SYDNEY DESALINATION PLANT

SDP Report: Prudency of membrane replacement in 2019

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Table of Contents

List of tables

List of figures

List of appendices

No table of contents entries found.

Executive summary

This document:

- Summarises Sydney Desalination Plant Pty Limited's (SDP's) reverse osmosis (RO) membrane replacement program (Program) which involved removal and disposal of old RO membranes, purchasing and installing a new set of membranes on restart of the Plant in January 2019.
- Explains why the full replacement of membranes in the way undertaken by SDP was prudent given the circumstances existing and the information available at the time of the decision and SDP's regulatory and commercial requirements.
- Demonstrates that the depreciated actual expenditure from this Program should be rolled into the Membrane Regulatory Asset Base (RAB) for Regulatory Review Period number 3 (RP3) consistent with IPART's RAB roll-forward methodology.

During Regulatory Review Period number 2 (RP2), SDP was required to restart the Sydney Desalination Plant (The Plant) and in doing so was required to develop a Program to guide the removal and disposal of old RO membranes, and purchase, replace and install a new set of RO membranes.

This paper explains why the full replacement of membranes in the way undertaken by SDP as part of the Program was prudent given the circumstances existing and the information available at the time of the decision and SDP's regulatory and commercial requirements.

IPART applies prudence and efficiency tests in its price reviews.[1] It applies a prudence test to actual investment decisions. Its efficiency test is a forward-looking test. Therefore, for the purposes of the membrane replacement, it will be the *prudence test* that IPART will apply in RP3 as it conducts its ex-post assessment. In our view the decisions to invest in a full replacement of all membranes on restart and the processes undertaken to execute this investment were consistent with those that a business acting prudently would have been expected to make in the circumstances existing **at the time**. The prudence test assesses how the decision to invest was made and how the investment was executed having regard to information available at the time (i.e. not in hindsight).

The key conclusions in relation to the prudency of investing in replacement membranes are:

- As already accepted by IPART in providing for a $30m capital allowance for a full replacement of membranes on first restart in its 2017 Determination, there are strong grounds that a strategy to replace the full set of membranes upon restart of the Plant represents a prudent investment decision. This took into account the prevailing circumstances of the Plant being in water security mode for an unprecedented length of time which meant that the performance and robustness of the existing membranes would be highly uncertain. IPART preferred this option to an alternate option proposed by SDP to undertake a high flow test during water security mode to test membrane performance and the Plant's mechanical and electrical assets.
- The time it would take to test existing membranes and determine if they were fit for purpose, coupled with the long lead times for securing new membranes, would pose major risks to restoring the Plant to full production as quickly as possible unless a new set of membranes were installed on restart. It would have not been possible to achieve this within the required 8-month restart period.

[1] For example, see IPART, Murray River to Broken Hill Pipeline WaterNSW, Final Report, May 2019, p41.

- The lead time to purchase, install and commission new membranes was a major consideration as the lead time would also jeopardise SDP's critical role as drought response asset for Sydney and put at risk its ability to expedite and maximise water production.
- The warranty period on the existing membranes expired on 22 June 2019.
- The decision to procure new membranes (manufactured by Dow) in multiple batches involved a market testing process, and subsequent negotiation of terms and conditions and prices, resulting in capital expenditure which represents the best way of meeting customers' needs given the:
    - circumstances existing at the time, including the high demand state of the international membrane market;
    - information available at the time, including the rapidly falling levels of the dam storages and the medium and long term rainfall outlook; and
    - SDP's regulatory and commercial requirements.
- A range of options for beneficial reuse of existing membranes were considered, with the only practical option being to dispose of the existing membranes by transferring their ownership to Veolia Industrial Services after a small amount of membranes were initially sent to landfill. This preferred option enabled SDP to avoid additional disposal costs and related risks, and to provide the best chance of the membranes being recycled and avoiding their disposal to landfill.

SDP considers that the depreciated actual expenditure from this Program should be rolled into the RAB for RP3 consistent with IPART's RAB roll-forward methodology.

1. Background

This section:

- Recaps the role of SDP in securing Sydney's water supply, the restart and operation of the Plant in the last few years
- Outlines the allowance which IPART provided in its 2017 Determination for replacement of membranes should the Plant be required to restart.
- Reports the costs actually incurred by SDP in replacing the membranes
- Outlines the approach SDP has adopted to demonstrating that full replacement of membranes in the way undertaken by SDP was prudent given the circumstances existing and the information available at the time of the decision and SDP's regulatory and commercial requirements.

SDP has a key ongoing role in securing Sydney's water supply by supplying non-rainfall dependent drinking water and ensuring availability of the desalination Plant to supply non-rainfall dependent drinking water at, or above the design production limits when it is required under the operating rules.

Under the operating rules set out in the 2017 NSW Metropolitan Water Plan, SDP is required to operate its Plant with the objective of maximising production and supplying Sydney Water Corporation's (Sydney Water) area of operations when combined metropolitan Sydney dam levels fall below a specified point (currently 60%) and continue to do so until dam levels rise to a certain point (currently 70%).

In addition, a key requirement of SDP's operating rules is that the Plant returns to full capacity, reliable supply within eight months of the restart trigger being reached (the Restart Period). An abatement mechanism imposes significant financial penalties on SDP should it fail to return to and maintain full production of the Plant within this timeframe. During the Restart Period the abatement mechanism does not apply.

On 27 January 2019, dams fell below 60% and the Plant entered the restart phase which required a major program of works to recommission the Plant from a state of mothball to reliable full production within the Restart Period. In doing so SDP incurred significant capital expenditure on replacing and installing a new set of membranes.[2]

Following successful restart of the Plant, greater than 250 million litres per day (ML/ day) on average of high-quality drinking water was produced from the Plant into the Sydney Water system. The Plant fulfilled and exceeded its drought response and availability role in full, by producing in excess of the drinking water requirements during the drought response period thereby maximising water production.

On 12 February 2020, dam levels rose above 70%, and SDP began to prepare for a shutdown as per the operating rules. Supported by Sydney Water, SDP opted into its minimum run time of 14 months and continued to produce drinking water until 27 March 2020. On this date, Sydney Water issued an Emergency Response Notice to request SDP to continue to produce water at a low production rate for six months to mitigate potential water quality issues in the dams due to the high inflows in the February 2020 rain event and to help mitigate against the potential adverse impacts of recent bushfires in the dam catchment. A second Emergency Response Notice was issued by Sydney Water in September 2020 to extend operations for a further six months. Further Emergency Response Notices have been issued by Sydney Water that continue the Plant's operations and availability to December 2021.

[2] In December 2015 a tornado hit the Plant, which caused significant damage leading to an insurance claim to reinstate the plant. However, the membranes did not form part of the insurance claim because the membranes were not destroyed in the tornado and SDP preserved the membranes as part of good practice.

1.1 IPART's 2017 Determination of Prices for SDP's Water Supply Services

The prices for SDP's Water Supply Services are regulated by IPART in accordance with a standing Ministerial reference under section 52 of the Water Industry Competition Act 2006 (WIC Act).[3]

In its 2017 Determination, IPART provided an opening RAB of $30 million ($2016-17) in a specific membrane RAB to cover the cost of membrane replacement in the event the Plant was required to restart during the RP2 regulatory period, subject to conducting an ex-post review of the prudency of this expenditure.

This allowance reflected IPART's consultant's (Atkins) estimates of both the number of membranes which would need to be replaced and a unit cost for first pass and second pass membranes respectively. The assumed unit costs were based on:

- inflating the original contract unit costs by a specified membrane price index;
- allowing for the membrane guarantee pricing in the existing membrane contract with Dow;
- a USD/AUD exchange rate of 1.35;
- the likelihood of being able to achieve quantity discounts from competition between suppliers; and
- a further allowance on top of the supply price of 11% for installation (including removal and disposal costs of existing membranes) – although no basis for this mark-up was provided.

Adjusting for $AUD:$USD exchange rate (1.39 achieved by SDP compared with 1.35 assumed in Table 1.1) and applying CPI indexation, the final allowance for membrane replacement can be calculated as $32.3m.

Table 1.1: Membrane replacement costs - IPART allowance (as capital expenditure in the membrane RAB)

	Number to be replaced	Unit cost ($US)	Unit cost ($AUD)	Supply ($m)	Installation ($m)	Total ($AU 2016-17) ($m)
First pass membranes to be replaced	26,936	550	743	20	2	22.20
Second pass membranes to be replaced	9,800	530	716	7	1	7.78
	36,736			**27**	**3**	**29.98**

Source: Atkins 2017, Sydney Desalination Plant Expenditure Review- Final Report, 21 February, p.66

[3] IPART received the initial Terms of Reference on 6 May 2011. The initial Terms of Reference were replaced by the current Terms of Reference on 16 February 2012.

1.2 Costs incurred by SDP

The total costs actually incurred by SDP in replacing and installing the new membranes and disposing of the existing membranes was $29,104,323.26.

Table 1.2: Summary Costs for membrane procurement, installation and disposal

Item	Unit Cost	Ave Ex Rate*	Number	Total ($AU 2018-19 ex GST)
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]				[redacted]

* Membranes were bought in batches of varying volumes at the exchange rate in place when the purchase order was approved and committed for each batch (i.e. when each cancellation date for each batch was achieved)

1.3 Approach to demonstrating that this expenditure was prudent and efficient

While the actual membrane expenditure incurred by SDP was more efficient than the *ex-ante* allowance provided by IPART (~$32.3m $2018-19 adjusted for exchange rate), there is still a need to demonstrate that the expenditure incurred by SDP was prudent.

The prudence test adopted by IPART assesses whether the decision to invest in the asset (the membranes) was one that SDP, acting prudently, would have been expected to make in the circumstances existing at the time, assessing both:

- How the decision to invest was made and
- How the investment was executed (i.e. whether the construction or delivery of the asset was cost effective).

Importantly, the prudence test is based on the information available to the utility at the point in time it incurred the expenditure (i.e. whether the utility acted prudently in the circumstances prevailing at the time it incurred the expenditure).

IPART also requires that in seeking to justify capital expenditure incurred, regulated businesses should provide details of major projects, explaining the options analysis undertaken and the overall basis for the cost estimate[4].

[4] IPART, Guidelines for Water Agency Pricing Submissions, Water – Guidelines, April 2018, p.11

The remainder of this paper summarises the business case for the Program, outlining:

- the underlying service need or objective;
- the identification and assessment of strategic options for achieving this service need; and
- options identification and assessment for execution of the preferred strategic option.

2. The objective/service need

This section identifies:

- the objective or service need associated with the replacement of the membranes.

The overarching purpose or objective associated with the expenditure to replace a full set of membranes in the Plant was to ensure SDP could fulfil its drought response role in accordance with regulatory requirements. The key component of which to prepare the Plant before the end of the Restart Period to maximise drinking water production in a consistent manner.

After an initial two-year proving period when the Plant was constructed, the Plant was placed into 'water security mode' to minimise ongoing operating costs. During water security mode the RO membranes are stored in preservation fluid. It is unusual for desalination plants to be put into such a long-term, deep shutdown as the Plant was when it entered water security mode. Due to these unusual circumstances, there is limited operational and condition data available on membrane deterioration over such a long period in preservation, and actual membrane condition would only be known once the Plant is restarted and the membranes operationally tested. The warranty period provided by the manufacturer (Dow) for the membranes is eight years (with an additional 12 months extension due to long term preservation irrespective of the time actually in preservation). The warranty on the membranes was activated in June 2010 which was the membrane contract commencement date following the site acceptance testing. The warranty would have expired on the 22 June 2019 – eight years plus an additional year for preservation from the commencement date. After the warranty period has elapsed, the manufacturer no longer guarantees operational performance parameters such as volume, energy consumption, and water quality to meet the specification and health based targets.

The ongoing RO membrane maintenance and replacement strategy for the Plant is crucial for both SDP and the Operator to meet their contractual obligations. RO membrane element condition (and subsequent water quality and quantity) plays a substantial role in SDP's ability to meet the eight-month Plant restart period when a restart trigger is reached, and to maintain production at the required volume and quality during the subsequent drought response operational period.

RO is one of the final stages of the treatment process and thus comprehensive testing of the existing membranes is not possible until late into any restart period. Additionally, a period of 'run-in' time is required before permeate quality stabilises (up to four weeks per membrane). If RO membranes are then found not to meet water quality or quantity specifications, long lead-times would have rendered it impossible to meet regulated restart timeframes. **Figure 4.1** shows a timeline of the membrane order, installation and testing (total period of approximately 10 months), and an estimation of when the existing RO membranes could have been tested upon a restart (approximately five months after a restart trigger). A timeframe of 15 months would have exceeded the Restart Period.

Thus, to meet its regulatory requirements, it was necessary for SDP to replace a full set of membranes to ensure the Plant can restart and return to full production within eight months from the restart trigger. Furthermore, membranes would realistically need to be delivered and installed within six months of a restart trigger to allow commissioning, testing of water quality and sufficient time to run and stabilise the Plant at full capacity to test the end to end process.

3. The membrane replacement strategy

This section:

- Outlines the alternative strategic options which SDP considered to meet the service need of replacing the membranes to achieve the regulatory requirements to restart within eight months of the restart trigger being reached and returning to full reliable production, and to do so in a cost-effective manner.
- Provides its assessment of these strategic options which confirmed that a full replacement of membranes on restart was the correct preferred strategy.

3.1 Options

SDP considered a range of options for replacing the membranes to achieve the regulatory requirements to restart within eight months of the restart trigger being reached and returning to full reliable production, and to do so in a cost-effective manner.

These options included:

- Progressive replacement of membranes on restart and Plant operation
- A full replacement of the membranes on restart
- A restart with existing membranes.

In addition, a number of options around the execution of the full replacement of membranes were also considered (these implementation issues are discussed further in the sections below).

3.1.1 Strategy 1: Progressive replacement

A desalination plant that is operating on an ongoing basis would target a rolling annual replacement of membranes in order to achieve a targeted average age of the membranes (i.e. membranes will be a range of different ages, but on average they would tend towards a design life age) to achieve the desired water quality and plant efficiency. Assuming a plant starts with a new set of membranes, there would typically be a period of low replacement (non-performing or faulty elements only), a period of close to zero replacement over the first 2-3 years, and then progressive replacement until a steady state replacement is reached.

As membranes age, they will not be as efficient and will incur higher operating costs (e.g. requiring more energy and chemicals to produce the same volume of water as new membranes). Older membranes will have a higher operating cost due to:

- Fouling increasing feed pressure and power consumption,
- Lower salt rejection requiring more chemicals to meet Boron and Bromide specification, and
- Poorer quality first pass permeate is produced thus minimising the efficiencies of bypassing the second pass process, lowering output and increasing energy and chemical cost.

The actual percentage replacement each year would then be contingent on analysis of actual operational water quality, volume and energy efficiency data, and on the membrane warranty requirements, while also allowing for the logistics of replacement (i.e. it may be operationally difficult or impossible to replace a large amount of membranes in one year and meet availability and water production requirements, or simply to procure the required number of membranes in any one year due to supply side scarcity). The original

design of the Plant, membrane design life and the membrane warranty are based on a maximum Average Membrane Life (AML) of 3.5 years for the first pass membranes and 5 years for the second pass membranes.

While the Plant was in water security mode, no membrane replacement was undertaken. Therefore, based on the Plant design, at restart, a significant number of elements would be required to be replaced to achieve the design AMLs. This would keep the RO system in the state that the membrane manufacturer considers is required to meet the quality, volume, efficiency and reliability obligations of the Plant. The membrane warranty is contingent on this level of replacement or better and the manufacturer would not accept any liability if the membranes were not able to meet performance requirements at higher AML.

In its last price submission, SDP proposed a phased replacement of membranes over the restart and full operation mode. However, this option was contingent on performing a partial Plant test which included some evaluation of the condition and performance of the existing membranes. From this SDP would have been able to collect the operational data required to make decisions on membrane condition, performance and replacement. Provision for the partial Plant test was not included in the RP2 Determination.

The approach of progressively replacing the membranes after a very long period without operational data carries the risk that the membranes do not perform as required (volume, water quality and to a lesser part, energy) and therefore need to be replaced during or after restart, reducing the volumes of water produced and/or delaying the timeframe for returning the Plant to full reliable production. The issue of insufficient time to test, order, receive, install and test membranes ultimately discounted the strategy of progressive replacement in this case.

3.1.2 Strategy 2: A full replacement of the membranes on restart

This strategy involves a full replacement of all of the membranes on restart. While this option involves higher upfront costs for membrane replacement, it offers scope for lower operating costs and eliminates risk of poor condition and performance from the existing membranes and if poor condition and performance is determined, the additional risk of not being able to procure and replace these membranes within the Restart Period.

Funding for full replacement of RO membranes on restart instead of partial replacement of the membranes was recommended by IPART's consultant's, Atkins in the 2017 IPART Determination for the following reasons:

- It eliminates risk to the water quality from the use of existing RO membranes operating beyond their warranted life (nine years when more than one year in preservation);
- The ordering lead time of the RO membranes will likely require that the membranes are ordered before the existing membranes could be fully tested;
- It eliminates the need to have an expensive Partial Plant Test to assess the condition of the existing membranes;
- Full membrane replacement will allow maximum RO membrane supply competition which should drive down the price of membranes and improve the delivery terms; and
- There should be no need for further replacement membranes in the first two years of operation.

IPART (in accordance with Atkins recommendations) “considered that the 8-month duration was sufficient to restart from a prolonged water security shutdown, including ordering membranes and full Plant testing…[such that] within a restart period SDP can procure membranes, carry out essential asset replacement, recruit and train additional operators and test the individual processes and the complete works”.

As noted above, the cost of a full replacement set of RO membrane elements was estimated by Atkins as AUD $30M $2016/17 (procurement, installation and disposal of existing membrane elements). IPART provided for a membrane RAB, with a $30M capital allowance, should the Plant restart.

3.1.3 Strategy 3: No replacement of membranes

In principle, a third possible strategy identified by SDP was to restart the Plant with the existing membranes.

While this option would avoid the cost of replacing any membranes upfront, it would involve higher risks around the performance of the existing membranes, which would not be covered by the membrane warranty, and had not been used for drinking water production in nearly seven years. In addition, if the membranes did not perform as required when the Plant was restarted, the lead time to order and install a full set of new membranes would mean SDP could not rectify any underperformance for a significant period (10 months based on actual experience - **Figure 4.1**, but likely to have been more than a year as the membrane market tightened into 2019). The regulatory requirements are such that SDP would bear a financial penalty under the abatement mechanism should that underperformance occur. This would equate to approximately $15m per annum under a reduction in production volume of only 10%.

3.2 Assessment of strategic options for membrane replacement

SDP considered and accepted the conclusion reached by Atkins in relation to membrane replacement that it was prudent and efficient to replace all the membranes upon the restart trigger being reached given the imperative of reaching full, reliable production at acceptable water quality as soon as possible to enable SDP to perform its drought response role of maximising water production.

In doing so, however, SDP also undertook its own additional analysis and investigations. In particular, SDP sought to improve its knowledge of the state of the existing membranes by performing autopsies on a sample number of membranes. These autopsies showed some signs of permanent membrane damage. However, an independent review (undertaken by Emerald Process Engineering, who specialise in process engineering and commissioning with extensive industry experience) concluded that, due to the small relative sample size of autopsies possible, the membrane autopsy results did not provide a clear picture of current membrane condition. This is the difficulty of testing only a subset of membranes at a laboratory scale only.

There were also concerns regarding the structural integrity of the membranes. The membranes are constructed by gluing and rolling multiple individual membranes sheets together. Questions were raised by the membrane manufacture, the Plant Operator and Emerald Process Engineering that there could not be a guarantee that the membrane element would be structurally sound due to its age, the long term effects of preservation and the lack of imperial evidence from similar long term preserved membranes (it does not exist).

SDP also carefully considered undertaking a program of RO membrane element testing. SDP received expert advice from the University of NSW that at least 300 elements would be required to be tested for a

plant the size of SDP's Plant. SDP concluded that it was not prudent to utilise resources on extensive testing given the other evidence (from autopsies) that existing membranes cannot be relied on for a restart, and as there was not sufficient time to replace membranes after testing under actual operational conditions. While SDP did undertake Plant testing as part of the reinstatement project in 2018 (at its own cost), the testing was only focused on mechanical and electrical full load testing rather than membrane performance, which would require longer run times and therefore be considerably more expensive. Thus, no membrane condition testing was undertaken as part of the reinstatement and no drinking water was produced.

SDP came to the conclusion that given the uncertainty of the performance and robustness of the existing membranes, the potential inability to meet its drought response obligation, the abatement risk profile and the state of the high demand membrane market at the time of the restart trigger (further details in Sections 4.2 and 4.3), it was too risky to rely on untested membranes well past their operational life. In addition, SDP had regard to the fact that the Manufacturer Performance Warranty was due to expire in mid-2019 and after this time the manufacturer would no longer guarantee the required water quality and production volume performance.

The lead time between ordering membranes and subsequent delivery to site and installation is important to consider when forming the replacement strategy. The timeframes set out in the 2017 IPART Determination did not provide sufficient time to assess the existing elements before ordering the large number of membranes required. This factor was key to the Atkins Expenditure Review relied upon by IPART. The review stated that "the ordering lead time of the RO membranes will likely require that the membranes are ordered before the existing membranes could be fully tested" (see **Figure 4.1**). On this basis the IPART recommendation was to provide allowance for "SDP to procure a full set of membranes upon the first restart over the 2017 determination period." However, the determination recommended provision for prudent and efficient capital expenditure on a full set of membranes upon restart with ex-post review of prudency and efficiency.

There are therefore strong grounds, as already accepted by IPART, that a strategy of replacing the full set of membranes upon restart of the Plant was prudent and efficient given the prevailing circumstances of the Plant being in water security mode for an unprecedented length of time and the lead time for securing new membranes given the state of the membrane market.

In summary, the following factors contributed to SDP's decision to replace a full set of membranes:

- The strategy aligns with Atkins' assessment, adopted in the final determination by IPART, that it was prudent and efficient to replace a full set of membranes upon restart;
- It eliminates risk to the water quality and volume from the use of existing RO membranes operating beyond their warranted life (eight years, or nine years if in preservation for greater than 12 months);
- There was no reliable information (operational data at the Plant, or case studies from other desalination plants) on how the old membranes would perform upon restart after such an extended period in preservation;
- The ordering lead time of the RO membranes was such that it was impossible to test existing membranes before making a decision on replacement. In fact in order to replace membranes within the Restart Period, membranes needed to be ordered four months prior to a Restart trigger being reached) (see section 4 for details);
- While RO membrane supply competition was not possible through a full tender process due to unacceptable supply lead time limitations from manufacturers, competitive tension to be sole supplier

allowed SDP negotiating power to drive down the price of membranes and improve the delivery terms (SDP gained approximately >20% discount to prevailing contractual terms by procuring (see Section 4 for details);

- There should be no need for further replacement membranes over the current regulatory period; and
- Energy consumption and chemical consumption allowance targets were set based on operation with new membranes and would be very unlikely to be met with existing membranes.

4. Execution of procurement of full replacement of membranes

This section:

- Outlines the approach SDP adopted to implementing the preferred strategy of replacing the full set of membranes which encompassed market sounding of the international membrane supply market and monitoring the dam storage levels, engaging with potential installation suppliers, and managing membrane procurement, installation and disposal.
- Identifies the options assessed for executing each stage of the membrane replacement strategy and explains why the chosen approach was adopted.

Having demonstrated that the strategy of replacing a full set of membranes can be justified as being prudent and efficient, the question becomes one of whether the execution of this strategy was also prudent and efficient, given the circumstances prevailing at the time.

The execution of the membrane replacement strategy by SDP entailed a number of elements including:

- Monitoring of the state of the international membrane market and potential restart timing based on dam storage levels;
- Approach to a number of potential membrane suppliers in the market;
- Determination of a preferred procurement approach and supplier;
- Negotiation of membrane supply contract with preferred supplier;
- Installation of membranes; and
- Developing and implementing a strategy for disposing of the existing membranes in an manner that reduces environmental impacts.

Details are presented in chronological order in subsequent sections.

4.1 Monitoring of the state of the international membrane market and storage levels – 2017 and early 2018 (Storage levels >75%)

While the regulatory framework provides for an eight month period from the reaching of the restart trigger to full operation of the Plant (including procurement and installation of membranes), SDP was monitoring both the state of the international membrane market (and in particular any implications for likely lead times for the procurement and delivery of membranes) and the dam storage and depletion levels (reflecting the possible timing of the restart trigger being reached) well in advance of storage levels approaching the 60% restart trigger for the Plant.

SDP's awareness of the relatively tight state of the international membrane market and the continuing fall in storage levels led it to approach the market well in advance of the restart trigger being reached. The membrane market was overheated in the months leading up to the restart trigger. There was heightened demand for seawater RO membranes due to major desalination plant construction activity in the Middle East that was driving delivery times from a few months to over nine months and in some cases far longer.

Given the state of the membrane market it would not have been prudent to wait until the formal trigger was reached to do so.

4.2 Approach to the market – April to August 2018 (Storage levels < 70%)

The existing RO membrane supplier for SDP is Dow, and as part of the pre-existing contract SDP had a guaranteed RO element pricing for 25 years based on the initial project price escalated by a price index. However, this does not lock SDP in to using Dow membranes. A key element of SDP's procurement strategy was a market review to assess the potential offerings of alternative membrane suppliers.

SDP initiated contact with potential membrane suppliers in April 2018. There are only three major manufacturers of seawater RO membrane elements - Toray, Hydranautics and Dow. All three suppliers were approached to discuss membrane supply options. All suppliers can supply membranes that will fit the Plant's existing infrastructure with minimal modifications. The market review with each supplier encompassed:

- Assessment of latest technology offering including energy saving and benefits to assist replacement business case;
- Project specific warranty conditions;
- Project specific membrane pricing;
- Assessment of manufacturing capacity;
- Assessment of RO element autopsy cost and capacity;
- Manufacturing location(s) and freight times;
- Willingness to enter into a pre-negotiated sole source RO membrane supply contract with a defined periodic review;
- The ongoing arrangements required for the RO membrane supplier to enter into the supply agreement (e.g. a yearly fee to maintain the RO membrane supply agreement) and terms would vary if the agreement was non-exclusive or for a defined portion of the Plant (i.e. 50%);
- Water quality/quantity risks based on supplier capabilities and quality of product; and
- Cost.

The initial discussions with the three potential suppliers which occurred over the period of April to June 2018 revealed valuable information on a range of key issues:

- **Lead times**: the manufacturers initially nominated lead times in the range of 5 to 6 months for initial delivery (a subset of the full volume of membranes only), with further staged membrane manufacture adding 3 to 4 months before a full set would be available. This confirmed Atkin's view that given that membrane testing could not be expected until the latter half of a restart, there would be no possibility of testing existing membranes before initiating an order.
- **Guaranteed delivery times:** All potential suppliers indicated that lead times would not be guaranteed until an order was placed and confirmed with a non-refundable deposit. This further complicated the planning process, as all delivery times were indicative.
- **Indicative Pricing:** The ranking of manufacturers on least to most indicative pricing was: Toray, Hydranautics, Dow.

- **Quality/reliability:** The ranking of manufacturers on least to most reliable quality (based on expertise within SDP and its industry contacts) was; Toray, Hydranautics, Dow. Note, this was only anecdotal evidence and the membranes may have all had similar performance and reliability outcomes.
- **Splitting of order**: All manufacturers were willing to supply a full or half set of membranes. Splitting supply between two manufacturers would reduce lead times and could also drive the manufacturer to compete on price and ongoing performance. However, after further market testing discount prices were offered for a full set.

A key take-out from the initial market approaches was that to secure, install and commission membranes within the required lead times (6 months from the restart trigger to allow time for whole Plant testing at capacity) was likely to be problematic and therefore require SDP to commit to membrane orders in advance of reaching the restart trigger to ensure it could meet the required timeframes for restart. However, the earlier a confirmed order was made (which entailed a non-refundable deposit), the greater the likelihood that dam storages would recover, a trigger for a restart of the Plant would not occur, and new membranes would not be required (leaving SDP with significant expenditure and no means of recovery). This meant that determining the appropriate procurement approach and timing required carefully balancing of these considerations.

Another key conclusion was that there was a likely trade-off between costs and reliability of the membranes supplied by the alternative manufacturers, and in particular there was limited reliable information on performance of the membranes from the cheapest supplier, Toray, particularly in Australian conditions. Thus, switching manufacturer from Dow (which had a proven and tested design configuration) would add an element of process risk, particularly given the tight restart timeframe and the regulatory framework.

SDP continued discussions with manufacturers over subsequent months and also continued to monitor the state and outlook for storage levels. As these discussions continued, some of these factors changed. In particular, the lead times offered by several of the manufacturers blew out to unacceptable levels.

4.3 Determination of a preferred procurement approach and supplier – August to September 2018 (Storage levels <65%)

In order to achieve the best outcome with respect to membrane cost and performance, different procurement strategies were considered including:

- A one-off full replacement;
- Full replacement combined with an exclusive contract for a defined period; and
- Splitting the order between two (or more) manufacturers (across the two process modules of the plant).

As dam storage levels continued to drop during the course of 2018, SDP further investigated these options, and the offerings from the potential membrane manufacturers. By August/September 2018 the likelihood of reaching the restart trigger was deemed to be sufficiently high to justify considering some commitment to procurement of new membranes. The Government also started discussions with SDP on the likelihood that a restart trigger would be reached, including how the Government could potentially assist SDP to maximise the production of water during the Restart Period. These discussions did not result in any assistance from the Government, but SDP were nonetheless encouraged to do all it could to maximise water production as early as possible to protect Sydney from rapidly falling dam levels.

During this time SDP sought updated information on lead times for delivery of new membranes from the potential suppliers. Lead times had increased further, with the following advice received:

- Hydranautics advised they were unable to supply seawater RO membranes until mid-2020. Due to committed projects and they indicated they would exclude themselves from further discussions.
- Toray advised that if an order was confirmed by mid-November 2018 it could supply half the membranes by May 2019 and the second half by November 2019, not accounting for delivery time from the manufacturer's site to Sydney.
- Dow also flagged that lead times were under considerable pressure given the worldwide demand for seawater RO membranes, but that they were willing to support SDP where possible due to the relationship as current supplier.

Given that two of the suppliers were clearly unable to meet the required timeframes for delivery of the membranes:

- It was impracticable to conduct a full formal tender process for procurement of the membranes;
- now that it was evident an order would need to be placed in advance of a dam trigger, time was already of the essence to enter into a procurement contract if membranes were to be received in time. It would have been too great a draw on resources to negotiate with two parties at once, agree terms, and manage the logistics of international transport from two separate manufacturers while also undergoing a Plant restart;
- SDP considered that the regulatory framework and timing made it difficult to consider full replacement of all membranes from a new supplier due to the residual risk of unproven system performance (noting that it would have been more practical to test relatively small batches, i.e. a single RO membrane train, of different, unproven membranes through an ongoing replacement program rather than replacing all membranes in a single procurement exercise); and
- The only manufacturer that could meet required lead times, Dow, indicated that they would be able to offer improved pricing only on a full replacement. Otherwise pricing for partial replacement under the prevailing contract would apply.

4.4 Negotiation of membrane supply contract with preferred supplier – September to October 2018

While SDP ultimately concluded that it was prudent given the circumstances to seek to secure all of the new membranes from its existing supplier (Dow), it utilised its buying power and the prospect of turning to alternative suppliers (both now and in the future) to negotiate with Dow to secure the best possible price and terms for the new membranes. Further, Dow considered that it was in a competitive process at the commencement of the discussions and SDP sought to maintain competitive tension by continuing discussions with the other manufacturers and not declaring its decision making on the number of membranes to be purchased. The pre-existing agreement with Dow incorporated provision for a prescribed unit rate for membranes based on original purchase price and relevant indexation. SDP was able to negotiate unit prices for membranes at the original purchase price without the indexation mark-up (approximately 50% saving on the contractual price), but this was contingent on full replacement.

Through September 2018, Dow exerted significant pressure to confirm SDP's order and lock in delivery times.

- An order by October 2018 saw an estimate of first delivery by December 2018, with balance of the order completed manufacture by 1Q 2019. Significant cancellation charges would apply;
- A delay in order until November 2018 would push initial delivery out to February 2019; and
- A December 2018 order would delay the first batch until April/May 2019. Dow could not commit to lead times for the balance of the membranes, but delay would likely push order completion to late 2019 (or beyond).

Based on this advice and analysis of dam levels and depletion rates at the time, SDP confirmed an order on 2 October 2018, and Dow got to work on confirming a delivery schedule. The initial schedule had the final delivery arriving in August 2019, and SDP had to negotiate hard to push for more favourable terms.

In particular, SDP was able to negotiate:

- Substantially improved delivery times from those first proposed by Dow (all membranes guaranteed delivery by June 2019 with Liquidated Damages connected to those dates);
- An extended warranty for average membrane life at 4 years and 6 years for first pass and second pass membranes respectively (up from 3.5 and 5 years respectively); and
- More favourable cancellation terms should it had proven necessary to subsequently cancel the membrane order/s (e.g. if there had been significant inflows into the storages and the Plant was not required to restart). This would have been to the benefit of customers because they would not need to pay for the membrane RAB[5].

SDP negotiated cancellation risks and terms clauses batch by batch and committed progressively to the order of membranes in batches, with hold points for deciding whether to confirm the orders in light of prevailing conditions (i.e. storage levels etc). The timing for these are presented in Table 4.1.

Table 4.1: Summary of membrane batches, including cancellation allowances.

	Batch						
	1	2	3	4	5	6	Total
Dispatch	6-Nov-18	18-Jan-19	20-Feb-19	13-Mar-19	2-Apr-19	2-May-19	
Arrival	24-Dec-18	10-Mar-19	9-Apr-19	30-Apr-19	20-May-19	18-Jun-19	
Cancelation until	n/a	30-Nov-19	15-Jan-19	5-Feb-19	25-Feb-19	27-Mar-19	
Number	5,580	3,880	5,850	6,700	7,000	7,990	37,000
Ordered/Confirmed	2-Oct-18	30-Nov-19	15-Jan-19	5-Feb-19	25-Feb-19	27-Mar-19	

Even though the trigger had not been formally reached for Batch 1 – 3 (and SDP therefore bore financial risk), SDP decided at each point it would not have been prudent or efficient to cancel the order given that:

- The likelihood of the trigger being reached imminently was seen as very strong, taking into account ongoing WaterNSW reports on dam storage levels and Bureau of Meteorology (BOM) rainfall forecasts;

[5] Subject to IPART ex-post review of prudency of expenditure.

- Cancelling would mean going to the end of the queue with major implications for delivery times of new membranes and thus SDP's ability to reach full production within eight months of the formal trigger; and
- Financial penalties would be incurred for cancellation.

The restart trigger level was eventually reached on 27 January 2019, however SDP continued to wait for each hold point before confirming continuation of the order (the last decision point was 27 March 2019). This was to protect customers from any avoidable costs, regardless of restart, to mitigate against the circumstance where heavy inflows led to dam recovery prior to the final hold point.

4.5 Installation

The removal of the existing membranes and installation of an entire new set of membranes in the Plant, under restart conditions, while also producing significant volumes of drinking water as drought response for Sydney represented an unprecedented undertaking. The restart was very complex and challenging – the first membranes were ordered on 2 October 2018, delivered by late December 2018 and SDP was still installing the final batch of membranes at the end of July 2019, with final commissioning and optimisation of the installation still underway in September 2019 and beyond. Over 28 gigalitres (GL) of drinking water was transferred to the Sydney Water distribution system over this time. A key challenge was to ensure safety for personnel undertaking the loading tasks given the volume of work required, the high pressure application and the challenges of working around an operating Plant.

The task of installing the new membranes was awarded via a competitive tender process. The process involved issuing an expression of interest (EOI) to six contractors with previous similar experience and a subsequent Request for Proposal to the four contractors who confirmed an interest, from whom proposals were received from three (Illawarra Engineering Services, Turnkey Global and Veolia Industrial Services).

Veolia Industrial Services (Veolia IS) were selected as preferred contractor on the basis that:

- They were the lowest cost option ([redacted];
- This would result in a single client-facing party for SDP (Veolia);
- The second lowest tenderer raised some issues with the proposed contract terms and were seeking departures; and
- The Veolia IS proposal included fatigue management risk for optimisation of performance and safety.

SDP met with Veolia IS and further challenged the input assumptions to the tender. SDP was able to negotiate a $500k reduction in the preferred contractor's fee. The total cost of installing the membranes was [redacted].[6] Given the majority of the [redacted] installation and disposal cost resulted from a competitive tender process, the costs should be considered prudent and efficient.

This cost of installation and disposal correspond to a [redacted]% premium on the procurement costs, in comparison to the [redacted]% premium estimated by Atkins.

4.6 Membrane disposal

Replacing the full set of membranes required SDP to dispose of the existing set of membranes. SDP undertook a review of options in order to determine the most beneficial means of dealing with old RO elements taking into account environmental benefit, practicality and cost.

[6] This included [redacted] install contractor fee and [redacted] Operator project management, construction supervision and margin/overhead.

In recent years with the growing use of RO membranes in the water industry there has been increasing interest in exploring options for what to do with used membranes and in particular re-use or recycling options which may be more environmentally sustainable than disposal to landfill[7].

The options considered by SDP included (listed in order of the waste hierarchy):

- Re-use
- Recycle
- Disposal

4.6.1 Re-use

This approach involves re-use of the membranes in an alternative application. As noted by Lawler et al[7], reuse options include:

- direct application of old membranes within lower throughput systems (i.e. brackish water treatment), or
- converting RO membranes into microporous membranes and reusing these for ultrafiltration (UF) purposes.

In this context, as noted by Atkins, RO elements that are no longer suitable for operation in the Plant may have some asset value for less stringent applications such as second hand RO membrane replacements. For example, Atkins had observed that it may be possible to re-sell the old membranes overseas to minimise the cost of disposal:

> *The old membranes will need to be disposed of when the replacement membranes are fitted. These old membranes will not likely have a significant residual resale value in Australia as they will be without manufacturer's warranty. However, there may be considerable life left in these membranes identified during plant restart testing which could be useful for use in other desalination plants in low income countries such as Egypt and Tunisia. It might be possible to make a commercial arrangement for the bagging with preservative and transport of the membranes to another country to cover just the disposal cost of the membranes. We have assumed that there is no residual value for membranes but the costs for their disposal are included in the installation allowance and unit costs of the new replacement RO membranes.*

4.6.2 Recycle

This option involves recycling material components of the membranes. As discussed by Lawler et al, however, there are challenges in the technical (and economic) viability of various types of recycling of old membranes. RO modules contain a large number of compounds including the membrane sheet (which comprises a dense and thin polyamide layer and webbing materials), glass fibre housing, permeate tube and ends and stream spacers.

As noted by Lawler et al, current efforts have focussed mainly on the combustion and energy recovery from the polymeric materials, but other options might include the recycling of sheets and spacers as geotextiles in residential gardens or use of the spaces for bird netting or windbreakers in agricultural applications.

4.6.3 Disposal

This option involves disposing of old membrane to landfill. To date, this has been the default approach but as the volumes of used membranes is expected to rise substantially in the future across the industry, there has been increasing concern that this practice is not sustainable, particularly given the large variety of substances present with the RO element.

[7] See for example Lawler, W. et al (2012) 'Towards new opportunities for reuse, recycling and disposal of used reverse osmosis membranes', Desalination 299, pp.103-112.

4.6.4 Assessment of options for old membranes

SDP, through its operator, Veolia, explored all of these options and detailed the findings in a RO membranes end-of-life options study. Use was also made of a Membrane end-of-life (MemEOL) Tool developed by the University of New South Wales that recommends an optimum end-of-life option for used RO membranes based on data entered by the use relating to the characteristics of the membranes, as this has a major influence on the feasible options. In this case, the model recommended recycle or re-use options as being feasible for SDP's RO membranes.

In exploring the opportunities for recycling the old membranes, Veolia made contact with a global recycler, certified and specialised in recycling RO membranes. However, the cost associated with recycling was found to be more substantial than any other option, mostly driven by the freight cost from Sydney to Europe.

Options for re-sale of the membranes to external parties were also explored. Veolia made contact with several parties locally and overseas selling or dealing with RO membranes to investigate whether the parties would be interested in purchasing or just obtaining some membranes for re-use. However, two local parties responded with no interest. Dow the supplier of these existing membranes also declined taking the existing membranes for reuse or recycling options.

During this period, Veolia, as the main contractor for the construction and operation of the SpringVale Mt Piper Power Station facility, requested the use of around 2,000 membranes as commissioning consumables. SDP approved this arrangement which resulted in a reduction in packing and disposal costs to SDP of around $26 000. Membranes were provided 'as is' with no warranty or guarantee.

Aside from those used in the Springvale project, a portion of the first two batches of membranes to be replaced were disposed of to landfill. SDP subsequently reached an agreement to transfer ownership of the remainder of the existing membranes to Veolia IS rather than sending them to landfill, provided Veolia incurred the cost of packing them and removing them from site. Veolia IS was to package, preserve, transport and store the existing membranes at a location to be determined by Veolia IS for potential future reuse in the local or overseas markets. The agreement entailed:

- SDP providing no warranty or guarantee on the performance or structural integrity of the RO membranes;
- No cost to SDP for the packaging, preservation, transport and storage of the membranes;
- No delay to or changes in the scheduling of works to maximise water production at the Plant and achieve full Plant capacity as soon as possible;
- A reduction of $234 000 in disposal costs chargeable to SDP reflecting avoidance of landfill disposal costs of the RO membrane being diverted to potential reuse; and
- Veolia IS bearing all costs associated with disposal of the membranes should it be unable to find a suitable reuse option for the RO membranes.

This agreement enabled SDP to achieve the desired outcome of avoiding additional disposal costs (overall reduction of $260,000) and related risks and is therefore considered to be prudent and efficient.

4.7 Summary of Membrane procurement timeline

Figure 4.1 shows a summary timeline of membrane procurement from the initial order date until the end of the Restart period.

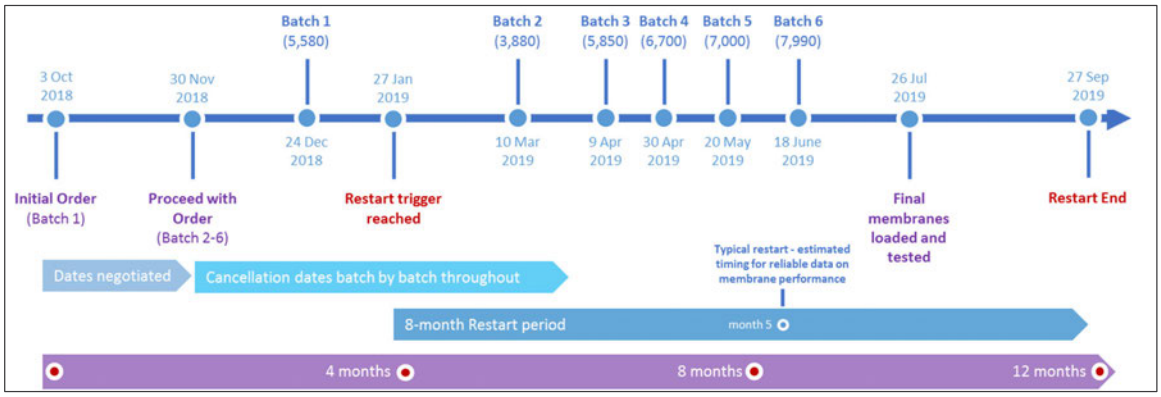

Figure 4.1: Membrane order timeline (batch dates are agreed arrival date at Sydney seaport)

Key points to note:

- Prior to 3 October 2018, it became evident that due to a tight membrane market only one of the three membrane suppliers contacted could meet project timeframes.
- The initial order for Batch 1 was placed with Dow on 3 October 2018, with storage levels at 63%.
- The decision to proceed with Batch 2 was made on 30 November 2018, with storage levels at 61%.
- The delivery of all membranes, installation and preliminary testing was not complete until 26 July 2019, 10 months from the initial order, and well in excess of the 8-month Restart Period.
- It is estimated that it would take five months after a restart trigger before subsequent processes had been commissioned to allow testing of the existing membranes. If SDP had waited until then to replace membranes, it would have been at least 15 months (based on actual procurement timeframes) from the restart trigger before all could have been replaced. This is well in excess of the 8-month Restart Period and would have placed unacceptable risk on SDPs drought response role.
- The period between the final membrane loading and the end of the restart period identified optimisation required to elements of the membrane install. Not all of this optimisation was complete prior to the Restart Period end due to time constraints. It has been challenging to fully optimise the install even to current situation and in future, more time would be sought for membrane replacement, and a strategy be put in place to minimise the number of membranes to be replaced at any one time. Observations include:
  - It takes significant time to test the many membrane pressure vessels and identify optimisation opportunities (e.g. renewal of o-rings or membrane connectors) due to the number of tests and the inherent risk of working on high pressure applications;
  - It takes significant time to make any improvements and then iterate the testing to assess efficacy;
  - It is challenging to stop Ro membrane trains and complete rectification during drought as there is a risk to water supply volume and abatement; and

- It has been challenging to test RO membrane trains and complete rectification during the emergency response mode as the energy allowance is not sufficient to allow trains to be rotated and testing completed while recovering reasonable costs through the determination.

5. Conclusions

The key conclusion from the analysis in this paper is that the membrane replacement costs incurred by SDP are prudent and efficient given:

- a strategy of replacing the full set of membranes upon restart of the Plant was prudent given the prevailing circumstances of the Plant being in water security mode for an unprecedented length of time, a partial plant test being denied in favour of a full replacement, the lead time for securing new membranes, and the need to restore the Plant to full production as quickly as possible to enable SDP to fulfil its role as a drought response;
- The execution of this strategy was prudent taking into account the market and other circumstances at the time; and
- The cost of this strategy was efficient, as:
  - it was completed within the efficient allowance provided for in the 2017 IPART Determination, despite installation costs being more than double what was estimated by IPART's Consultant;
  - the installation was competitively tendered and the lowest cost solution was selected, and
  - the membrane selection was limited to one manufacturer due to lead time considerations, and the unit cost negotiated was well below the guaranteed pricing in the membrane warranty.

However, the experience in the replacement of the membranes also highlighted some deficiencies of the current regulatory framework. In particular, the assumption that eight months was sufficient time to order and install a new set of membranes proved not to be realistic taking into account the state of the membrane market and the consequent lead times. This meant that SDP had to commit to membrane orders in advance of reaching the restart trigger in order to ensure it could meet the required timeframes for restart, taking on considerable regulatory and financial risk (approximately $10m) in doing so (in the event that storages recovered and the trigger had not been reached) even though the early order of membranes was a prudent action to take.