Review of water and sewerage services demand forecasting methodology

Icon Water submission on ICRC Draft Decision

25 October 2021

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1 Executive summary

1.1 Background

The Independent Competition and Regulatory Commission (the Commission) is reviewing demand forecasting methodologies for regulated water and sewerage services in the Australian Capital Territory (ACT). The review is a reset principle under the 2018–23 Price Direction,[1] and will set the approach for forecasting demand in the 2023–28 regulatory period. In September 2021, the Commission published a draft report (the 'Draft Report') setting out its initial positions and invited stakeholders' feedback. This submission presents Icon Water's responses to the Draft Report.

1.2 Icon Water views on the draft decision

Icon Water supports nearly all the positions set out in the Draft Report, including:

- retaining the current Autoregressive Integrated Moving Average (ARIMA) model for forecasting dam abstractions;
- using the relationship between water demand and climate variables (temperature, rainfall and evaporation) as the primary basis of forecasting;
- adopting NSW and ACT Regional Climate Modelling (NARCliM) projections for climate change, which are more recent and localised compared to the South Eastern Australian Climate Initiative (SEACI) data;
- using ACT population growth projections, rather than historical trends, to forecast future connections growth; and
- applying post-model adjustments to account for policy or demographic changes which are not reflected in historical data (such as potential changes to the Sustainable Diversion Limit).

Icon Water wishes to acknowledge the Commission's approach to the review, which has included two stakeholder workshops, public submissions, and the engagement of an independent economic consultant to assess the demand methodologies. The Commission's Draft Report has provided valuable, independent confirmation of Icon Water's own findings that the current forecasting methods are generally working well, as outlined in our submission to the Commission's issues paper.[2] Icon Water also commends the Commission for making balanced, well-reasoned decisions on matters raised by stakeholders in submissions to the review.

Noting that demand forecasting is a complex and technical subject, Icon Water believes the Commission's approach will help the broader community have confidence that Icon Water's demand forecasts are the best available for the ACT region.

1.3 Specific matters addressed in Icon Water's submission on the draft decision

Icon Water's submission focusses on several key matters pertaining to the ICRC's draft decision and how it will apply to the 2023–28 regulatory period:

1) **The Commission's proposal to use aggregated weekly data with additional climate variables.** Icon Water welcomes changes that improve forecast accuracy and remains open

[1] Independent Competition and Regulatory Commission, Price Direction Regulated water and sewerage services 1 July 2018 to 30 June 2023, 1 May 2018.

[2] Icon Water, Icon Water Submission to ICRC Issues Paper, 9 July 2021.

to considering using weekly data in the model. However, Icon Water wishes to note some of the risks associated with data aggregation, including the potential loss of explanatory power. Icon Water considers it is premature to conclude that the proposed changes genuinely improve the forecasts until the model has been fully specified using appropriate statistical methods. Icon Water understands that model specification will occur at a later stage of the review.

2) **The application of NARCliM climate change data within the demand model**. Icon Water supports the Commission's draft decision to use NARCliM data. However, Icon Water notes that the Commission's decision to restrict the NARCliM data to 2023–28 may not provide a representative sample for estimating climate change impacts. Icon Water recommends using an extended, 20-year period of climate change data. Icon Water also recommends de-trending historical climate data before applying NARCliM adjustments to avoid double counting.

3) **The choice of statistical software**. Icon Water understands the Commission intends to develop an updated demand model using *Stata,* a proprietary statistical software package, and move away from using *R,* which is free and open-source software. Icon Water considers this may reduce the transparency and replicability of the forecasts and recommends that the Commission's final decision be software-agnostic. The demand methodologies should not be prescriptive of the software to be used and should provide sufficient information for stakeholders to implement the forecasts using freely available tools to improve transparency.

The remainder of this submission addresses the above points.

2 Use of weekly data and additional climate variables

2.1 The Commission's draft decision

The Commission's draft decision is to use weekly data to forecast dam abstractions rather than daily data. This decision is based on initial findings by the Commission's consultant, Marsden Jacob Associates, that using weekly data improves forecasting accuracy using two measures: the Mean Absolute Percentage Error (MAPE) and Root Mean Squared Percent Error (RMSPE). The out-of-sample forecast accuracy was measured over the period July 2018 to June 2021. The Commission proposes aggregating daily data to weekly data by taking the sum of daily dam abstractions and averaging daily climate variables (temperature, rainfall, and evaporation). The Commission also tested using monthly data but found that this did not improve forecast accuracy relative to daily data.

The Commission's Draft Report similarly proposes to include additional climate variables, if they are shown to be statistically significant:

- number of days where the daily temperature exceeded 30 degrees or 35 degrees in a week;
- number of days without rain in a week; and
- interaction between rainfall and evaporation (*rainfall x evaporation*).

Notably, the Commission's draft decision is based on initial modelling estimates. The Commission notes that its draft position is subject to further refinement of the model before the release of its final report. In particular, the initial results are based on preliminary analysis that does not follow the standard Box-Jenkins procedure for model identification. Similarly, the technical report from Marsden Jacob Associates contains several disclaimers that model implementation, testing and refinement during later stages of the review may result in a different model specification and parameter values than presented in the Draft Report.

2.2 Icon Water's response to the Draft Report

Icon Water's objective is to ensure that its demand forecasts are as accurate as possible to achieve the best outcome for the ACT community. Therefore, Icon Water welcomes changes to the demand forecasts if there is strong evidence presented that they genuinely improve forecast accuracy. Given the importance of demand forecasts in setting Icon Water's prices, we consider that changes should be made conservatively and only if supported by robust statistical analysis. This view aligns with the Commission's assessment criterion of 'Regulatory Stability' for its review of forecasting methods.

Due to the preliminary nature of the Commission's conclusions, Icon Water does not consider there is currently sufficient evidence presented to support the proposed changes. A meaningful and objective assessment of the ARIMA model's forecast accuracy can only be made after full specification using the Box-Jenkins method, as outlined in our submission to the issues paper. We note that the Commission intends to apply the Box-Jenkins procedure at a later stage of the review. Icon Water also understands that the Commission will publish the updated model code with its final report, and therefore we have not been able to verify the model outputs presented in the Draft Report. Accordingly, at this time, Icon Water is unable to support the Commission's draft decision to use weekly data and additional climate variables.

For avoidance of doubt, Icon Water does not have an in-principle objection to using weekly data or additional climate variables if it genuinely improves the forecasts. Instead, we wish to highlight some of the risks surrounding changes of this kind which we believe should be considered before finalising the demand model. Our comments on these matters are outlined in the sections below.

Icon Water recognises the possibility that the model specification process undertaken before the Commission's Final Report may identify additional changes to the model (such as new variables) that

have not been included in the draft report for consultation. If this occurs, Icon Water requests that the Commission provide stakeholders with additional opportunities to comment on these changes. Icon Water's feedback in this submission relates only to the matters identified in the Commission's Draft Report.

2.2.1 Aggregation results in a loss of data granularity, which may diminish the model's explanatory power

The current demand forecasting methodology uses daily data, which provides a rich data set for establishing the statistical relationship between dam abstractions and climate variables. Daily climate data was used by the Commission to set Icon Water's demand forecast for 2018–23, as well as the 2013–18 regulatory period. In statistical analysis, large data sets are often desired to capture, with greater precision and nuance, how the dependent variable moves with the explanatory variables. Using many data points allows the model to be trained on many combinations of different temperature, rainfall and evaporation values. This should generally be expected to improve the model's explanatory power.

Aggregating to weekly data reduces the number of data points by a factor of seven, which can significantly diminish the model's ability to capture statistical relationships. Data aggregation (whether by averaging or other means) is necessarily a destructive process that leads to some information being lost about the phenomenon being studied. Indeed, it is intuitive to expect that water demand will vary with climate on a daily basis. For example, one can reasonably expect that people are less likely to water their gardens if it has rained on the same day. Moving to weekly data may have a blunting effect on this relationship.

The Commission's Draft Report notes that using weekly data is intuitively sound because daily information is not relevant for a five-year forecast horizon.[3] Icon Water agrees that it is not necessary, for regulatory purposes, to produce a daily forecast of water demand. However, this does not mean that daily data is not relevant for establishing the statistical relationship between water use and climate. In this regard, a distinction should be drawn between the desired output of the model (a forecast over five years) and the inputs into the model (where greater granularity may be advantageous).

The Commission's Draft Report also suggests that using daily data introduces 'noise' because it will reflect intra-week variation in water use (e.g. weekends vs weekdays), which is irrelevant for a five-year forecast. In statistical analysis, the usual treatment is to isolate intra-week effects by introducing 'dummy variables' for each day of the week, as is the current approach in the daily ARIMA model. Icon Water considers that isolating statistical relationships should be preferred to data aggregation. While data aggregation can 'smooth' the impact of less important variables, such as days of the week, it also has the effect of smoothing critical variables such as dam abstractions and climate.

For the reasons outlined above, Icon Water considers that, as a starting presumption, more data should be preferred to less data, and data aggregation should generally be avoided. Any rebuttal of this presumption should be backed by strong theoretical justification.

2.2.2 Aggregation reduces the variance of the data, which is needed to establish statistical relationships

Econometric models, such as the ARIMA model, provide a formal approach to estimating how changes in one variable (e.g. climate) affect another (e.g. water demand). It follows that the ARIMA model requires sufficient variation in the input data to determine the causal relationships between the variables.

Data aggregation (e.g. by averaging) has the effect of 'smoothing' the variables and reducing the data's variance (or 'spread'). Data aggregation makes it more challenging to estimate how variation in one variable relates to another and may bias the model. This is particularly the case with climate data,

[3] ICRC, Draft Report: Review of water and sewerage demand forecasting methods, p32.

where consumer responses to shocks in weather variables (e.g. water usage on a very hot day) may be significant and non-linear.

For illustration, consider the hypothetical daily temperature series in Table 1 showing two different weeks. The average temperature is the same for both Week 1 and Week 2, which means they would appear identical if aggregated into weekly data. However, the variance ('spread') is significantly higher in Week 2 than Week 1. Week 2 also has a significant spike in temperature over the weekend. Therefore, we may expect that Week 2 would have higher water demand than Week 1. Using aggregated data may fail to capture such nuances in the data.

Table 1: Daily temperature for two hypothetical weeks (illustrative only), (ºC)

	Mon	Tue	Wed	Thur	Fri	Sat	Sun	Average
Week 1	25	26	24	25	26	25	24	**25**
Week 2	28	20	18	20	24	31	36	**25**

This table illustrates that averaging climate variables result in a loss of granularity, potentially leading to a biased forecast model. Week 1 and 2 have the same average temperature, but Week 2 is likely to have higher water demand.

In addition, the current daily ARIMA model incorporates daily lag terms which account for the observation that water demand on a particular day is influenced by the weather and water demand in preceding days. The daily lag effect was found to be statistically significant for temperature, rainfall, evaporation, and dam releases. Moving to weekly data will lose this 'daily lag' relationship. It is less intuitively clear that a weekly or monthly lag effect is relevant for water demand.

The Commission's draft decision seeks to address some of these potential issues by proposing additional variables for the model. Specifically, the Commission is considering new variables to capture the number of days in a week where the temperature exceeds 30 degrees; and the number of days without rainfall. The construction of these variables appears to imply that variations in weather during the week may be important for the demand model. Icon Water notes that this seems inconsistent with the draft decision to move away from using daily data on the grounds that it is not relevant for forecasting demand.

It may be the case that these additional variables are, in effect, proxies for using daily data and daily lag effects and not necessarily representative of newly identified statistical relationships. If this is true, the resulting model may be suboptimal compared to simply using daily data. This is because proxy variables may be imperfect substitutes for daily data, particularly when narrowly defined (e.g. number of days above a specific temperature threshold).

Another consequence of data aggregation is that it may provide a false impression of improved forecast accuracy by reducing the size of the regression 'residuals'.[4] This is because aggregation averages out larger observations and reduces the number of data points. Whilst it may be easier to fit a model to fewer data points, this does not necessarily represent an improved model. The Commission's Draft Report assess forecast accuracy using the MAPE and RMSPE. Both measures include the term:

$$\frac{F_t - A_t}{A_t}$$

Where F_t is the forecast value at time *t* and A_t is the observed (or 'actual') value at time *t.* Aggregating to weekly data has the effect of reducing the variance of A_t by smoothing out more extreme values. This will tend to reduce MAPE and RMSPE regardless of whether it genuinely improves the model's accuracy. In particular, RMSPE is a scale-dependent measure and places more importance on larger errors. Even a small number of significant forecast errors (such as outliers in daily data) can heavily

[4] The residual is the difference between the estimated value and the observed value.

skew the RMSPE to suggest a poorer model. Similarly, the MAPE (which divides each error by the observed demand at that point in time), can be skewed upwards when there is a large error while demand is low. Accordingly, caution should be exercised when comparing RMSPE and MAPE across models with a different number of data points and different variances.

2.2.3 Sensitivity of results to the choice of the validation period

The Commission's draft decision is to evaluate the model specification using an out-of-sample validation period of July 2018 to June 2021. Icon Water acknowledges that this is standard practice and consistent with the 2018–23 demand forecast approach. However, when testing relatively minor refinements to the model specification, it is essential to account for the possibility that the forecast accuracy may be sensitive to the choice of the validation period. This is particularly the case when testing new variables or where the purported increase in forecast accuracy is relatively small.

Icon Water notes that the period July 2018 to June 2021 was atypical in several respects. The first two years of this period exhibited significantly below-average rainfall. As a result, water sales in 2019–20 were approximately 12% higher than forecast. This was followed by a period with above average rainfall and water demand being lower than forecast in 2020–21. Consequently, the 2018 to 2021 period has shown greater variance in water demand than a typical, representative climate period. As discussed above, data aggregation reduces the variance of the data, which may lead to a specious appearance of improved forecast accuracy during periods of demand volatility.

It is important to ensure that the model selection process does not lead to a specification that is fitted to an idiosyncratic climate pattern but may not perform well generally.

3 Application of NARCliM data

3.1 The Commission's draft decision

The Commission's draft decision is to use NSW and ACT Regional Climate Modelling (NARCliM) climate change projections to forecast water demand in the 2023–28 regulatory period. This is a change from the 2018–23 water demand forecast which used data from the South East Australian Climate Initiative (SEACI). The Commission determined that NARCliM data is widely accepted and provides a single, up-to-date data source for localised climate change projections.[5]

The Commission states that it will retain the current approach to develop future climate scenarios. The draft decision is to develop future climate scenarios based on a reference climate scenario, which will use climate data from 1965 onwards. The reference climate scenario will be derived by dividing the historical data into 50 overlapping 6.5 year periods and calculating average climate data across the 50 periods. The Commission's draft decision is to calculate climate change adjustment factors using NARCliM data from 2022 to 2028, and to apply these to the reference climate scenario.

3.2 Icon Water's response to the draft decision

Icon Water welcomes the Commission's draft decision to adopt NARCliM data. As outlined in our response to the Issues Paper, Icon Water considers that NARCliM is a more up-to-date and robust source of climate data compared to SEACI.[6]

Our response to the Commission's Draft Report focusses on how the NARCliM adjustment factors will be calculated and applied in the demand forecast for 2023–28. This includes:

1) the sample period for NARCliM data;
2) accounting for climate change trends in historical data; and
3) accounting for differences in climate reference periods between the NARCliM data and the demand model.

We also wish to clarify the steps outlined in the Commission's Draft Report for estimating a reference climate scenario. These issues are discussed in the sections below.

3.2.1 Sample period for NARCliM data

The Commission's draft decision is to use monthly NARCliM data for the period 2022 to 2028 to coincide with the forecast period. Icon Water considers that restricting the data to a six-year period does not provide a representative sample for estimating climate change.

Each of the twelve NARCliM scenarios represent one possible timeseries of future climate outcomes. It is not appropriate to interpret the NARCliM data as forecasts of average climate conditions. The NARCliM timeseries exhibit significant volatility due to climate variability, similar to actual weather observations. This is illustrated in Figure 1 which shows two NARCliM scenarios for rainfall at Canberra Airport.

Icon Water recommends using an extended sample period of 20 years to capture the climate variability in the NARCliM data. This will help ensure that the NARCliM reference period is not biased by the volatility in the NARCliM data series over shorter periods. The 20-year period can be centred around the 2023–28 regulatory period, with the first NARCliM data point being January 2016 and the last being December 2035.

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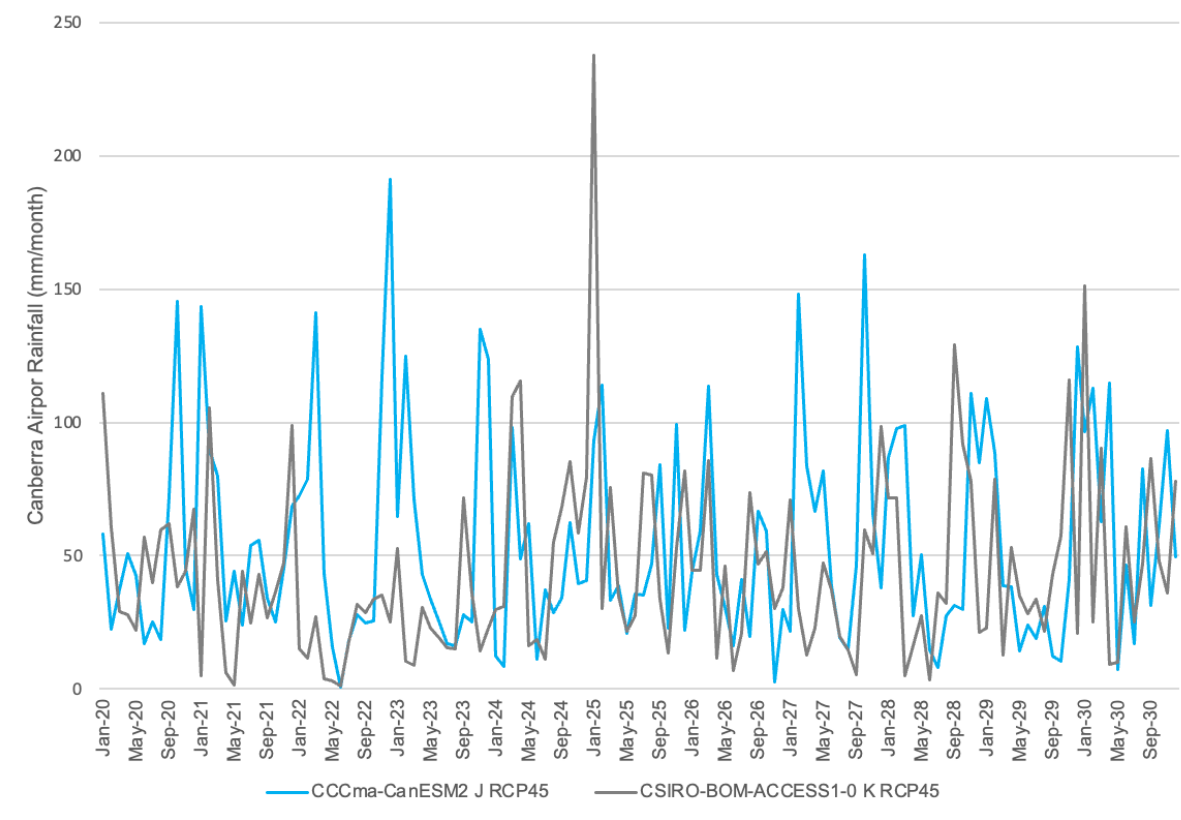
[5] ICRC, Draft Report: Review of water and sewerage demand forecasting methods, p23-24

[6] Icon Water, Icon Water Submission to ICRC Issues Paper, 9 July 2021, p19

Figure 1: Two illustrative future rainfall scenarios for Canberra Airport (NARCliM)



Source: Icon Water analysis of NARCliM data.

3.2.2 Accounting for climate trends in historical data

The current forecasting methodology involves applying climate change adjustment factors to historical climate data commencing in 1965.[7] The same adjustment factors are applied to climate observations from 1965 as to much more recent data. This process fails to account for climate change trends that are present in historical data. As a result, the model may under-adjust earlier data for climate change and over-adjusts data from later years. The reference period for NARCliM is 1951–2005, so it is especially necessary to account for this difference because 2006–2021 data falls outside the reference period and is influenced by climate change.

Icon Water recommends that the model could be improved by first de-trending the historical climate data prior to applying NARCliM adjustment factors. Icon Water suggests a three-step process to remove climate change trends from the data:

(1) select a start-year of climate change influence for each weather variable. Initial analysis by Icon Water indicates 1984 as a potential structural break point for evaporation and temperature,

(2) estimate the trend in annual climate data, and

(3) adjust all data post the start-year to remove the influence of the trend.

Analysis by Icon Water has not identified a clear trend in annual rainfall, so it may not be necessary to adjust this variable. Icon Water would be pleased to share its initial calculations with the Commission.

[7] This is the first year for which evaporation data are available for Burrinjuck dam.

3.2.3 Accounting for differences in climate reference periods.

The Draft Report describes the Commission's proposed approach to calculating the NARCliM adjustment factors. The Commission proposes to use monthly historical climate data from NARCliM between 1951 to 2005, grouped by season. This historical data will then be compared to seasonal averages of NARCliM projections for the forward climate change reference period.[8] The adjustment factors are calculated as the percentage change between the seasonal averages for rainfall and evaporation across the two periods. The temperature adjustment factor is calculated as the difference. The adjustment factors are then applied to historical climate data in the water demand model (from July 1965 to December 2021).

Icon Water notes that this process may lead to a mismatch between the climate data used in the model (from 1965 to 2021) and the NARCliM data (1951 to 2005). These periods are likely to have different climatic conditions because of climate change trends, and random variations in weather. Failing to account for this difference may result in the adjustment factors under- or over-stating the effects of climate change.

Icon Water supports the general process outlined by the Commission for calculating the adjustment factors. However, to align with the climate period used in the demand model, Icon Water recommends that the factors are calculated:

1) using seasonal averages of NARCliM climate data between 1965 to 2005, not 1965 to 2005; and
2) accounting for the differences in seasonal means between the observed 1965 to 2005 period and the 1965 to 2021 model input data (adjusted to remove climate change trends).

3.2.4 Establishing the reference climate scenario

The Commission's Draft Report states that it will "retain the current approach to develop future climate scenarios by adjusting historical climate data by climate change projections developed by reputed external agencies".[9] However, the Draft Report describes a series of steps to calculating the reference climate scenario that indicate a potential departure from the current approach. Specifically, the Draft Report states that:

"*[...] we will develop the reference climate scenario using the average data for the 50 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"*[10]

This appears to suggest that the Commission intends to calculate a reference climate scenario by averaging historical climate data. Icon Water does not support this approach because averaging climate data into a single 6.5 year time period would produce an artificial climate timeseries without variability. Removing climate variability may compromise the model's ability to consider above- and below-average weather conditions and their impact on water demand.

Icon Water continues to support the approach implemented in the current ARIMA model. This approach involves:

1) dividing the historical climate data into a series of overlapping 6.5 year time periods;
2) conditioning the historical data by applying adjustment factors for a given climate change scenario;

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[8] The Commission proposes to use a climate change reference period of 2022 to 2028 to coincide with the forecast period. As discussed in Section 3.2.1, Icon Water recommends using a longer, 20-year period for climate change projections.

[9] Ibid, p22-23.

[10] Ibid, p50.

3) iteratively running a forecast of water demand for each 6.5 year period, based on the estimated ARIMA parameter values;

4) averaging the forecast results across all the time periods to produce the final demand forecast for the chosen climate scenario; and

5) Repeating steps 1-4 for each climate change scenario[11].

The key distinction is that the current approach involves averaging the outputs of the demand model, whereas the Draft Report appears to suggest that the input climate data will be averaged.

Icon Water understands that the Commission's intent may indeed be to retain the current approach, given that no explanation is provided to support a change. However, we wish to clarify this point and confirm our position on this matter.

[11] The SEACI climate change data used in the 2018–23 model provides four scenarios. Icon Water supports the use of NARCliM data for the 2023–28 regulatory period, which provides twelve climate scenarios.

4 Choice of statistical software

4.1 The Commission's draft decision

The Commission developed the current demand forecasting model in *R*[12] with an accompanying spreadsheet containing model inputs and outputs. The Commission's Draft Report presents model outputs and results from *Stata*.[13] Icon Water understands that *Stata* is the preferred software tool of the Commission's consultant, Marsden Jacob Associates, and the Commission intends to transition to using *Stata* for the updated demand model.

The Commission's Draft Report does not explicitly identify this proposed change nor the reasons for the change. It is noted that the focus of the review is on the methodologies for demand forecasting (and not specifically the software tools).

4.2 Icon Water's response to the draft decision

Icon Water acknowledges that the Commission's review is focussed on the methods used to forecast water and sewerage services to ensure they are fit for purpose. This includes identifying robust statistical methods and data sources. In this regard, the implementation of the methodology in a particular software environment may be seen as a secondary consideration. However, Icon Water submits that the choice of software is, in practice, inseparable from the forecasting methodology because:

- the methodology will ultimately be written and published by the Commission in the chosen programming language;
- stakeholders wishing to investigate the methodology will need to have the ability to read, understand and run the model code in the chosen programming language; and
- there is significant time and difficulty involved in developing a model in an alternative programming language or software package, which may be prohibitive for many stakeholders, leaving them no practical option other than to use the Commission's chosen software tool.

Icon Water wishes to note that it does not have a preferred software vendor and does not have any comment on the technical capabilities and programming conventions of various software options. We acknowledge that *R*, *Stata*, and many other software packages are available and widely used by statistics practitioners across industry, government and academia.

Our feedback on this matter relates to the Commission's decision to transition from one software tool to another and ensuring this continues to meet the overarching assessment criteria for the review. Icon Water wishes to draw attention to the following assessment criteria proposed by the Commission: [14]

- **Economic logic, transparency and replicability**: stakeholders should reasonably understand the processes involved and be able to replicate the results
- **Regulatory stability:** methods should only be updated where there is sufficient evidence that the change would increase the accuracy of predictions
- **Simplicity**: the methods should be simple for consumers to understand and straightforward for the utility service provider to implement.

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[12] R is a language and environment for statistical computing and graphics. See https://www.r-project.org

[13] Stata is a statistical software package developed by StataCorp. See https://www.stata.com

[14] ICRC, Draft Report: Review of water and sewerage demand forecasting methods, p9.

Icon Water notes that the Commission's Draft Report does not explain the decision to transition from *R* to *Stata*. The Commission does not suggest that using *Stata* would improve the accuracy of the predictions or the simplicity of the model.

We note that *R* is a free and open-source software environment that can be freely downloaded and used for personal and commercial use. In contrast, at the time of writing, a single-user license for *Stata* starts at $1,201 per year for business or government entities.[15] Using Stata will impose additional regulatory costs on both Icon Water and the Commission. For other stakeholders, the price may be altogether prohibitive, significantly limiting the transparency and replicability of the results.

Icon Water recommends that the following principles be applied to inform the Commission's final decision and choice of statistical software:

- To promote regulatory stability, preference should be given to implementing updates and/or improvements in the current programming language, before considering moving to an alternative.
- The choice of software and/or programming language should not affect the forecast results. If an alternative software package produces different forecast results, the Commission should justify why this is appropriate.
- The forecasting methodology should be described in a software-agnostic way and provide sufficient information for stakeholders to implement the methodology using freely available tools.
- The demand forecast methodology should not rely on features exclusive to a particular software package and are not reasonably available in free software packages.
- Icon Water, independent experts, and other stakeholders should not be disadvantaged if they choose to use alternative software as the basis for their submissions to the Commission.

[15] Pricing data sourced from the official Stata distributor in Australia: https://www.surveydesign.com.au/stata/buy.html