



# ICRC

independent competition and regulatory commission

**Technical paper 2**  
**Marginal cost pricing**  
**in the ACT**  
**Tariff Review 2016**  
**Regulated water and sewerage services**  
Report 4 of 2016, June 2016

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## How to make a submission

The technical paper on the marginal cost of water and sewerage services in the ACT provides another opportunity for stakeholders 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.

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The closing date for submissions on the issues paper, the technical paper on water demand elasticity and this technical paper is **5 pm, 15 July 2016**.

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# Executive summary

## Introduction

This technical paper is the third paper published by the Commission as part of its review of Icon Water's water and sewerage services tariff structure. The first publication was an issues paper released by the Commission in November 2015.<sup>1</sup> The second was a technical paper on the elasticity of demand for water in the ACT released in February 2016.<sup>2</sup>

The current ACT water tariff structure comprises an annual supply charge and a two-tier volumetric charge that with a lower price for the first 200 kilolitres (kL) of water use and a higher water price, double that of the first tier price, for water used above that level. This is known as a two part inclining block tariff. The level of prices is set using a backward-looking approach, based on the cost of providing the most recent realised supply augmentation. At the current level of prices, Icon Water recovers about 10 per cent of its water revenue from the fixed charge, with the remaining 90 per cent recovered from volumetric charges.<sup>3</sup>

The current sewerage services tariff structure comprises a fixed annual supply charge for residential premises, and the same fixed supply charge plus an annual charge per flushing fixture (in excess of two) for non-residential premises. The same backward-looking approach as for water is applied to determine the level of sewerage service prices.

## The hierarchy of objectives

The current structure of Icon Water's water and sewerage services tariffs has served the ACT community well over the last 15 or so years. Nonetheless, in recent years a number of questions have been raised about whether improvements could be made to the way tariffs are structured.

The issues paper proposed a frame of reference to guide the Commission's evaluation of Icon Water's existing tariff structure and potential alternatives. The framework comprises an overarching economic regulation objective and set of pricing principles (see Box ES.1).

The proposed overarching efficiency objective is to promote the efficient investment in, and efficient operation and use of, Icon Water's regulated water and sewerage services to maximise the social welfare of the community over the long term.

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<sup>1</sup> ICRC, 2015a: 1-90. Available for download from: <http://www.icrc.act.gov.au/wp-content/uploads/2015/11/Report-7-of-2015-Issues-Paper-Tariff-Review-2016-November-2015.pdf>.

<sup>2</sup> ICRC, 2016: 1-31. Available for download from : [http://www.icrc.act.gov.au/wp-content/uploads/2015/11/TariffRev\\_Elasticity\\_paper8.pdf](http://www.icrc.act.gov.au/wp-content/uploads/2015/11/TariffRev_Elasticity_paper8.pdf).

<sup>3</sup> Icon Water's costs are predominantly fixed.

Box ES.1 Commission's proposed economic regulation objective and pricing principles

***Economic regulation objective***

To promote the efficient investment in, and efficient operation and use of, Icon Water's regulated water and sewerage services to maximise the social welfare of the community over the long term.

***Pricing principles***

*Economic efficiency stream*

**Principle 1:** Tariff structures and prices should promote the economically efficient use of Icon Water's water and sewerage services infrastructure, and in the case of water should also encourage economically efficient use of the water resource.

*Financial viability stream*

**Pricing principle 2:** Tariff structures and prices should reflect the full recovery of the prudent and efficient costs of providing regulated water and sewerage services to ensure business viability.

**Pricing principle 3:** Tariff structures and prices should facilitate the recovery of Icon Water's allowed revenue over the regulatory period.

*Community impact stream*

**Pricing principle 4:** Tariff structures should be robust enough to promote the economically efficient use of Icon Water's water and sewerage services infrastructure over a reasonable period of time.

**Pricing principle 5:** Any change to the structure of tariffs and prices that will have substantial customer impacts should be phased in over a transition period to allow customers reasonable time to adjust to the change.

**Pricing principle 6:** Tariff structures should be simple for customers to understand and straightforward for the utility to implement.

**Pricing principle 7:** Tariffs should be set using a transparent methodology and subject to public consultation and scrutiny.

Source: ICRC, 2015: 46.

The purpose of the tariff review is to assess whether the current water and sewerage services tariff structure will continue to deliver the best social welfare outcome for the ACT community, or whether changes are required. More specifically, the objective of

the tariff review is to ensure that Icon Water has in place a tariff structure that best enables the overarching efficiency objective to be achieved.

An economically efficient tariff structure and component prices is one that provides price signals—often called cost-reflective pricing—to customers about the efficient costs and therefore the efficient use of the service infrastructure and water resource.

The objective of this technical paper is therefore to answer two questions:

1. Is Icon Water’s current tariff structure providing suitable price signals to its customers about the efficient costs of water and sewerage services?
2. If not, what would a more efficient tariff structure look like?

### **The link between marginal cost, pricing and efficiency**

The set of proposed pricing principles for the tariff review is categorised into three streams: economic efficiency, financial viability and community impacts. The first principle follows directly from the overarching economic regulation objective and deals with the efficient allocation of water and sewerage services to Icon Water customers. While the focus here is on the efficiency stream, when making its final decision about the structure of tariffs at the conclusion of the tariff review, the Commission will take into account all three streams.

Marginal cost, as defined by Turvey (1976), ‘is the effect upon future system costs of a small increment or decrement to the projected growth of demand.’<sup>4</sup> Marginal cost is therefore a forward-looking concept as it is only concerned with future costs.

Economic theory suggests that marginal cost pricing—that is setting price with reference to the marginal cost of providing an additional unit of the service in question—is the key to ensuring that cost-reflective price signals are provided to customers to enable them to make efficient consumption decisions.<sup>5</sup>

This forward-looking pricing approach, which is commonly advocated when setting regulated monopoly utility prices, provides a yardstick by which to assess the efficiency of Icon Water’s current tariff structure.

This paper first examines a number of theoretical issues relevant to the development of marginal cost pricing and its application in public utility pricing as well as a range of issues associated with measuring marginal cost in a public utility industry.

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<sup>4</sup> Turvey, 1976: 159.

<sup>5</sup> It is important to note that prices can be cost-reflective only if the costs reflected are prudent and efficient.

## **Theory and application of marginal cost pricing**

### *Do consumers respond to average or marginal prices*

Economic theory suggests that consumers react to marginal prices when making consumption decisions. However, there are a number of characteristics of the water market in particular, including in the ACT, that indicate this may not necessarily be the case.

In the ACT water consumption is measured using accumulation meters which simply record the volume of water used, with customers billed on a quarterly basis after consumption has taken place. If customers base their future consumption decisions on the most recent available information, this would mean basing them upon an analysis of average costs calculated from recent bills, rather than the marginal price (the tier price) to which they are exposed.

A review of the economic literature reveals evidence of consumers responding to marginal cost in some studies and to average price in others. The Commission examined this issue in its recent technical paper on demand elasticity and consistently found that using marginal price produced a better model fit than average price. As such, the evidence indicates that ACT water consumers are likely to respond to marginal price signals.

### *Short- versus long-run marginal cost*

The choice between using short- or long-run marginal cost when setting prices is another matter requiring consideration.

In the short-run, with capital equipment fixed, this cost is usually the operating cost associated with, for example, the additional pumping and chemical treatment of supplying an extra unit of water through the existing network. In the long-run, with all inputs variable, the long-run marginal cost can be defined as ‘the difference in the present value of the future stream of costs associated with producing an additional unit of output.’<sup>6</sup>

The distinction between short- and long-run marginal cost, and the debate about which to apply when setting prices, largely arises due to the presence of what is known as capital indivisibility, common in public utility industries such as the provision of water and sewerage services. What this means is that additions to capacity, such as a new dam, come in large indivisible lumps exceeding one year’s growth in demand.

In principle, short-run marginal cost pricing is the efficient basis for pricing. This is because the sale of water to consumers is a short-term agreement that does not bind the consumer to take any more water at a later date and the utility is therefore faced with the short-run problem of selling water given its current capacity. The downside of this approach is that it can result in price instability. From a practical perspective therefore,

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<sup>6</sup> Della Valle, 1988: 283.

the Commission will need to be mindful of the broader set of proposed pricing principles for this tariff review, and in particular those concerning price path stability.

### *Marginal resource cost*

Another matter, specific to water, is whether the marginal cost or value of the resource itself, that is the water stored in Icon Water's dams, should be considered in addition to relevant marginal infrastructure costs associated with delivering water to customers. This notion brings into play the short-term flexibility to adjust price to respond to periods of unusual climate, such as a prolonged drought, flexibility that is less readily available in the world of planned capacity investments in the water network.

While this makes sense in principle, in practice the Commission has chosen to not include a marginal resource cost element in the marginal cost estimates calculated in this paper, for two reasons. The first is that the ACT Government's Water Abstraction Charge (WAC) already includes a scarcity charge, although undefined in magnitude. The second reason is that the likelihood of any need to restrict consumption through temporary water restrictions in the near or indeed medium-term is relatively low.

### *Marginal cost pricing in a decreasing cost industry*

The application of marginal cost pricing in a decreasing cost natural monopoly industry, such as the provision of regulated water and sewerage services in the ACT, raises particular difficulties for revenue recovery. In such an industry, as marginal cost is less than average cost, pricing at marginal cost will not allow the utility to recover all of the costs of providing the service.

In order to price at marginal cost for efficiency purposes, and achieve full cost recovery, the regulator is essentially faced with three alternatives, all of which provide a second-best solution with some efficiency loss, to recover the revenue shortfall.

The first is to recover the revenue shortfall through general taxation. The second is to adopt a multi-part tariff comprising a price for additional units based on marginal cost, and an additional charge, independent of consumption, set to ensure that total supply costs are recovered. The third alternative is Ramsey pricing. This involves deliberate price discrimination on the basis of elasticities of demand to allow the monopoly business to recover residual costs while minimising the deviations from optimal consumption patterns – that is, those based on marginal cost pricing.

The first alternative is untenable as the Commission is required to have regard to the full recovery of Icon Water's prudent and efficient costs. The third alternative, which requires price discrimination between customer classes, has high information requirements and is likely to raise equity concerns. This leaves the second alternative, multi-part pricing, which is the current structure in the ACT, as the preferred alternative.

### *Inclining block tariffs*

Inclining block tariffs, commonly applied as pricing mechanism in regulated public utility industries such as Icon Water, present an added complication for the implementation of marginal cost pricing.

Inclining block tariffs are adopted by regulators for a range of reasons, but most often on equity and water conservation grounds. The first consumption block is intended to provide essential water to households at a relatively cheap rate, while the second, more expensive block encourages water conservation as the more discretionary consumption increases.

The difficulty with inclining block tariffs is that the key requirement for economic efficiency, which is that the volumetric charge should equal the opportunity cost of water, implies a single marginal price for water. If two customers are paying for water at different marginal prices due to different levels of consumption under an inclining block structure, one of the two prices cannot be efficient.

An inclining block tariff is therefore likely to be less efficient than a single volumetric charge and the pursuit of economic efficiency would dictate a move towards a single volumetric price, set with reference to marginal cost.

### **Measuring marginal cost in practice**

In order to apply marginal cost pricing in practice, it is necessary to first decide what we mean by marginal cost, in particular the scope and timing elements, and then consider the range of methods available to estimate that marginal cost.

#### *Defining marginal cost*

The first point to make with respect to scope is that we are only concerned with marginal cost with respect to changes in the quantity or volume or services. The second point, using water as an example, is that we are only concerned with costs associated with the central system of supply, treatment and trunk mains, as distinguished from the distribution network comprising local water reservoirs and pipes. The difference between the two is that growth in the distribution element is largely driven by new land developments and therefore occurs through many small regular investments, while the central system expands with infrequent large investments.

With regard to timing, we are concerned with the estimation of future marginal costs associated with an increment in demand over the forward period from 2016 to 2062. This is the current period over which Icon Water models water supply and demand for water security planning purposes.

#### *Measurement methods*

Short-run marginal cost is relatively straightforward to calculate and is essentially the pumping and treatment cost required to deliver an additional kilolitre of water from Icon Water's supply sources to the customer.

There are a range of methods to calculate long-run marginal costs, with three of the most common described in this paper: ‘Textbook’ marginal cost (TMC), marginal incremental cost (MIC), also known as the Turvey perturbation method, and average incremental cost (AIC). All three methods are similar in that they are only concerned with future cost and output and take into account both the short- and long-run. The key difference between them is the degree to which they account for short- versus long-run marginal cost.

## Marginal cost estimates in the ACT

### Water

In order to calculate the long-run marginal cost of water in the ACT, the Commission has assessed when the next water supply augmentation is likely to be required (assumed to be the Tennent Dam on the Gudgenby River), utilising Icon Water’s water supply and demand model. For this purpose, a baseline and three future water supply and demand scenarios are considered, all of which incorporate climate change assumptions. Scenario 1, which assumes minor demand growth, is considered the optimal investment scenario for the purposes of this paper.

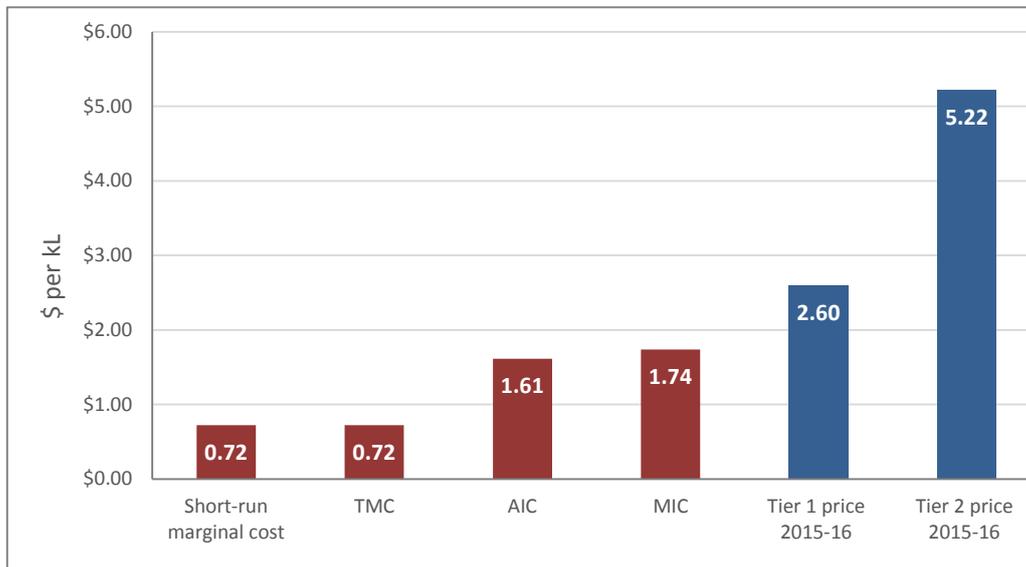
Table ES.1 shows the approximate timing of when the next supply augmentation is likely to be required for each of the scenarios. The timing ranges from as early as 2035 for the upper bound high demand growth scenario, to as late as 2060 for the minor demand growth scenario.

Table ES.1 Indicative augmentation timing, by scenario

Scenario	Description	Comments	Augmentation timing
Baseline	No demand growth	Baseline or no change scenario	Post 2062
1	Minor demand growth	Optimal investment scenario – medium series population growth with 50 per cent contribution to aggregate demand	2060
2	Medium demand growth	Incremental adjustment above Scenario 1 – medium series population growth with 100 per cent contribution to aggregate demand	2043
3	High demand growth	Upper bound investment scenario – high series population growth with 100 per cent contribution to aggregate demand	2035

A summary of the current short- and long-run marginal cost estimates for water in the ACT is shown in Figure ES.1. For the three long-run methods, estimates range from a low of \$0.72 per kL for TMC, the same as the short-run marginal cost estimate, to a high of \$1.74 using the MIC method. The two most common long-run measurement methods, AIC and MIC, return estimates of similar magnitude.

Figure ES.1 Marginal cost estimate for water, summary



Icon Water’s current two tier volumetric prices for water are \$2.60 per kL for the first 0.548 kL per day and \$5.22 per kL thereafter. It is clear that, irrespective of which measure is used, all the marginal cost estimates are well below even the first tier price. This conclusion holds in the face of a range of sensitivity tests run on the various measures.

### *Sewerage services*

The short-run marginal cost of sewerage services in the ACT comprises the following:

- treatment cost – the cost of chemicals, electricity, fuel and freight to treat an additional kilolitre of sewage at the LMWQCC; and
- pumping – the electricity costs to pump an additional kilolitre of sewage through the sewerage network to the treatment plant.

Icon Water estimates the marginal treatment cost at \$0.25 per kL, and the marginal pumping cost at \$0.005 per kL, for a total short-run marginal cost of about 0.26 per kL.

## **Conclusions**

### *Water*

The current pricing methodology is primarily based on recovering historical cost. The evidence in this paper indicates that the objective of economic efficiency in the provision of regulated water services in the ACT would be better served by moving toward a forward-looking marginal cost pricing approach.

The findings of the technical paper on water demand elasticity in the ACT provide evidence that ACT consumers are likely to respond to marginal price signals.

On the choice between short- and long-run marginal cost, in principle, short-run marginal cost pricing is the efficient basis for pricing. The sale of water to consumers is a short-term agreement that does not bind the consumer to take any more water at a later date and the utility is therefore faced with the short-run problem of selling water given its current capacity.

Nonetheless, in practice, the Commission sees merit in a long-run measure, for two reasons. First, although the short-run approach is unlikely in the present supply and demand circumstances to lead to any great instability in prices over the near to medium term, this may not always be the case as the supply and demand conditions change over time. Second, as discussed further below, the gap between the current tariff structure and one based on marginal cost pricing is substantial, and likely to require a long transition period. In these circumstances, aiming to transition the volumetric price to a long-run marginal cost estimate is a more realistic goal.

From a measurement perspective, the Commission's preference is to calculate long-run marginal cost using the MIC method as this approach is more explicitly concerned with decision-making at the margin. There is scope within the short-run element of the MIC method to add a resource value element in the future, in addition to the WAC, that rises as the next augmentation approaches as the value of water in the Icon Water's dams increases.

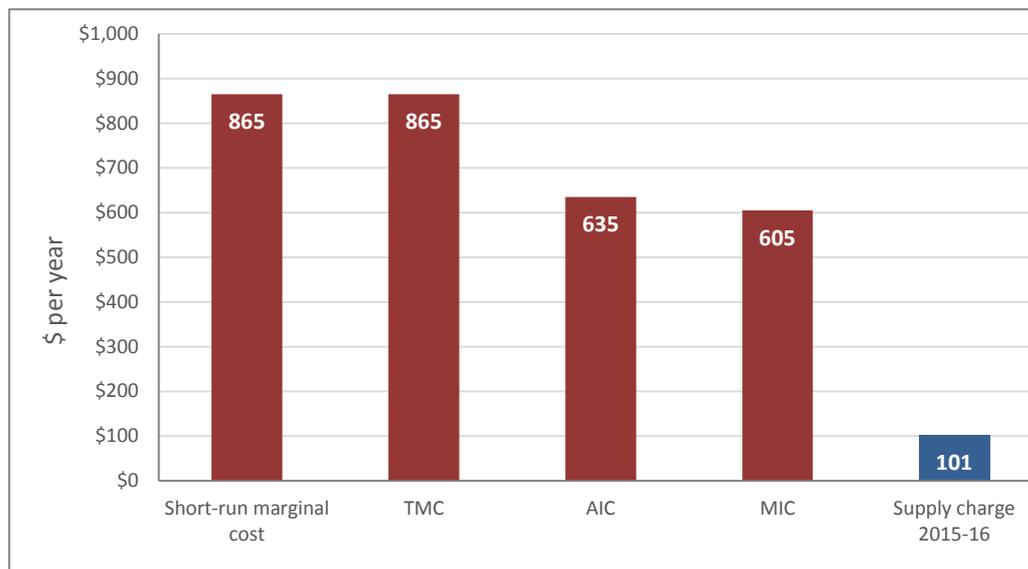
The application of marginal cost pricing in a decreasing average cost industry such as we are facing here, requires the retention of the current multi-part tariff structure, that is a supply charge and one or more volumetric prices, for cost recovery reasons.

It is also evident that all the marginal cost estimates calculated for the purposes of this paper, short- and long-run, are well below even the first tier current water price of \$2.60 per kL. On this basis, the answer to the first question posed earlier as one of the objectives of this technical paper is that Icon Water's current water tariff structure does not appear to be providing suitable price signals to customers about the efficient use of the service infrastructure and water resource.

As to the second question about what a more efficient tariff structure would look like, the pursuit of economic efficiency would dictate a move towards one volumetric price, set with reference to marginal cost. The Commission recognises that moving from the current inclining block structure and price levels to a new, more efficient, single volumetric charge structure with the price set with reference to marginal cost will require a significant adjustment in the level of the supply charge.

For indicative purposes, Figure ES.2 shows the upper bound scenario – the supply charge that would be required to recover the same revenue for Icon Water as 2015–16 water prices for each marginal cost estimate, should a single volumetric charge be introduced, priced at marginal cost. The indicative annual charges are considerably higher than the current supply charge of about \$101, ranging from \$865 for the short-run marginal cost and TMC measures to \$605 for the MIC estimate.

Figure ES.2 Indicative water supply charge, with single volumetric charge set at marginal cost



There will be welfare losses for households and the ACT community if the price of water continues to not reflect the cost of providing that water to customers. A more efficient tariff structure will also reduce the possibility of uneconomic bypass of Icon Water’s primary water system, with welfare benefits for all ACT water customers and non-residential customers in particular.

A benefit for Icon Water from such a new pricing arrangement would be reduced volumetric revenue risk as the share of revenue recovered from fixed charges would rise from the current 10 per cent to between 60 and 80 per cent depending on which measure of marginal cost is applied.

On the other hand, moving from the current pricing situation to a more efficient arrangement with a higher supply charge and lower volumetric charge will have substantial distributional impacts on customers. In particular, low volume water users will face substantial negative impacts, which may require a long transition period, possibly over more than one regulatory period, as a mitigation measure. This issue will be discussed in detail in the Commission’s draft report for the tariff review, taking into consideration all the proposed pricing principles.

The Commission recognises that some members of the ACT community strongly support water conservation and the role played by the current inclining block tariff, particularly with the second tier priced at double the first, in reducing discretionary water use. The scarcity value of water in ACT dams should be recognised but is better addressed by adjusting the marginal cost estimate as appropriate. Given the current water supply and demand balance, with a low likelihood of temporary water restrictions in the near or indeed medium-term, the scarcity value of water is not likely to be high at present.

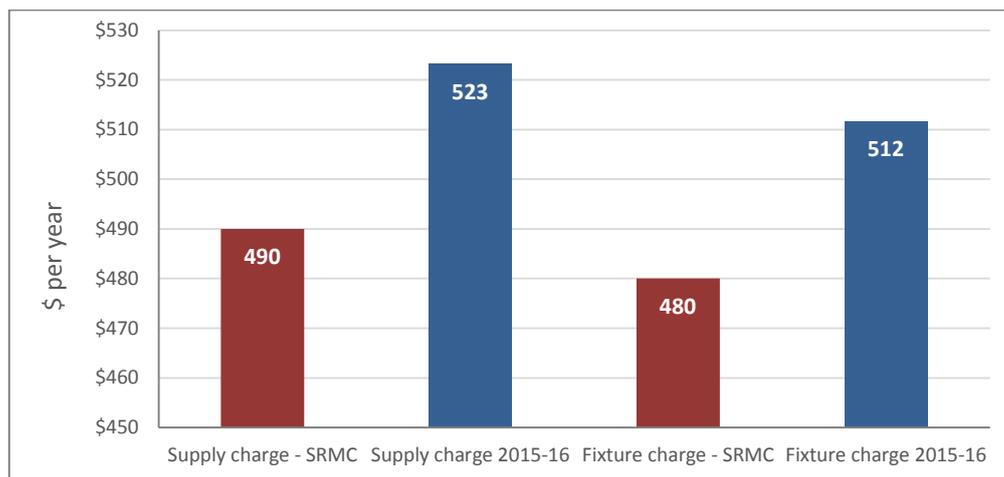
### *Sewerage services*

The situation in relation to sewerage services is different to that for water in that there is no volumetric charge in the current tariff structure. This in itself implies that the current structure, based entirely on fixed charges, is incapable of providing suitable price signals to customers about the efficient costs of sewerage services in the ACT.

In line with the Commission's view on water pricing, a more efficient structure would entail a multi-part tariff which would include a volumetric sewerage charge set with reference to marginal cost.

Figure ES.3 shows the indicative supply and fixture charges that would be required to recover the same revenue for Icon Water as 2015–16 prices should a volumetric sewage charge be introduced at the short-run marginal cost of \$0.26 per kL. The indicative annual charges are about 6 per cent lower than the current charges.

Figure ES.3 Indicative sewerage service supply and fixture charges, with volumetric charge set at short-run marginal cost



The distributional impacts of such a change in tariff structure and price levels are likely to be less dramatic than would be the case for water as described above. Once again, as for water, these matters will be discussed in more detail in the Commission's draft report for the tariff review, taking into consideration all the proposed pricing principles.

### **Next steps**

The closing date for submissions on the issues paper, this and the other technical papers is **15 July 2016**.<sup>7</sup> Stakeholder submissions received by the closing date will inform the Commission's development of the draft report for the tariff review scheduled for release in September 2016.

<sup>7</sup> Note that the submission period has been extended by two weeks from the 1 July 2015 date advertised in previous tariff review papers to allow additional time for stakeholders to respond to this technical paper.

# 1 Introduction

## 1.1 Background and purpose of this technical paper

This technical paper is the third paper published by the Commission as part of its review of Icon Water's water and sewerage services tariff structures. The first publication was an issues paper released by the Commission in November 2015.<sup>8</sup> The second was a technical paper on the elasticity of demand for water in the ACT released in February 2016.<sup>9</sup>

The issues paper proposed a frame of reference to guide the Commission's evaluation of Icon Water's existing tariff structures and potential alternatives. The framework comprises an overarching economic regulation objective and set of pricing principles (see Box ES.1).

The overarching objective seeks to promote the efficient investment in, and efficient operation and use of, Icon Water's regulated water and sewerage services to maximise the social welfare of the community over the long term.<sup>10</sup> Social welfare is maximised at the point at which it is impossible to make some individuals better off without making some other individuals worse off. Such an outcome is termed Pareto-optimal or Pareto-efficient.

Pareto optimality addresses the organisation of production and the allocation of resulting commodities among consumers. The 'organisation of production' part deals with what is commonly termed productive or technical efficiency and is concerned with the allocation of factors of production to ensure goods and services are produced at the lowest possible resource cost. The 'allocation of resulting commodities among consumers' part deals with what is often called 'allocative efficiency' and is concerned with the efficient allocation of resources and commodities between competing uses. A Pareto optimal outcome is one where the commodities, or services in this particular case, are produced at least cost and allocated efficiently between consumers.

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<sup>8</sup> ICRC, 2015a: 1-90. Available for download from: <http://www.icrc.act.gov.au/wp-content/uploads/2015/11/Report-7-of-2015-Issues-Paper-Tariff-Review-2016-November-2015.pdf>.

<sup>9</sup> ICRC, 2016: 1-31. Available for download from : [http://www.icrc.act.gov.au/wp-content/uploads/2015/11/TariffRev\\_Elasticity\\_paperv8.pdf](http://www.icrc.act.gov.au/wp-content/uploads/2015/11/TariffRev_Elasticity_paperv8.pdf).

<sup>10</sup> Since the publication of the issues paper the ACT Government has tabled a bill that will amend the *Independent Competition and Regulatory Commission Act 1997*. The amendments include a new objective that relates specifically to price directions: 'The objective of the commission, when making a price direction in a regulated industry, is 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.' (ACT Legislative Assembly, 2016: 5).

The productive efficiency of the delivery of water and sewerage services is a key consideration in the Commission’s review of the prudence and efficiency of Icon Water’s operating and capital costs as part of a price investigation process leading up to a new regulatory period. In considering the design of water and sewerage services tariffs in this review, it is the allocative efficiency aspect of Pareto optimality which is of primary relevance – that is, the efficient allocation of water and sewerage services to Icon Water customers.<sup>11</sup>

The set of proposed pricing principles has been categorised into three streams: economic efficiency, financial viability and community impacts. For the purposes of this paper on marginal cost pricing, it is the first principle that is the primary focus.

The first principle follows directly from the overarching objective and deals with the efficient allocation of water and sewerage services to Icon Water customers. An economically efficient (to the extent possible given the natural monopoly situation and a revenue constraint) tariff structure will assist in achieving the objective of maximising social welfare by providing price signals – often called cost-reflective pricing – to Icon Water customers about the efficient costs and therefore the efficient use of the service infrastructure and water resource.<sup>12</sup> Marginal cost pricing is an approach commonly advocated to give effect to this proposed principle when regulating monopoly utility prices.

In its simplest form, marginal cost pricing involves setting price equal to the marginal cost of providing water and sewerage services. Marginal cost, as defined by Turvey (1976):

is the effect upon future system costs of a small increment or decrement to the projected growth of demand.<sup>13</sup>

As such, marginal cost is a forward-looking concept. This differs from the Commission’s current approach to setting Icon Water’s prices which can be characterised as backward-looking as, in the case of water for example, prices are ‘based on the annualized cost of providing the most recent realized supply augmentation’.<sup>14</sup>

The pricing principles relating to full cost recovery, price path stability and the transition to a new tariff structure, are also relevant to marginal cost pricing, albeit

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<sup>11</sup> This encompasses both the total amount of water and sewerage services consumed and the distribution of that consumption among customers. The objective is to secure an outcome in which social welfare could not be improved by consuming more of the services, nor by reallocating consumption between users, nor by some combination of the two.

<sup>12</sup> It is important to note that prices can be cost-reflective only if the costs reflected are prudent and efficient.

<sup>13</sup> Turvey, 1976: 159.

<sup>14</sup> Grafton and Ward, 2010: 4.

from the perspective of the Commission’s recommendation at the conclusion of this tariff review on whether or not to implement such a pricing approach in the ACT.

The objective of this technical paper is therefore to answer two questions:

1. Is Icon Water’s current tariff structure providing suitable price signals to its customers about the efficient costs of water and sewerage services?
2. If not, what would a more efficient tariff structure look like?

The marginal cost pricing approach provides a yardstick by which to assess the efficiency of Icon Water’s current tariff structure. However, before this yardstick can be applied, two things need to be done. First, a number of theoretical issues relevant to the development of marginal cost pricing and its application in public utility pricing need to be considered. Second, a range of issues associated with measuring marginal cost in a public utility industry require examination.

Against the backdrop of the overarching economic efficiency objective and relevant pricing principles, this paper first examines the theory and practice of marginal cost pricing and methods for estimating marginal cost, before providing a current estimate of the marginal cost of providing regulated water and sewerage services in the ACT.

Chapter 2 examines the textbook economic motivation for marginal cost pricing, before exploring the threshold issue of whether consumers respond to marginal or average prices. The debate about whether prices should reflect short- or long-run marginal cost is then canvassed.

This is followed by consideration of the application of marginal cost pricing in a natural monopoly industry, such as the provision of urban water and sewerage services, which is characterised by conditions of decreasing average costs. This section includes a brief excursion into the key theoretical debate in the economic literature; that between those who support utility revenue shortfalls being made up through general taxation, such as Harold Hotelling and William Vickrey, and those that favour utility customers footing the total costs, such as Ronald Coase.<sup>15</sup> It was this debate that led to the multi-part tariff pricing approach that is commonly applied in regulated natural monopoly industries worldwide. This section also considers the implications of inclining block tariffs for marginal cost pricing, and the Ramsey pricing approach.

Chapter 3 considers methods for measuring marginal cost in a regulated industry. This chapter starts with defining what we mean by marginal cost, including the scope and timing elements, both of which directly impact the marginal cost calculation. A range of different methodologies for calculating long-run marginal cost are then discussed. A brief review of the methods applied by other utility regulators in Australia and overseas is also presented.

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<sup>15</sup> Ronald Coase received the Nobel Prize in Economics in 1991. William Vickrey posthumously received the Nobel Memorial Prize in Economic Sciences in 1996.

Chapter 4 provides a current estimate of the marginal cost of the provision of regulated water services by Icon Water in the ACT using the methods described in Chapter 3.

Chapter 5 provides a current estimate of the marginal cost of the provision of regulated sewerage services by Icon Water in the ACT.

The paper concludes in Chapter 6 by considering the implications of implementing marginal cost pricing for water and sewerage services in the ACT. As this is a technical paper, the focus is primarily on economic efficiency. Other matters that the Commission is required to have regard to, such as the social or distributional impacts of adopting this pricing approach, will be considered in the draft report.

## 1.2 Tariff review timeline and submission process

The indicative timeline for the remainder of the review is set out in Table 1.1.

Table 1.1 Indicative timeline for the tariff review

Task	Date
Release of issues paper	23 November 2015
Release of technical paper 1: Water demand elasticity	29 February 2016
Release of technical paper 2: Marginal cost pricing	17 June 2016
Submissions on issues and technical papers close	15 July 2016
Release of draft report	September 2016
Public forum	September 2016
Submissions on draft report close	October 2016
Final report	December 2016

The closing date for submissions on the issues paper, this and the other technical papers is **15 July 2016**. Details on how to make a submission are shown in the **How to make a submission** section at the front of this paper. Stakeholders are free to make submissions on any of the papers at any time before the closing date and may make multiple submissions if so desired. Written submissions received by the closing date will be considered in the development of the draft report.

A separate submission process will be undertaken to allow stakeholders to respond to the draft report. Details on this submission period will be provided at the time the draft report is published.

## 1.3 Technical paper structure

The remainder of this paper is structured as follows:

- Chapter 2 presents the economic basis for marginal cost pricing and theoretical issues associated with this pricing approach and its application in a decreasing cost industry.
- Chapter 3 describes matters relevant to measuring marginal cost in practice for a regulated industry, including a range of different measurement approaches.
- Chapter 4 presents a current estimate of the marginal cost of the provision of regulated water services by Icon Water in the ACT.
- Chapter 5 presents a current estimate of the marginal cost of the provision of regulated sewerage services by Icon Water in the ACT.
- Chapter 6 concludes by considering the implications of implementing marginal cost pricing for water and sewerage services in the ACT.
- Appendix 1 presents more detail on the marginal cost controversy.
- Appendix 2 provides a summary of Icon Water’s water supply and demand modelling process.

## 2 Theory and application of marginal cost pricing

### 2.1 Introduction

This chapter commences with a short exposition on the textbook motivation for marginal cost pricing as a means to maximise social welfare. A number of theoretical issues relevant to the development of marginal cost pricing and its application in public utility pricing are then considered. These include the overarching questions of whether consumers respond to marginal or average cost and whether prices should be set with reference to short- or long-run marginal cost, and the more specific matter of how to deal with the revenue issue when applying marginal cost pricing in a decreasing cost natural monopoly industry.

### 2.2 Textbook motivation for marginal cost pricing

#### 2.2.1 Introduction

In his 1976 article on public utility pricing in the *Bell Journal of Economics and Management Science*, Ronald Coase took a dim view of what he referred to as ‘blackboard economics’ stating:

As I see it, the argument for marginal cost pricing, like many propositions in modern welfare economics, is more concerned with diagrams on a blackboard than with the real effects of such policies on the working of the economic system.<sup>16</sup>

However, in order to explain the motivation for marginal cost pricing, and in particular its application in a decreasing average cost industry, we first need to turn to the blackboard economic welfare concept introduced in Chapter 1, starting with the first fundamental theorem of welfare economics.

#### 2.2.2 Benchmarking the socially optimal outcome

The first fundamental theorem of welfare economics states that when markets are complete, any competitive equilibrium is necessarily Pareto optimal. This theorem is a demonstration of Adam Smith’s ‘invisible hand’ of the market, which equates private goals with optimum social outcomes. The first theorem establishes the perfectly competitive case as a benchmark for considering optimal outcomes in market economies, and, perhaps more importantly, for thinking about optimal outcomes in

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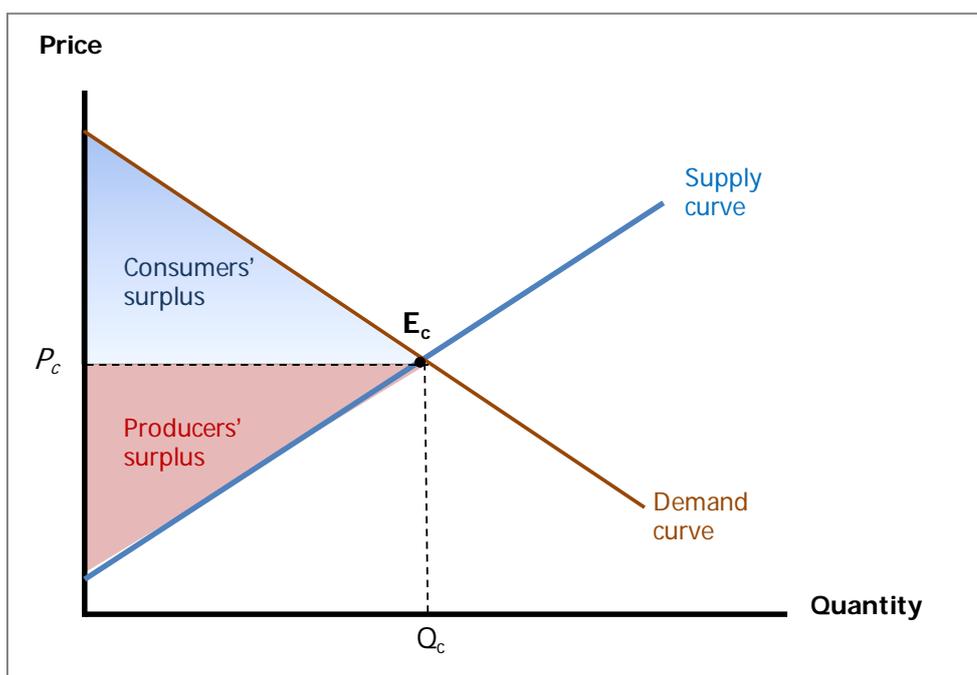
<sup>16</sup> Coase, 1970: 119.

cases of market failure, such as the natural monopoly example. As noted by Mas-Colell et al. (1995):

In particular, any inefficiencies that arise in a market economy, and hence any role for a Pareto-improving intervention, must be traceable to a violation of at least one of the assumptions of this theorem.<sup>17</sup>

While, in principle, the analysis of Pareto optimal outcomes requires general equilibrium analysis—that is, simultaneous consideration of the whole economy—partial equilibrium analysis allows us to consider equilibrium outcomes in a particular market in isolation from all other markets.<sup>18</sup> It also allows us to apply the concept of Marshallian surplus, which conveniently lends itself to graphic representation, as shown by the competitive equilibrium demonstrated in Figure 2.1.<sup>19</sup>

Figure 2.1 The socially optimal competitive equilibrium



Consumers' surplus, the blue-shaded area under the demand curve and above the market price line  $P_c$ , is the difference between the total value consumers place on the all the units consumed of some good and the total amount they are required to pay for the good.<sup>20</sup> Producers' surplus, the pink-shaded area under the price line and above the

<sup>17</sup> Mas-Colell, Whinston and Green, 1995: 308.

<sup>18</sup> For full treatment of Marshallian partial equilibrium analysis, see Mas-Colell, Whinston and Green, 1995: Part 3.

<sup>19</sup> Note that consumers' surplus is the aggregate of all individual consumers' surplus in the particular market, and likewise for producers' surplus.

<sup>20</sup> George Stigler, in his 1966 textbook on the theory of price, provides an apt description of consumers' surplus: 'When a reflective man buys a crowbar to pry open a treasure chest, he may well remark to

supply curve, is the difference between the total value of all the units sold of some good at the market price and the total value at the minimum price at which the seller would be prepared to sell the good.<sup>21</sup> Marshallian aggregate surplus is the sum of the consumers' and producers' surplus.

In the perfectly competitive case, firms equate marginal cost to price in order to maximise their profits, which produces a market outcome where the demand and supply curves intersect, the point  $E_c$  in Figure 2.1. The Marshallian aggregate surplus is maximised at the same point. Recalling that the socially optimal outcome is the one in which Marshallian aggregate surplus is maximised, *ipso facto*, the economically efficient outcome achieved by setting price equal to marginal cost is the one which maximises social welfare.<sup>22</sup>

The analysis above has presented an economic basis for marginal cost pricing in the perfectly competitive world. However, before turning to its application in the imperfect monopoly world which we are concerned with here, it is necessary to reflect on a number of theoretical matters, all of which have direct practical implications.

## 2.3 Do consumers respond to average or marginal prices?

### 2.3.1 The debate

The first major theoretical debate in the economics literature, whether consumers react to marginal or average prices when making consumption decisions, was canvassed in the Commission's technical paper on the price elasticity of demand for water in the ACT.<sup>23</sup> That discussion is worth repeating here.

Carter and Milon (2005) note:

A central tenet of microeconomic theory is that well-informed, rational households will consider marginal prices when making their budget allocation decisions. Nevertheless, there has been considerable debate concerning the "correct" price to include in empirical models of household demand for public utility services.<sup>24</sup>

Economic theory suggests that consumers react to marginal prices when making consumption decisions. However, there are a number of characteristics of the water market, including the market in the ACT, that indicate this may not necessarily be the

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himself that if necessary he would have been prepared to pay tenfold the price. When a parched man drinks a free beer on a hot day, he is apt to consider it a bargain. Marshall gave the odd name of 'consumer's surplus' to these fugitive sentiments.' (Stigler, 1966: 78).

<sup>21</sup> Producers' surplus can also be defined as the earnings of firms over and above their variable costs.

<sup>22</sup> Remembering, of course, that this conclusion depends on the same assumptions as those underpinning the first fundamental theorem of welfare economics, as discussed above.

<sup>23</sup> ICRC, 2016: 1-54.

<sup>24</sup> Carter and Milon, 2005: 265.

case. These characteristics are a result of the manner in which water consumption is measured and bills calculated and presented to customers.

In the ACT water consumption is measured using accumulation meters. These meters simply record the volume of water used, with customers billed on a quarterly basis. Accumulation meters store no information about when consumption has occurred and are often in inaccessible locations, making it impractical for customers to monitor their own consumption. This results in customers being generally unaware of how much they have consumed. The only time at which customers receive information about their consumption is on receipt of a bill, which typically covers the preceding three-month period. Because water customers are unaware of their level of consumption (and therefore the tier price to which they are exposed), they may be unaware of the price they are being charged.

This situation differs from that which exists for products provided in a competitive market, for example, petrol. Motorists purchasing petrol know the price they face in advance and determine their level of consumption based upon that knowledge. In that situation it is reasonable to consider that consumption decisions are based on an analysis of the marginal price per litre of petrol. However, water customers, who receive their bills after consumption has occurred, may base their future consumption decisions on an analysis of the most recent available information. This would mean that customers may make consumption decisions based upon an analysis of average costs calculated from recent bills.

An added complication is the presence of inclining (or declining) block tariffs such as the two-tier inclining block tariff applied in the ACT. Ito (2014) cites two alternatives to marginal price that customers may respond to when faced with complex nonlinear price schedules. The first is the expected marginal price, which Ito argues is a rational response in the presence of uncertainty about consumption. The second is average price:

Alternatively, consumers may use average price as an approximation of marginal price if the cognitive cost of understanding complex pricing is substantial. This suboptimization is described as “schmeduling” by Liebman and Zeckhauser (2004).<sup>25</sup>

There have been a number of empirical studies in the economics literature examining the question of whether consumers respond to marginal or average price. Shin (1985) examined residential electricity consumption under a declining block tariff and found that the empirical evidence supported the hypothesis that customers who are not well-informed respond to perceived average price as opposed to marginal price.

A later study by Nieswiadomy and Molina (1991) found that residential water customers respond to marginal price when faced with inclining block structures and average price under declining block structures. A further study by Nieswiadomy (1992), which among other things investigated the effect of price structure on

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<sup>25</sup> Ito, 2014: 538.

residential water demand, confirmed the Shin hypothesis that customers react more to average price than marginal price.

The study by Ito (2014) on customer response to nonlinear electricity prices using household-level panel data, found ‘strong evidence that consumers respond to average price rather than marginal or expected marginal price.’<sup>26</sup>

### 2.3.2 Commission’s consideration

The mere existence of a debate about whether customers respond to marginal or average price has important consequences. Clearly, if consumers appear not to respond to marginal prices there is limited benefit in setting prices with reference to marginal costs.

In developing the preferred model specification for estimating the demand elasticity of water in the technical paper on demand elasticity, the Commission assessed a number of price variables, including average price and a number of marginal price variants.<sup>27</sup> The Commission consistently found that using marginal price produced a better model fit than average price.<sup>28</sup> This evidence indicates that ACT water consumers are likely to respond to marginal price signals.

Nonetheless, it is important to note the broader implications of this issue for tariff design. The more complex the tariff structure, the less likely that consumers will be able to calculate marginal prices and therefore respond to them. For example, all other things being equal, an inclining block structure is more complex than a single volumetric rate.

## 2.4 Short- versus long-run marginal cost

### 2.4.1 Introduction

The second major theoretical debate in the economic literature is about the choice between using short- or long-run marginal cost when setting prices. Even where it is agreed that price should be set at marginal cost to ensure the economically efficient allocation of resources, there is still the question of whether this should be the short-run or the long-run marginal cost or somewhere in between.<sup>29</sup> As noted in Chapter 1,

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<sup>26</sup> Ibid.: 537.

<sup>27</sup> ICRC, 2016: 25-5.

<sup>28</sup> The preferred marginal price specification is essentially the weighted average marginal price faced by the consumer over the billing period. This measure involves dividing water consumption charges over the billing period by the volume of water consumed.

<sup>29</sup> Della Valle, 1988: 283.

marginal cost is the cost of providing an additional increment of output or unit of service.

In the short-run, with capital equipment fixed, this cost is usually the operating cost associated with, for example, the additional pumping and chemical treatment of supplying an extra unit of water through the existing network.

In the long-run, with all inputs variable, the long-run marginal cost can be defined as ‘the difference in the present value of the future stream of costs associated with producing an additional unit of output.’<sup>30</sup>

The distinction between short- and long-run marginal cost, and the debate about which to apply when setting prices, largely arises due to the presence of what is known as capital indivisibility, common in public utility industries such as the provision of water and sewerage services. What this means is that additions to capacity, such as a new dam, come in large indivisible lumps exceeding one year’s growth in demand. Turvey (1976) explains that while marginal cost may be presented in dollars per megalitre, it is usually calculated in terms of a large increment in supply over many years and therefore the actual cost relates to a particular year.

#### **2.4.2 Short- vs long-run debate**

Early marginal cost pricing advocates such as Jules Dupuit and Harold Hotelling, supported basing prices on short-run marginal cost. Later short-run enthusiasts included William Vickrey, who in a 1985 article about the fallacy of using long-run costs for peak-load electricity pricing, stated:

One cannot get around the problems posed by indivisibilities or economies of scale by attempting to bring fixed costs into the picture through notions of long-run marginal cost. To attempt to do so leads only to confusion and inefficiency. Pricing decisions are relatively short-run decisions, or at least they should be flexible enough to adapt to changing conditions, even when physical plant cannot be.<sup>31</sup>

In the long-run camp, much effort has gone into proving that the two concepts are equivalent when the firm is in an equilibrium state, implying that it is optimal to set prices at long-run marginal cost. Marcel Boiteux was one of the earliest advocates of the concept, in the context of peak-load electricity pricing in France:

Provided there is an optimal investment policy, short-term pricing is also long-term pricing, and there is no longer any contradiction between the two.<sup>32</sup>

This view was supported by Ralph Turvey, who noted:

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<sup>30</sup> Ibid.: 283.

<sup>31</sup> Vickrey, 1985: 1333.

<sup>32</sup> Boiteux, 1960: 165.

If capacity is optimally adjusted to output, the enterprise is on the long-run cost curve and on that short-run cost curve which is [tangential] to it at that point. Hence the two curves have the same slope, that is, marginal short- and long-term costs are equal. If the industry is a constant cost industry, pricing at marginal cost will just cover total costs.<sup>33</sup>

Della Valle (1988), writing about the US electricity industry, argues that economic efficiency is maximised when price is set at short-run marginal cost at each moment in time, stating:

It is the SRMC that reflects the actual incremental cost to society imposed by the use of one more unit of output. For greatest overall social efficiency, the consumption decision should be based on this cost.<sup>34</sup>

Della Valle identifies and then rebuts the four main arguments put forward by proponents of long-run marginal cost pricing. These are price stability, price signalling, equality of short- and long-run marginal costs in equilibrium and revenue recovery.

### **Price stability**

Della Valle agrees that short-run marginal cost pricing may result in price instability but contends that there is a better way of dealing with this than by using long-run marginal cost:

The best solution to this problem, from the standpoint of welfare maximization, is to find the optimal uniform price over time periods with differing SRMCs.<sup>35</sup>

### **Price signalling**

Della Valle suggests that the long-run approach assumes that consumers only make purchase decisions based on current price:

Thus for example, the view would argue that in deciding what new refrigerator to buy, consumers look only at today's price of electricity. The argument seems to be that if electricity is going to be more expensive several years in the future, then it should be overpriced (relative to cost) today, so that consumers will make long-run decisions that will be efficient when the long run arrives.<sup>36</sup>

Della Valle argues that this approach ignores the efficiency losses due to mispricing electricity between the present and some hypothetical future time. Della Valle sees no contradiction between pricing correctly in the present and pricing correctly in the future. Della Valle's proposed solution to this 'information argument' is to set price equal to the current short-run marginal cost and separately inform customers of the best available forecasts of future prices.

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<sup>33</sup> Turvey, 1964: 427.

<sup>34</sup> Della Valle, 1988: 283.

<sup>35</sup> Ibid.: 284.

<sup>36</sup> Ibid.: 284.

## Equality in equilibrium

Della Valle dismisses the long-run enthusiasts' reliance on the argument that short- and long-run cost are equivalent in equilibrium on the basis that:

This theoretical equality holds only under numerous restrictive assumptions. In particular, the capital stock must be continuously adjusted so as to be of optimal size. This requires both that the planner has perfect foresight and that capital equipment can be increased or decreased by very small continuous increments.<sup>37</sup>

This view is supported by Andersson and Bohman (1985) who state:

The equivalence, however, is valid only under the very restrictive assumption that the capacity can be varied continuously. This means that indivisibilities, irreversibilities and durability of investments are ignored. Where such phenomena exist, as in electricity production and distribution, pricing according to LRMC is neither theoretically valid nor applicable.<sup>38</sup>

## Revenue requirement

Della Valle disagrees with the argument that long-run marginal cost pricing is the only policy that ensures full cost recovery in a decreasing cost industry on the basis that since such costs are based on static hypothetical cost curves they are likely to differ significantly from the actual costs incurred over time. Della Valle suggests a more efficient alternative is multi-part pricing with a consumption charge based on the short-run marginal cost and a separate flat charge sufficient to meet the required revenue constraint.

Vickrey (1971), on the subject of long-distance telephone rates, supports this approach:

In an ideal world free from budgetary or financial constraints, it is clear that the rate should be equal to the expected short-run marginal cost of the call as of the time of the decision. Even in a second-best world subject to revenue requirements or where there are no perfect taxes that might be used for subsidizing the intra-marginal residue, short-run marginal cost is still the primary factor to be considered in setting the rate.<sup>39</sup>

### 2.4.3 Long-run in practice

While the debate between those in the short-run camp and their long-run opponents appears very polarised, it is important to note that in practice the long-run approach utilises both short- and long-run marginal costs. Vickrey (1971), citing the example of lumpy investments in water supply, explains:

What ought to be done, however, if demand grows gradually, is to increase the water rates for a period before the new supply is available sufficiently to curtail demand to the capacity of the old supply, thereby permitting the investment in the new supply to be postponed and saving the corresponding interest charges. Then when the new

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<sup>37</sup> Ibid.: 285.

<sup>38</sup> Andersson and Bohman, 1985: 279.

<sup>39</sup> Vickrey, 1971: 338.

supply becomes available the rate should be dropped sharply to the point where the new supply is fully utilized, or to zero if capacity remains incompletely used, being subsequently raised as demand grows so as to keep the actual consumption within the capacity of the new supply.

Mann et al. (1980) also describe this approach, with the introduction of some new terminology. When capacity is less than fully utilised, prices are set with reference to short-run marginal cost. That is the additional operating costs – or ‘marginal operating cost’ – of supplying an additional unit of water, for example.

As full capacity is approached, in addition to the marginal operating cost, consumers are charged a ‘marginal capacity cost’. The latter reflects the cost of the next capacity augmentation. This has the effect of rationing existing capacity and therefore delaying the next capacity investment. This point was also made by Turvey (1976):

Hence, it is not the total costs of the system expansion which require examination; it is the effect upon those costs of slowing down or speeding up the expansion. In other words, economy in water use might enable the next scheme to be postponed but would scarcely enable it to be altogether dropped. It is therefore the cost saving that would result from postponing a scheme, not the cost saving from abandoning it entirely, which is relevant to marginal cost.<sup>40</sup>

Once the investment is made price should once again fall to short-run marginal cost. Mann et al. (2008) note that under this approach:

Price thus plays the dual roles of (1) obtaining an efficient utilization of resources when operating at less than full capacity and (2) providing a signal to invest in additional system capacity.<sup>41</sup>

#### 2.4.4 Commission’s consideration

Hirshleifer et al. (1960) made their position clear on the choice between short- and long-run:

In principle, it should be at short-run marginal cost, for the reason that the normal sale of water is in the nature of a short-run agreement; a purchase of water at this minute does not bind the customer to take more water at any later date. At each moment of time, therefore, the enterprise is faced with the short-run problem of selling its output given its current capacity.<sup>42</sup>

In principle, in accord with Hirshleifer et al. (1960) and others such as Della Valle (1988), Andersson and Bohman (1985), short-run marginal cost pricing is the efficient basis for pricing. From a practical perspective, however, the Commission needs to be mindful of the broader set of proposed pricing principles for this tariff review, and in

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<sup>40</sup> Turvey, 1976: 159.

<sup>41</sup> Mann, Saunders and Warford, 1980: 602.

<sup>42</sup> Hirshleifer, DeHaven and Milliman, 1960: 97.

particular those concerning price path stability. This issue is discussed further in Chapter 3.

## 2.5 Marginal resource cost

### 2.5.1 The proposition

The discussion thus far has related to the marginal infrastructure costs, short- and long-run, associated with increments to supply to deal with the long-term growth in demand for public utility services. A related matter, specific to water, is whether the marginal cost or value of the resource itself, that is the water stored in Icon Water's dams, should be considered in addition to relevant short-run marginal infrastructure costs.

Vickrey (1971), in his paper on more responsive public utility pricing, comments on this subject, noting that there are 'some rather interesting special rules that can be applied in determining the short-run marginal cost of water'.<sup>43</sup> In summary, Vickrey proposes the following:

- If there is water going over the dam spillway (in excess of environmental flow requirements), the marginal cost of water either is zero or has a very low value reflecting pumping costs.
- If the dam is just full, ignoring the contribution of the overflow to downstream flows, and assuming an accurate supply and demand forecast, the rate of increase in the water price should be greater than or equal to the relevant rate of interest. Vickrey argues that if the price were declining, or rising less rapidly than the interest rate, this would mean that water could be drawn from the dam and sold now at a price representing a higher present value in lieu of keeping it and using it later when its value would be less, on a discounted basis.
- If the dam is neither full nor empty, the price should rise at exactly the rate of interest. Otherwise a gain would be possible by diverting water from use at a time when it has a lower present value to a time when it has a higher present value.
- If the dam is empty, the price should be set to limit use to the current flow into the dam, provided that the price trend is not greater than the interest rate. If it were rising more rapidly, it would be advantageous to divert water from current use, store it in the dam, and use it later when the usage would have a higher present value.

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<sup>43</sup> Vickrey, 1971: 343.

A similar argument was employed by the Commission in its 2012 investigation into secondary water use in the ACT as a means to value the contribution of publicly-funded secondary water projects.<sup>44</sup>

In its final report, the Commission noted that the lumpiness of investments in augmenting Icon Water’s primary water supply, and the long lead times required for planning purposes, argue for such investments to be decided in the framework of a long-term plan.<sup>45</sup> By supplementing supply, take-up of secondary water options can potentially postpone the requirement to make further investments in the primary water system.<sup>46</sup> The value of an extra kilolitre of secondary water depends on the level of the primary water bucket – that is the level of water in Icon Water’s dams.

If the bucket is full, providing an extra kilolitre of secondary water simply causes an extra kilolitre of water to flow over the spillways of the dams in the primary water system. The only saving from the provision of the extra kilolitre of secondary water is the cost of treating a kilolitre of dam water to render it potable and transporting it through the primary reticulation system to users.

If the bucket is not full but significantly above the level that would trigger the imposition of temporary water restrictions, the provision of an extra kilolitre of secondary water means that one less kilolitre of water needs to be taken from the bucket to satisfy the demand for water. This kilolitre of water remains available for future use, thereby making a contribution to water security in the future. Depending on future circumstances, the contribution to water security may be more or less valuable. For example, if the time at which an investment in the primary water system is due is very close, provision of the extra kilolitre of secondary water could give rise to the postponement of that investment, yielding immediate value. Alternatively, if the time at which such an investment is due is far distant, any postponement achieved is also in the far future and thus of lower current value.

Finally, if the level of water in the bucket is close to the trigger level, providing an extra kilolitre of secondary water may postpone or prevent the imposition of water restrictions and therefore be of significant immediate value.

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<sup>44</sup> See ICRC, 2012: 1-150. Available for download from [http://www.icrc.act.gov.au/wp-content/uploads/2013/02/Report\\_6\\_of\\_2012\\_July\\_2012.pdf](http://www.icrc.act.gov.au/wp-content/uploads/2013/02/Report_6_of_2012_July_2012.pdf).

<sup>45</sup> Primary water is potable water provided through Icon Water’s reticulated water supply network. Secondary water is water provided from any other source, including water sourced from wastewater (such as treated effluent from a water treatment plant or sewer mining scheme and greywater from bathrooms and laundries), stormwater and rainwater.

<sup>46</sup> This assumes that demand is independent of the source of the water—that is, that users will not, for example, use more recycled water because it is believed to have a lower impact on the environment than using primary water. Presumably, the extent of any such offset to the general reduction in demand for primary water would be small.

## 2.5.2 Commission's consideration

The notion of marginal resource cost brings into play the short-term flexibility to adjust price to respond to periods of unusual climate, such as a prolonged drought, flexibility that is less readily available in the world of planned capacity investments in the water network.<sup>47</sup> While this is to be welcomed, there are a number of other matters that require consideration.

The first issue concerns the price elasticity of demand for water – that is, the likely consumption response to a change in price. The Commission's first technical paper for the tariff review found that the price elasticity of demand for residential water in the ACT, consistent with the empirical literature, while not zero is relatively small:

The point estimate of -0.14 across the 1999 to 2015 period for the RESS charge class implies that a 10 per cent increase in the marginal price of water, which is the weighted average volumetric price of water in the preferred specification, would lead to a 1.4 per cent reduction in household water consumption on average.<sup>48</sup>

This result suggests that prices would likely have to be raised to a significant degree to generate any meaningful reduction in demand, exposing customers to potentially large and frequent price fluctuations.

The second issue is that of double-counting. Practical implementation of such a concept would require care to be taken to ensure that costs are not being double counted in the marginal cost estimation exercise. For example, the ACT Government's Water Abstraction Charge (WAC), which is levied on each kilolitre of water abstracted from Icon Water's dams, includes a scarcity value element.<sup>49</sup> This matter is considered further in Chapter 4.

## 2.6 Marginal cost pricing in a decreasing cost industry

### 2.6.1 Market failure and deadweight loss

Natural monopoly is the classic case of a market failure. Train (1991) loosely defines a natural monopoly as existing 'when the costs of production are such that it is less expensive for market demand to be met with one firm than with more than one'.<sup>50</sup> Natural monopolies arise due to economies of scale or scope. The former, in which we are primarily interested here, arises when the average cost of production decreases as

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<sup>47</sup> The astute reader will have observed that that this concept can be described as scarcity pricing, a matter discussed in the Commission's issues paper for the tariff review. See ICRC, 2015a: 66-68.

<sup>48</sup> ICRC, 2016: 43.

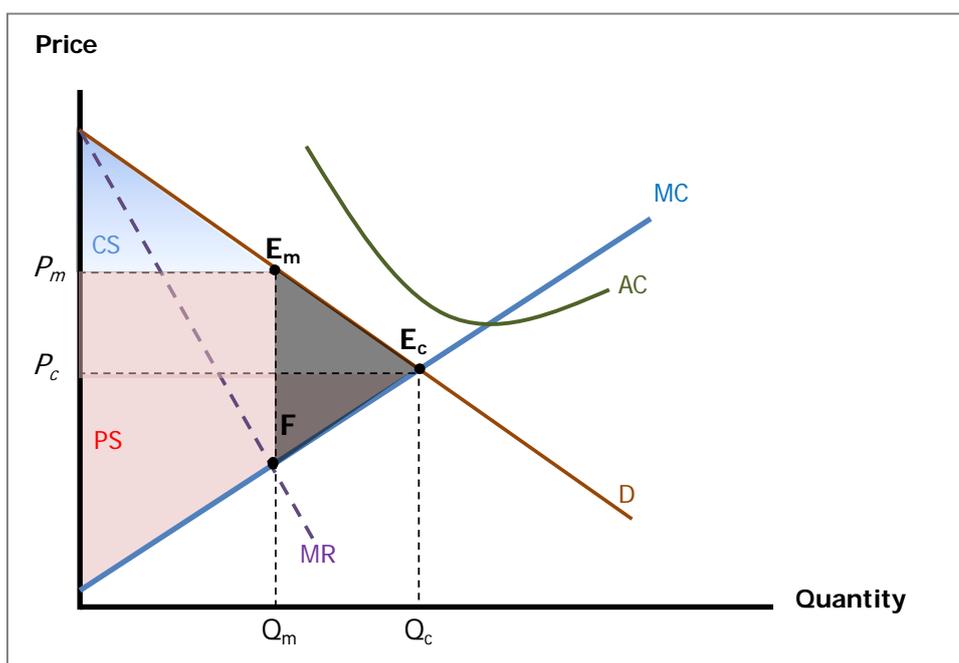
<sup>49</sup> Ibid.: 69-70.

<sup>50</sup> Train, 1991: 1.

output expands – that is, the average cost curve slopes downwards up to and perhaps beyond the overall size of the market.

The monopoly situation, which requires one firm to achieve least-cost production and is characterised by market power, violates the first fundamental welfare theorem's assumption that all agents act as price takers.<sup>51</sup> As such, the market equilibrium will not be Pareto optimal with a resulting welfare loss. This can be demonstrated graphically by recourse once again to Marshallian aggregate surplus, as shown in Figure 2.2.

Figure 2.2 Deadweight welfare loss under monopoly



Assume we are dealing with a natural monopoly, with a declining average cost curve with a minimum scale beyond market demand. The monopolist maximises profits by producing quantity  $Q_m$  at price  $P_m$  determined by the intersection of its marginal revenue and marginal cost curves. This outcome is not Pareto optimal as the Marshallian surplus is smaller than that attainable with price  $P_c$ . The difference,

<sup>51</sup> The second fundamental welfare theorem states that if household preferences and firm production sets are convex, there is a complete set of markets with publicly known prices, and every agent acts as a price taker, then any Pareto optimal outcome can be achieved as a competitive equilibrium if appropriate lump sum transfers of wealth are arranged. Mas-Colell, Whinston and Green (1995) note that the second welfare theorem also runs into difficulties, in the presence of nonconvex production sets that characterise the natural monopoly situation, even if price taking can somehow be relied on. See Mas-Colell, Whinston and Green, 1995: 570-71 for more detail.

referred to as the efficiency or deadweight loss, is equal to the area of the grey-shaded triangle bounded by  $E_m$ ,  $E_c$  and  $F$ .<sup>52</sup>

In the case of a regulated monopoly, the regulator could direct the monopolist to set price equal to marginal cost at  $P_c$  in an attempt to ensure a Pareto optimal outcome. The problem facing the regulator is that in many cases, as here, the monopolist is on the falling portion of its average cost curve. This means that its marginal cost is less than its average cost, as depicted by the AC curve in Figure 2.2. Such a direction from the regulator will result in the monopolist not recovering enough revenue to cover its total costs, leading to an unsustainable financial situation.

Directing the monopolist to set prices based on average cost to ensure full cost recovery, with a quantity produced somewhere between  $Q_m$  and  $Q_c$ , will also result in a suboptimal Pareto outcome. Brown et al. (1992) state:

Regulated natural monopolies are usually required to recover losses in the marketplace. Average cost pricing is frequently used, though the resulting allocation has no hope of being Pareto-efficient.<sup>53</sup>

In short, in the monopoly case the first-best Pareto optimal outcome—that achieved by setting price equal to marginal cost—is infeasible due to the cost recovery constraint. In order to allow cost recovery, the regulator is faced with achieving the second-best outcome. This exercise can be broadly described as maximising social welfare subject to a revenue constraint.

The divergence between average and marginal costs and how prices should be determined under conditions of decreasing average cost gave rise to one of the most spirited debates in the marginal cost economics literature: whether to charge at marginal cost and recover any revenue shortfall through general taxation or from consumers directly by means of a multi-part tariff. The principal protagonists were Harold Hotelling, who supported the taxation approach, and Ronald Coase who favoured the multi-part tariff.

## 2.6.2 The marginal cost controversy<sup>54</sup>

When faced with a divergence between average and marginal costs, Hotelling in his seminal article on general welfare and the relationship between taxation and the setting of railway and public utility charges, postulated that ‘the optimum of the general

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<sup>52</sup> If the monopolist was able to perfectly discriminate among its customers by knowing customer preferences and making a distinct offer to each customer, there would be no welfare deadweight loss. Mas-Colell, Whinston and Green (1995) note that such discrimination is impractical, in particular due to a lack of information about customer preferences and the possibility of customer resale.

<sup>53</sup> Brown, Heller and Starr, 1992: 53.

<sup>54</sup> For a fuller treatment of the marginal cost controversy see Appendix 1.

welfare corresponds to the sale of everything at marginal cost’ and that the difference between this amount and total cost be made up by taxation.<sup>55</sup>

Ronald Coase is perhaps the most well-known opponent of subsidising decreasing cost industries, especially after the publication of his seminal article on marginal cost pricing in 1946.<sup>56</sup> Coase did not disagree that price should equal marginal cost, but rather than the alternatives of pricing according to marginal cost thereby incurring a loss, or pricing at average cost and avoiding any loss, Coase proposed the introduction of multi-part pricing, on the basis that:

A consumer does not only have to decide whether to consume additional units of a product; he has also to decide whether it is worth his while to consume the product at all rather than spend his money in some other direction.<sup>57</sup>

Coase’s view was that marginal cost pricing for additional units would provide for the former, while an additional charge, independent of consumption, set to ensure that total supply costs are recovered would deal with the latter.

The multi-part tariff structure provides a means to enable regulators to use marginal cost pricing to achieve an outcome that, while not Pareto-efficient, at least approaches second-best. As stated by Train (1991):

Multipart tariffs have important welfare implications. Perhaps the most relevant is the fact that a regulator, by applying an appropriately designed multipart tariff, can induce a natural monopolist to operate closer to the first-best outcome than would be possible with only one price.<sup>58</sup>

### **Commission’s consideration**

On the application of marginal cost pricing in a declining average cost industry with consequent revenue problem, Hirshleifer et al. (1960) state:

The most obvious way of covering the loss is through a government contribution (subsidy). Aside from the argument that such a guaranty might promote inefficiency and that the collection of public funds is itself not costless, there is the objection that the procedure does not distinguish between projects or operations that should be abandoned and those that should not.<sup>59</sup>

The Commission notes that this is a significant issue that cannot be ignored in determining an appropriate price structure in a decreasing cost industry. In any case, the Commission is required to have regard to full cost recovery.

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<sup>55</sup> Hotelling, 1938: 242.

<sup>56</sup> Coase, 1946: 169-82.

<sup>57</sup> Ibid.: 173.

<sup>58</sup> Train, 1991: 191.

<sup>59</sup> Hirshleifer, DeHaven and Milliman, 1960: 90-1.

As discussed in the issues paper, Section 20(2) of the *Independent Competition and Regulatory Commission Act (1997)* requires the Commission to have regard to the cost of the provision of regulated water and sewerage services. The 2004 National Water Initiative (NWI), to which the ACT Government is a signatory, also commits jurisdictions to full cost recovery for water services to ensure business viability. This commitment is mirrored in the 2010 NWI pricing principles, the first of which requires the full recovery of efficient costs.

Moreover, should the Hotelling approach be applied, the ACT Government would be required to meet any revenue shortfall by providing a subsidy on behalf of the ACT community as taxpayers. To avoid any reduction in the level of existing government services, this would likely result in the level of taxation going up commensurate with the shortfall. Given that the ACT community as water and sewerage customers and the ACT community as taxpayers are not necessarily the same, this shifting of the burden between the two is likely to be controversial.<sup>60</sup>

Recalling the discussion above, the situation the regulator is faced with is that the first-best Pareto optimal outcome – that achieved by setting one price equal to marginal cost—is likely to be infeasible due to the need for revenues. In order to allow full cost recovery, one of the pricing principles for this tariff review, the Commission is confronted with achieving the second-best outcome—that is maximising social welfare subject to a revenue constraint. This can be achieved either by means of a multi-part tariff or the application of Ramsey pricing.

### 2.6.3 Ramsey pricing

In the case of monopolies that produce more than one good or service or have different prices for customer groups, Ramsey pricing provides another means to recover the revenue shortfall—or residual cost—associated with pricing at marginal cost—an alternative to recovering the residual equally from all consumers through a fixed or supply charge.

Ramsey pricing, also known as the inverse elasticity rule, deals with the problem of how to set prices to minimise changes in the pattern of demand caused by deviating from marginal cost in order to recover the residual costs.<sup>61</sup> The Ramsey formula enables the calculation of prices that results in the smallest surplus loss when prices must be raised above marginal cost in order for the business to remain financially viable.

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<sup>60</sup> In its 2013 final report on regulated water and sewerage services, the Commission noted the distinction between the ACT community as customers and taxpayers on the basis that there are likely to be taxpayers who consume virtually no water and large water customers who may pay little tax (ICRC, 2013b: 63).

<sup>61</sup> Frank Ramsey, in his 1927 seminal article on optimal taxation, provided at least implicitly a solution to the optimal pricing problem for an industry in which marginal cost prices do not cover total costs (Ramsey, 1927: 47–61).

Baumol and Bradford (1970) presented a formal analysis of the rule for setting prices under this approach to minimise price distortions.<sup>62</sup> The rule is that each price be set so that its percentage deviation from marginal cost is inversely proportionate to the item's price elasticity of demand.<sup>63</sup>

Ramsey pricing, somewhat counter-intuitively, involves deliberate price discrimination on the basis of elasticities of demand to allow the monopoly business to recover residual costs while minimising the deviations from optimal consumption patterns—that is, those based on marginal cost pricing. Customers who are price inelastic are charged a higher price than those who are price elastic, with more of the residual costs recovered from customers who are price inelastic than from the customers with elastic demand.

The Brattle Group (2014) considered the Ramsey pricing approach as part of the Australian Energy Market Commission's 2014 electricity tariff reform process. They note that in the electricity context, at the customer class level, Ramsey pricing would suggest that residential customers pay a greater proportion of residual costs, and industrial customers a lesser portion, if the former are less price elastic and the latter are more price elastic.

The Brattle Group also notes that Ramsey pricing has rarely been applied, at least not explicitly, for price discrimination across customers in the same class, for equity reasons:

It is often asserted that individuals who are relatively better-off are likely to show a higher elasticity for consuming certain goods such as electricity than individuals who are less well-off, because the better-off customers use some electricity for “luxuries”, whereas the less well-off customers use electricity only for “essential” purposes.<sup>64</sup>

A similar point is made by Train (1991):

It is important to note that Ramsey prices might not be considered equitable in certain situations. Inelastic demand can reflect a lack of options by consumers (e.g., demand for medical care, demand for bus service by low-income households without cars). Yet, under Ramsey concepts, prices for goods and services that consumers have no option to buy would be raised *more* than prices for less essential goods.<sup>65</sup>

### **Commission's consideration**

There are two main issues that need to be considered in relation to the application of Ramsey pricing for Icon Water. The first is the availability of information on relevant

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<sup>62</sup> Train, 1991: 125-35 also provides a derivation of the Ramsey pricing rule.

<sup>63</sup>The price elasticity of demand is the percentage change in quantity demanded divided by the percentage change in price that brought it about. Demand is said to be elastic if the percentage change in quantity is greater than the percentage change in price (elasticity is greater than one). Demand is inelastic if the percentage change in quantity is less than the percentage change in price (elasticity is less than one).

<sup>64</sup>The Brattle Group, 2014: 5.

<sup>65</sup> Train, 1991: 116.

price elasticities of demand, without which Ramsey prices cannot be calculated. The second is the equity issue associated with differential charging between consumers for the same product.

The application of Ramsey pricing in the case of Icon Water’s regulated water and sewerage services requires an estimate of the price elasticity of demand for the service for different customer groups.

The Commission’s first technical paper for the tariff review provides estimates of the price elasticity of demand for water for Icon Water’s residential (stand-alone houses), units and flats, and commercial customers. The results are shown in Table 2.1.

Table 2.1 Price elasticities of demand for water in the ACT, 1999 to 2015

Customer category	Elasticity estimate
Residential (RESS charge class)	-0.14
Units and flats (ACP1 charge class)	-0.07
Commercial (COMM)	-0.32

Source: ICRC (2016).

The technical paper concluded that, in general and bearing in mind the caveats around the estimates for units and flats and commercial customers, the demand response is the most price elastic for commercial customers and least elastic for units and flats customers, with residential customers in the middle. Should Ramsey pricing be contemplated, this would imply that units and flats customers, who are price inelastic, could be charged a higher price than the more price elastic commercial and residential customers. Alternatively, both residential and units and flats customers could pay a higher charge. Clearly, the application of Ramsey pricing in the ACT is likely to raise equity concerns.

In contrast to water, there is a dearth of information on the elasticity of demand for sewerage services, as noted by Hanke and Wentworth (1981) who note the general ‘lack of knowledge of price elasticities of wastewater use.’<sup>66</sup> Moreover, given that the volume of sewerage services provided in the ACT is not measured at the household level, the necessary consumption response to price information is not available to enable the Commission to undertake its own demand elasticity analysis.

#### 2.6.4 Inclining block tariffs

Inclining block tariffs, commonly applied as pricing mechanism in regulated public utility industries, present an added complication for the implementation of marginal cost pricing. An inclining block tariff differs from the simple two-part tariff in that there is more than one volumetric rate. Under an inclining block structure, the volumetric rate increases in a stepped manner as consumption increases. Current ACT

<sup>66</sup> Hanke and Wentworth, 1981: 560.

water tariffs are an example of an inclining block. A lower price is set for consumption up to 0.548 kilolitres (kL) per day (equivalent to 200 kL per year) with a higher price for consumption above this level.<sup>67</sup>

Inclining block tariffs are adopted by regulators for a range of reasons, but most often on equity and water conservation grounds. The first consumption block is intended to provide essential water to households at a relatively cheap rate, while the second, more expensive block encourages water conservation as the more discretionary consumption increases.

The difficulty with inclining block tariffs is that the key requirement for economic efficiency, which is that the volumetric charge should equal the opportunity cost of water, implies a single marginal price for water. If two customers are paying for water at different marginal prices due to different levels of consumption under an inclining block structure, one of the two prices cannot be efficient. As such, inclining block tariffs are often criticised for being inefficient.

### **Commission’s consideration**

There are essentially two issues facing the Commission with respect to inclining block tariffs for water in the ACT in the context of this tariff review.

The first, and threshold issue, is whether to continue with an inclining block tariff or move to a single volumetric rate. The Commission agrees that an inclining block tariff is likely to be less efficient than a single volumetric charge. Moreover, it is clear that following the recent investments in water security, the current levels of water in Icon Water’s expanded storages, and the relatively low levels of per capita demand post the Millennium Drought, there appears to be little need for an inclining block to encourage water conservation.<sup>68</sup>

The equity issue associated with providing households with sufficient water at a lower cost to meet their essential health and hygiene needs is a little more delicate. Grafton and Ward (2010) cite empirical studies that show that the number of people in a household increases water consumption. The implication of this is that an increasing block structure may have the unfortunate consequence that large and poor households, who may have little discretionary use about water they can use, may pay a higher price for water than small, high-income households.

Saunders et al. (1977) also comment on this issue, in the developing country context, noting that:

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<sup>67</sup> Icon Water’s 2015–16 volumetric prices are \$2.60 per kL for the first 0.548 kL per day and \$5.22 per kL thereafter.

<sup>68</sup> The combined ACT dam storage level was 77 per cent as at 7 June 2016. See <https://www.iconwater.com.au/Water-and-Sewerage-System/Dams/Water-Storage-Levels.aspx>.

There are many influences on water consumption other than income, a reliable correlation between water consumption and household per capita income being particularly difficult to establish.<sup>69</sup>

The second issue relates to the distributional impacts between high and low water use customers. As the Commission noted in the issues paper, due to the cost recovery constraint, a move from the current to any new tariff structure may result in winners and losers. For example, should the Commission recommend changing the water tariff structure to a single volumetric price from the current two-tier structure while keeping the supply charge the same, the resulting single price will be somewhere between the first- and second-tier price. Such a change is likely to benefit the large volume water user while low-volume customers may pay more.

These matters will be addressed in more detail in the draft report, with any recommendations considered in the context of all the proposed tariff review pricing principles.

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<sup>69</sup> Saunders, Warford and Mann, 1977: 18.

## 3 Measuring marginal cost in practice

### 3.1 Introduction

This chapter moves from the theory of marginal cost pricing to practical matters associated with estimating marginal costs in a public utility industry, and the ACT water and sewerage services industry in particular.

The chapter starts by defining what we mean by marginal cost in practice, including the scope and timing elements, both of which directly impact the marginal cost calculation. A number of matters relevant to setting ACT water and sewerage services prices are then considered, including the price elasticity of demand for water, the WAC and the appropriate discount rate to apply when calculating marginal cost.

This is followed by an examination of a range of different methods for calculating marginal cost. A brief review of the marginal cost pricing methods applied by other utility regulators in Australia and overseas is then presented.

### 3.2 Defining marginal cost

When applying marginal cost pricing in practice, and before considering the preferred method of estimating marginal cost, it is first necessary to put some boundaries around what we mean by marginal costs. At this stage of the technical paper, we can define the scope and timing elements.

#### 3.2.1 Scope

The first point to make with respect to scope is that we are only concerned with marginal cost with respect to changes in the quantity or volume of services (for a given level of quality). This point was made by Turvey (1976):

The cost of a newly introduced water-softening plant, for example, cannot be said to constitute a marginal cost since it changes quality, not quantity, and we are here considering only marginal cost with respect to quantity.

.....

The fundamental notion is that one examines the effect upon costs of faster or slower growth in the quantity of water to be supplied; one does not go through projected expenditures in order to classify certain of them as marginal.<sup>70</sup>

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<sup>70</sup> Turvey, 1976: 159.

In the case of Icon Water project classification therefore, this means the immediate focus is on growth rather than renewal or improvement projects.

The second point, again following Turvey (1976), and using water as an example, is to distinguish the central system of supply, treatment and trunk mains from the distribution network comprising local water reservoirs and pipes.<sup>71</sup> The key difference between the two is that growth in the distribution element is largely driven by new land developments and therefore occurs through many small regular investments, while the central system expands with infrequent large investments. For the purposes of estimating marginal cost in this paper we are only concerned with the central system.

### 3.2.2 Timing

As noted in Chapter 1, marginal cost pricing is a forward-looking concept. In this paper we are interested in the estimation of future marginal costs associated with an increment in demand over the forward period from 2016 to 2062.<sup>72</sup> This is the current period over which Icon Water models water supply and demand for water security planning purposes.

Another point to note is that marginal cost is a dynamic concept in that any estimate is dependent on the circumstance prevailing at the time it is estimated, and will be different as conditions change. For example, the short-run marginal operating cost for water will be dependent on dam levels and source of supply at the time. Demand requirements can also change significantly from one estimation point to the next.<sup>73</sup>

## 3.3 Marginal cost estimation methods

### 3.3.1 Short- or long-run?

Recalling the discussion in section 2.4, the first question to be resolved at the practical level is whether to use short- or long-run marginal cost as the reference point for setting prices. The Commission agrees that short-run marginal cost pricing is the efficient basis for pricing. In addition to the efficiency benefits, short-run marginal cost is relatively straightforward to calculate.

However, as noted by Marsden Jacob Associates (2004) and London Economics (1997), short-run marginal cost can show significant variability. Costs may rise as capacity constraints are approached due to, for example, inefficient production capacity has to be utilised, and then fall away following the capacity upgrade, as illustrated in

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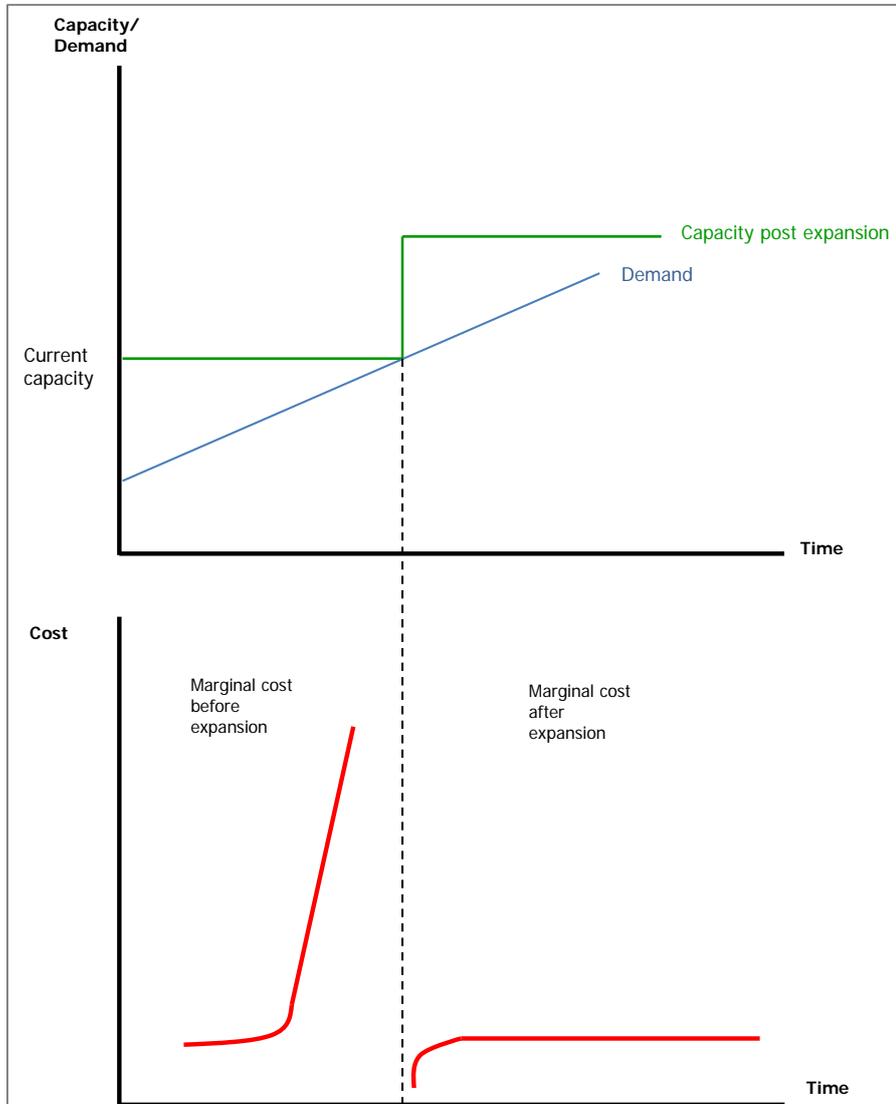
<sup>71</sup> Ibid.: 158-68.

<sup>72</sup> It is important to note that a Pareto efficient outcome requires that the services are produced at least cost. This principle applies to any system changes required in response to an incremental increase in demand.

<sup>73</sup> This point was made by the Commission in its final report on secondary water use in the ACT in relation to the value of a kilolitre of secondary water varying over time depending on how full the primary supply is and how close we are to the next investment in augmenting the primary supply.

Figure 3.1. Setting prices on this basis may result significant price instability, even on an annual basis, an unhelpful characteristic if one is seeking a stable charging base.

Figure 3.1 Short-run marginal cost variability



Source: Adapted from Marsden Jacob Associates (2004).

In contrast, Hirshleifer et al. (1960) dismiss objections to price fluctuations as ‘prejudice’:

While a popular prejudice against such changing prices may be a real difficulty, we would emphasize that it is just that—a prejudice. No buyer has any good reason to expect that prices will remain fixed while conditions of demand and supply change, unless indeed he is willing to bind himself to a long-range contract.<sup>74</sup>

<sup>74</sup> Hirshleifer, DeHaven and Milliman, 1960: 98.

The Commission, however, needs to be mindful of the broader set of proposed pricing principles for this tariff review, and in particular those concerning price path stability. The fourth proposed principle states that tariff structures should be robust enough to promote the economically efficient use of Icon Water’s water and sewerage services infrastructure over a reasonable period of time. While this principle is fundamentally concerned with a stable tariff structure (inclining block or single volumetric charge, for example), it would be remiss not to also consider the variability of constituent price levels.

For the purposes of this paper, following Mann et al. (1980), short-run marginal cost of water is defined as set out in equation (1), and is estimated in Chapter 4.

$$SRMC_t = \frac{R_{t+1} - R_t}{Q_{t+1} - Q_t} \quad (1)$$

where

- $t$  is the year for which short-run marginal cost is being calculated;
- $R_t$  is operating expenditure in year  $t$ ; and
- $Q_t$  is the volume water produced in in year  $t$ .

### 3.3.2 Long-run marginal cost

While the foregoing suggests that long-run marginal cost may provide a more stable basis for setting utility prices, short-run cost still has an important role to play. There are a range of methods to calculate long-run marginal costs, with three of the most common described in this section, following Mann et al. (1980). All of the methods are similar in that they are only concerned with future cost and output and take into account both the short- and long-run. The key difference between them is the degree to which they account for short- versus long-run marginal cost.

#### ‘Textbook’ marginal cost

The textbook definition of marginal cost is straightforward where total cost is a continuous single-valued function: it is the first derivative of total cost with respect to output.<sup>75</sup> This is of course not the case where capital indivisibilities are present which means that in practice we are more concerned with the per unit change in cost caused by a substantial change in output.

The ‘Textbook’ marginal cost (TMC) definition shown in equation (2) adopts this approach by taking each increment to be the change in output which occurs in one year. Accordingly, TMC:

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<sup>75</sup> Differential calculus is applied to find the slope of the tangent to the total cost curve at any particular output level.

makes use of two concepts—i.e., short-run marginal cost (SRMC), which reflects increments in operating costs brought about by increases in output, and marginal capacity cost (MCC), which reflects increments in capital expenditures necessary to increase output.<sup>76</sup>

$$TMC_t = SRMC_t + MCC_t = \frac{R_{t+1} - R_t}{Q_{t+1} - Q_t} + \frac{rI_t}{Q_{t+1} - Q_t} \quad (2)$$

where

- $t$  is the year for which TMC is being calculated;
- $R_t$  is operating expenditure in year  $t$ ;
- $Q_t$  is the volume of water produced in in year  $t$ ;
- $I_t$  is capital expenditure in year  $t$ ;
- $r = \frac{i(1+i)^n}{(1+i)^n - 1}$  = the capital recovery factor, where  $i$  is the appropriate interest rate and  $n$  is the useful life the investment.<sup>77</sup>

Mann et al. (1990) note that with a lumpy investment stream TMC can involve significant fluctuations in price. This is because TMC reflects both short-run marginal cost and marginal capital cost for the years in which capacity expenditure occur while during years in which no capital expenditure take place, TMC equals short-run marginal cost.

### Marginal incremental cost<sup>78</sup>

Following NERA (2014b), marginal incremental cost (MIC), also known as the Turvey or perturbation method, can be summarised as follows:

- Step 1: forecast supply and demand under the optimal expansion plan for the water utility.
- Step 2: hypothesise a permanent increment (or decrement) to the expected demand forecast, and estimate a new optimal expansion plan in light of that increment (or decrement).
- Step 3: calculate the MIC as the change in the present value of expenditure in step 1 and step 2, divided by the present value of hypothesised increment (or decrement) in expected demand.

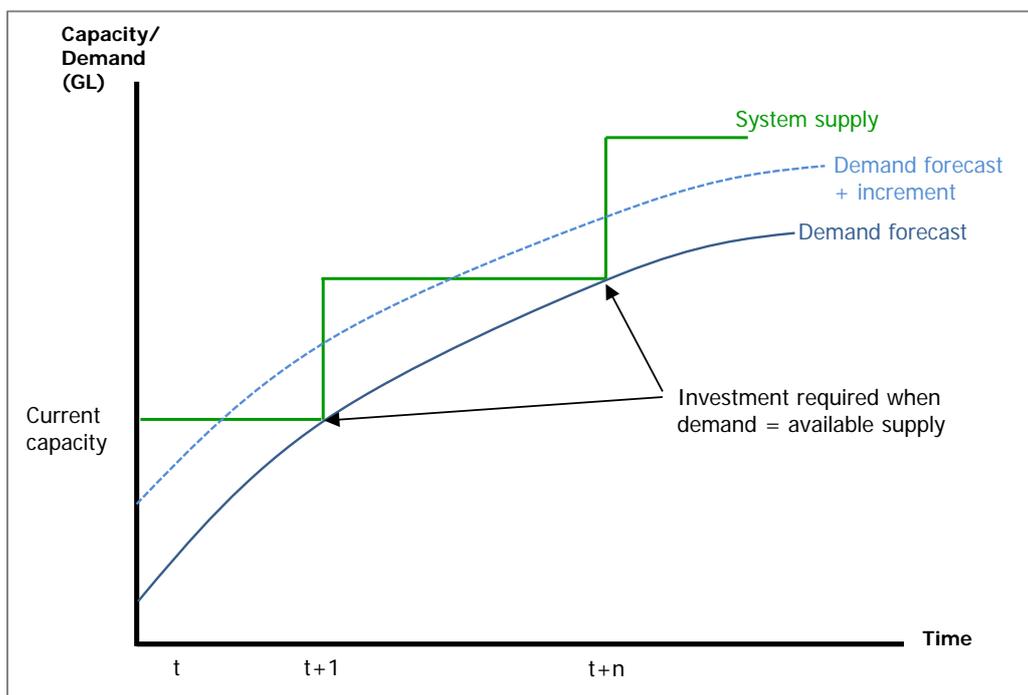
This approach is shown graphically in Figure 3.2.

<sup>76</sup> Mann, Saunders and Warford, 1980: 603.

<sup>77</sup> The capital recovery factor,  $r$ , is the annual payment that will repay a \$1 loan over the useful life of the investment with interest equal to the opportunity cost of capital.

<sup>78</sup> The terminology incremental cost is used rather than marginal cost to reflect the lumpy investment profile.

Figure 3.2 Marginal incremental cost illustration



Source: Adapted from: NERA (2011).

Following NERA (2011), MIC can be expressed informally and formally, as set out in equations (3) and (4), respectively.

$$MIC_t = \frac{NPV(\text{revised optimal capex plus opex} - \text{optimal capex plus opex})}{NPV(\text{revised demand} - \text{initial demand})} = \quad (3)$$

$$MIC_t = \left[ \frac{I_j + R_j}{(1+i)^{j-t}} - \frac{I_j + R_j}{(1+i)^{j+1-t}} \right] / \left[ \frac{Q_j}{(1+i)^{j-t}} - \frac{Q_j}{(1+i)^{j+1-t}} \right] \quad (4)$$

where

- $t$  is the year for which MIC is being calculated;
- $I_j$  is the capital expenditure in year  $j$ , the year in which the next large investment expenditure takes place or the year in which the system reaches capacity;
- $R_j$  is operating expenditure in year  $j$ ;
- $i$  is the opportunity cost of capital; and
- $Q_j$  is the water demand in year  $t$ .

The MIC approach recognises that an increment of demand can be satisfied by expanding output at existing capacity (incurring additional operating costs) and/or by expanding the total capacity (incurring additional capital and operating costs). This

reflects Turvey’s view that given some growth in demand, additional capacity increments cannot be totally avoided, but can be postponed by reductions in demand.<sup>79</sup>

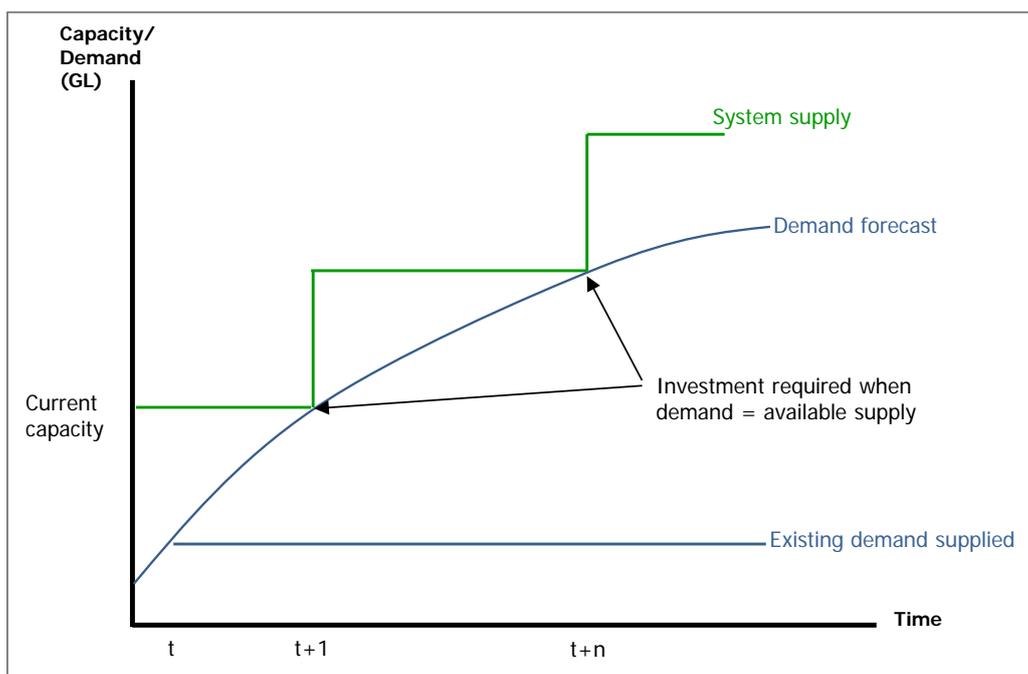
### Average incremental cost

Again following NERA (2014b), the average incremental cost (AIC) approach can be summarised as follows:

- Step 1: forecast the costs of servicing demand including anticipated growth under the optimal expansion plan for the water utility (the same as under the MIC approach);
- Step 2: forecast costs without demand growth.
- Step 3: calculate the AIC as the change in the present value of expenditure in step 1 and step 2, divided by the present value of additional demand served.

This approach is shown graphically in Figure 3.3.

Figure 3.3 Average incremental cost illustration



Source: Adapted from: NERA (2011).

AIC can be expressed informally and formally, as set out in equations (5) and (6), respectively.

$$AIC_t = \frac{NPV(\text{new capex plus opex})}{NPV(\text{additional demand served})} \quad (5)$$

<sup>79</sup> Turvey, 1976: 159.

$$AIC_t = \sum_{k=1}^T \left[ \frac{(R_{t+k}-R_t)+I_{t+k-1}}{(1+i)^{k-1}} \right] / \frac{(Q_{t+k}-Q_t)}{(1+i)^{k-1}} \quad (6)$$

The notation is similar to that used for the MIC definition, except for  $T$  which is the forecasting planning horizon.

The key difference between AIC and MIC is that the former takes account of incremental demand over the whole planning period while MIC only deals with incremental demand in the first year. As such, the AIC gives marginal cost estimates that smooth out any expenditure lumps while at the same time reflecting the trend of future costs which will have to be incurred as consumption increases.

### Summary

Mann et al. (1980) conclude their analysis of the four marginal cost measurement methods described above with the following:<sup>80</sup>

- Of the three methods, TMC adheres most strictly to the actual marginal costs incurred, but has the drawback of price fluctuations when investments are lumpy.
- TMC and MIC adequately signal the need for investment in capacity.
- AIC, which takes a longer view of costs and avoids price fluctuations, is a compromise solution that neither adequately signals the justification for any specific investment, nor adheres closely to TMC either at capacity points or during periods of excess capacity.
- With the introduction of capital indivisibility, AIC becomes more appropriate, compromising between avoiding price fluctuations, signalling justification for investment, and making the best use of existing capacity.

NERA (2011) expresses a preference for the MIC approach over AIC, citing the principal shortcoming of the latter as the fact that it uses average future capital costs to approximate the likely marginal costs associated with a change in demand:

Put another way, the AIC does not discriminate across the ‘size’ of increments to capacity, ie, ignoring the time value of money each unit of new investment is treated equally in their ability to match supply and demand.<sup>81</sup>

Marsden Jacob Associates (2004) note that MIC and AIC are the most common methods used in the water industry. They also note that that MIC is more explicitly concerned with decision making at the margin, which may increase price instability as prices are adjusted more frequently, in contrast to the AIC approach. Marsden Jacob Associates conclude that overall the AIC method is preferred as it:

<sup>80</sup> Mann, Saunders and Warford, 1980: 604.

<sup>81</sup> NERA, 2011: 9.

- is easy to understand;
- is computationally straightforward;
- consistent with future infrastructure planning;
- forces businesses to think long-term;
- produces stable results over time; and
- minimises opportunities for regulatory gaming.<sup>82</sup>

The Australian Energy Market Commission examined this issue in formulating its advice on best practice retail electricity pricing, noting that:

The average incremental cost method represents a relatively straightforward means of estimating the LRMC, but is generally considered to be a less precise method than the perturbation method.<sup>83</sup>

### Commission’s consideration

Of the three methods for calculating long-run marginal cost discussed above, TMC best reflects the forward-looking marginal costs associated with servicing an increment (or decrement) in demand. However, the drawback is price fluctuations before and after a new lumpy investment. The AIC approach relies on average costs and this limits its usefulness as a basis for setting prices to encourage efficiency. The MIC method, which is more closely associated with decision-making at the margin, is likely to better reflect economic efficiency objectives. However, this needs to be balanced against all the other pricing principles. The Commission has estimated, for comparative purposes, the long-run marginal cost of providing water services in the ACT using all three methods in Chapter 4.

### 3.3.3 Other practical measurement matters

#### Elasticity of demand

The marginal cost pricing concept relies on a consumption response to a change in price. If demand were perfectly inelastic ( $\eta = 0$ ), that is there was no consumption response to a change in price, ‘marginal cost pricing would be irrelevant for efficient resource allocation’.<sup>84</sup> As noted earlier, the Commission recently estimated a relatively inelastic, but not zero, elasticity of demand for water in the ACT of -0.14 across the 1999 to 2015 period.

As noted earlier, the Commission’s general preference is to take account of the price elasticity of demand in calculating marginal cost, if practically possible, even though

<sup>82</sup> Marsden Jacob Associates, 2004: 33.

<sup>83</sup> AEMC, 2013: 29.

<sup>84</sup> Saunders, Warford and Mann, 1977: 32.

demand is relatively inelastic and therefore unlikely have a material effect on the end result. This matter is discussed further in the next chapter.

### **Water Abstraction Charge**

As noted in Chapter 2, the ACT Government levies a WAC on each kilolitre of water abstracted from ACT water resources. The rate for 2015–16 is \$0.55 per kilolitre for water abstracted for the purposes of urban water supply. This cost, payable by Icon Water customers, is collected by Icon Water through water charges and then remitted to the ACT Government.

From a practical perspective therefore, in addition to any marginal pumping and treatment costs, an additional kilolitre of water abstracted from ACT dams will attract a further \$0.55 for the WAC.<sup>85</sup>

### **Discount rate**

All four of the long-run marginal cost estimation methods rely on a discount rate (or interest rate). The rate is required to calculate the capital recovery factor for the TMC method, and for the net present value calculation for the MIC and AIC techniques.

There is limited discussion in the marginal cost pricing literature about the choice of discount rate to apply when calculating long-run marginal cost. The terminology used is generally broad referring to an ‘appropriate interest rate’ or ‘the opportunity cost of capital’.

Opportunity cost can be broadly defined as the benefit foregone by using a scarce resource for one purpose instead of its next best alternative. Gittinger (1982), in the context of determining the discount rate for measuring project worth, defines the opportunity cost of capital as ‘the rate that will result in utilization of all capital in the economy if all possible investments are undertaken that yield that much or more return.’<sup>86</sup> Gittinger notes, not unexpectedly, that no one knows what the opportunity cost of capital really is. As such, in the interests of practicality, the search turns to a proxy measure.

For the purposes of financial analysis, the proxy measure is often the rate at which the business or enterprise is able to borrow money. Alternatively, where the capital to be obtained is a mixture of equity and borrowed capital, the proxy is usually the weighted average of the return required by the equity holder and the borrowing rate. In the public utility context, this is known as the weighted average cost of capital (WACC).

In Icon Water’s case, the WACC is determined by the regulator and applied over the course of a regulatory period. Currently, under the substitute price direction, Icon

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<sup>85</sup> As the WAC is based on abstracted volume, it is adjusted in the long-run marginal cost calculation to account for network losses. This is discussed further below.

<sup>86</sup> Gittinger, 1982: 314.

Water is subject to a WACC of 7.2 per cent.<sup>87</sup> According to the Industry Panel, this is intended to reflect ‘the rate of return investors would earn by investing in another asset of equivalent risk’.<sup>88</sup>

For the purposes of estimating Icon Water’s marginal costs for this technical paper, the Commission’s view is that it is appropriate to use the WACC as the discount rate where required for calculation purposes. In addition, it would seem sensible to test marginal cost estimates for sensitivity to changes in the WACC.

### **Water network losses**

The volume of water received by Icon Water’s customers is always less than the amount of water abstracted from ACT dams for that purpose due to network losses from leaking pipes and the like. In its 2013 draft determination report, the Commission used a figure of 8.1 per cent to account for network losses through leakage.<sup>89</sup> Network losses need to be taken into account for any costs that are calculated on the basis of water abstracted (rather than consumed by customers), such as the WAC.

### **Developer charges**

The Commission raised the issue of developer charges (also known as capital contributions) in the tariff review issues paper.<sup>90</sup> Such charges are often imposed by water and sewerage service utilities on land developers to recover network augmentation or upgrade costs to the existing network that are required to service a new development. For example, this could include the construction of additional trunk assets such as mains pipelines or water reservoirs.

Icon Water currently does not have formalised system of levying developer charges.<sup>91</sup> Nonetheless, should developer charges be introduced at some future time, the interaction between such charges and marginal cost pricing, given that the capital cost of future augmentation may already be included in long-run marginal cost estimates, will need to be explored.<sup>92</sup>

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<sup>87</sup> This is a nominal vanilla WACC. For calculation purposes, as the cost streams are in real 2015–16 prices, the real WACC is used. Applying the Fisher equation, the real WACC is calculated as 4.59 per cent.

<sup>88</sup> Industry Panel, 2015: 65. The substitute price direction was determined by the Industry Panel in May 2015.

<sup>89</sup> ICRC, 2013a: 133. Note that the network loss figure of 14.5 per cent used by the Commission in 2013 final determination included an allowance for the bulk water service provided to Queanbeyan City Council by Icon Water.

<sup>90</sup> ICRC, 2015a: 73.

<sup>91</sup> A formal arrangement would require the development of a capital contributions code under the *Utilities Act 2000* (ACT).

<sup>92</sup> See Marsden Jacob Associates, 2004: 26-27 for a discussion on this issue.

## 3.4 Experience in other jurisdictions

A number of Australian and overseas economic regulators apply marginal cost pricing techniques when setting prices for regulated water and sewerage businesses.

### 3.4.1 Water

#### New South Wales

In its review of Sydney Water Corporation's prices for the 2012 to 2016 regulatory period, the Independent Pricing and Regulatory Tribunal of New South Wales (IPART) noted that it:

usually set the usage price of water for retail customers with reference to the long-run marginal cost of the next increment of augmentation (LRMC), to provide a price signal of the incremental costs of consumption'.<sup>93</sup>

IPART estimated Sydney Water's long-run marginal cost at between \$1.82 and \$2.54 per kL, with a mid-point of \$2.18 per kL.<sup>94</sup> In the Hunter Water case, IPART used a long-run marginal cost calculation from a previous determination for reference purposes.

#### Tasmania

In contrast, the Office of the Tasmanian Economic Regulator (OTTER) determined TasWater's prices to apply from 1 July 2015 with reference to short-run marginal cost estimates, which ranged from \$0.29 to \$0.45 per kL. More accurately, OTTER agreed to TasWater's proposal to set the volumetric price above the short-run marginal cost, stating:

The extent to which variable charges may be set above cost is a matter of judgement. It should be noted that setting variable charges at levels above cost results in large water users (such as industrial customers, hospitals and schools) subsidising low use customers (residences and office blocks). This has the effect of creating a cross subsidy and is inconsistent with the Pricing Principles in relation to cost reflective charging.<sup>95</sup>

OTTER decided to set the variable charge at around \$1.00 per kL, double the highest short-run marginal cost estimate.

#### Western Australia

In Western Australia, the Economic Regulatory Authority (ERA) recommended water prices for residential customers in 2013–14 be set with reference to long-run marginal cost at the lower estimate (\$1.39 per kL), mean estimate (\$1.85 per kL), and upper

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<sup>93</sup> IPART, 2012: 101.

<sup>94</sup> Ibid.: 215.

<sup>95</sup> OTTER, 2015: 78.

estimate (\$2.61 per kL) for the first tier, second tier and third tier usage charges, respectively. Three estimates were derived to account for 'the uncertainty surrounding long-term rainfall patterns and hence infrastructure requirements as well as future levels of demand'.<sup>96</sup> ERA used the MIC method to calculate long-run marginal cost.

### South Australia

The Essential Services Commission of South Australia (ESCOSA) set water usage charges consistent with long-run marginal cost estimates provided by SA Water. In its 2010–11 price review, ESCOSA decided to adopt a long-run marginal cost estimate of \$2.40 per kL, which was calculated using the AIC approach.<sup>97</sup> ESCOSA went on to note, however, that while the usage charge for the second tier was now relatively close to the long-run marginal cost estimate, the third tier charge was significantly above the estimate:

If the LRMC provides an accurate reflection of the costs associated with water consumption (including externalities), then there is limited justification for charging prices well in excess of the LRMC. Such an outcome would be likely to lead to an inefficient allocation of resources in terms of customers' decisions about using water and SA Water's decisions about investing in infrastructure.<sup>98</sup>

### Queensland

In its 2000 statement of regulatory pricing principles for the waters sector, the Queensland Competition Authority (QCA) recommended that volumetric water prices be set with reference to long-run marginal cost estimated using the AIC approach.<sup>99</sup>

### Victoria

In the case of Melbourne Water, the Essential Services Commission of Victoria (ESC) emphasised the importance of setting volumetric tariffs with reference to long-run marginal cost to gain from economic efficiency and to 'provide appropriate signals about the costs associated with future supplies or disposal'.<sup>100</sup> In its 2016 price review guidance paper, ESC required Melbourne Water to 'describe the relationship between the proposed price and the associated LRMC' in its 2016 price submission.<sup>101</sup>

### Overseas

Despite its growing popularity in Australia, the international regulatory literature cites only a few practical examples of marginal cost pricing in the water sector. Especially pertinent in this regard includes the Water Services Regulation Authority (OFWAT) in

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<sup>96</sup> ERA, 2013: 24

<sup>97</sup> ESCOSA, 2010: 54.

<sup>98</sup> Ibid.: 57-8.

<sup>99</sup> QCA, 2000: 6.

<sup>100</sup> ESC, 2011: 12

<sup>101</sup> ESC, 2015: 34.

the United Kingdom and the Canadian Water and Wastewater Association (CWWA).<sup>102</sup>

Following a series of reports highlighting the relevance and importance of marginal cost pricing in determining water tariffs in the United Kingdom, OFWAT required water companies in England and Wales to provide annual long-run marginal cost estimates in their price submissions from 2001.<sup>103</sup> Given the choice between the MIC or AIC approaches, most of the companies opted for AIC. NERA (2014b) note that the long-run marginal cost estimates were not used to set prices for customers, partly due to the lack of metering for many household customers.

The CWWA has been promoting the importance of marginal-cost pricing since the 1990s and published a manual in 1993 that set out its approach.<sup>104</sup> The CWWA has decided to adopt a two-part tariff structure, with the volumetric component based on long-run marginal cost and estimated using the AIC approach.<sup>105</sup>

### 3.4.2 Sewerage services

The application of marginal cost pricing in the provision of sewerage services is more limited than for water as it presupposes a volumetric charge for sewage disposal.

#### New South Wales

IPART's view on sewerage usage pricing in NSW is that:

SRMC is more applicable for sewerage usage pricing since the current sewerage systems are based around individual sewerage plants that are not interconnected. Hunter Water has 18 sewerage treatment catchments.<sup>106</sup>

In its 2012 review of Sydney Water prices, IPART stated:

To improve cost reflectivity, and send appropriate price signals, we consider that this [sewerage usage] charge should reflect Sydney Water's short run marginal cost (SRMC) of sewage transportation, treatment and disposal, which is estimated to be \$0.23/kL.<sup>107</sup>

Given that this estimate is much lower than the usage charge prevailing at the time, IPART determined a transition towards this cost over the regulatory period.

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<sup>102</sup> Previously called the Canadian Water and Wastewater Authority.

<sup>103</sup> NERA, 2014a: 8.

<sup>104</sup> See [http://www.cwwa.ca/publicationorder\\_e.asp#ratemanual](http://www.cwwa.ca/publicationorder_e.asp#ratemanual).

<sup>105</sup> Marsden Jacob Associates, 2004: 22.

<sup>106</sup> IPART, 2013: 118.

<sup>107</sup> IPART, 2012: 103.

## Victoria

In its 2013 price review for metropolitan water businesses, ESC's draft decision noted that the proposed bulk variable sewerage tariff proposed by Melbourne Water does not reflect the long run marginal cost of providing sewerage services. Melbourne Water was then compelled to resubmit a more cost reflective proposal having regard to long run marginal cost.<sup>108</sup> In its final decision, ESC approved the revised variable charges on the basis that they reasonably reflect long-run marginal cost.<sup>109</sup>

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<sup>108</sup> ESC, 2013a: 177.

<sup>109</sup> ESC, 2013b: 134.

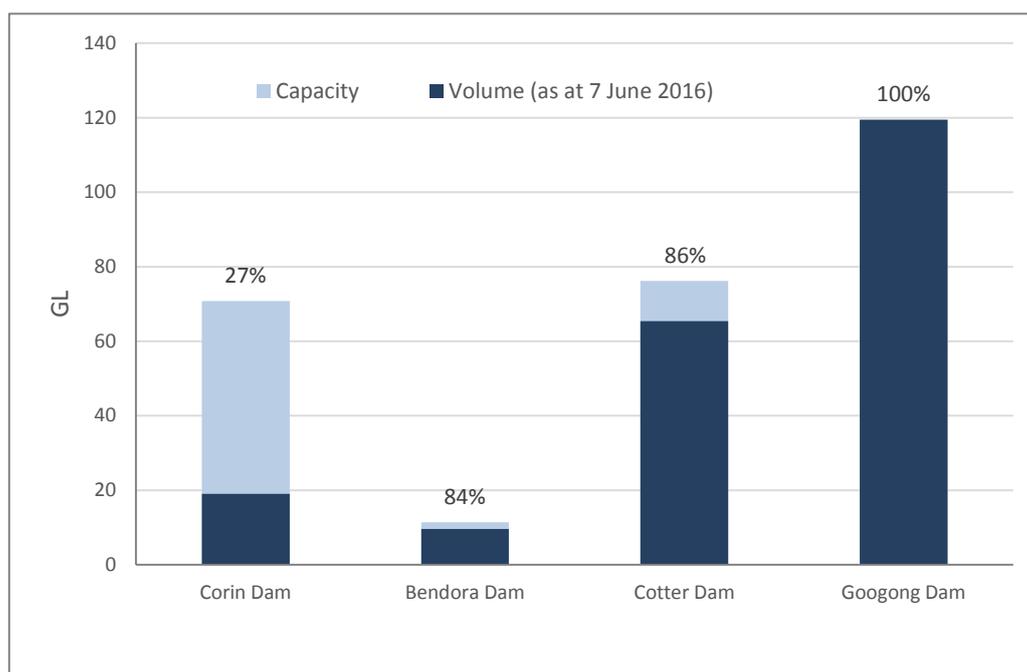
## 4 Marginal cost of water in the ACT

### 4.1 The water network

The ACT water network comprises a number of dams, water treatment plants and a reticulation system.<sup>110</sup>

The ACT has four major water storages. These are the three dams to the west of Canberra on the Cotter River; Corin Dam, Bendora Dam and Cotter Dam; and Googong Dam to the east of Canberra on the Queanbeyan River. The current total storage capacity is about 278 gegalitres (GL). In addition, Icon Water can also draw water from two pump stations located on the upper Murrumbidgee River. Water can also be released to the river from Snowy Hydro's Tantangara Reservoir and transferred to Googong Dam via the Murrumbidgee to Googong pipeline.

Figure 4.1 Icon Water dam storage capacity and levels



Source: <https://www.iconwater.com.au/Water-and-Sewerage-System/Dams/Water-Storage-Levels.aspx>.

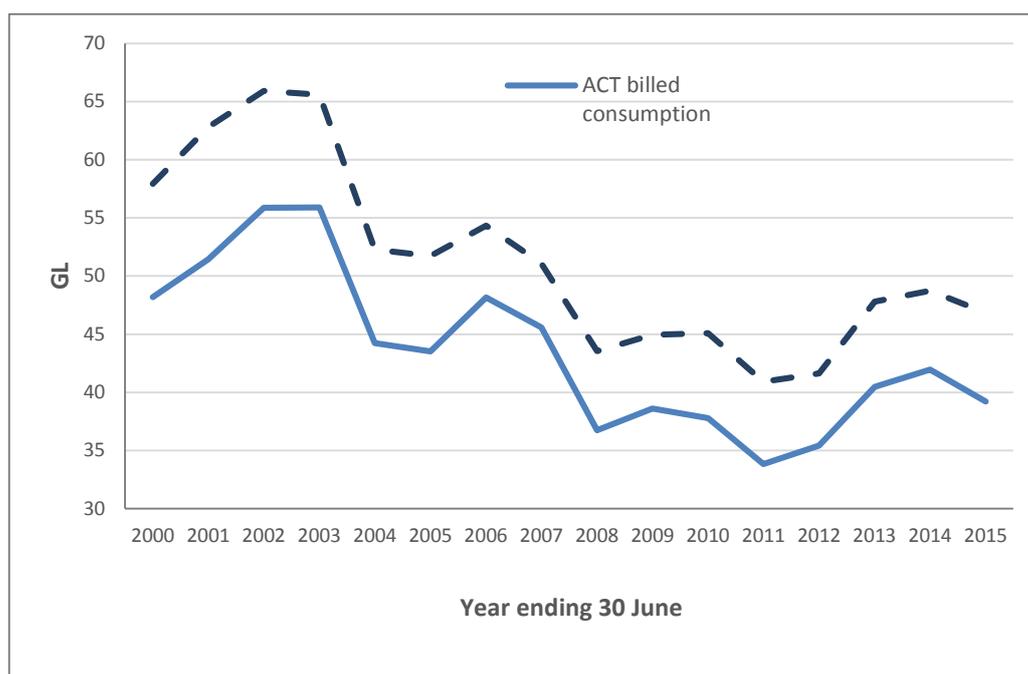
The ACT has two main treatment plants that treat water from the various storages to the required potable standard before supply to consumers. The first is Mt Stromlo, which treats the water from the dams to the west of Canberra. The second is located at the base of the Googong Dam. Water from the various dams is piped to the ACT's water treatment plants when required for usage. Water from the treatment plants is

<sup>110</sup> For more detail see: <https://www.iconwater.com.au/Water-and-Sewerage-System.aspx>.

transferred to the 46 local reservoirs, via the reticulation network, where it is stored until required by ACT water users.

Figure 4.2 shows Icon Water dam releases and ACT billed consumption over the last 15 years. The difference between the two data series is due to network losses and bulk water provided to Queanbeyan City Council.

Figure 4.2 Icon Water dam releases and billed consumption, 2000 to 2015



Source: Icon Water.

## 4.2 Short-run marginal cost estimate

For the purposes of this paper, the short-run marginal cost of water is taken to comprise the following:

- operating cost – the pumping and treatment costs required to deliver an additional kilolitre of water from Icon’s supply sources to the customer, which varies by water source; and
- the WAC – the \$0.55 per kL charge levied by the ACT Government on water abstracted for urban supply purposes.<sup>111</sup>

<sup>111</sup> An additional water resource marginal cost element has not been included in the marginal cost estimate in this paper for two reasons. The first is that the WAC already includes a scarcity charge, although undefined in magnitude. The second reason is that the likelihood of temporary water restrictions in the near or indeed medium-term is relatively low.

The operating costs associated with supplying an additional kilolitre of water to customers in the ACT, primarily energy costs for pumping and chemical costs for treatment, varies significantly depending on the supply source. The three main sources of supply are Bendora Dam, Cotter Dam and Googong Dam. The estimated operating cost by source, as shown in Table 4.1 and Figure 4.3, ranges from \$0.07 per kL for Bendora to \$0.25 per kL for Cotter.

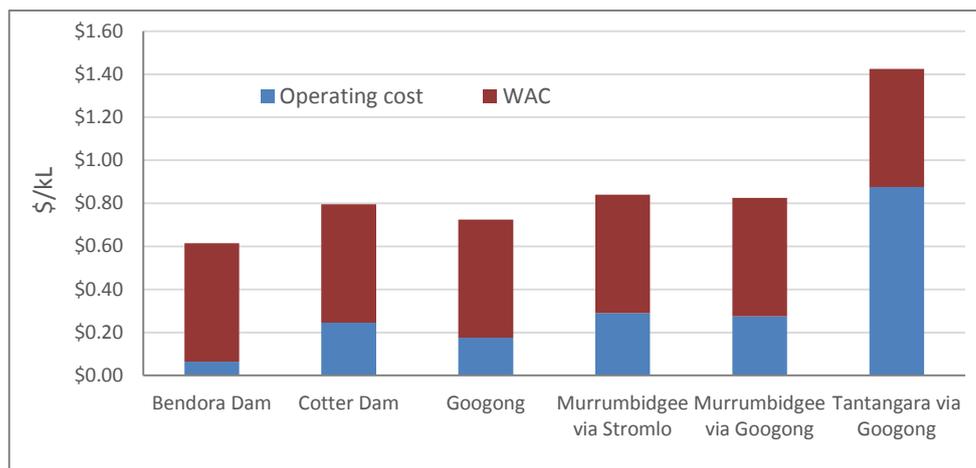
Table 4.1 Estimated short-run marginal cost of water by supply source, current prices<sup>112</sup>

Source	Operating cost (\$ per kL)	Short-run marginal cost (\$ per kL)
Bendora Dam	0.07	0.62
Cotter Dam	0.25	0.80
Googong	0.18	0.73
Murrumbidgee via Stromlo	0.29	0.84
Murrumbidgee via Googong	0.28	0.83
Tantangara via Googong	0.88	1.43

Source: Icon Water (2016).

Bendora is the cheapest delivery source as, given its elevation, no pumping costs are involved as the water is gravity fed to the Mt Stromlo water treatment plant. When the WAC is added, short-run marginal cost estimates range from \$0.62 per kL for Bendora to \$0.80 per kL for Cotter. As far as the supply options that could be employed during times of prolonged water shortages, the Tantangara option is the most expensive at about \$1.43 per kL, more than twice the cost of Bendora.

Figure 4.3 Short-run marginal cost of water by component and supply source, current prices



Source: Icon Water (2016).

<sup>112</sup> The costs are presented per kL of water abstracted.

Applying equation (1) from section 3.3.1 to the baseline scenario for the AIC calculation (discussed in section 4.3 below), gives a short-run cost marginal cost estimate across the supply sources modelled in use of about \$0.72 per kL of water delivered to ACT customers.<sup>113</sup>

## 4.3 Water supply and demand modelling

### 4.3.1 Introduction

In order to sensibly calculate the long-run marginal cost of water in the ACT, it is necessary first to forecast when the next capacity augmentation is likely to be required. In the ACT context, this means modelling the future urban water supply and demand balance against the ACT Government's water security objective of less than 1 year in 20 in temporary water restrictions.<sup>114</sup> For this exercise, the Commission has, as it did for the secondary water review in 2012, relied on Icon Water's water supply and demand model. The Commission thanks Icon Water for running the model on the Commission's behalf.

Armed with the supply and demand modelling results, attention can then turn to estimating the relevant operating and capital costs associated with meeting the modelled increments to demand over the relevant forward period.

### 4.3.2 ACT water security objective

Modelling water supply and demand requires understanding the level of water security that the ACT Government wishes to attain. For the purposes of this paper, for all scenarios modelled, the Commission has adopted the common interpretation of the ACT Government's water security objective, which is that for any year over the modelled period, there should be less than a 5 per cent probability of any level of temporary water restrictions.<sup>115</sup>

### 4.3.3 The Icon Water model

Icon Water's water supply and demand model is illustrated in Figure 4.4 with a summary of its key processes provided in Appendix 2.

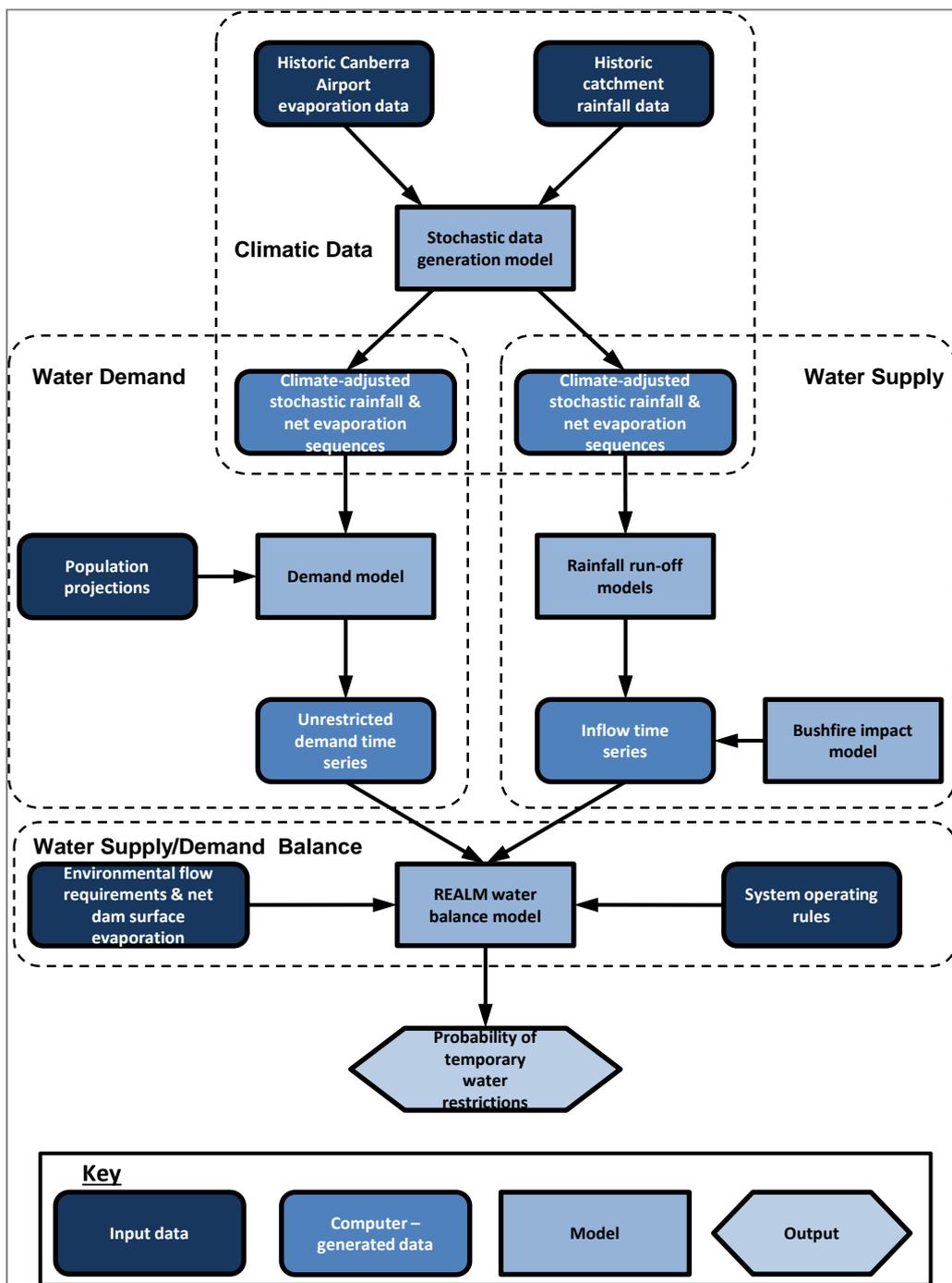
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<sup>113</sup> This estimate has been adjusted to account for network losses through leakage and the like of about 8.1 per cent.

<sup>114</sup> The most recent articulation of the water security objective is in the 2014 ACT Water Strategy document which states 'Using best available modelling and assumptions, the current water supply system should meet unrestricted demand for the ACT and Queanbeyan 95% of the time until at least 2030' (ACT Government, 2014b: 20).

<sup>115</sup> The Commission has previously commented on the lack of specificity in the ACT Government's water security objective (ICRC, 2010: 10).

Figure 4.4 Water supply and demand model representation



Source: Adapted from ACTEW (2011a), p. 2.

Note: The inflow time series for the Murrumbidgee goes through an additional model before input to REALM. This model estimates monthly pumping availability with and without Tantangara releases based on the daily stochastic flow and assumed water quality.

As a simplification, a bucket analogy of the ACT water supply system can be used to describe the water supply and demand modelling process described in this chapter.

The ACT primary water supply system is comparable to a bucket of water. Water flows into the bucket via precipitation falling in ACT catchments. Water is removed from the bucket for urban use and environmental flows. The bucket is required because of a timing mismatch between when water is available to flow into the bucket and when it is required for use. The challenge is to ensure that there is sufficient water in the bucket (water supply) to provide the amount of water required for urban use and environmental flows (water demand) over time. Ensuring that the water supply and demand are in balance is known as providing water security.

The desired level of water security can be expressed in several ways. A common approach is for a government to set a level of service, such as supplying a minimum volume of water per household each year that a water provider is required to meet over a future period of time. As discussed above, the ACT Government has adopted an alternative approach, announcing an objective that temporary water restrictions occur no more than one year in 20, or 5 per cent of the time. The level and duration of water restrictions depends on the level of water in the bucket. The lower the level, the more severe and the longer the restrictions will be in place.

For the purposes of this paper, the current level of ACT water security is estimated by starting with the existing amount in the bucket, and then modelling the projected flows of water into and out of the bucket every year over the next 47 years—over the modelling period from 2016 to 2062.

There is a great deal of uncertainty about future climatic conditions. For example, we do not know the timing, extent or duration of a future dry spell that may require temporary water restrictions to be imposed. Modelling this uncertainty requires assessing the relative frequency of the future range of climatic conditions—wet, dry and average—based on historical climate experience, with allowance made for future impact of climate change. Given these relative frequencies, the Icon Water model generates a set of 1,000 climate paths, each of which specifies the climate in each of the years of the modelling period.

Future water inflow volumes are dependent on climatic conditions and the state of the ACT water catchments. Accordingly, for each of the generated future climate paths, the model generates a corresponding path of future dam inflows, allowing for bushfire effects on water catchments. Future outflows from the bucket are largely determined by the demand for water by the ACT community. This in turn is influenced by a number of factors, including population growth, weather conditions (including climate change), efficiency of water use and the price of water.<sup>116</sup> Again, for each generated climate path, future water demand for each year is modelled by estimating per capita

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<sup>116</sup> Water price is the only factor that is not considered in the model.

water demand based on previous experience, and multiplying this number by the projected population for that year to give total demand in that year.

Each pair of supply and demand paths is input to the water balance module of the model, REALM, in turn. REALM models the management of the dam system and is able to indicate, month by month, whether the level of water in the bucket has fallen enough to require the imposition of water restrictions. For each year of the modelling period, the proportion of the paths in which water restrictions needed to be imposed gives us an estimate of the probability of being in water restrictions in that year.<sup>117</sup>

This estimated probability of being in water restrictions can be compared to the 5 per cent water security objective. If the probability starts trending above the 5 per cent level, this indicates that augmentation of the bucket may need to be delivered around this time if water security is to be maintained at the set objective.<sup>118</sup>

#### 4.3.4 Commission model scenarios, assumptions and constraints

For the purposes of estimating the long-run marginal cost of water in this paper, the Commission has considered a baseline and three future water supply and demand scenarios, as shown in Table 4.2. In addition, for sensitivity purposes, the scenarios were also run without climate change.

Table 4.2 Commission model scenarios

Scenario	Description	Comments
Baseline	No demand growth + likely climate	Baseline or no change scenario
1	Minor demand growth + likely climate	Optimal investment scenario – medium series population growth with 50 per cent contribution to aggregate demand
2	Medium demand growth + likely climate	Incremental adjustment above Scenario 1 – medium series population growth with 100 per cent contribution to aggregate demand
3	High demand growth + likely climate	Upper bound investment scenario – high series population growth with 100 per cent contribution to aggregate demand

This section provides a summary of the key assumptions and constraints that are applied in the scenarios undertaken for this paper. This section draws on ActewAGL (2011), ACTEW (2014a) and ACTEW (2014b).

<sup>117</sup> The technique described here is often referred to as Monte Carlo simulation.

<sup>118</sup> It is important to note that meeting the ACT Government's water security objective does not imply that the ACT will never be in water restrictions over the modelling period. Rather it implies that the probability of being in water restrictions in any given year over this period is no more than 5 per cent. Thus, the statement that the ACT is water secure means that water restrictions may be imposed but only rarely.

## Water supply infrastructure

Water supply assumptions for all the scenarios include the current major supply sources—Corin, Bendora, Enlarged Cotter and Googong Dams—with a total capacity 278 GL, and the upgraded Mt Stromlo and Googong Water Treatment Plants and the Murrumbidgee Pump Station. In extended dry periods, when storage levels are low, Icon Water can also draw water from two pump stations located on the upper Murrumbidgee River. During more protracted dry periods, when the river’s natural flows are low, additional water can be released to the river from Snowy Hydro’s Tantangara Reservoir and transferred to Googong Dam via the Murrumbidgee to Googong pipeline.

## Water demand

### *Introduction*

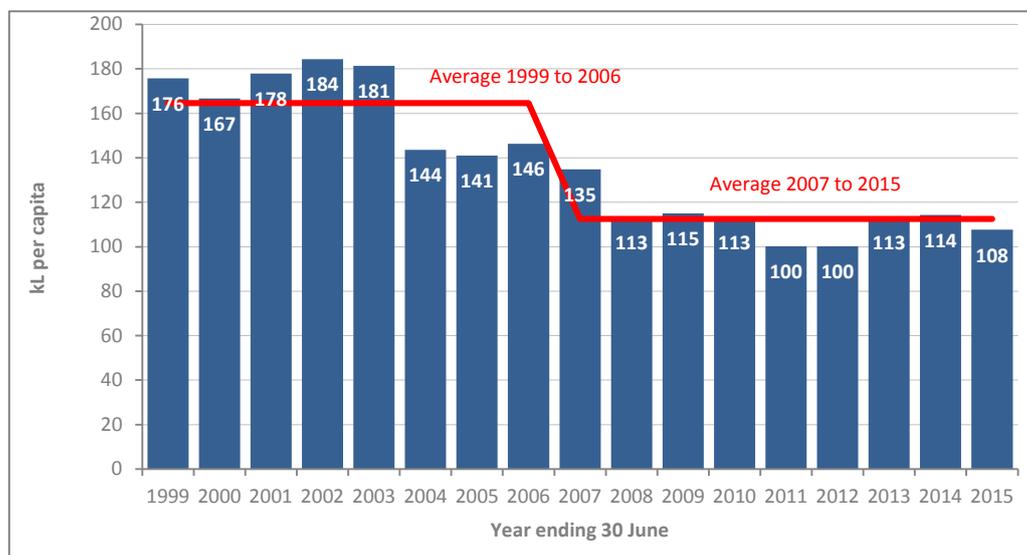
For modelling purposes, demand can primarily be considered a function of the expected population growth rate and the level of per capita consumption. Aggregate demand can then be calculated using generated stochastic rainfall and evaporation sequences, adjusted for climate change in the relevant scenarios. The demand model used by Icon Water in its water supply and demand model is that provided to the Industry Panel in August 2014.<sup>119</sup>

### *Recent history*

Figure 4.5 shows Icon Water per capita dam releases from 1999 to 2015. This shows a substantial decline in per capita consumption, with levels in recent years well below those seen in the early to mid-2000s. Beginning roughly at the onset of severe water restrictions in 2006, ACT water consumers have been subject to three experiences that may have set in train processes of adaptation that resulted in the structural break in 2006. These are a substantial increase in the volumetric price of water, incentives and campaigns to encourage more frugal use of water inside and outside the home, and lifestyle change to accommodate lower water consumption.

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<sup>119</sup> ACTEW, 2014b: 1-21. Available for download at: [http://apps.treasury.act.gov.au/\\_\\_data/assets/pdf\\_file/0016/630034/Information-Return-Demand-Forecasts-15-August-2014.pdf](http://apps.treasury.act.gov.au/__data/assets/pdf_file/0016/630034/Information-Return-Demand-Forecasts-15-August-2014.pdf).

Figure 4.5 Annual Icon Water dam releases per capita, 1999 to 2015<sup>120</sup>

Source: ABS, ACT Treasury and Icon Water data.

The relationship between population and water demand has been investigated in the development of a number of ACT forecasting models in the last few years.

Icon Water used the Breusch-Ward model, which excludes population as an explanatory variable, as the basis for its demand forecasts for the 2013 water and sewerage services price investigation. Breusch and Ward (2012) state that population was excluded from the final model as it is not statistically significant and the coefficient is negative, rather than positive as one would expect.<sup>121</sup> Breusch and Ward surmised that water-saving efficiencies may be increasing at a rate to roughly offset population growth.<sup>122</sup>

Similarly, Icon Water's 2015 biennial recalibration forecasting model contains no allowance for population growth, implicitly assuming that population growth is offset by demand reductions.

The Commission came to an analogous conclusion in its 2015 time series forecasting work:

The Commission chose not to include a population variable because there is no trend in the Releases data over the estimation period. As the Commission noted in the

<sup>120</sup> Per capita volumes are obtained by dividing total dam releases by the sum of the ACT and Queanbeyan population.

<sup>121</sup> Breusch and Ward, 2012: 18.

<sup>122</sup> Ibid.: 5.

January 2015 paper and as is illustrated in Figure 2.7, over the period 1998 to 2014, there has been a significant, downward trend in Releases.<sup>123</sup>

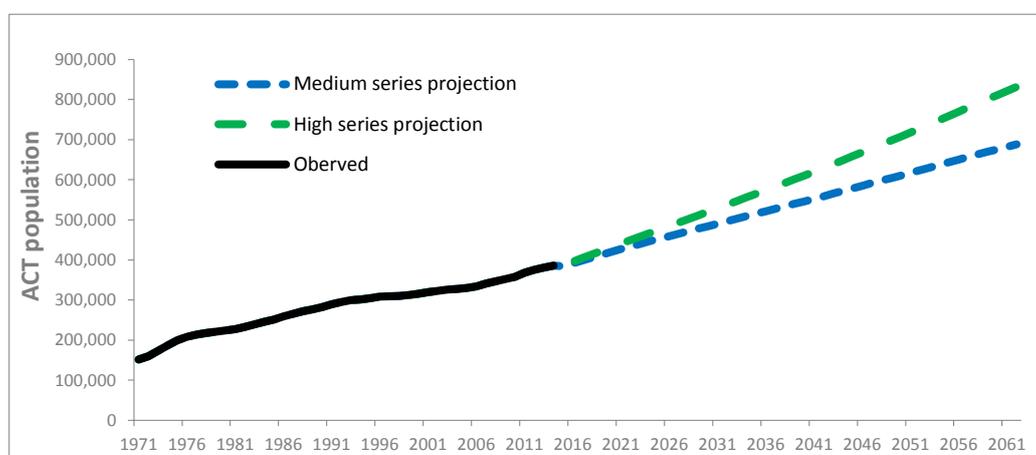
While the above work suggests that, at least in the near term, population should be excluded as a demand factor, for the purposes of this paper, the Commission agrees with Breusch and Ward’s view that ‘population growth would likely be an important factor for long-term forecasting and water-security planning.’<sup>124</sup>

The two key modelling assumptions: what population growth rate to apply and how to treat the per capita contribution of any population increase to aggregate demand; are discussed in turn below.

### Population growth rate

In 2013 the Australian Bureau of Statistics (ABS) released its latest high, medium and low series population projections for the ACT. Subsequently, the ACT Government published its population projection for the ACT over the 50 years to 2062, based on the ABS medium series. This projects an ACT population of about 682,000 by the end of the forecast period. The scale of difference the ABS high series and the medium series, which increases substantially in the outer years, is illustrated in Figure 4.6.

Figure 4.6 ACT observed and projected population—high versus medium growth



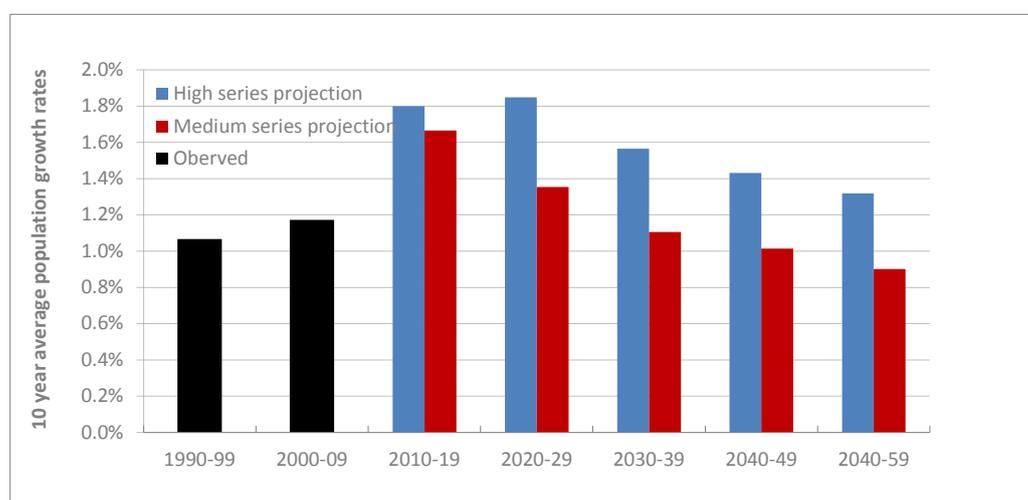
Source: ACT Government (2014a); ABS (2013).

Figure 4.7 shows the ten-year observed, medium and high series projected population growth rates. This shows that the high series growth rates are well above the rates observed over the previous two decades. On this basis, and consistent with the ACT Treasury’s approach, for the purposes of this paper the Commission’s preference is to use the ABS medium growth series for projecting future water demand for the optimal investment scenario.

<sup>123</sup> ICRC, 2015b: 12.

<sup>124</sup> Breusch and Ward, 2012: 5.

Figure 4.7 ACT historical and projected population ten-year average growth rates



Source: ACT Government (2014a).

For the purposes of forecasting the Queanbeyan population, the Commission has utilised New South Wales Government population projections for Queanbeyan to 2031, and, consistent with the ACT approach, applied the ACT medium series average growth rates to 2062.<sup>125</sup>

A summary of the Commission's medium series population projection assumptions for the ACT and Queanbeyan is shown in Table 4.3.

Table 4.3 Commission medium series population projection assumptions

Year	ACT	Queanbeyan	Total population serviced
2016	399,899	44,500	444,399
2022	437,032	50,040	487,072
2032	499,463	59,292	558,755
2042	559,569	67,042	626,611
2052	621,492	73,907	695,399
2062	681,187	80,844	762,031

Source: ACT Government (2014a), NSW Government (2014) and Commission's calculations.

For sensitivity purposes, the Commission has also modelled a scenario with high population growth.

<sup>125</sup> The Commission has not included a population allowance for additional cross-border supply given the uncertainty of Icon Water supplying additional water to areas such as Yass or Murrumbateman in the future.

### *Demand by scenario – per capita contribution*

The baseline scenario assumes no demand growth. That is, aggregate demand remains at current levels, fluctuating only in response to the stochastic weather and climate patterns over the modelling period.<sup>126</sup>

The minor demand growth option, Scenario 1, assumes that only 50 per cent of any incremental population at the medium series growth rate contributes to aggregate demand growth. For the purposes of estimating the long-run marginal cost of water in this paper, Scenario 1 is treated as the optimal, or most likely, investment scenario.

In Scenarios 2 and 3, demand increases with population at the medium and high series rate, respectively, with a more conservative assumption that 100 per cent of any incremental population contributes to aggregate demand growth. Scenario 2 represents the demand perturbation scenario required in order to apply the MIC measurement method. Scenario 3 is considered as an upper bound for demand growth.

### **Climate variability and climate change**

Prior to 2014, Icon Water modelled climate change on the basis of the dry case 2030 ACT climate projections made by the Commonwealth Scientific and Industrial Research Organisation in 2003. In 2014 Icon Water updated its climate change approach to account for the recent climate change modelling by the South Eastern Australian Climate Initiative (SEACI) and more recent climate observations to take into account in particular the observed cooler month rainfall reductions.<sup>127</sup> The new approach incorporates the following climate scenarios:<sup>128</sup>

- dry climate change—stochastic data produced using outputs from the second driest of the 15 global climate models included in the SEACI project;
- medium climate change—stochastic data produced using outputs from the median global climate model included in the SEACI project;
- wet climate change—stochastic data produced using outputs from the second wettest of the 15 global climate models included in the SEACI project;
- last 20 years, stochastic data produced so that the seasonal means of rainfall in each catchment and evaporation are adjusted to match the means observed in the past 20 years from June 1993 to May 2013; and
- repeat of the Millennium Drought, where performance is tested using observed historical inflows from 1997-2009.

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<sup>126</sup> The baseline scenario assumes that zero per cent of any incremental population growth contributes to aggregate demand growth.

<sup>127</sup> Autumn rainfall, for example, has decreased significantly, with an almost 40 per cent reduction observed over the period 1997 to 2010.

<sup>128</sup> See ACTEW, 2014a: for more information. Available for download at <https://www.iconwater.com.au/About/Reports-and-Publications/Key-Publications.aspx>.

In addition, Icon Water has updated its stochastic data generation approach to produce 50,000 years of stochastic data rather than the previous 10,000 years. The new climate change assumptions are applied in the model by adjusting the generated rainfall and evaporation path.

All scenarios in this paper that include climate change have been modelled using the dry climate change scenario.

### **Environmental flows**

Environmental flows are the flows of water in ACT streams and rivers that are necessary to maintain aquatic ecosystems. The *ACT Water Resources Act 2007* (Water Resources Act) gives first priority to environmental flows, and specific flow requirements are set out in the 2013 Environmental Flow Guidelines.<sup>129</sup> The environmental flows are made either by releases or spills from ACT dams, or by putting restrictions on the volume of water that can be abstracted from a catchment. Icon Water's licence to take water under the Water Resources Act requires Icon Water to ensure that environmental flows are given first priority in accordance with the guidelines. The requirements in relation to dam releases and water abstraction limitations are applied as constraints in REALM.

Environmental flows are applied in the same fashion to all scenarios modelled in this paper.

### **Bushfire impact**

Icon Water assumes that the impact of the 2003 Canberra bushfires is reducing streamflow in ACT catchments due to increased evapotranspiration as vegetation recovers. Based on reports from environmental consultants, Icon Water assumes a maximum streamflow reduction of 15 per cent about 17 years after the fires, with reduced inflows continuing for more than 50 years.

Icon Water applies the bushfire assumptions by using a bushfire impacts model to reduce the inflow levels on the paths generated by the rainfall run-off models. The potential for future bushfires to reduce streamflows over the future is also factored into the bushfire impacts model.

Icon Water's bushfire assumptions are applied in the same fashion to all scenarios modelled in this paper.

### **Water conservation and restriction measures**

The ACT has recourse to two administrative schemes, administered by Icon Water to reduce water use by ACT and Queanbeyan residents, and therefore extend supply.

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<sup>129</sup> ACT Government, 2013: 1-42. Available for download at: <http://www.legislation.act.gov.au/di/2013-44/current/pdf/2013-44.pdf>.

Permanent water conservation measures (PWCM) and a temporary water restrictions scheme, both approved under the *Water Utilities Act 2000*.<sup>130</sup>

In practice, PWCM and temporary water restrictions can be considered as one extended suite of administrative demand-reduction measures with five levels. PWCM always apply, with Stages 1 through 4 temporary water restrictions progressively imposing more stringent water reduction measures over and above the PWCM requirements. Icon Water has responsibility for the decision to implement temporary water restrictions and takes a number of factors into account in making the decision to introduce and lift the various restriction stages. These include dam storage levels, climate outlook and community considerations.

For modelling purposes, REALM has dam storage level triggers that introduce and remove restrictions which vary seasonally and increase with time as demand increases. Restrictions are initially applied when storage drops below about 100 GL (about 36 per cent of current storage capacity). To minimise continual restriction level changes, the removal trigger levels for each stage are 10 to 20 per cent higher than the introduction trigger.

Operating rules for sourcing water are optimised to balance the trade-off between water security and operating cost. This is achieved by minimising a total cost function comprising the cost of restrictions and operating cost.

Icon Water's restrictions modelling assumptions are applied in the same fashion to all scenarios modelled in this paper.

## 4.4 Modelling results

The probability of temporary water restrictions under all the scenarios, except the baseline, is illustrated in Figure 4.8. The timing of the next water supply augmentation (or demand reduction intervention) can be gauged from the point, if any, at which the probability rises above the 5 per cent water security target.

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<sup>130</sup>ACT Government, 2010b: 1-9 and ACT Government, 2010a: 1-6.

Figure 4.8 Probability of water restrictions, all scenarios

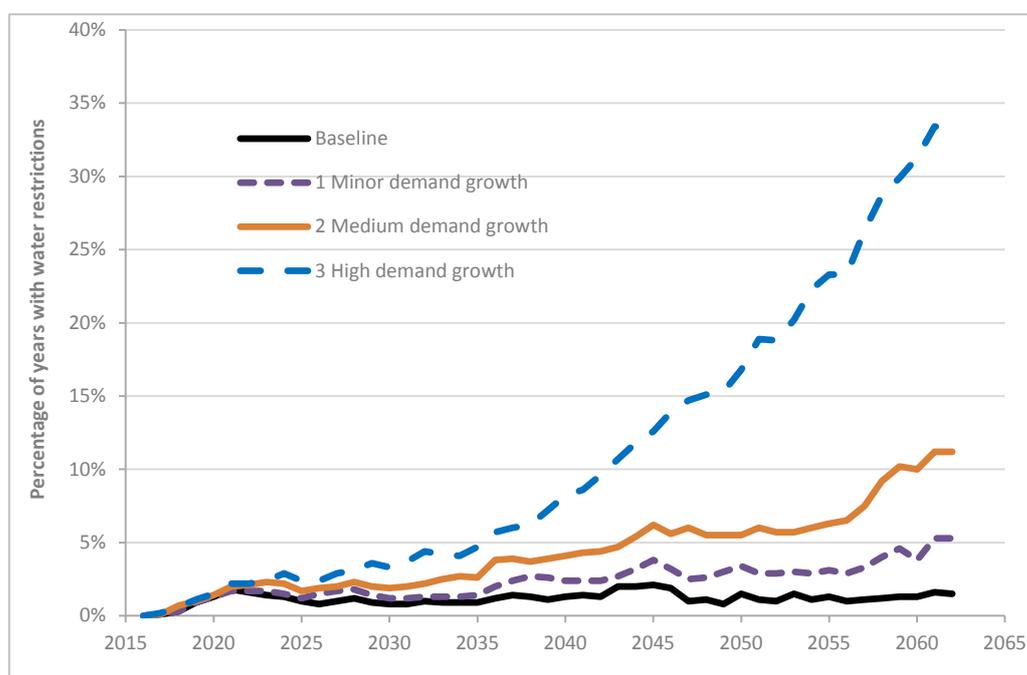


Table 4.4 shows the approximate timing of when the next supply augmentation is likely to be required for each of the scenarios, with and without climate change. Under the likely climate assumption, the timing ranges from as early as 2035 for the upper bound high demand growth scenario, to as late as 2060 for the minor demand growth scenario.

Table 4.4 Indicative augmentation timing, by scenario

Scenario	Description	Likely climate	No climate change
Baseline	No demand growth	Post 2062	Post 2062
1	Minor demand growth	2060	Post 2062
2	Medium demand growth	2043	Post 2062
3	High demand growth	2035	2047

For sensitivity purposes, all scenarios were also modelled with the assumption that there will be no climate change effects on supply and demand. Not surprisingly this significantly delays augmentation timing, with Scenario 3 being delayed by 12 years from 2035 to 2047. It is also clear that increasing demand growth significantly accelerates the estimated augmentation timing.

## 4.5 Long-run marginal cost estimate

### 4.5.1 Introduction

This section provides estimates of the long-run marginal cost of water in the ACT using the four methods discussed in section 3.3.2.

For the purposes of the MIC and AIC methods, a planning horizon or forecast period of 47 years has been applied for water services, to match that of Icon Water's modelling timescale. The planning horizon therefore runs from 2016 to 2062.

The next capacity augmentation is assumed to be the Tennent Dam on the Gudgenby River.<sup>131</sup> Icon Water considered this option in its water security review in 2007, recommending that it be retained as a future water supply option.<sup>132</sup> For the purposes of this paper, the following assumptions have been made in respect of the Tennent Dam:<sup>133</sup>

- Estimated capital cost of about \$716 million in current prices (adjusted for inflation from \$606 million in 2009 dollars), which includes the dam and associated assets such as a delivery pipeline, pump stations and water treatment plant.<sup>134</sup>
- Capacity of 159 GL.
- Construction timeline of seven years to build and fill the dam and construct the associated assets.
- Operating cost the same as that of the Googong Dam.

The Icon Water modelling process produces, for each year of the forward period, unrestricted demand volumes, restricted demand (as a result of water temporary water restrictions) volumes, differentiated by supply source, which enables calculation of the operating costs. The model is not however designed to allocate demand to sources after a supply augmentation. In order to calculate post-augmentation operating costs, two things are assumed post the Tennent Dam coming on stream. First, demand is assumed to revert to the unrestricted demand in the relevant year. Second, it is assumed that the proportion of supply from the more expensive Murrumbidgee and Tantangara sources will reduce back to their 2016 proportions and then scale up as in the original modelling projection.

As noted in section 3.3.3, the Commission's general preference is to take price effects on demand into account, using an estimate of the price elasticity of demand, when

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<sup>131</sup> This assumption is made for the purposes of calculating indicative marginal costs for the purposes of this paper only. The same applies for the assumptions about cost and construction timing.

<sup>132</sup> ACTEW, 2008: 19.

<sup>133</sup> See ACTEW, 2005: 1-100 for more information on the Tennent Dam option. Available for download from: <https://www.iconwater.com.au/About/Reports-and-Publications/Reports-Archive.aspx>.

<sup>134</sup> Halcrow, 2010: 19.

estimating long-run marginal cost. From a practical perspective however, the price of water ideally needs to be incorporated into the water supply and demand modelling process as an additional endogenous variable, which is not currently the case. As such, in this paper, the Commission has not taken the impact of the water price on demand into account. Nonetheless, given the Commission's recent inelastic ACT demand estimate of -0.14 over the 1999 to 2015 period, and the even less elastic estimate over the post-structural break period from 2006 to 2015 of -0.04, this is unlikely to have a material effect on the long-run marginal cost results.

#### **4.5.2 'Textbook' marginal cost**

The TMC estimate for this paper is based on applying equation (2) as described in section 3.3.2. Recall that, for years in which no capital expenditures take place, TMC equals short-run marginal cost. This situation applies in the current circumstances with no requirement for immediate capital expenditure on supply augmentation. As such, the TMC estimate for this paper is the short-run marginal cost, estimated at \$0.72 per kL of water delivered to ACT customers as calculated in section 4.1.

#### **4.5.3 Average incremental cost**

For the purposes of this paper, the AIC approach involves a comparison of the incremental costs and water volumes supplied between the baseline supply and demand situation and the most likely future scenario when a supply augmentation is required, the optimal Scenario 1. Under Scenario 1, the probability of being in restrictions rises above 5 per cent from about 2060, with construction assumed to start on the Tennent Dam from 2054. Applying equation (6) the AIC is estimated at \$1.61 per kL of water delivered to ACT customers.

#### **4.5.4 Marginal incremental cost**

For the purposes of this paper, MIC is calculated by comparing the incremental costs and water volumes supplied moving from the optimal Scenario 1 with minor demand growth to Scenario 2, which assumes medium demand growth. Under Scenario 2, augmentation is required from 2043, 17 years earlier than under Scenario 1. Applying equation (4), the MIC is estimated at \$1.74 per kL of water delivered to ACT customers.

#### **4.5.5 Sensitivity analysis**

The Commission assessed the sensitivity of the AIC and MIC estimates to the discount rate. As shown in Table 4.5, both are sensitive to the level of the discount rate. Reducing the discount rate increases the AIC estimate while decreasing the MIC estimate (and vice-versa).

Table 4.5 Long-run marginal cost sensitivity to discount rates

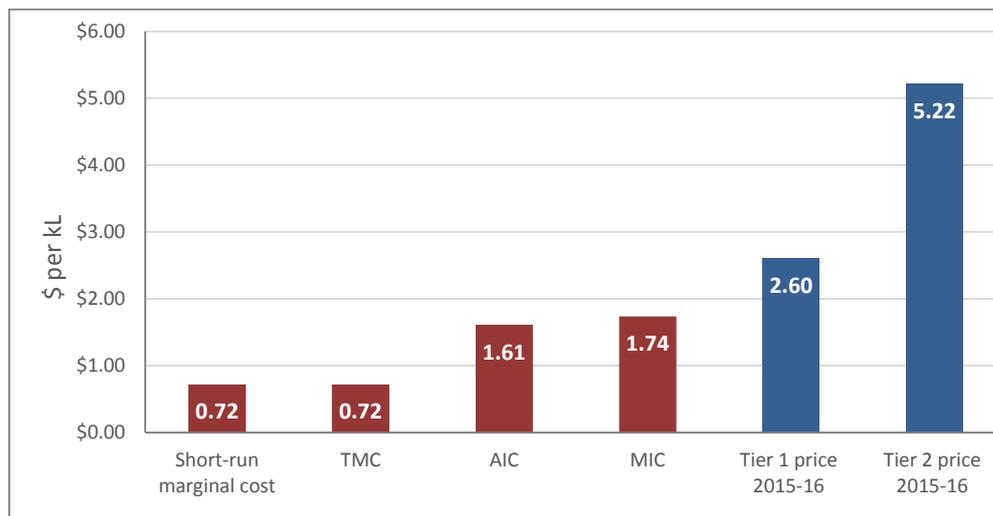
Nominal rates	\$/kL		\$/kL
	5 per cent	7.20 per cent	10 per cent
AIC	1.91	1.61	1.31
MIC	1.39	1.71	1.95

The AIC measure was tested for sensitivity to demand growth. Assuming that Scenario 2, with medium demand growth, rather than the minor demand growth Scenario 1 is the optimal investment scenario, returns an AIC estimate of \$1.67 per kL of water delivered. This is four per cent higher than the \$1.61 per kL estimate for Scenario 1. The MIC measure was tested for sensitivity to the increment assumed for the demand perturbation. Using the difference between Scenario 1 and 3 generates an estimate of \$1.57 per kL delivered, nine per cent smaller than the \$1.74 per kL for the comparison between Scenario 1 and 2.

## 4.6 Summary

A summary of the short- and long-run marginal cost estimates for water in the ACT is shown in Figure 4.9. For the long-run methods, estimates range from a low of \$0.72 per kL for TMC, the same as the short-run marginal cost estimate, to a high of \$1.74 using the MIC method. The two most common long-run measurement methods, AIC and MIC, return estimates of similar magnitude.

Figure 4.9 Marginal cost estimate for water, summary



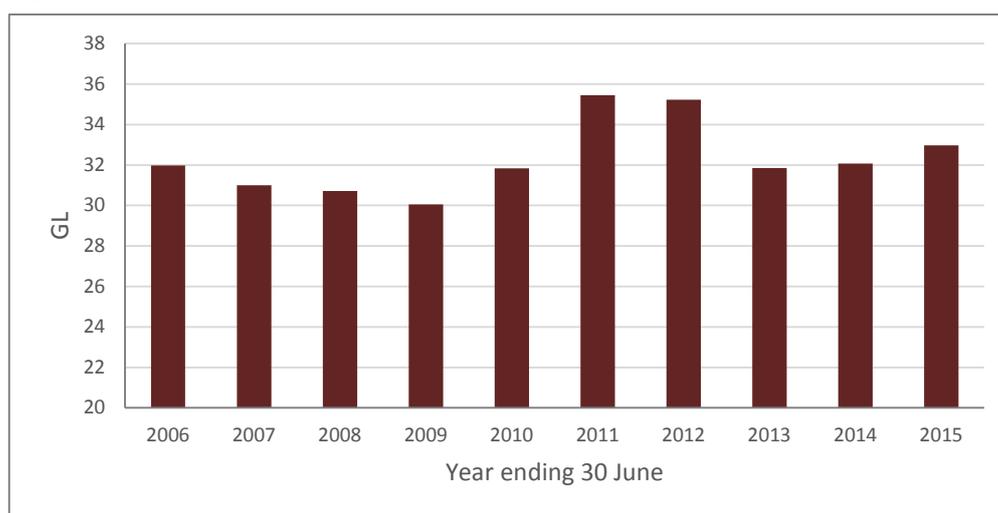
Recall that Icon Water’s current two tier volumetric prices for water are \$2.60 per kL for the first 0.548 kL per day and \$5.22 per kL thereafter. What is clear is that, irrespective of which measure is used, all the marginal cost estimates are well below even the first tier price. This conclusion holds in the face of all the sensitivity tests run on the various measures.

## 5 Marginal cost of sewerage services in the ACT

### 5.1 The sewerage network

Icon Water's sewerage system consists of a network of approximately 3,100 km of underground pipes which collect sewage from ACT residential and commercial customers and transport it to the Lower Molonglo Water Quality Control Centre (LMWQCC) and the Fyshwick Sewage Treatment Plant for treatment.<sup>135</sup> The bulk of the treated sewage is then released into the Murrumbidgee River. Figure 5.1 shows the total volume of sewage collected from ACT customers over the last decade. In its most recent review of future options, Icon Water notes that the sewerage system 'was planned for a future ultimate population of a million people'.<sup>136</sup>

Figure 5.1 Icon Water total sewage collected, 2006 to 2015



Source: Icon Water

### 5.2 Short- or long-run?

The Commission has chosen to focus on estimating the short- rather than long-run marginal cost of sewerage services in this chapter, for two reasons.

<sup>135</sup> See <https://www.iconwater.com.au/Water-and-Sewerage-System.aspx> for more information on Icon Water's sewerage network.

<sup>136</sup> ACTEW, 2011b: 2.

The first is, as noted in the previous chapter in relation to water, the Commission’s general view is that, in principle, the objective of economic efficiency is best served by setting prices with reference to short- rather than long-run marginal cost.

As discussed in Chapter 3, we are primarily concerned with marginal cost with respect to changes in the quantity or volume of services provided through the central sewerage network, that is the central treatment plants and trunk sewer pipes, as opposed to the suburb-level collection network. The second reason for the focus on short-run marginal cost is that the capacity of Icon Water’s central sewerage network is sized to deal with rainfall events. As such there is currently no immediate need to augment capacity for reasons of expanding demand.

### 5.3 Short-run marginal cost estimate

For the purposes of this paper, the short-run marginal cost of sewerage services in the ACT is taken to comprise the following:

- treatment cost – the cost of chemicals, electricity, fuel and freight to treat an additional kilolitre of sewage at the LMWQCC; and
- pumping – the electricity costs to pump an additional kilolitre of sewage through the sewerage network to the treatment plant.<sup>137</sup>

Icon Water estimates the marginal treatment cost at \$0.25 per kL, and the marginal pumping cost at \$0.005 per kL, for a total short-run marginal cost of about 0.26 per kL.

It is important to note at this juncture that lower volumes of discharge entering the sewerage network, which could eventuate following the introduction of a volumetric charge, do not necessarily translate into reduced costs for Icon Water. For example, low sewage volumes during a drought can result in difficulties moving sewage through the network. A classic example of this was played out in the Zimbabwean city of Bulawayo in 2012, which involved a simultaneous ‘big flush’ by all community residents to move congealed sewage through the system.<sup>138</sup>

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<sup>137</sup> This is an average cost across the network, with some areas not requiring any pumping.

<sup>138</sup> Gotora, 2012: 1.

## 6 Concluding remarks on marginal cost pricing in the ACT

### 6.1 Introduction

While fuller consideration will await the tariff review draft report, some preliminary observations are made below on the Commission's views on setting prices for regulated water and sewerage services in the ACT with reference to marginal cost.

As stated in the introduction, it is the first pricing principle for the tariff review, the one that follows directly from the overarching efficiency objective for the review and deals with the efficient allocation of water and sewerage services to Icon Water customers, that is the primary focus of this technical paper. The pricing principles concerning full cost recovery, price path stability and the transition to a new tariff structure, are also pertinent to the decision on whether to adopt a marginal cost pricing approach in the ACT, but are better considered in the context of the tariff review draft report.

### 6.2 Water

The current pricing methodology is primarily based on recovering historical cost. The evidence in this paper indicates that the objective of economic efficiency in the provision of regulated water services in the ACT would be better served by moving toward a forward-looking marginal cost pricing approach.

The findings of the technical paper on water demand elasticity in the ACT provide evidence that ACT consumers are likely to respond to marginal price signals.

On the choice between short- and long-run marginal cost, in principle, short-run marginal cost pricing is the efficient basis for pricing. The sale of water to consumers is a short-term agreement that does not bind the consumer to take any more water at a later date and the utility is therefore faced with the short-run problem of selling water given its current capacity.

Nonetheless, in practice, the Commission sees merit in a long-run measure, for two reasons. First, although the short-run approach is unlikely in the present supply and demand circumstances to lead to any great instability in prices over the near to medium term, this may not always be the case as the supply and demand conditions change over time. Second, as discussed further below, the gap between the current tariff structure and one based on marginal cost pricing is substantial, and likely to require a long transition period. In these circumstances, aiming to transition the volumetric price to a long-run marginal cost estimate is a more realistic goal.

From a measurement perspective, the Commission's preference is to calculate long-run marginal cost using the MIC method as this approach is more explicitly concerned with

decision-making at the margin. There is scope within the short-run element of the MIC method to add a resource value element in the future, in addition to the WAC, that rises as the next augmentation approaches as the value of water in the Icon Water's dams increases.

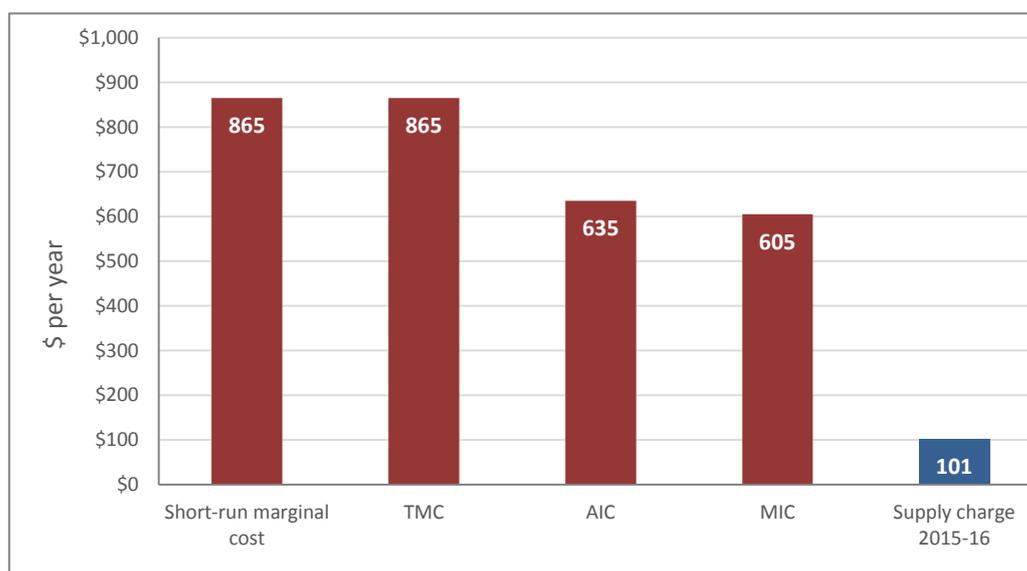
The application of marginal cost pricing in a decreasing average cost industry such as we are facing here, requires the retention of the current multi-part tariff structure, that is a supply charge and one or more volumetric prices, for cost recovery reasons.

It is also evident that all the marginal cost estimates calculated for the purposes of this paper, short- and long-run, are well below even the first tier current water price of \$2.60 per kL. On this basis, the answer to the first question posed earlier as one of the objectives of this technical paper is that Icon Water's current water tariff structure does not appear to be providing suitable price signals to customers about the efficient use of the service infrastructure and water resource.

As to the second question about what a more efficient tariff structure would look like, the pursuit of economic efficiency would dictate a move towards one volumetric price, set with reference to marginal cost. The Commission recognises that moving from the current inclining block structure and price levels to a new, more efficient, single volumetric charge structure with the price set with reference to marginal cost will require a significant adjustment in the level of the supply charge.

For indicative purposes, Figure 6.1 shows the upper bound scenario—the supply charge that would be required to recover the same revenue for Icon Water as 2015–16 water prices for each marginal cost estimate, should a single volumetric charge be introduced, priced at marginal cost. The indicative annual charges are considerably higher than the current supply charge of about \$101, ranging from \$865 for the short-run marginal cost and TMC measures to \$605 for the MIC estimate.

Figure 6.1 Indicative water supply charge, with single volumetric charge set at marginal cost



There will be welfare losses for households and the ACT community if the price of water continues to not reflect the cost of providing that water to customers. A more efficient tariff structure will also reduce the possibility of uneconomic bypass of Icon Water’s primary water system, with welfare benefits for all ACT water customers and non-residential customers in particular.

A benefit for Icon Water from such a new pricing arrangement would be reduced volumetric revenue risk as the share of revenue recovered from fixed charges would rise from the current 10 per cent to between 60 and 80 per cent depending on which measure of marginal cost is applied.

On the other hand, moving from the current pricing situation to a more efficient arrangement with a higher supply charge and lower volumetric charge will have substantial distributional impacts on customers. In particular, low volume water users will face substantial negative impacts, which may require a long transition period, possibly over more than one regulatory period, as a mitigation measure. This issue will be discussed in detail in the Commission’s draft report for the tariff review, taking into consideration all the proposed pricing principles.

The Commission recognises that some members of the ACT community strongly support water conservation and the role played by the current inclining block tariff, particularly with the second tier priced at double the first, in reducing discretionary water use. The scarcity value of water in ACT dams should be recognised but is better addressed by adjusting the marginal cost estimate as appropriate. Given the current water supply and demand balance, with a low likelihood of temporary water restrictions in the near or indeed medium-term, the scarcity value of water is not likely to be high at present.

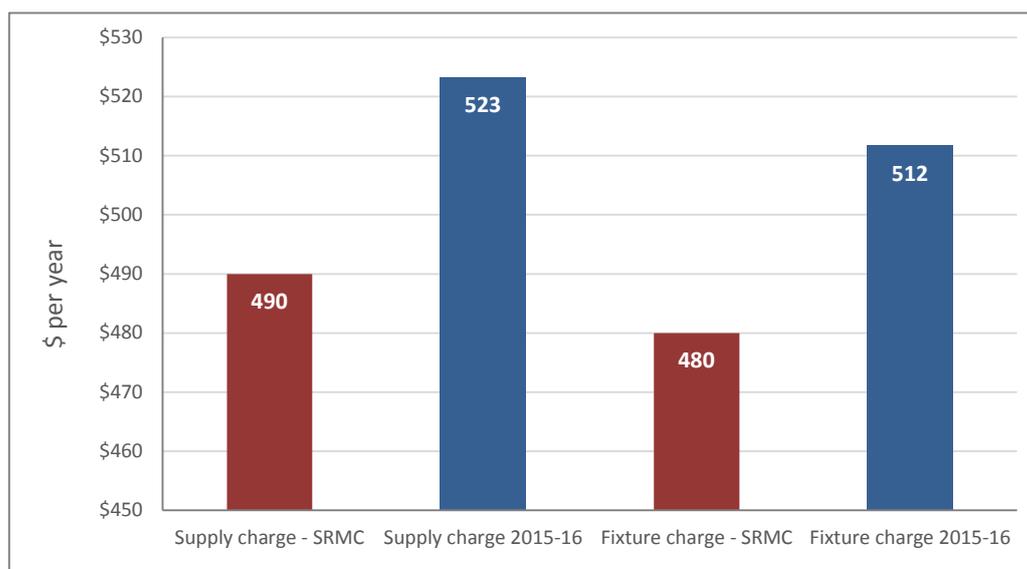
### 6.3 Sewerage services

The situation in relation to sewerage services is different to that for water in that there is no volumetric charge in the current tariff structure. This in itself implies that the current structure, based entirely on fixed charges, is incapable of providing suitable price signals to customers about the efficient costs of sewerage services in the ACT.

In line with the Commission’s view on water pricing, a more efficient structure would entail a multi-part tariff which would include a volumetric sewerage charge set with reference to marginal cost.

Figure 6.2 shows the indicative supply and fixture charges that would be required to recover the same revenue for Icon Water as 2015–16 prices should a volumetric sewerage charge be introduced at the short-run marginal cost of \$0.26 per kL. The indicative annual charges are about 6 per cent lower than the current charges.

Figure 6.2 Indicative sewerage service supply and fixture charges, with volumetric charge set at short-run marginal cost



The distributional impacts of such a change in tariff structure and price levels are likely to be less dramatic than would the case for water as described above. Once again, as for water, these matters will be discussed in more detail in the Commission’s draft report for the tariff review, taking into consideration all the proposed pricing principles.

# Appendix 1 The marginal cost controversy

While Alfred Marshall is credited with first suggesting that the allocation of resources might be improved by subsidizing decreasing cost industries, it is the later work of Harold Hotelling, an influential mathematician, statistician and economic theorist, that is commonly cited as the basis for the marginal cost pricing debate.<sup>139</sup> In 1938 Hotelling wrote a seminal article on general welfare and the relationship between taxation and the setting of railway and public utility charges.<sup>140</sup>

Hotelling, who chose to build on the work of the French engineer and economist Jules Dupuit (rather than Marshall and others), postulated that ‘the optimum of the general welfare corresponds to the sale of everything at marginal cost’ and that the difference between this amount and total cost be made up by taxation.<sup>141</sup> Hotelling saw railway charges (and public utility charges) as essentially the same as a tax – and more specifically as an excise tax, hence the intersection between taxation and public utility pricing. Hotelling established his fundamental theorem that:

if a person must pay a certain sum of money in taxes, his satisfaction will be greater if the levy is made directly on him as a fixed amount than if it is made through a system of excise taxes which he can to some extent avoid by rearranging his production and consumption.<sup>142</sup>

In a subsequent article on the same topic, Hotelling commented on the implications of his hypothesis:

This proposition has revolutionary implications, for example in electric-power and railway economics, in showing that society would do well to cut rates drastically and replace the revenue thus lost by subsidies derived largely from income and inheritance taxes and the site value of land.<sup>143</sup>

Hotelling was strongly opposed to the alternative view that total costs be met by consumers stating:

Defenders of the current theory that the overhead costs of an industry must be met out of the sale of its products or services hold that this is necessary in order to find out whether the creation of the industry was a wise social policy. Nothing could be more absurd. Whether it was wise for the government to subsidize and its backers to construct the Union Pacific Railroad after the Civil War is an interesting historical

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<sup>139</sup> Marshall, 1920: 472-75. For an excellent exposition on the marginal cost pricing debate between the proponents of taxation and those in favour of full cost pricing see Ruggles, 1950: 107-126.

<sup>140</sup> Hotelling, 1938: 242-69.

<sup>141</sup> *Ibid.*: 242.

<sup>142</sup> *Ibid.*: 252.

<sup>143</sup> Hotelling, 1939: 151.

question which would make a good subject for a dissertation, but it would be better, if necessary, to leave it unsolved than to ruin the country the Union Pacific was designed to serve by charging enormous freight rates and claiming that their sum constitutes a measure of the value to the country of the investment.<sup>144</sup>

Ronald Coase is perhaps the most well-known opponent of subsidising decreasing cost industries, especially after the publication of his seminal article on marginal cost pricing in 1946, the title of which adorns this appendix.<sup>145</sup> As noted by Nancy Ruggles a few years later:

Coase did not disagree with the thesis that that price should equal marginal cost, but argued that total cost would also have to be covered if there was not to be a redistribution of income in favour of the consumers of products in which fixed costs form a high proportion of total costs.<sup>146</sup>

When faced with a divergence between average and marginal costs, rather than the alternatives of pricing according to marginal cost thereby incurring a loss, or pricing at average cost and avoiding any loss, Coase proposed the introduction of multi-part pricing, on the basis that:

A consumer does not only have to decide whether to consume additional units of a product; he has also to decide whether it is worth his while to consume the product at all rather than spend his money in some other direction.<sup>147</sup>

Coase's view was that marginal cost pricing for additional units would provide for the former, while an additional charge, independent of consumption, set to ensure that total supply costs are recovered would deal with the latter.

Another key figure, William Vickrey, then entered the fray in support of the Hotelling approach in his 1948 article that considered a number of objections to the Hotelling approach and dismissed all of them.<sup>148</sup> In particular, Vickrey concluded that:

In nearly all cases involving decreasing costs, even the best scheme of multi-part pricing will be unable to cover costs and, at the same time, achieve optimum consumption ...<sup>149</sup>

In addition, on the matter of price stability, Vickrey argued that even 'though marginal cost may fluctuate erratically, this indicates not that marginal cost should be discarded

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<sup>144</sup> Hotelling, 1938: 268.

<sup>145</sup> Coase, 1946: 169-82.

<sup>146</sup> Ruggles, 1950: 114-15.

<sup>147</sup> Coase, 1946: 173.

<sup>148</sup> Vickrey, 1948: 218-38.

<sup>149</sup> *Ibid.*: 237.

as a basis for prices but that, where the administrative costs would not be prohibitive, prices should likewise fluctuate fairly drastically.<sup>150</sup>

Vickrey subsequently wrote an article in 1955 that appeared to soften his support for Hotelling's approach.<sup>151</sup> Although reaffirming his view that marginal cost must play a major role in the design of any price structure intended to promote the efficient utilisation of available resources and facilities, he added this caveat:

As a preface to a discussion of the role of marginal cost pricing, it is perhaps well to state explicitly that in common with any other theoretical principle, the principle of marginal cost pricing is not in practice to be followed absolutely and at all events, but is a principle that is to be followed insofar as this is compatible with other desirable objectives, and from which deviations of greater or lesser magnitude are to be desired when conflicting objectives are considered.<sup>152</sup>

More tellingly, Vickrey then elaborated on what he considered the most striking of these considerations:

By far the most important of the considerations that conflict with the strict application of marginal cost pricing is the need for revenues. Many of the more extreme advocates of marginal cost pricing for decreasing-cost industries seem tacitly to assume that the government has some perfectly costless and neutral source of revenue that is capable of very substantial expansion without ill effects. Such a state might be approached, for example, if we had an income tax free of its multiple defects, evasion proof, with no marginal costs of administration or compliance, and including in its base not only money income but all forms of direct income in kind, including an imputed value for leisure. Needless to say, this is far from the case.

In a much later article on public utility pricing, Coase, who indicated that he had trouble restraining a cheer when reading Vickrey's comments on the need for revenues, concludes that:

What this seems to indicate is that there is no difference of any substance between the position of someone who, like Vickrey, claims to be a supporter of marginal cost pricing and someone who, like myself, regards himself as an opponent. The only substantial difference seems to be one concerning terminology, and that is hardly worth spending much time on.<sup>153</sup>

This exchange essentially saw the end of the 'marginal cost controversy' in relation to revenue shortfalls, with multi-part tariffs incorporating a consumption charge based on marginal cost now commonplace in public utility pricing.

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<sup>150</sup> Vickrey, 1955: 238.

<sup>151</sup> Ibid.: 605-20.

<sup>152</sup> Ibid.: 605.

<sup>153</sup> Coase, 1970: 122.

Brown et al. (1992) and Vohra (1990) both contend that equilibria under two-part marginal cost pricing are not Pareto optimal:

Two-part marginal cost pricing equilibria are not generally Pareto-efficient. This is in contrast to the impression left by much of the partial equilibrium literature on two-part tariffs.<sup>154</sup>

The multi-part tariff structure therefore provides a means to enable regulators to use marginal cost pricing to achieve an outcome that, while not Pareto-efficient, at least approaches second-best. As stated by Train (1991):

Multipart tariffs have important welfare implications. Perhaps the most relevant is the fact that a regulator, by applying an appropriately designed multipart tariff, can induce a natural monopolist to operate closer to the first-best outcome than would be possible with only one price.<sup>155</sup>

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<sup>154</sup> Brown, Heller and Starr, 1992: 71.

<sup>155</sup> Train, 1991: 191.

## Appendix 2 Water supply and demand modelling process

### A2.1 Introduction

Icon Water has developed a computer-based model of the ACT water resources system which it uses for its water resources planning. The model is designed for assessing medium- to long-term ACT water security requirements and can be used to predict at what stage additional supply augmentations (or increased demand reduction initiatives) are likely to be necessary and to compare alternative supply and demand options.

### A2.2 The model

In summary, the model consists of the following components: stochastic data generation model, water supply, water demand and water balance.

#### A2.2.1 Stochastic data generation model

The model of the ACT water resources system incorporates the natural variability in the climate by employing a stochastic data generation model. Looking forward, there is natural variation in climate as the community can expect that there will be dry years and wet years. It is this natural variation in future climate that is applied to future climate outcomes.

The advantage of this form of modelling is that it allows the modeller to examine potential uncertain future outcomes in a systematic manner. The alternative would be to calculate the probability of potential outcomes directly under an assumed distribution of future climate. This cannot be done in this case due to the complexity of the modelling, especially the water balance model.

Historical data provides the range and scope of the variability in the climate variables used in the modelling. Climate outcomes are updated to take into account the potential effect of climate change on rainfall and evaporation.

The model generates 50,000 years of climate data (rainfall and evaporation) based on historical data. The 50,000 years of climate data are grouped into 1,000 sequences, each 50 years long. All of the models are populated and solved using all of the 50-year climate outcomes.

The output of the models is 1,000 sequences, each 50 years long, of inflows, water demand and level of water restrictions. One output of particular interest is the

proportion of the 1,000 sequences that result in water restrictions over each of the next 50 years.

### **A2.2.2 Water supply**

Based on historical rainfall data for particular water catchments and historical evaporation data at Canberra Airport, the stochastic data generation model is used to generate a time series of stochastic rainfall and evaporation sequences.<sup>156</sup> The time series is then adjusted for climate change on the basis of the SEACI modelling discussed in Chapter 4.

Catchment-specific rainfall run-off models then convert the time series rainfall and evaporation data into projections of water inflow volumes into the four ACT water storages.

A bushfire impacts model then reduces the inflow data projections generated by the rainfall run-off models to account for lower water catchment yields as vegetation recovers following the 2003 Canberra bushfires.

### **A2.2.3 Water demand**

Based on historic Canberra Airport rainfall and evaporation data, a stochastic data generation model is used to generate a time series of stochastic rainfall and evaporation sequences adjusted for climate change.

A water demand model, calibrated to current ACT demand patterns, converts the time series data into projections of future unrestricted ACT and Queanbeyan per capita water demand.<sup>157</sup> The per capita demand data is then multiplied by ACT and Queanbeyan population projections to calculate time series water demand volumes.

### **A2.2.4 Water balance**

A water balance model (REALM) of the ACT water supply system projects monthly dam storages on the basis of water inflows (using data from the bushfire and climate-adjusted rainfall run-off models), water releases (using unrestricted demand data from the demand model, reduced to account for temporary water restrictions if necessary), dam spills and evaporation.<sup>158</sup> Icon Water system operating rules (such as physical pipe constraints, water treatment plant capacities and trigger levels for turning on Googong, Cotter, Murrumbidgee and Tantangara) and ACT Government environmental flow requirements are additional modelling input constraints.

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<sup>156</sup> Random data generated using numerical methods to match the statistical properties of the historical time series data.

<sup>157</sup> Unrestricted demand is the output of the demand model before any reduction in demand due to temporary water restrictions is applied.

<sup>158</sup> A linear program-based water supply system simulation model that optimises water allocation within a network for each time step of the simulation period, in accordance with user-defined operating rules.

REALM calculates when, at what level (Stages 1 to 4) and for how long temporary water restrictions apply. This has the effect of reducing demand when dam storages fall to certain restriction trigger levels. It is these calculations that enable the ACT's water security situation to be estimated in terms of the probability of being in water restrictions over a certain period of time.

## Abbreviations and acronyms

ABS	Australian Bureau of Statistics
ACT	Australian Capital Territory
AIC	Average incremental cost
Commission	Independent Competition and Regulatory Commission
CWWA	Canadian Water and Wastewater Association
ERA	Economic Regulatory Authority (Western Australia)
ESC	Essential Services Commission (Victoria)
ESCOSA	Essential Services Commission of South Australia
GL	gigalitre (one thousand megalitres)
ICRC	Independent Competition and Regulatory Commission
ICRC Act	<i>Independent Competition and Regulatory Commission Act 1997 (ACT)</i>
IPART	Independent Pricing and Regulatory Tribunal (New South Wales)
kL	kilolitre (one thousand litres)
LMWQCC	Lower Molonglo Water Quality Control Centre
LRMC	long-run marginal cost
MIC	marginal incremental cost
ML	megalitre (one thousand kilolitres)
NWI	National Water Initiative
QCA	Queensland Competition Authority
OFWAT	Water Services Regulatory Authority (United Kingdom)
OTTER	Office of the Tasmanian Economic Regulator
PWCM	Permanent water conservation measures

*Abbreviations and acronyms*

SEACI	South Eastern Australian Climate Initiative
SRMC	short-run marginal cost
TMC	‘Textbook’ marginal cost
WAC	Water Abstraction Charge
WACC	weighted average cost of capital

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