term forecasts, provided that the time frequency of the data analysed matches sufficiently the interval at which forecasts need to be generated (forecasting granularity). Time series analysis is capable of accounting for structural changes over time. However, time series analysis can be vulnerable to structural changes across different segments of the population, which is due to the aggregation of the data and the potential presence of omitted variables.
Flexibility	ARIMAX is deemed not to be flexible because the use of bulk water time series data does not allow for estimating the impact of segment- and household-specific factors on water usage, such as prices, water efficiency programs, property area size, type of property or business, etc.

Criteria	Comment
Simplicity	Data requirements are minimal. Modelling can be conducted in-house.
Regulatory stability	The ARIMAX methodology represents the status quo approach to forecasting bulk water usage by Icon Water.

4.1 Transparency and reproducibility

The ARIMAX methodology is based on well-established statistical processes, and it has many applications outside water demand, especially in the context of analysing and forecasting high frequency data.

Most assumptions underpinning the statistical analysis of ARIMAX are documentable in a clear manner. Moreover, model specification can be guided using well-established procedures and standard diagnostic tests, including the Box-Jenkins method.

The above considerations imply that the analysis is transparent and reproducible.

4.2 Predictive ability

Our assessment is that the ARIMAX approach is suitable for producing medium to long-term forecasts of bulk water consumption, provided that the time frequency of the data analysed matches sufficiently the interval at which forecasts need to be generated (forecasting granularity).

In particular, an ARIMAX model based on high frequency data, such as daily observations, may be well-suited to produce forecasts of bulk water usage over short-term horizons.

Similarly, an ARIMAX model based on low frequency data, such as monthly or quarterly observations, may be well-suited to produce forecasts of bulk water usage over medium/long-term horizons.

Climate change adaptation can be estimated meaningfully based on low frequency data. This is not the case with high frequency data, such as with daily observations. The reason is that the rate of adaptation of human behaviour to exogenous shocks is typically slow, due to habit formation and technological constraints. Thus, adjustments to climate change require a long time to complete. On the other hand, daily observations are heavily affected by intra-week seasonal variation and short-term fluctuations in weather conditions, which can mask the influence of those components that are important in terms of forecasting over longer horizons, such as trends and cycle.

The ARIMAX model can produce forecasts using alternative weather scenarios. This is because the model provides estimates of the impact of weather conditions on bulk water consumption. This being as different values of temperature are associated with different forecasts of total water volumes.

Moreover, ARIMAX is capable of accounting for structural changes over time, in the sense that there are several structural break tests (with known or unknown break dates), which are well established in the time series literature.

On the other hand, ARIMAX is not capable of accounting for structural changes across different segments of the population. This is because the use of aggregate data (bulk water consumption) masks any differential trends in water usage patterns among different segments of customers over time.

For example, consumers respond differently to changes in water usage prices and/or weather conditions, where consumers in detached dwellings are likely to be more sensitive to prices and/or weather compared

to units. Moreover, new properties often occupy smaller outdoor area than existing properties and therefore they may be less sensitive to weather conditions.

To the extent that the structure of the housing stock (dwelling mix) changes over time, past experience obtained from bulk water data may not be highly informative about future water usage patterns.

Similarly, some industries/sectors are more water intensive than others. To the extent that water-intensive sectors grow at a different pace than others, in-sample fit may not be indicative of out-of-sample performance.

We note that even if data on the structure of the housing stock or industry composition are available (e.g., the number of blocks of units as a proportion of total residential consumers), in practice it may be difficult to identify the effect of such variables using time series analysis alone, and to disentangle the effect of these variables from other trends in aggregate water consumption. This is because the structure of the housing stock (or industry composition) is likely to be slowly moving on a quarter-by-quarter basis, whereas identification of the model parameters using time series analysis requires sufficient variation of the variables over time.

An additional source of structural change in water usage demand constitutes the level of prices. In particular, the existing tiered pricing scheme implies a simultaneous relationship between prices and water consumption, i.e. not only the level of prices influences consumption, but the level of consumption influences prices as well. Such complex relationship cannot be accounted for using data on aggregate consumption. Thus, to the extent that price changes alter consumer behaviour, past experience may not be informative about future water usage patterns.

These issues can increase estimation uncertainty, thus lowering predictive ability. However, in practice the materiality of these issues on demand forecasts depends on available evidence, which is beyond the scope of this report.

The accuracy of the forecasts obtained from the ARIMAX approach, conditional on a set of forecasts for the exogenous predictors, can be assessed in a straightforward manner, using well-established measures, such as the Mean Square Error (MSE) and the Mean Absolute Per cent Error (MAPE). The former is defined as the average *squared* difference between the forecasts and the actual values, whereas the latter is defined as the average *absolute* difference between the forecasts and the actual values. For this reason, MAPE is easier to interpret than MSE.

In the current regulatory period to date, the average *absolute* difference between the forecasts and the actual values obtained from Icon Water's ARIMAX approach, computed based on yearly forecasts, equals approximately 6.2%. The average difference between the forecasts and the actual values equals about 4.9%. The latter is smaller in value than the average absolute difference because some forecasts errors are positive and some negative and so they partially cancel out across different years.

4.3 Flexibility

The use of bulk water time series data does not allow for estimating the impact of segment- and household-specific factors on water usage, such as water efficiency programs, prices and changes in dwelling structures and mix; nor does it allow for establishing links between potable water demand and recycled water. Similarly, it is difficult to incorporate demographic trends into the forecasts. These issues were also identified by the ICRC in its 2018 price review, which stated that Icon Water's ARIMA model did not account for changes in climate, policy and demographic projections (ICRC, 2018).

4.4 Simplicity

The ARIMAX methodology satisfies the criterion of simplicity. In particular, the data requirements for this method are minor since bulk water dam releases are readily observed daily.

Some understanding of statistics or econometrics is required, but, overall, the ARIMAX methodology is transparent.

In addition, there are numerous resources available to water businesses to better understand ARIMAX analysis, including textbooks for business, software and courses (online, face-to-face).

The method can be implemented using well-established methodologies using standard statistical software. Sophisticated packages and toolkits for time series analysis exist in open-source software, like Python and R, both of which can be used free of charge. Estimation can be implemented in-house.

Daily forecasts can be updated quickly. Obviously, the predictive ability of long-range forecasts can only be verified in the long-term.

4.5 Regulatory stability

By construction, the ARIMA methodology satisfies this criterion because it presents the status quo approach to forecasting bulk water usage by Icon Water.

5. Assessment of the Panel Data methodology

A panel is a data set that follows the same individual agents (such as households, businesses, etc.) over time. That is, panels provide repeated observations for the same individual agents over different periods of time.

Panel data analysis takes advantage of information provided by the variability of the sample both across individuals and over time. Cross-sectional analysis uses only the former and time series analysis the latter.

Panel data analysis is currently the main approach used for forecasting water usage by Sydney Water Corporation (Abrams et al, 2012). Panel data analysis has also been used for modelling water usage demand elsewhere; see e.g. Nauges and Thomas (2003), Fenrick and Getachew (2012), and Juodis and Sarafidis (2021) among others.

A simple dynamic panel data model can be expressed as follows:

$$y_{i,t} = \alpha y_{i,t-1} + \beta x_{i,t} + \eta_i + \varepsilon_{i,t}; \quad t = 1, \dots, T; \quad i = 1, \dots, N,$$

where $y_{i,t}$ denotes (say) the billed water consumption of user i at time period t , $y_{i,t-1}$ denotes the value of billed water usage during the previous time period, $x_{i,t}$ denotes (say) average temperature during period t for user i , η_i denotes an unobserved consumer-specific and time-invariant effect that is allowed to be correlated with the control variables (such as, geographical location, pool ownership, garden size, household size etc.) and $\varepsilon_{i,t}$ is the unobserved error term of the model. Further lagged values of the dependent variable, or lagged values of predictors can also be included.

Panel data regression analysis can potentially provide more data points compared to time series analysis. This is because the dataset contains observations over time for each household/business included in the sample, rather than for total consumption (dam release). As such, the accuracy of estimation and the forecasting ability can be improved.

This section outlines our assessment of the Panel Data methodology against the assessment criteria. We summarise our findings in the table below.

Table 9: Assessment of Panel Data Methodology: headline findings

Criteria	Comment
Transparency and reproducibility	The panel data approach is transparent and reproducible.
Predictive ability	The predictive ability of panel data analysis for medium or long-term horizons is potentially high.
Flexibility	Panel data analysis is flexible because it can account for climate change, demographic trends, and policy changes.
Simplicity	A panel data approach would be more complex in comparison to time series approaches, especially regarding data collection and estimation.
Regulatory stability	A panel data approach deviates substantially from the existing ARIMAX methodology.

5.1 Transparency and reproducibility

Panel data analysis is based on well-established statistical processes and has many applications outside water demand, especially in the context of policy analysis and identifying structural relationships.

Some understanding of econometrics and regression is required, but, as it is the case with the ARIMAX methodology, the forecasts can be implemented in a transparent way. Note that forecasting based on panel data analysis can be implemented at the level of each segment. Thus, the forecasts can be reproduced without necessarily releasing detailed data from Icon Water's billing system, which can be confidential.

There are numerous resources available to water businesses to better understand panel data analysis, including textbooks, software and courses.

The assumptions underpinning panel data analysis are documentable in a clear manner. Model specification can be guided using diagnostic tests and well-established procedures, including model information criteria.

5.2 Predictive Ability

Panel data analysis is suitable for medium\long-term forecasting. Notably, the variability of the sample across different households/businesses implies that the total number of data points will be large even when low time-frequency data are used in estimation (e.g. quarterly observations).

Panel data analysis is suitable for estimating climate change adaptation and other dynamic processes that take place over time, including demographic and dwelling mix changes.

Moreover, panel data analysis can produce forecasts using alternative weather scenarios for the same reason as with ARIMAX; namely, because it provides estimates of the impact of weather conditional on water usage.

Panel data analysis can adapt its forecasts to account to structural changes over both time series and cross-sectional dimensions.

Firstly, similarly to time series analysis, there exist well-established methods for testing for structural breaks over time. Secondly, unlike time series regression, panel data analysis allows modelling different segments of consumers separately, at the level of individual households or businesses. Thus, it is less vulnerable to the problem of aggregation and omitted variables bias (such as prices).

As is the case with time series regression, panel data analysis enables one to assess the accuracy of the forecasts in a straightforward manner, using well-established performance measures, such as the Mean Square Error (MSE) and the Mean Absolute Per cent Error (MAPE).

5.3 Flexibility

Panel data analysis can incorporate exogenous predictions of demographic trends into the forecasts. In particular, since water usage is estimated (and forecasted) separately for each segment of the population, different rates of growth among segments can be easily adopted in the total forecast, by means of using different weights.

Panel data analysis can be used to analyse the effect of policies designed for (or adopted by) a subset only of the entire base of consumers, such as the introduction of water/energy efficiency programs for household appliances.

Panel data analysis can account for climate change and differential demographic trends in a straightforward manner.

5.4 Simplicity

Panel data analysis requires data over two dimensions, namely over time and across different segments. To obtain the highest amount of information among different segments of the customer base, it is desirable to obtain data at the household level. A sample of representative customers can be collected by stratifying the population (e.g., based on distinct types of households, or residential vs non-residential users). This will allow for systematic differences between different segments.

Data required to estimate a panel model include (i) billed water usage for each customer/household; (ii) prices; (iii) weather conditions; (iv) information about participation to water efficiency programs (if applicable); (v) economic conditions (particularly relevant for businesses).

Information on property-specific characteristics, such as household size, property area size, pool ownership, whether there exists recycled water, and so on, may add value to the analysis but are not essential, so long as these variables vary little over time.

Water usage per household can be readily extracted from water business billing systems. Most billing systems will encapsulate adequate detail to enable simple panel data analysis, with a breakdown between standalone houses, units and flats typically sufficing.

Weather data can be obtained as per current practice. One complication is the requirement to align the meter reading cycle with the weather data to accommodate for the fact that water meters are usually read on a rolling basis (with a meter reading cycle that depends on the size of the water utility), rather than instantaneously.

Standard panel data models can be estimated in a straightforward manner using open-source software, such as R. However, sophisticated panel data techniques would mostly be available in specialised statistical/econometric software, such as Stata and EViews, both of which cost around \$1,500 for a single license.

Some upfront training on the topic could be desirable, but updates of forecasts can be implemented in-house.

5.5 Regulatory stability

Panel data analysis is based on regression, as it is the case with ARIMAX. Thus, it shares the same underpinnings with time series analysis.

However, in comparison to other (time series) methodologies that are based on bulk water data, panel data analysis deviates substantially from the existing ARIMAX methodology in two ways.

Firstly, panel data analysis uses data at the household (or user) level, as opposed to bulk water volumes. Therefore, the data requirements increase substantially.

Secondly, since household-specific consumption is not observed daily, the time span of the panel would be relatively short. As such, statistical inference based on panel data needs to rely on estimation methods

suitable for samples that contain a large number of individual consumers. Thus, panel data estimation necessitates the use of different methods than time series analysis.

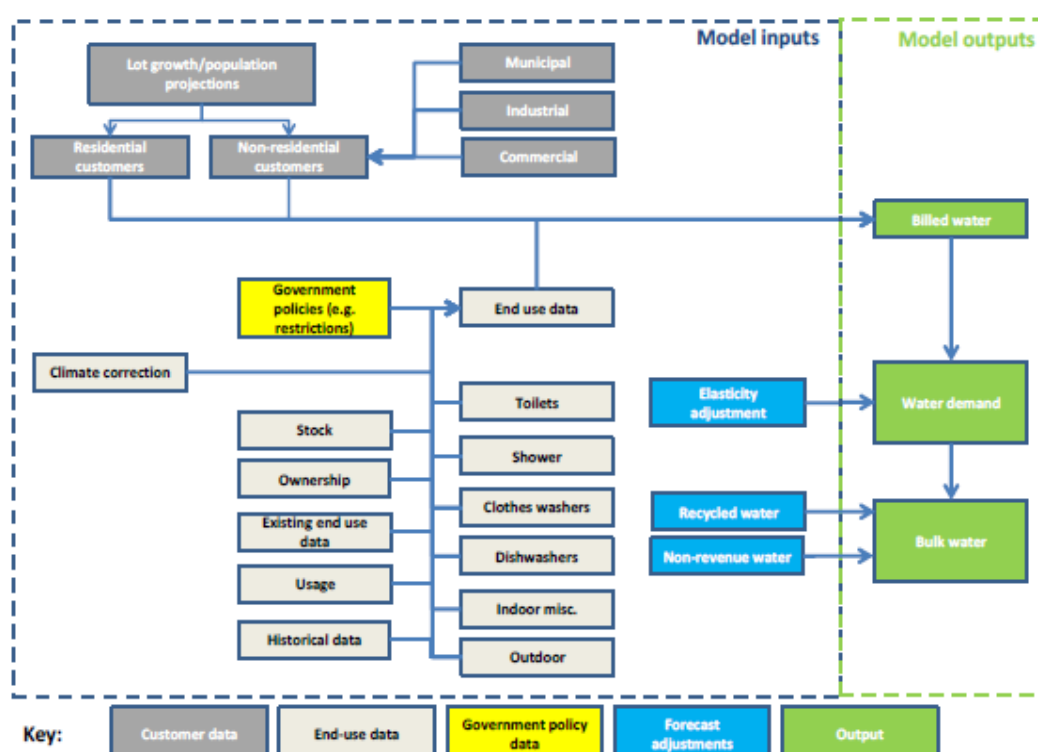
6. Assessment of End-use Modelling

End-use modelling (EUM) estimates water usage by ‘end use’ customer supply points. Individual end uses are then aggregated to produce demand forecasts for each customer segment, and a prediction of total water demand for a water business.

This section outlines our assessment of the end use methodology against the assessment criteria.

End use modelling has been employed in the past for demand forecasting by Melbourne metropolitan water businesses, for revenue projections, as well as long-term demand and supply outlooks. An overview of the EUM is outlined in figure 1.

Figure 6: Overview of process for EUM



Source: Smart Water Fund, Demand modelling alternatives, June 2013, p.22.

The next section outlines our assessment of end-use modelling approach against the assessment criteria. Our headline findings are summarised in the table below.

Table 10: Assessment of EUM: headline findings

Criteria	Key findings
Transparency and reproducibility	Assumptions are documentable in a clear manner, but they are not easily testable. There are several EUM models available, and it is not clear which one to choose.
Fit for purpose	EUM is capable of undertaking short and long-term water usage forecasts. However, it relies on customer end-use surveys on a small sample of customers and appliance stock surveys, both of which are undertaken infrequently.
Predictive ability	Model parameters are calibrated rather than estimated to make the model fit the data. Therefore, it is difficult to identify causes for discrepancy between forecast and actual water consumption.
Flexibility	EUM are flexible because they rely on individual end-use scale obtained from customer surveys. Therefore, they are useful in terms of understanding specific factors that influence water usage by each end-use
Simplicity	It can be costly and time consuming to update inputs for an EUM as they generally rely on customer studies on water demand and appliance stock surveys.
Regulatory stability	Moving to a EUM is a significant change from the current approach.

6.1 Transparency and reproducibility

The assumptions behind EUM can be documented but are not easily tested.

EUM approaches are usually developed in Excel, which permits some traceability, though this can become less transparent the more granular the detail on each individual end use is.

Moreover, there are several end-use models available, and it is not clear which one to select. Examples of end-use models include the Demand Generator Model (Duncan and Mitchell, 2008), the SIMDEUM model (Blokke et al, 2010) and the ISDP model (see Turner et al, 2010). Unlike time series and panel data analysis, selection among these different models cannot be guided based on statistical evaluation and goodness of fit of the data.

6.2 Predictive Ability

Model parameters are calibrated, i.e. their values are assigned based on exogenous sources, rather than estimated from the sample with the objective to make the model fit the data. Therefore, it may be difficult to identify causes for differences between forecasts and actual consumption.

In addition, It is difficult to know whether individual inputs are being correctly forecast.

On this basis the EUM approach does not meet the predictive ability.

6.3 Flexibility

EUM is very flexible in terms of running various scenarios by changing key input assumptions particularly related to changes in appliance efficiency and end-use water demand.

In particular, EUM can be useful to understand factors that influence water usage by each end-use, such as household size, typology of dwellings and demography (age, gender, culture etc.); policy decisions (price, restrictions, awareness, rebates etc.), technology take-up rates, and climate.

Data are collected at individual end-use scale for a sample of customers, and therefore they are richer compared to aggregate time series data or panel data at the household level.

6.4 Simplicity

The EUM approach does not meet the simplicity criterion due to the granularity of data required, which is somewhat complex to develop and costly to update, as it generally relies on customer studies on water demand and appliance stock surveys.

An EUM approach is also resource intensive and would also require a dedicated internal resource to manage the modelling process, though this is consistent with other approaches.

6.5 Regulatory stability

Moving to a EUM constitutes a significant change from the current approach and therefore would not meet the criteria of regulatory stability. There is also not sufficient evidence to suggest that moving to an EUM would increase the accuracy of predictions.

7. Assessment of the Historical Average methodology

Historical water data can be used for forecasting demand to establish a base level of usage across different segments of the population and then project demand going forward based on estimates of customer or population growth.

Adjustments to forecasts are often made based on a variety of factors considered to be contributors to demand, including changes in demographic factors (such as penetration of water efficient appliances or rainwater tanks), corrections for weather or price impacts, assumptions about the impact of restrictions or other policy initiatives, and assumptions or estimates of use by specific customers or groups (e.g. large, non-residential customers).

An historical average methodology is a commonly used practice across water businesses for specific customer segments, including non-residential water usage, trade waste and sewerage volumes, where usage is expected follow a predictable trend over time (Smart Water Fund, 2012).

The next section outlines our assessment of a historical average methodology approach against the assessment criteria. Our headline findings are summarised in the table below.

Table 11: Assessment of the historical average methodology: headline findings

Criteria		Comment
Transparency and reproducibility		Many assumptions underpinning the model are not testable. Modelling is not guided based on well-established methods for statistical evaluation. The various steps can be understood by a third party and the results are reproducible.
Predictive ability		Parameters are not estimated to make the model fit the data, instead they are calibrated based on certain assumptions or with reference to exogenous sources. Therefore, the ability of the model to produce accurate forecasts is overly sensitive to the validity of the above assumptions.
Flexibility		The method is not flexible because it does not use past data to estimate the impact of specific drivers of water consumption, such as prices, weather conditions and water restrictions; instead, the magnitude of the impact of such drivers is an assumption (input) of the model.
Simplicity		Data requirements are minor. Modelling can be conducted in-house.
Regulatory stability		Moving to an historical average approach would be a significant change from the current approach and therefore would not meet the criteria of regulatory stability.

7.1 Transparency and reproducibility

An historical average approach typically adjusts the basic demand forecast using a range of assumptions concerning factors that are considered likely to influence demand. Often, these assumptions are not testable. Moreover, the adjustments can be difficult to justify without sufficient data. Additionally, the approach is not based on well-established methods for statistical evaluation.

However, in principle the results can be understood by a third party and are reproducible.

7.2 Predictive Ability

When demand for a service and as its drivers, are both expected to remain consistent with historical usage, this approach would be fit for purpose. However, an historical average approach would not easily take into account future changes in demand due to weather conditions and climate change, policy changes and water efficiency initiatives.

Parameters are not estimated to make the model fit the data, instead they are calibrated based on certain assumptions or with reference to exogenous sources. Therefore, the predictive ability of the model could be severely compromised when the underpinning assumptions employed are violated.

In general, it is likely that this approach would not perform as well as other models over the longer term. This is because the method is only accounting for historical usage trends, whereas future structural changes in water demand cannot be accounted for.

7.3 Flexibility

In general, it is difficult to incorporate alternative scenarios using an historical average approach because the methodology does not estimate the effect of water demand drivers from past data; instead, it assumes what the impact of these factors is.

For example, incorporating changes in prices into the forecasts would be challenging because there is no variable in the underlying methodology to which the price impact could be applied.

7.4 Simplicity

An historical average approach to demand forecasting would meet the simplicity criterion because the data is readily available, assuming it would only require actual bulk water consumption or water sales and customer growth projections. Moreover, costs related to upfront development, as well as ongoing costs, are minor.

7.5 Regulatory stability

Implementing an historical average approach would be a material change to the current approach to demand forecasting of water usage.

There is also no evidence that using this methodology would produce a higher level of accuracy to justify any regulatory instability due to the change in approach.

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Appendix 4: Approaches used by other regulators to forecast water demand

Hunter Water

Hunter Water uses a supply demand planning model called the Integrated Supply-Demand Planning (iSDP) model to forecast water demand. Hunter Water's iSDP model forecasts the water demand for average climate conditions. Unanticipated climate events such as drought or above average rainfall are not considered in Hunter Water's model. Therefore, these events can significantly affect the accuracy of forecasts.

The model uses demographic factors such as population growth, number of dwellings/connections and household size to forecast demand. Hunter Water updates demographic and connection numbers annually as part of its planning process.

The model forecasts water demand for residential customers and non-residential customers separately.

For residential customers, it forecasts demand based on expected water uses for various activities such as residential toilets, showers, taps, washing machines and gardens. The iSDP model has separate model modules to calculate demand for each activity. These modules forecast demand based on detailed information on installed equipment and the frequency of use. Hunter Water has access to annual sales data for individual appliances which it uses as an input to the model. In some cases, Hunter Water estimates the sales using data on appliance ownership in each year in combination with assumptions about the duration of time that appliances remain in service prior to being replaced.

For non-residential customers, it uses a trend analysis to forecast the demand. Hunter Water uses economic trends, changes in recycled water demand and water conservation measures as inputs to the model.

The model calculates non-revenue water using Water Services Association of Australia national reporting methodology.

More information on the model used by Hunter Water is available at Hunter Water (2019).

Sydney Water

Sydney Water uses a panel data regression approach to forecast water demand. Panel data regressions use repeated observations over time to forecast demand.

Sydney Water uses a three-part approach for water demand forecasting:

- 1) It uses historical information to determine what factors influence water consumption. To do this, Sydney Water divides its customer base into 34 segments based on factors such as dwelling or

business type, lot size and whether the property was built under the Building Sustainability Index⁴ system.

- 2) Sydney water then estimated an econometric panel data model for each segment based on historical customer usage. The parameters of this model capture the impact of the factors that influence water consumption within each group, such as price elasticity, weather, and seasonality on water demand.
- 3) Sydney Water then forecasts water demand by feeding in the forecast growth in customer numbers in each customer segment, climate projections, and estimates of system water losses and price elasticity to the econometric model (IPART 2020).

Sydney Water's model forecast water demand based on average climate conditions because the model is not able to accurately predict climate conditions over the regulatory period (IPART 2020).

Melbourne Water

Melbourne Water forecasts bulk water demand based on forecasts provided by retail water businesses that use integrated-supply demand planning models to forecast demand. The inputs for the model are taken from periodic end use studies (ESC 2021). Key features of this modelling approach are:

- total demand estimate is a function of separate residential, non-residential water and non-revenue water forecasts
- efficiencies of appliance-based end uses and other parameters such as showering frequency and duration can be incorporated
- various calibration variables can be used such as residential water demand for outdoor water use, non-residential water demand and non-revenue water
- most recently completed end use studies are used.

Non-residential forecasts rely on bottom-up aggregation of historical demands and projections using observed trends or relationships. Non-revenue water forecasts rely on observed trends or relationships to factors and are adjusted for any future non-revenue water management activities.

⁴ The Building Sustainability Index is a sustainability planning system in the NSW. Its requirements apply to all residential dwelling types in NSW and meeting its requirements is a part of the development application process.

Abbreviations and acronyms

ACT	Australian Capital Territory
AIC	Akaike Information Criteria
ARIMA	Autoregressive Integrated Moving Average
ICRC	Independent Competition and Regulatory Commission
IPART	Independent Pricing and Regulatory Tribunal
KL	kilolitres
ML	Megalitres
SEACI	South Eastern Australian Climate Initiative

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