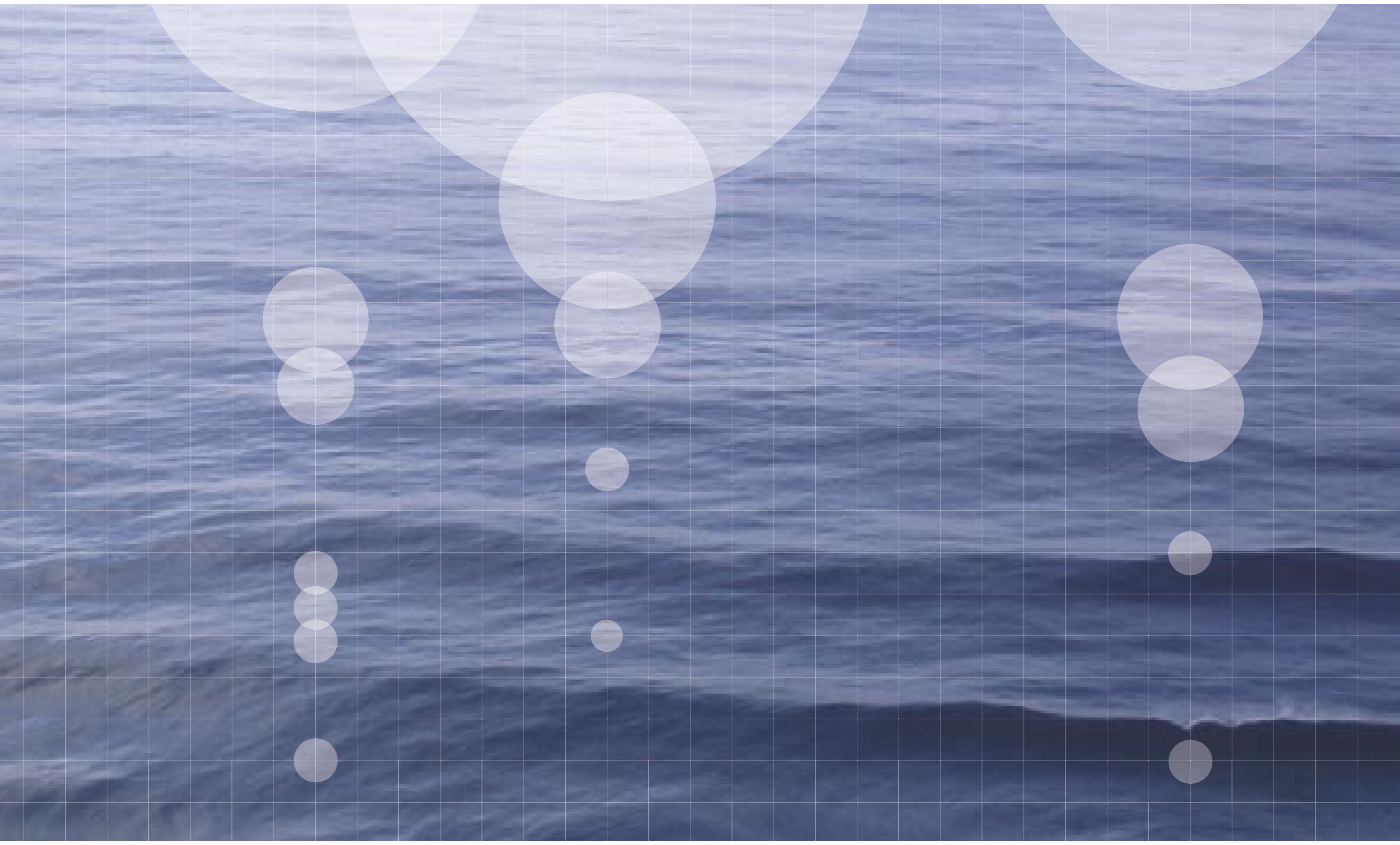
GHD FICHTNER

Sydney WATER

Planning for Desalination



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1. The Desalination Planning Study at a Glance

In the event of ongoing severe drought, desalination represents a viable method of supplementing supplies of drinking water for Sydney.

The key findings are:

- A desalination plant could achieve a water quality that meets NSW Health requirements and the Australian Drinking Water Guidelines published by the National Health and Medical Research Council (NHMRC). This water could be integrated directly into Sydney's existing drinking water network;
- Seawater desalination using reverse osmosis is the preferred technology over thermal technology;
- In the event of ongoing severe drought, desalination represents a viable method of supplementing supplies of drinking water for Sydney, despite having a relatively high cost of water compared to current sources of supply;
- Plants in the range of 100 - 500ML/day[1] would cost in the order of $470 million to $1.75 billion[2] and could supply a estimated 7% and 35% of greater Sydney's daily water demand;
- Power for the desalination plant would be best supplied from the electricity grid;
- Desalination is a relatively high user of energy compared to current sources of water supply. This results in correspondingly high greenhouse gas generation compared to current sources of supply. These emissions can be mitigated by methods such as forest sequestration (tree-planting), use of renewable or lower greenhouse energy such as gas or purchase of abatement certificates;
- Modelling of the seawater around the intake zones has shown that the effects of the deep ocean outfalls at the ocean sewage treatment plants and other point sources in the zones would be negligible. The seawater quality monitoring program shows that the intake water is of good quality;
- A number of potential locations for desalination plants have been considered. However, only sites at Malabar or Kurnell would allow for staging of a plant up to 500ML/day, which is the size of plant that could stabilise Sydney's water supply;
- In the event of continuing drought, the preferred location for a large desalination plant that needs to be constructed quickly is at Kurnell. The costs for construction of a plant are similar for the two sites. However, the complexities of managing land use issues, potential contamination and ease of construction issues could result in significant delays at the Malabar location; and
- In order to provide the necessary drought contingency, a sequential approach to planning, design and if necessary, construction could be implemented. This would allow construction to proceed if required but avoid over-expenditure in the event of drought-breaking rains.

1 One megalitre (ML) is one million litres.

2 In 2005 Australian dollars and not including greenhouse mitigation costs.

2. Overview

The work undertaken has concluded that desalination is a feasible option for water supply management in Sydney.

2.1 Introduction

The Desalination Planning Study (Planning Study) is a feasibility study with the aim of defining a shortlist of options that could provide security for Sydney's water supply. Ultimately the decision to proceed to construct a desalination plant will be driven by need, either as a contingency for drought or as a long-term supplementary water supply source in the context of the Metropolitan Water Plan.

This chapter provides a summary of the key outcomes associated with provision of desalination in Sydney. The following chapters provide more detail regarding the planning process.

2.2 The Project's Big Questions Answered

2.2.1 Is Desalination a Feasible Water Supply Option for Sydney?

The work undertaken has concluded that desalination is a feasible option for water supply management in Sydney.

The preliminary design undertaken has shown that water could be produced and delivered into the water distribution system for a cost in the order of $1.44 per kL[3][4][5]. Depending upon the greenhouse reduction strategy chosen this cost could increase (potentially in the order of $0.10/kL) as discussed in Section 6.8.

Unit water costs fall as the size of the plant increases. This reflects scale economies in infrastructure and development.

3 One kilolitre (kL) is one thousand litres.

4 The recent plant at Perth is quoted at $1.16/kL. The difference is attributable to the nature of Sydney's coastline and required intake and discharge structures.

5 This is for a 500ML/day plant operating at full capacity 94% of the time. As with all water supply systems if the operational capacity was reduced the unit cost of water would rise substantially.

2.2.2 What Desalination Technology to Adopt?

Sampling has shown Sydney's current seawater quality to be suitable for desalination. Thermal and reverse osmosis technologies for treating seawater were considered. Both technologies can provide water that meets the Australian Drinking Water Guidelines published by National Health and Medical Research Council (NHMRC). The preferred process for treatment of seawater in Sydney is reverse osmosis primarily based on economic and environmental reasons. Thermal desalination uses three times more energy and results in the cost of water production being more than double that of reverse osmosis.

A 500ML/day plant could supply a third of greater Sydney's daily water needs.

2.2.3 What Size Plant(s)?

Plant sizes of 50-500ML/day have been considered. Should the drought persist, a 500ML/day plant could supply Sydney with a third of greater Sydney's (including Blue Mountains and Illawarra) daily water needs, which would significantly reduce the depletion of dam storages.

If the drought breaks, smaller plant sizes may be considered to augment long-term water supply and address potential climate variability.

2.2.4 Should Grid Power Or On-site Power Be Used?

Grid and on-site gas fired power were considered as potential energy sources. For the purpose of analysis it was assumed it was required to mitigate the additional greenhouse gases from grid power (coal fired plants) compared to that generated from gas power.

The analysis has indicated that for a 500ML/day desalination plant the cost of power from a gas fired power plant[6] is less than the cost of grid power, with the mitigation as discussed above. This is not the case for smaller sized desalination plants.

[6] Assumes continual operation and adjacent to the desalination plant.

The benefits of providing a gas power plant adjacent to the desalination plant have been addressed in detail during the Planning Study. The conclusions reached are:

- In terms of drought response, where time is critical, the complexity of constructing a gas power plant on site could potentially delay the project compared to power sourced from the grid; and
- There are significant social and environmental impacts of locating a dedicated gas fired power plant in an urban area and these were considered not acceptable.

The construction of a desalination plant (with an associated greenhouse gas mitigation commitment) may encourage the development of renewable energy sources.

At this stage it is not considered appropriate in terms of a drought response plant to co-locate a gas power plant with the desalination plant. This does not preclude using gas power in the future that is generated elsewhere. As gas is playing an increasing role in power generation and greenhouse gas mitigation, its future use for base load power is becoming more likely. At this time the cost of gas power is estimated to be significantly greater than for grid-supplied power.

The construction of a desalination plant (with an associated greenhouse gas mitigation commitment) may also encourage the development of renewable energy sources. In the future the energy market may be able to supply power to the desalination plant from these sources, at a cost comparable to the mitigation options.

2.2.5 How Do We Mitigate Greenhouse Impacts?

Depending on the size of the plant, a one-off increase in NSW's electricity demand of 0.2-1.2% could result when the plant is fully operational. This compares with a predicted ongoing annual increase of around three per cent to meet the State's needs.

However, the greenhouse emissions can be mitigated in a number of ways.

These options include:

- Forest sequestration (tree planting);
- Purchasing tradeable credits such as Renewable Energy Credits or NSW Greenhouse Abatement Certificates; and
- Purchasing gas fired power or renewable energy, such as wind power.

2.2.6 Where to Locate the Desalination Plant(s)?

As discussed in Section 7, fourteen sites were short-listed for 50 to 500ML/day plants but only three locations met the evaluation criteria for site selection.

The criteria for choosing plant sites were that they should be located:

- close to the coast for good quality source water and for the discharge of seawater concentrate;
- close to available power; and
- close to the existing major distribution mains.

The locations identified are Kurnell, Malabar and Port Kembla. The sites identified are at:

- Kurnell – industrial land in proximity to the oil refinery (three sites identified);
- Malabar – Sydney Water owned land and part of Commonwealth owned Anzac Rifle Range; and
- Port Kembla – industrial land.

Table 2.1 Plant Capacity at each of the Sites

	Capacity ML/day					
Site	50	100	200	300	400	500
Kurnell	✓	✓	✓	✓	✓	✓
Malabar (Anzac Rifle Range)	✓	✓	✓	✓	✓	✓
Malabar (Sydney Water land)	✓					
Port Kembla	✓					

Only Malabar and Kurnell are suitable locations for staging to a larger plant. Potential locations are shown on Figure 2.1.

Sites elsewhere suffer from a lack of adequate land (staging ability), unsuitable and variable intake water quality, limited capacity of the water supply distribution system, environmental and social impacts.

Only Malabar and Kurnell are suitable locations for staging to a larger plant.

All plant locations present challenges in terms of environmental, social and technical management. Issues to be addressed in more detail during the environmental assessment stage of the Planning Study will include environmental and social impacts, ocean discharge, greenhouse gas impacts (as discussed above), threatened species, and local impacts such as traffic and noise.

At Malabar the rifle range abuts the natural vegetation on the headland. A plant of 500ML/day would occupy approximately 20% of the cleared rifle range. In addition to its current use as a rifle range, part of the site has historically been used as a commercial tipping operation and there may be contamination present. Current investigations indicate that the contamination present would significantly affect the cost and ease of construction of a desalination plant. This would have the potential to cause delays in construction and increase cost. The risk of delays is particularly important in terms of a drought response plant.

The sites under consideration at Kurnell are zoned industrial and distant from Cook's Landing and the Kurnell village. Two of the sites are partly cleared and the other has remnant vegetation. Technical studies have indicated that there are a number of alternatives for water distribution from Kurnell. However, all will require transmitting water across Botany Bay to the larger population in the main Sydney supply zone. The preferred option is to lay a pipe across the bay[7] .

7 An alternative is to tunnel under Botany Bay. The geology of Botany Bay is characterised by significant glacial valleys (palaeochannels). The nature of this geology requires careful consideration to select the most appropriate route would take about two months longer and is subject to greater delay uncertainty.

Summary

The Planning Study has shown that there are feasible options available that would satisfy the following criteria:

- Providing security if the current drought persists;
- Providing security if drought occurs in the future; and
- Providing a diversity of supply at several levels in the long-term.

These options have been subjected to planning level design and investigation during the Planning Study.

Ultimately the decision to proceed will be driven by need, either need for a long-term supplementary water supply source or through continuing drought.

Ultimately the decision to proceed will be driven by need; either need for a long-term supplementary water supply source or through ongoing drought. This need will manifest itself in terms of plant size.

In the event of continuing drought, the preferred location for a large desalination plant is at Kurnell. The costs and timing for construction of a plant are similar for Kurnell and Malabar. However, the management of potential contamination issues could result in significant delays at the Malabar location and the complexities of current land uses on the rifle range have the potential to delay the project.

Figure 2.1 Potential Locations

3. Background and Context to this Report

3.1 Overview

In October 2004, the New South Wales Government released the Metropolitan Water Plan (MWP), *Meeting the Challenges – Securing Sydney's Water Future.* The Plan charts a course towards a sustainable and secure water system for people of the greater Sydney area over the next 25 years.

The Plan contains a package of new actions the Government will implement which respond to the current drought and give certainty to our water supplies.

One component of the Plan is to undertake planning for desalination as a sensible contingency investment by Government. Sufficient planning and design is being undertaken to ensure that if the current drought continues, or if future droughts occur, a desalination plant for Sydney could be constructed relatively quickly. Other supply sources include transfers from the Shoalhaven catchment during high flows, wastewater recycling and deep storage access in select dams.

3.2 Purpose of this Report

This report has been produced to provide a concise overview of the findings to date.

3.3 The Planning Process

A rigorous Planning Study has been underway since January 2005 to ensure that Sydney would be ready if a desalination plant is required to supplement the water supply. A team of local and international experts from GHD and Fichtner were commissioned to work with Sydney Water on the feasibility Planning Study. To ensure that the Planning Study is robust and arrives at the best conclusions, the process was scrutinised by an independent panel with expertise in desalination, energy and greenhouse, environment economics, marine impacts, decision-making and public consultation.

Following the feasibility work, environmental approvals will be sought through an environmental assessment process to ensure that a desalination plant could be constructed quickly if a decision is made to proceed.

Once the preferred option/s for Sydney are selected, environmental approvals will be sought through an environmental assessment process to ensure that a desalination plant could be constructed quickly if a decision is made to proceed.

3.4 The Planning Study's Big Questions

There have been several significant questions during the Planning Study:

- Is desalination a feasible water supply option for Sydney?
- What desalination technology to adopt?
- What size plants?
- What power source should be employed (grid or co-located power station)?

- What are the greenhouse impacts of desalination and how could they be mitigated?
- What are the environmental and social impacts of a desalination plant likely to be and how can they be mitigated?
- What are the economics?
- What strategies are available for staging a desalination plant?

3.5 Why Might Sydney Need a Desalination Plant?

For Sydney, seawater desalination could increase the diversity of the water supply and reduce the risk of dependency on one supply.

The 2004 Metropolitan Water Plan charted a range of measures to help balance demand for water with a sustainable supply in the long-term. Water conservation initiatives such as recycling, building more water efficient homes, converting to water efficient products, reducing leaks and rebates on rainwater tanks are making a substantial contribution.

In response to the ongoing drought, the NSW Government has taken precautions to slow down the rate of depletion of the dams. Mandatory water restrictions have helped save more than 127 billion litres of water (as at July 2005) since they came into effect in 2003. However, even with stringent restrictions, severe ongoing drought would lead to further depletion of storages.

The Metropolitan Water Plan also includes other water supply initiatives including Shoalhaven transfers and accessing deep storages, and investigating groundwater sources.

Planning for desalination is another option in the Metropolitan Water Plan that could increase water supply for Sydney. Desalination is used extensively in other parts of the world, where water is scarce, to provide high quality drinking water. For Sydney, seawater desalination could increase the diversity of the water supply and reduce the risk of dependency on one supply.

If the pattern of low rainfall continues in the coming years, then current planning for desalination would ensure that Sydney has a contingency plan in place and the NSW Government would be ready to act quickly.

A staged approach that takes into account timing of construction of a plant and rate of dam depletion is an appropriate strategy.

3.6 Scope Of The Planning Study

The scope of the Planning Study includes options development, environmental impact assessment and undertaking the planning approval process associated with the preferred options.

The Planning Study is proceeding in two phases. Phase 1 comprised the feasibility study and Phase 2 consists of undertaking further technical investigations and environmental investigations for the preferred desalination options. It also includes environmental assessment studies, stakeholder and community engagement. This report summarises the findings of Phase 1.

4. Desalination Overview

A desalination plant for Sydney can be expected to supply water that is comparable in quality to the existing drinking water.

Drinking water produced by desalination is not new. Where circumstances dictate it, desalinated water is the principle source of drinking water in some countries. It is also used to produce fresh water on ships.

From an aesthetic perspective it is possible for desalination technologies to reduce the dissolved salts in the water to levels at which there is unlikely to be perceptible differences to freshwater.

The desalination processes available today can readily achieve aesthetic water quality (salt content, taste and odour) that is superior to the criteria set down in the Australian Drinking Water Guidelines published by National Health and Medical Research Council (NHMRC). In the case of Sydney, where customers currently receive water with aesthetic quality far better than Australian Drinking Water Guidelines, a desalination plant would readily achieve a similar water quality.

A desalination plant for Sydney can be expected to supply water that is comparable to the existing drinking water.

Similarly from a health perspective, desalinated water would comply with NSW Health requirements and Australian Drinking Water Guidelines published by National Health and Medical Research Council (NHMRC). Irrespective of the technology used, the process is an effective barrier to micro-organisms that may be harmful to human health. It should be noted that desalinated water has no health impact on immuno-compromised or dialysis patients.

4.1 Desalination – A Short Explanation

Desalination refers to the process of removing dissolved solids, primarily salts, from a water source such as seawater, estuarine water, advanced treated sewage effluent or brackish groundwater. Desalination plants are widely used in the Middle East and other parts of the world where fresh water supplies are scarce. In April 2005 Perth announced the construction of a 45GL[8]/annum reverse osmosis plant (130ML/day) and is currently undertaking planning for a possible second plant.

The two most widely applied and commercially proven desalination technologies are reverse osmosis (membrane based) methods and thermal distillation (evaporative). Both technologies will supply drinking water that meets NSW Health requirements and the Australian Drinking Water Quality Guidelines published by National Health and Medical Research Council (NHMRC).

Seawater desalination has emerged as a way to provide a drought-proof water source to meet long-term water demand in water scarce areas while increasing the diversity of supply.

It should be noted that large scale recycling for drinking water also requires desalination-style technology as the effluent contains dissolved salts although at levels much lower than in seawater.

Since the 1980s, reverse osmosis has been increasing its share of the desalination market, see Figures 4.1 and 4.2. The cost of desalinated water has reduced by over half during this time. This is due to advances in membrane

8 One gigalitre (GL) is one billion litres

Seawater desalination has emerged as a way to provide a drought-proof water source to meet long-term water demand in water scarce areas while increasing the diversity of supply.

technology, improved energy efficiencies (electricity usage has dropped by 40%), economies of scale using larger process trains and pumps and operational experience leading to optimisation.

For reverse osmosis, the seawater is pressurised to force water through a semi-permeable membrane while the salts, viruses, micro-organisms and other impurities are retained in a concentrated solution by the membrane for disposal.

Thermal methods remove salts by evaporating seawater to vapour and then condensing back to drinking water. This technology has dominated the seawater desalination market, particularly in the Middle East region. However, the energy intensive requirements of thermal methods and advances in reverse osmosis technology have lead to a significant increase in market share for reverse osmosis. Many new desalination plants utilise reverse osmosis technology.

For reverse osmosis, the seawater is pressurised to force water through a semi-permeable membrane while the salts, viruses, micro-organisms and other impurities are retained in a concentrated solution by the membrane for disposal.

Figure 4.1 Installed Worldwide Desalination Capacity in 1996

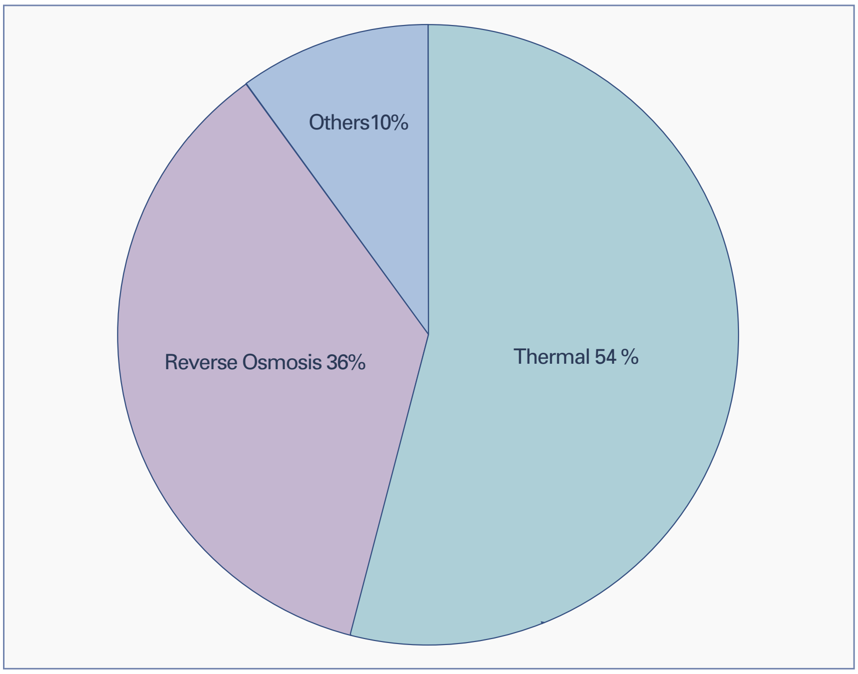
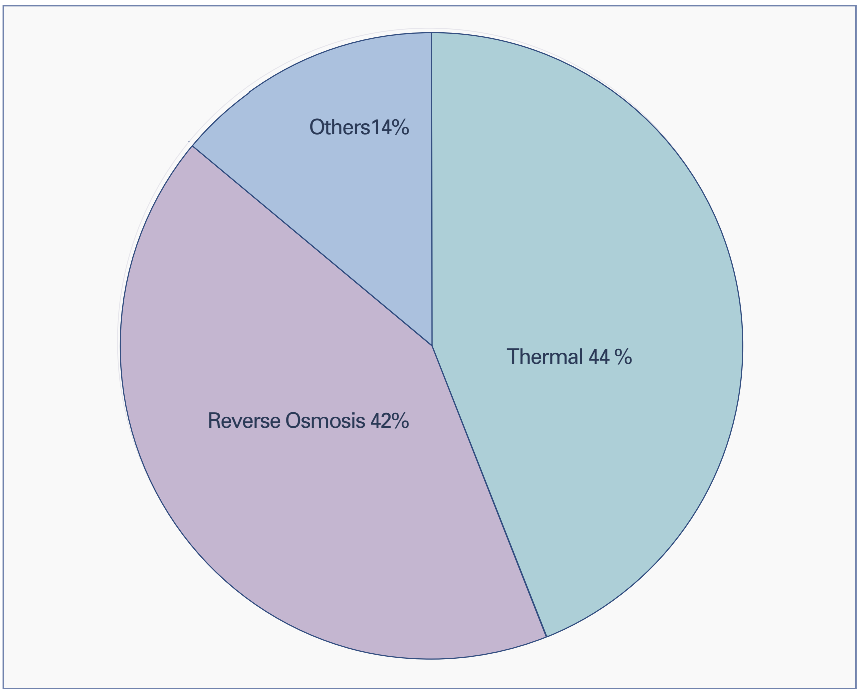


Figure 4.2 Installed Worldwide Desalination Capacity in 2000



4.2 Reverse Osmosis Process

The reverse osmosis desalination process uses less energy than thermal processes.

The reverse osmosis process uses a semi-permeable membrane for separating salts from the seawater. The membrane retains the salts, viruses, micro-organisms and other impurities, while desalinated water diffuses through the membrane. The seawater is pressurised to above its osmotic pressure to provide the driving force for the process.

Reverse osmosis membranes reject dissolved salts (ions) at different rates (depending upon their valency and atomic weight). On average, the rejection rate is in excess of 99% for seawater reverse osmosis membranes and greater than 97% for brackish water membranes.

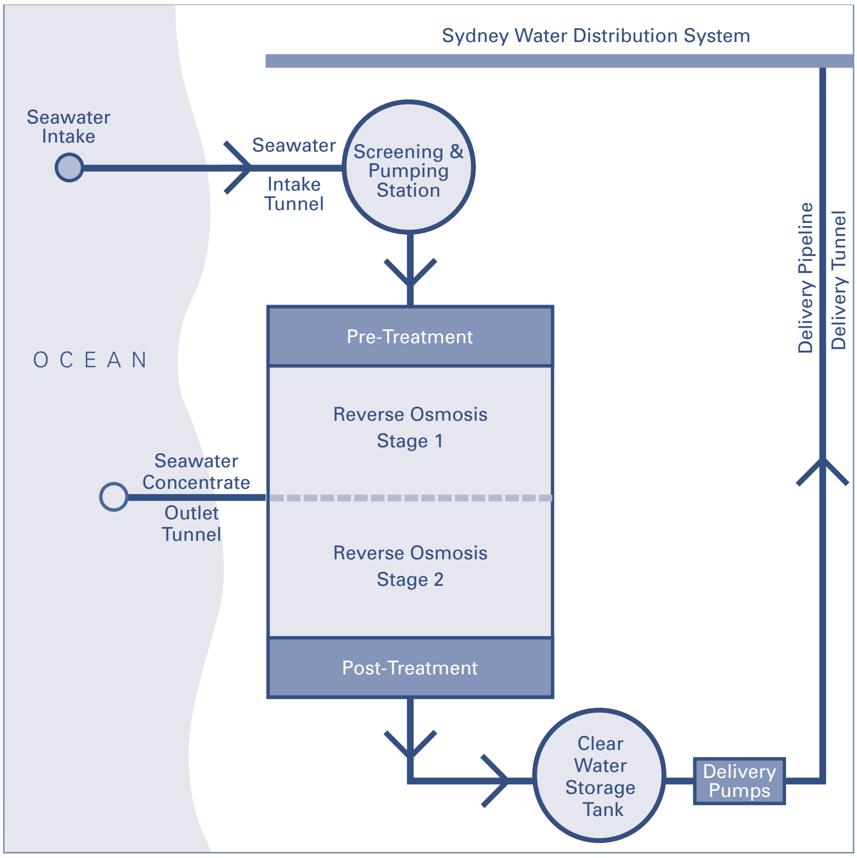
The reverse osmosis desalination process uses less energy than thermal processes. Electrical energy is only required to drive the high-pressure pumps to overcome the osmotic pressure of the seawater.

The desalinated water produced from a seawater reverse osmosis process is normally in the range of 40 to 45% of the feedwater flow. Therefore, between 55 and 60% of the feedwater needs to be returned to the ocean, as seawater concentrate.

Seawater reverse osmosis plants are normally configured as single pass or two pass arrangements. For single pass the seawater is passed through one set of membranes. For the two-pass arrangement a portion of the desalinated water from the first pass is treated through a second set of membranes. The purpose of providing a second pass is to achieve lower salinity product water or to achieve other water quality objectives. A two pass arrangement would be used for a desalination plant in Sydney.

A schematic of a reverse osmosis arrangement is shown in Figure 4.3 below.

Figure 4.3 Reverse Osmosis Schematic



To prevent membrane fouling and to maintain water production, reverse osmosis requires seawater free of suspended solids and oil. This is achieved through pre-treatment that can consist of direct filtration, coagulation sedimentation followed by filtration, or by using microfiltration or ultrafiltration membranes upstream of the reverse osmosis membranes. Optimisation of the pre-treatment and membrane operation is achieved during pre-construction testing.

4.3 Thermal Processes

There are two main thermal desalination processes that are commercially proven for large-scale desalination plants. These are:

- Multi Stage Flash (MSF); and
- Multi Effect Distillation (MED).

Within these two main processes there are a number of configuration options, for example, MED can be combined with thermal vapour compression (MED-TVC).

MSF involves seawater or recirculated seawater concentrate being pressurised and heated to its maximum operating temperature (around 110^{0}C for a high temperature plant). The recirculated seawater concentrate is normally mixed with feedwater to limit the salt content of the recirculated seawater concentrate. Once pre-heated the recirculated seawater concentrate is discharged into a chamber slightly below the saturated vapour pressure of water and a fraction of the water ‘flashes’ into steam. The flashed steam is stripped of suspended seawater concentrate droplets as it passes through a mist eliminator and condenses on the exterior surface of the heat transfer tubing. The condensed liquid drips into trays as hot product (fresh) water. This process is repeated through a number of stages, each at lower pressure.

MED processes use the same principles of heating and evaporation as MSF processes, however the process configuration is slightly different. The majority of the evaporation is achieved by evaporation from a liquid film surface (as opposed to flashing), however condensation and evaporation still occur at reduced pressure in the various effects (vessels), by applying a vacuum system.

4.4 Alternative Desalination Technologies

Several alternative desalination technologies were ruled out during the Planning Study.

These technologies included those in the developmental stage or those unproven on large-scale plants. These include among others, solar humidification, membrane distillation, electrodialysis, freeze distillation and deep sea reverse osmosis.

A safe and reliable source of good quality seawater is critical for a desalination plant.

4.5 Desalination Infrastructure

Seawater Intake and Seawater Concentrate Discharge

A reliable and high quality source of seawater is critical for a desalination plant. Adequate separation is required between the seawater intake and the seawater concentrate discharge to avoid cross connection occurring. In the case of reverse osmosis, the intake volumes are up to three times and the seawater concentrate volumes up to two times, the final desalinated water production volume.

A number of alternative options for intake and discharge pipes have been considered to suit the particular coastal features in Sydney including directional drilling, laying a pipeline on either a rocky or sandy seabed and tunnelling. While further review and optimisation of the intake and discharge design will occur during the pre-construction design of a plant, this Planning Study has found that tunnelling provides the most appropriate solution.

For the smaller plant sizes, a single tunnel has been included with provision for both intake and seawater concentrate discharge. For the larger plants, separate intake and discharge tunnels have been adopted. In all cases, the intake and discharge structures will be separated with the discharge well down current and away from the intake.

Modelling of the seawater around the intake zones has shown that the effects of the deep ocean outfalls at the ocean sewage treatment plants and other point sources in the zones would be negligible. The seawater monitoring program indicates that the intake water is of good quality.

Pre-treatment

The extent of pre-treatment is significantly different between the reverse osmosis and thermal processes. Both require coarse and fine screening but the reverse osmosis plants require significantly higher pre-treatment to prevent fouling of the reverse osmosis membranes. Design and optimisation of the pre-treatment process for a reverse osmosis plant will be addressed during pre-construction testing to ensure that costs are minimised and reliability is maximised.

Potabilisation

Before connection to the drinking water distribution system, desalinated water, like current drinking water, will be further treated to satisfy the requirements of the Australian Drinking Water Guidelines published by National Health and Medical Research Council (NHMRC), NSW Department of Health requirements and Sydney Water's operational guidelines. To meet these requirements, the desalinated water would be treated in a process called potabilisation with chloramine, fluoride, lime and carbon dioxide before being stored on-site and then pumped into the drinking water distribution system.

Distribution

The water will be pumped to either local service reservoirs in the case of the small plants or to a major city supply point (Waterloo Pumping Station), for the larger plants. Connection to local service reservoirs would be via new conventional trunk mains while connection to Waterloo would be via a new tunnel constructed by tunnel boring machines some 60 to 80 metres underground. For the Kurnell option laying a pipe across the bay will be required to connect to the city's main distribution network (the city's pressure tunnel) at Waterloo or another point along the tunnel.

5. Developing a Short List of Options

5.1 The Process

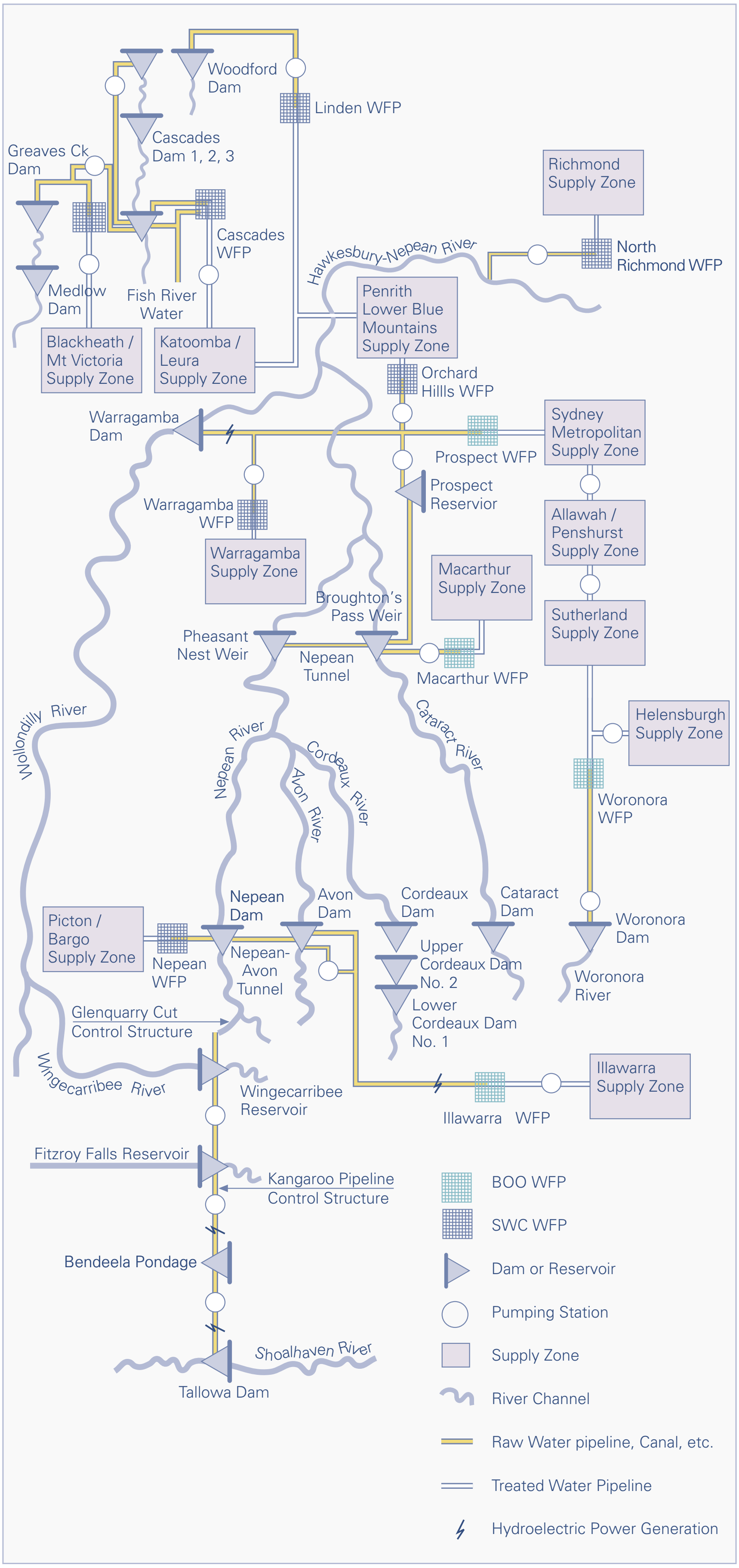
The Planning Study has followed an overall methodology. The steps within this process were as follows:

- Definition of objectives;
- Establishment of evaluation criteria;
- Undertaking key background technical studies;
- Undertaking a site selection process;
- Review technical studies and first round selection using the preliminary evaluation criteria;
- Develop and review a long list of options;
- Application of criteria for screening;
- Selection of the short-listed site options;
- Site based development configurations established;
- Design development;
- Environmental review; and
- Comparison against financial, technical, social and environmental criteria.

5.2 Overview of Sydney's Water Supply System

Water is provided from stored water reservoirs operated by the Sydney Catchment Authority. Figure 5.1 shows Sydney's drinking water system schematically and the location of major drinking water assets. The largest of these is Warragamba Dam, which supplies 80% of Sydney's water. The remaining supply comes from the Nepean, Avon, Cordeaux, Cataract and Woronora Dams in the Southern Highlands. Five small storage dams in the Katoomba area supply the upper Blue Mountains. Avon Dam is the principle stored water reservoir supplying the Illawarra region. The Nepean and Warragamba Dams can be augmented when required by the Shoalhaven Scheme, which comprises the Tallowa Dam, and the Fitzroy Falls and Wingecarribee Reservoirs.

Figure 5.1 Sydney's Water Supply System



All drinking water supplied by Sydney Water is treated at one of ten Water Filtration Plants (WFP). Drinking water is then distributed to people in Sydney, the Blue Mountains and the Illawarra.

The water distribution system of Sydney is divided into fourteen Delivery System Zones as shown in Figure 5.2. These Delivery Systems are typically aligned with specific water storages and Water Filtration Plants. The exception to this is the main metropolitan water supply, which due to its size, is split into five areas downstream of the Prospect WFP. These five areas consume 80% of the water supplied by Sydney Water. A summary of the population served by the delivery systems and the daily demand is shown in Table 5.1.

Table 5.1 Water Delivery Systems of Greater Sydney

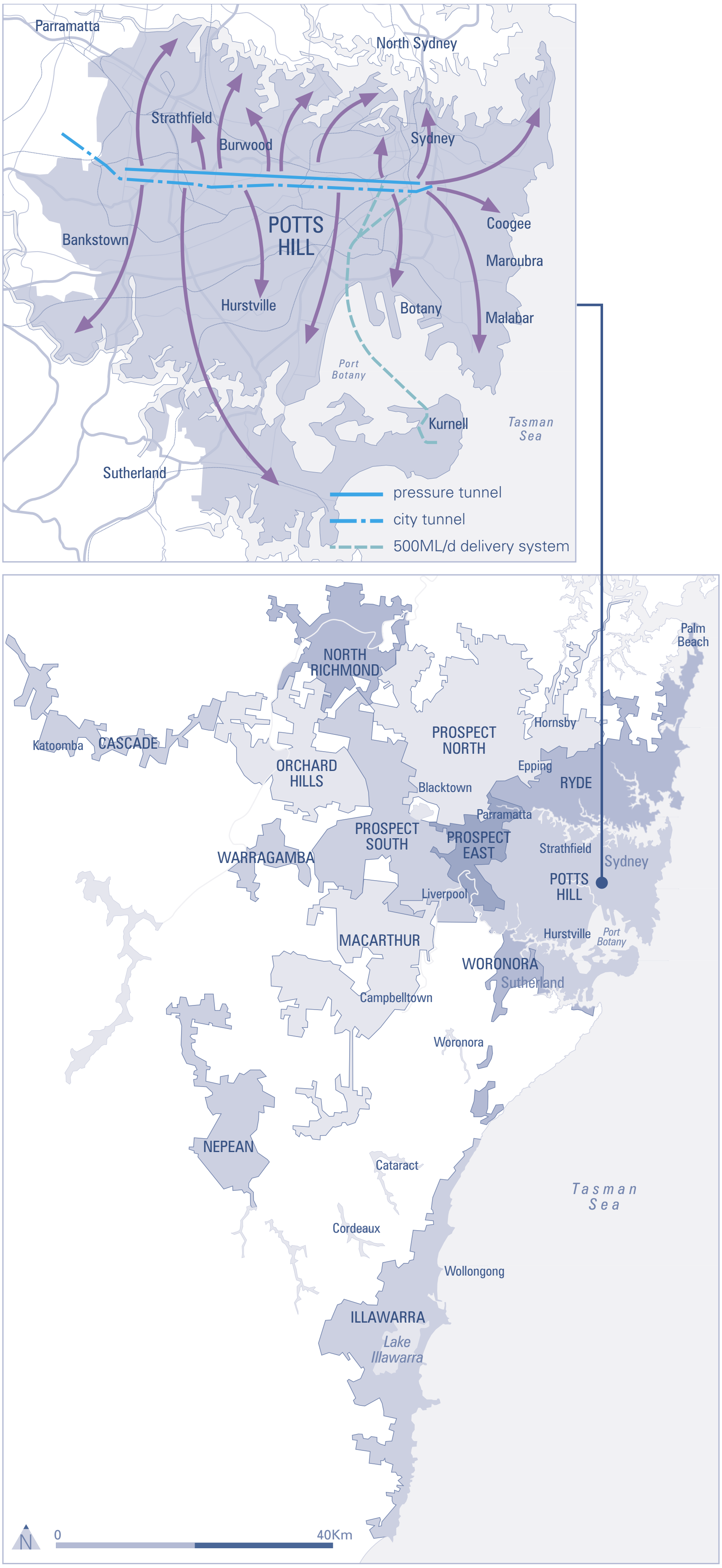
Delivery System	Areas Served	Population Served	Base Demand[9] ML/day	Current Demand[10] ML/day
Prospect South	Liverpool, Fairfield and parts of Blacktown	370,000	124	104
Prospect North	Baulkham Hills, Hornsby and parts of Blacktown, Holroyd, Ku-ring-gai and Parramatta	650,000	240	202
Prospect East	Parts of Auburn, Bankstown, Holroyd, Fairfield and Parramatta	210,000	100	86
Ryde	Pittwater, Warringah, Manly, Mosman, Hunters Hill, Lane Cove, Ryde, North Sydney and parts of Ku-ring-gai and Parramatta	660,000	250	210
Potts Hill	Ashfield, Botany Bay, Burwood, Canada Bay, Canterbury, Hurstville, Kogarah, Leichardt, Marrickville, Randwick, Rockdale, Strathfield, Sydney, Waverly and Woollahra and most of Auburn, Bankstown and Sutherland	1,400,000	620	526
Greaves Creek	Upper Blue Mountains – Mount Victoria, Blackheath and Medlow Bath	8,000	2.5	2.1
North Richmond	Hawkesbury	50,000	21	18
Orchard Hills	Penrith and parts of the Blue Mountains	200,000	69	57
Warragamba	Warragamba and Silverdale	7,000	3.9	3.3
Nepean	Wingecarribee and most of the Wollondilly Shire	24,000	12	10
Macarthur	Camden, Campbelltown and parts of Liverpool and Wollondilly	230,000	88	74
Illawarra	Wollongong, Shellharbour and Kiama	270,000	125	107
Woronora	Southern half of Sutherland Shire	100,000	41	35
Cascade	Lower half of the Blue Mountains	40,000	14	12

9 Demand with no water restrictions.

10 Demand under Level 2 water restrictions

Desalinated water transmitted to Waterloo would predominately supply the Potts Hill delivery system, as shown in Figure 5.2.

Figure 5.2 Sydney Water's Delivery System Zones



Water from a desalination plant will meet NSW Health requirements and the National Health and Medical Research Council (NHMRC) Guidelines.

5.3 Water Quality Target Specification

Several factors need to be considered in proposing water specification targets for a desalination plant in Sydney. These factors include NSW Health requirements and the Australian Drinking Water Guidelines published by National Health and Medical Research Council (NHMRC), the drinking water quality of Sydney's existing water supply system, and corrosion guidelines to prevent corrosion of water supply infrastructure.

The water quality of Sydney's existing supply is very good, with parameters such as total dissolved solids, chloride, sulphate, total hardness and alkalinity well below the maximum allowable values in the National Health and Medical Research Council (NHMRC) Guidelines. Given that the people of Sydney have been drinking this quality of water for many years it would be prudent to maintain any desalinated water supply at similar levels for these parameters. It also maintains current water quality for industrial customers.

The decision was taken to adopt Sydney's current aesthetic water quality as the target for the desalination plant. For other parameters, the target criterion is compliance with the National Health and Medical Research Council (NHMRC) Guidelines. Adopting these water quality parameters would allow the desalinated water to be introduced directly into the distribution system at any point without the need for blending and will be achieved using a two pass reverse osmosis arrangement.

5.4 Evaluation Criteria

In order to assess the many technological and site options available for a Sydney desalination plant, a set of evaluation criteria was developed. It was essential that these criteria covered a wide range of concerns to ensure all factors were considered in option selection.

The criteria included non-quantifiable and quantifiable criteria under the following headings:

- Operational/Process Performance;
- Infrastructure;
- Environmental;
- Energy;
- Financial; and
- Social.

Table 5.2 presents the final criteria for the project.

Table 5.2 Screening Criteria

Indicator	Description
Operational/Process	
Proven application of technology	Proof that a proposed option can operate at the capacity required for a Sydney desalination plant. Includes power generation technology
Ability of technology to meet current drinking water quality standards	Ability of technology to produce drinking water that meets Australian Drinking Water Quality Guidelines
Operability of technology	Ease at which the plant can be run and operated, including training of plant staff, shift work issues, automation of processes
Reliability and maintainability of technology	Reliability of plant technology based on previous experience, and the difficulty of maintenance of the technology

Table 5.2 Screening Criteria (Continued)

Indicator	Description
Operational/Process	
Plant start up/shut down	Plant start up / shut down characteristics. Includes time to start up/shut down, ease at which plant can be started up/ shut down, and length of down time
Ability to put plant in standby mode	Ability of a plant to be placed in standby mode
Sensitivity to intake seawater quality	Ability of a plant to handle differing qualities of intake seawater
Ability to scale down/stop production	Ability of a plant to operate at lower capacity
Interdependency of plant and related industries/ infrastructure	Degree to which plant relies on other industries/ infrastructure for its operation, and other industries/ infrastructure rely on the plant for their operation
Infrastructure	
Project completion time	Time taken to acquire a particular site, then construct the desalination plant and related infrastructure, giving consideration to current site ownership, planning approval pathway and timing, zoning requirements, site preparation, availability of specialised machinery and skilled labour, connection to existing water, gas and electricity networks
Constructability of plant and related infrastructure	Degree of risk associated with the construction of the plant and related infrastructure, due to the complex nature of the desalination plant technology, any site difficulties
Modular nature of plant	Ability of plant to have staged construction and future augmentation due to its modular nature
Ability to retrofit plant	Ability to retrofit plant with future desalination technologies
Opportunity for other applications	Ability of a plant to be used for applications other than seawater desalination, eg. recycling
Compatibility of plant location with existing and planned infrastructure	Compatibility of the location of the plant to the location of required utilities and other infrastructure, including water mains, gas mains, electricity network connections
Environmental	
Greenhouse Gas emissions per kL water produced	Equivalent greenhouse gas emissions per kL desalinated water produced. Includes equivalent emissions from electricity usage, pumping and process
Waste handling / disposal	Impact of handling and disposal of site wastes on the environment. Could include positive effects if wastes can be used as feeds for other industries
Terrestrial site impacts	Impact of plant on surrounding terrestrial environment. Includes flora and fauna impacts
Marine site impacts	Impact of plant on surrounding marine environment. Includes flora and fauna impacts
Air pollution impacts (if power plant required)	Impact of plant on air quality. Includes consideration of air shed, weather patterns, health impact of incremental increases
Noise pollution impacts	Impact of plant on local noise pollution. Includes health impact of incremental increases
Energy	
Energy use per kL water produced	Amount of energy used by the process and associated pumping, including both electrical, fuel and thermal sources
Possibility for future provision of alternative energy sources	Ability of desalination plant to accept power from different sources in the future

Table 5.2 Screening Criteria (Continued)

Indicator	Description
Energy	
Impact on energy networks	Impact made by desalination plant and purpose built power plant on the electricity and gas networks. Includes network stability, energy export to network, peaking issues, ability of plant to receive interrupted and curtailed power
Financial	
Capital cost of plant	Capital cost of plant. Includes site preparation, construction of plant and related infrastructure
Operating costs of plant	Cost of operating plant. Includes desalination plant, associated pumping, water treatment, chemical costs, waste disposal costs, maintenance
Levelised Cost – Net present value	Levelised cost of an option based on its net present value over a given life span.
Social	
Impact of construction and operation on public amenity	Impact that construction and operation of plant and related infrastructure could have on public amenity. Includes traffic and visual impacts
Impact of construction and operation on public access	Impact that construction and operation of plant and related infrastructure could have on public access to previously accessible areas. Includes impacts on bushwalking, recreational fishing, water sports, beach access
Proximity of plant to residential areas	Distance from plant to nearest residential area
Occupational Health and Safety	Risk a particular option poses to safety.
Aesthetic aspects of water produced	Aesthetic quality of water produced for consumers. Includes taste, odour, colour
Compatibility of land use	Compatibility of site location with existing land use, eg. industrial areas, residential. Includes zoning, existing use rights

5.5 Technical Findings

5.5.1 Consideration Of Desalination Plant Locations

The preliminary screening of potential plant locations was conducted using the Sydney Water's Geographical Information System.

Size of Land

In identifying potential sites, parcels of land with an area greater than five hectares were selected at this initial stage. This area was estimated as the size required for feasibly constructing and operating a 100ML/day plant. Similarly, approximately 20 hectares was estimated as the size required for a 500ML/day plant. However, depending upon the configuration of the 500ML/day plant, up to 25 hectares may be required. A maximum plant capacity of 500ML/day was chosen because this would stabilise Sydney's water supply in the event of extreme drought.

Potential Sites

Land use types specifically excluded from the search of potential sites included, for example, residential zoned land and National Parks.

Land use types specifically excluded from the search of potential sites included, for example, residential zoned land, and National Parks.

The site screening resulted in the following locations:

- Kurnell;
- Malabar;
- Botany;
- Taren Point;
- Ryde;
- Potts Hill;
- North Head;
- Seaforth;
- French's Forest;
- Brookvale;
- Warriewood;
- Mona Vale;
- Port Kembla; and
- Lake Illawarra.

These locations were further investigated to provide a shortlist of three locations – Kurnell, Malabar and Port Kembla.

5.5.2 Co-location Potential

The Planning Study has sourced where possible information on the potential for co-locating a desalination plant with a source of energy or dual use of infrastructure in the Sydney region.

Co-location opportunities identified included:

- Existing industry for heat energy - No feasible, economically sound opportunity was identified to co-locate with industry for the supply of low-cost incidental energy;
- Infrastructure sharing (such as Deep Ocean Outfalls, Northside Storage tunnel and power station intakes) – none were suitable, as co-location either compromised the asset or the assets were located in bays where intake water quality was not suitable; and
- Power stations – none were identified in close proximity to Sydney, so pumping costs for seawater intake and discharge and/or distribution of the desalinated water were significant.

No co-location opportunities were found to be feasible.

5.5.3 Reverse Osmosis Versus Thermal

The initial step in the screening process was to determine what desalination technology was preferred. If this could be achieved then the number of potential development options could be substantially reduced, thereby simplifying the next stage of short-listing.

For this assessment, thermal processes have only been considered in the context of dual-purpose configurations where additional power is produced for export to the grid in order to provide sufficient heat energy (steam) for the thermal process. This is the only option that makes efficient use of thermal energy. Given this, any decision in favour of the thermal desalination technology is inextricably linked to a decision to export power.

The assessment has been undertaken on the following basis:

- Using the MED thermal desalination process as representing thermal desalination processes. MED has a higher thermal efficiency when compared to the MSF process;
- A water production of 200ML/day was used as the case study; and
- Power for the reverse osmosis plant will be provided from the grid or a co-located power plant.

The thermal and reverse osmosis processes were initially considered against the key criteria of energy consumption, greenhouse gas emissions, and indicative water production costs ($/kL). The results of this assessment are presented below.

Energy Consumption and Greenhouse Gas Emissions

The calculation of energy consumption for desalination by the reverse osmosis process is straightforward, as all the energy input is used in the desalination process. This is not the case for the thermal process (due to the dual purpose configuration) where the energy input is distributed between the production of water and the production of electricity for export.

The thermal desalination process requires both heat and electricity. In order to generate the necessary heat in the form of steam, the power plant arrangement is less efficient (due to thermodynamic rules) than the power plant arrangement used to produce electricity only.

Analysis for a 200ML/day plant indicates that the fuel required for the thermal desalination process is 2,100 Gigawatt hours per year (GWh/annum) compared to only 730GWh/annum[11] for the reverse osmosis process. Therefore, the most efficient thermal process requires more than three times the energy of a reverse osmosis plant. This also means that the greenhouse gas emissions associated with the thermal process are more than three times those for a reverse osmosis plant.

[11] It should be noted that 730GWh/annum energy consumption corresponds to an electricity consumption of 371GWh/annum.

It was concluded that reverse osmosis is the preferred technology against the criteria of energy consumption. It is also the preferred technology against the criterion of greenhouse gas emissions (i.e. greater energy required leads to more greenhouse gases produced).

Indicative Water Production Costs

A thermal desalination plant must be located next to a source of steam (heat) whereas a reverse osmosis plant only requires electricity, which can be from the grid or from a power plant located at the site (captive). The energy input requirements of reverse osmosis are substantially less than that for thermal (730GWh/annum versus 2,100GWh/annum). A power plant sized only to meet the needs of a reverse osmosis plant would be much smaller than the power plant required for thermal desalination producing the same volume of water. This is reflected in the cost of water production, which is approximately half that of thermal.

Non-Quantifiable Criteria

In addition, the two technologies were also compared on non-quantifiable criteria, which were not site dependent.

The results of this assessment are summarised in Table 5.3 below. The relative position of each technology was compared against the criteria based on professional experience.

It was concluded that reverse osmosis is the preferred technology against the criteria of energy consumption, greenhouse gas generation and cost of water.

Table 5.3 Assessment of Reverse Osmosis and Thermal Technology Against Non-Quantifiable Criteria

Criteria	RO-plant	MSF/MED-plant
Operability of technology – response to load changes	better	acceptable
Operability of technology – robustness of process, operator skills required	more difficult	good
Reliability and maintainability of technology	acceptable	better
Ease of plant start up / shut down	acceptable	acceptable
Ability to put plant in standby mode	acceptable	more difficult
Ability to scale down or stop production	good	more difficult
Interdependency with power station	not dependent	dependent
Land area requirements	less	more
Environmental impact of discharge (temperature)	minimal	significant

The above assessment shows that reverse osmosis is more favourable than thermal for most of the criteria. The only significant benefit of thermal over reverse osmosis is that the process is more robust. Thermal does not require a substantial pre-treatment plant and is less sensitive to changes in seawater quality.

On financial grounds and other criteria including greenhouse gas emissions and lack of power co-location opportunities, the most suitable desalination technology for Sydney is reverse osmosis.

However, the pre-treatment requirements of seawater reverse osmosis plants are well developed and there is a good understanding of pre-treatment issues within the desalination industry. As thermal plants require a co-located source of heat or steam there is significant risk of social impacts due to air quality and visual impact, and resistance from the local community would be anticipated.

Conclusion

On financial grounds and other criteria including greenhouse gas emissions and lack of power co-location opportunities, the most suitable desalination technology for Sydney is reverse osmosis.

6. Power and Greenhouse Emissions

6.1 Overview

One of the key objectives of the Planning Study was to assess the greenhouse implications of a desalination plant in Sydney. The greenhouse gas emissions associated with desalination make this a major consideration.

In developing options and in the assessment of the energy requirements and greenhouse gas emissions the objectives of the Planning Study were to:

- Minimise energy consumption and cost;
- Increase the generation and/or use of renewable energy;
- Minimise energy related greenhouse gas emissions; and
- Comply with all relevant energy related regulations.

6.2 Energy Requirements for Desalination Plants

The energy requirements for various sizes of reverse osmosis desalination plants are summarised in Table 6.1 below.

Table 6.1 Electrical Energy Requirements of Reverse Osmosis Desalination Options

ML/Day	Electricity Consumption GWh per year	Demand Megawatts (MW[12])
50	91	11
100	189	23
200	371	45
500	906	110

[12] One megawatt (MW) is one million watts.

It should be noted that a 500ML/day plant would result in a one-off increase in NSW's electricity demand of less than 1.2%.

It should be noted that a 500ML/day plant would result in a one-off increase in NSW's electricity demand of less than 1.2%, which would not occur until the plant was fully operational. This is against a current predicted ongoing annual increase of around three per cent due to the State's ongoing needs.

6.3 Power Supply

A broad range of power plant options have been analysed. Three primary options; 'grid' electricity (the existing mix consisting pre-dominantly of coal fired generation), gas-fired generation, and renewable energy using wind were

A co-located power plant would most likely be fuelled by natural gas due to local environmental, space and infrastructure constraints.

considered. Other renewables were not considered viable at the scale required for this project.

6.4 Electricity or Gas Power

Both supply of electricity from the grid and gas fired generation were considered. Two options were also considered for power plant location: co-location with the desalination plant and remote (where the supply is delivered via the electricity network).

A co-located power plant would supply electricity 'over-the-fence' to a desalination plant and would avoid network charges applying to grid electricity supplies. A co-located power plant would most likely be fuelled by natural gas due to local environmental, space and infrastructure constraints. This may require some augmentation of the local gas distribution network. Remote power sources may be either grid electricity (a combination of all generation sources feeding into the National Electricity Market) or a dedicated plant. Remote plants can use various technology and fuel options to supply electricity to the desalination plant via the transmission and distribution network.

An analysis was conducted that compared supplying power for either a 100ML/day plant or a 500ML/day desalination plant with power from a dedicated gas plant adjacent to the desalination plant (co-located) or electricity from the grid. The cost of power and the cost of water for the gas-powered desalination plant were calculated based on zero greenhouse gas mitigation. The costs of power and water for the grid powered desalination plant were calculated incorporating the cost of mitigation equivalent to the additional greenhouse gas emissions resulting from sourcing power (coal fired) from the grid. The results of this analysis are shown in Table 6.2.

Table 6.2 Power Costs – Co-located Gas versus Grid

	Power Plant for 100 ML/day RO Plant	Power Plant for 500 ML/day RO Plant
Total cost of power from (gas power) plant	$121/MWh	$66/MWh
Levelised cost of water	~$2.71	~$1.51
Total cost for power from Grid[13]	$67/MWh	$71/MWh
Levelised cost of water	~$2.46	~$1.53

[13] Mitigation costs for the additional greenhouse gases due to coal fired power have been included.

The cost of power for a 100ML/day plant is substantially higher from a base-load gas power plant, being 80% more expensive than electricity from the grid, and the cost of water is higher by approximately 10%.

For a 500ML/day plant the cost of power from a gas power plant co-located with a desalination plant is marginally lower than for electricity from the grid. However, the significant social and environmental impacts of locating a dedicated gas fired power plant in an urban area were not considered acceptable.

The cost of purchasing power for the desalination plant from a remotely located gas power plant was also considered. At this time, the cost of gas power is estimated to be significantly greater than for grid-supplied power. If the cost of gas power becomes more comparable to the cost of other energy options, then sourcing gas power via the grid could become the preferred option.

6.5 Renewable Energy Options

Table 6.3 provides an indicative comparison of the renewable energy options for supplying energy to the desalination plant (100ML/day requires 189 GWh/annum and 500ML/day requires 906 GWh/annum)[14].

[14] A straight-line multiplication cannot be applied due to scale up features.

[15] First figure applies to 100ML/day desalination plant (189 GWh/annum) and second figure applies to 500ML/day desalination plant (906 GWh/annum).

[16] Compared to grid power of $53/MWh.

Table 6.3 Renewable Energy Options

		For Power Plant[15]		
Option	Proven, Large Scale Technology	Land Requirements	Capital Costs $million	Energy Cost[16] of Renewable Energy $/MWh
Wind	Yes	1.5/6km^2	$140/$560	80-100
Wave	No (developmental)	Minimal	$200/$950	>200
Solar Photovoltaic	No (small scale)	1.5/7km^2	$1,000/$4,800	300-400+
Solar Thermal	No (developmental)	2/5km^2	$250/$700	100-200
Hydro Electric	Yes (limited/ small scale opportunities)	Project specific	Project specific	50-200 (project specific)
Landfill Methane	Proven but small scale	Large	Project specific	40-60
Biomass	Proven but small scale	Project Specific	Project specific	60-100

The only renewable energy option in Australia that is proven at a large scale is wind power. Other renewable energy options are not yet at the stage of development or scale suitable for desalination.

Rather than directly investing in renewable energy options for energy supply, which may prove to be technically and/or commercially unviable, purchase of renewable energy certificates is preferred as a greenhouse gas mitigation mechanism. These certificates are created by a variety of renewable energy sources and their sale allows the projects to achieve commercial viability. This market-based approach ensures the most viable projects proceed.

As the market grows and availability increases there may be opportunities to purchase renewable power at a comparable cost with other energy supply options.

6.6 Greenhouse Emission Estimates

Water desalination plants are energy intensive and this results in significant greenhouse gas emissions. To minimise this environmental impact, it is possible to mitigate to varying degrees the greenhouse gas emissions through one or more greenhouse reduction strategies.

Water desalination plants are energy intensive and this results in significant greenhouse gas emissions.

As with any large infrastructure project, additional greenhouse gas emissions are associated with the construction of a desalination plant due to the production of materials such as steel and concrete and actual construction activities. Emissions are also associated with the manufacture and supply of consumables such as membranes and chemicals.

Operational emissions together with material related emissions are termed "Life Cycle Emissions". Total life cycle greenhouse gas emissions associated with construction and operation of the desalination plant and power plant have been estimated for various options. Of the total emissions, five per cent are associated with the materials and construction stages, the remaining 95% with operation.

6.7 Greenhouse Reduction Opportunities and Costs

To minimise this environmental impact, it is possible to mitigate to varying degrees the greenhouse gas emissions through one or more greenhouse reduction strategies.

In general reduction options include:

- Purchase of power from lower greenhouse gas emission fuels, such as gas;
- Purchase of renewable energy certificates – issued by energy retailers to finance renewable energy schemes;
- Forestry Sequestration – tree planting; and
- Purchase of NSW greenhouse abatement certificates.

A summary of the Australian mitigation mechanisms is provided in Table 6.4.

For a 500ML/day plant, given market availability and program life spans, forestry sequestration and/or renewable energy certificates are the likely mitigation mechanisms as both these mechanisms are currently available in the market and will continue to operate throughout the life of a desalination plant. The NSW greenhouse abatement certificate scheme has limited supply (but may expand with increased demand) of certificates and will now operate until 2020, with potential for further extensions. The use of gas fired power will also be further considered.

Table 6.4 Summary of Australian Offset Mechanisms

Mechanism	RECs Renewable Energy Certificates	Forestry Sequestration	NGACs - NSW Greenhouse Abatement Certificates
Scheme	Renewable Energy Target	NSW Greenhouse Gas Abatement Scheme; Kyoto Compliant, Other	NSW Greenhouse Gas Abatement Scheme
Type	Mandatory Federal	Mandatory or voluntary NSW	Mandatory NSW
Certificate Units	MWh of renewable generation	tonnes $CO_{2\text{-}e}$	tonnes $CO_{2\text{-}e}$ (1NGAC=1 tonne $CO_{2\text{-}e}$)
Duration	April 2001 – Dec 2020	NGAC compliant: Jan 2003 – Dec 2012; Kyoto compliant: 2008 – 2012	Jan 2003 – Dec 2020 extensions possible
Objective	Renewable energy industry stimulus, greenhouse gas abatement	Greenhouse gas abatement	Reduction in greenhouse intensity of NSW electricity sector
Liable Parties	Australian electricity retailers	NSW electricity retailers plus voluntary purchasers	NSW electricity retailers
Compliance Liability	4% of total retailer sales by 2010	20% of total sales by 2012 (NSW electricity retailers)	20% of total retailer sales by 2012
Scheme Penalty	$57/MWh after tax	$15/tonne after tax	$15/tonne after tax
Current Market Price	$36/REC	$13-17/tonne $CO_{2\text{-}e}$	$12/NGAC
Market Demand	9,500,000 per year (2010-2020)	17,000,000 per year (2007-2012)	17,000,000 per year (2007-2012)
Market Availability	6,000,000MWh in 2007	Potential (5 year lead-time to establish forest)	None available in 2007

6.8 Greenhouse Reduction

The greenhouse gas reduction strategy adopted will influence the final levelised cost of water,[17] based on the amount of mitigation required.

If a decision for mitigation were required then the following levels of offsets can be considered (See Figure 6.1):

- Offsets equivalent to those required of NSW energy retailers - the cost over 20 years would be $40 million (NPV). This adds $0.02/kL to the cost of water.
- The cost to offset the additional greenhouse gas emissions from a 500ML/day desalination plant powered from the grid relative to:

1. a large scale potable recycled water plant supplying water to Warragamba Dam. The additional cost would be $75 - $155 million[18] (NPV) over 20 years from forest sequestration or purchasing Renewable Energy Certificates. This adds between $0.04 and $0.08/kL to the cost of water; or
2. a 500ML/day desalination plant powered exclusively from gas. The additional cost would be $85 - $175 million (NPV) over 20 years from forest sequestration or purchasing Renewable Energy Certificates. This adds between $0.05 and $0.10/kL to the cost of water.

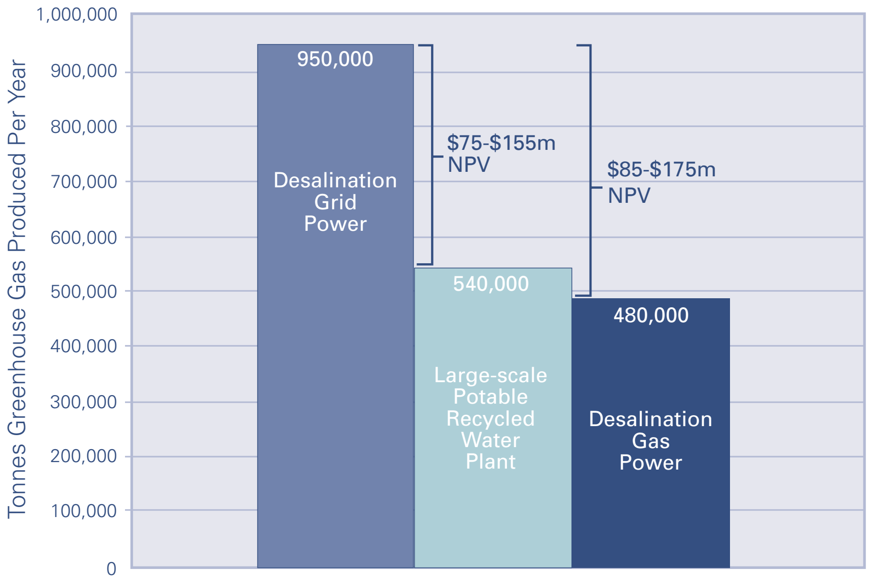
- The cost to fully mitigate greenhouse gas generation. The additional cost would be $170 - $350 million over 20 years from forest sequestration or purchasing Renewable Energy Certificates. This adds between $0.10 and $0.20/kL to the cost of water.

[17] Levelised water cost is defined as the Net Present Value of capital and operating expenditure divided by the net present value of water produced. Unless otherwise stated, levelised water costs have been calculated as a capacity factor of 100% and plant availability of 94%.

[18] Costs are based on estimates and could vary depending on where the effluent is treated and introduced into the water system.

The cost to mitigate greenhouse gas emissions would increase the cost of water. The cost increase would depend upon the mitigation strategy adopted.

Figure 6.1 Potential Offset Levels



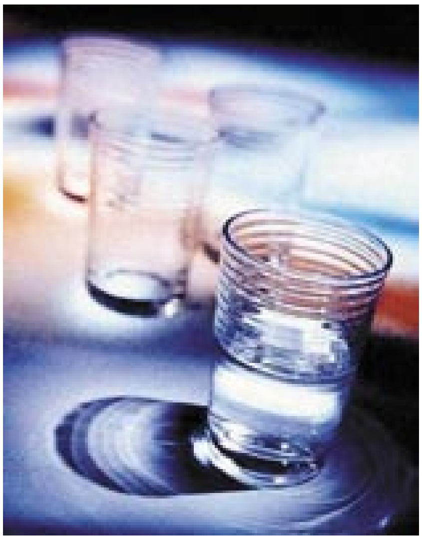
6.9 Conclusion

The cost to mitigate greenhouse gas emissions as discussed above would increase the cost of water depending upon the mitigation strategy adopted.

Once a target greenhouse offset is decided in the context of all the options in the Metropolitan Water Plan, an appropriate mitigation strategy will be finalised.

As the desalination plant will be a large user of energy, the construction of a desalination plant (with an associated greenhouse gas mitigation commitment) may encourage the development of renewable and other energy sources (such as gas) with lower greenhouse gas generation. In addition, the future energy market may be able to supply power to the desalination plant from these sources at a cost comparable to the offset options.

7. The Short-listed Desalination Plant Options



7.1 Overview

Of the fourteen short-listed sites for 50 to 500ML/day plants three locations were taken forward against the criteria of:

- location on the coast close to good quality seawater;
- effective discharge of seawater concentrate;
- access to power and the water distribution system; and
- ability to upscale to a larger size if required.

The locations identified are Kurnell, Malabar and Port Kembla. The sites identified are at:

- Kurnell – industrial land in close proximity to the oil refinery (three sites identified);
- Malabar – Sydney Water owned land and part of Commonwealth owned Anzac Rifle Range;
- Port Kembla – industrial land.

The northern beaches sites were eliminated due to the increased length of seawater access tunnels to reach suitable source water, the limited capacity of the local water distribution system and lack of suitable large sites. Other sites were rejected as source water was from a bay or estuary and of variable quality. Only Malabar and Kurnell are suitable locations for staging to a larger plant in the event of an ongoing drought.

Only Malabar and Kurnell are suitable locations for staging to a larger plant in the event of an ongoing drought.

7.2 Operational Philosophy

The designs presented in this report assume that when desalination plants are operating, they would be operated continuously at full capacity with an average plant availability of 94%. The drinking water from the plants would be pumped into the existing water distribution system at a location where the capacity of the infrastructure and the water demand would match the plant production. In most cases the existing water distribution systems flow from west to east. Hence a new desalination plant located on the coast would need some new infrastructure to transfer the water from the plant into the system to the west.

Desalinated water transmitted to Waterloo would essentially supply the Potts Hill supply zone, which serves areas as shown previously in Figure 5.2.

7.3 Kurnell Configurations

7.3.1 General

Three sites were identified at Kurnell that would be suitable for a desalination plant.

A 50ML/day plant could be constructed at Kurnell, and would deliver into the local water distribution system. A plant up to 500ML/day could be constructed with delivery to Waterloo Pumping Station.

For illustration purposes Figure 7.1 shows a possible 500ML/day desalination plant at one of the potential Kurnell sites[19]. Figure 7.2 shows one potential water distribution route for a 500ML/day plant at Kurnell. Figure 7.3 is a current aerial view at Kurnell. Figure 7.4 shows what a 500ML/day desalination plant could look like at Kurnell. Figure 7.5 shows what a 500ML/day plant could look like at one of the potential sites from Sir Joseph Banks Road, Kurnell.

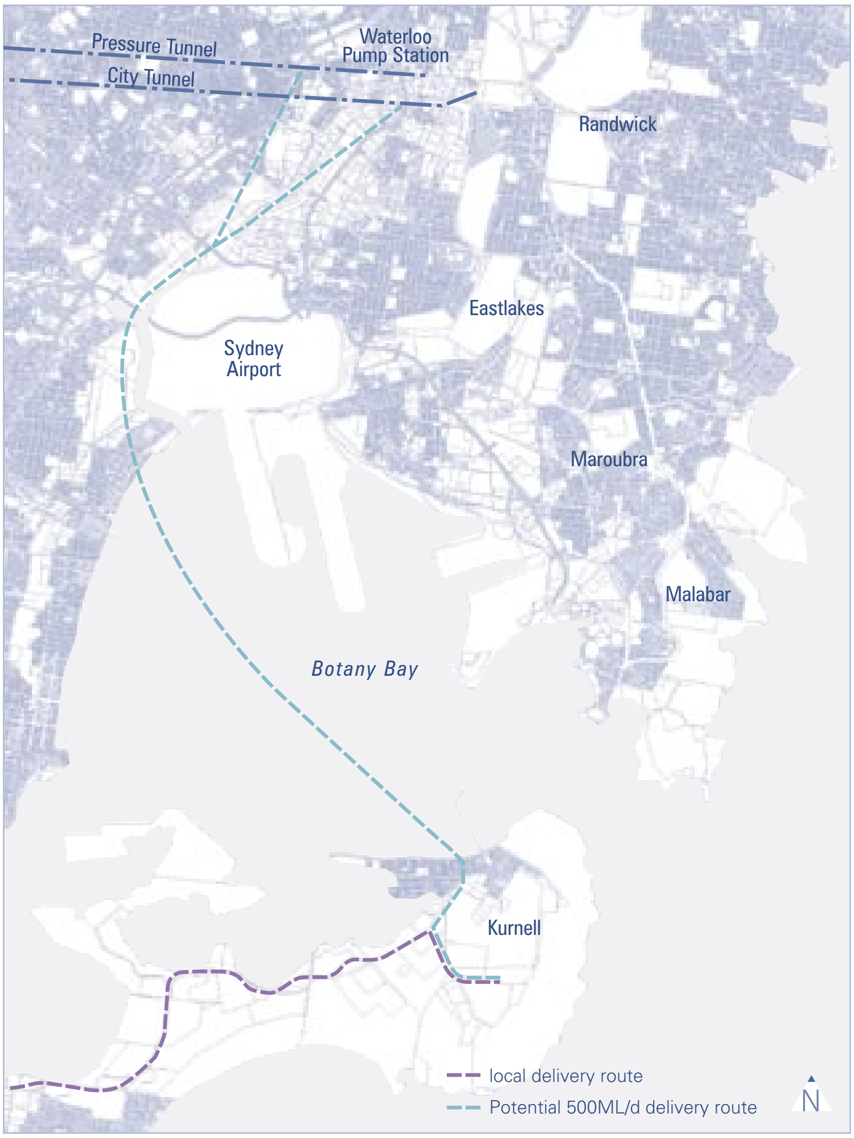
[19] There are three sites currently under consideration at Kurnell - this shows one possible site location.

7.3.2 Power Supply

The electricity network has capacity to supply all desalination plant capacities up to 500ML/day at Kurnell, i.e. there is no network augmentation required.

Figure 7.1 Possible 500ML/day Plant at one Kurnell Site

Figure 7.2 One Potential Water Distribution Route for a 500ML/day Desalination Plant at Kurnell



The sites vary in the level of modification in terms of vegetation cover. At this stage no site appears to have issues that cannot be managed.

7.3.3 Environmental Issues

At Kurnell the sites are not in close proximity to schools or residences and this reduces the sensitivity of the locality to any operational impacts of the proposal.

The sites vary in the level of modification in terms of vegetation cover. At this stage no site appears to have issues that cannot be managed.

The Botany Bay National Park is listed as a matter of national environmental significance under the Environment Protection Biodiversity Conservation Act, primarily due to the historical links to Captain Cook's landing place at Cape Solander that lies within the National Park. The general area also has aboriginal heritage significance. The three sites are adjacent to the oil refinery and some distance from the National Park and away from Cook's landing and are unlikely to have heritage significance.

As described in section 7.3.4, delivery of water greater than 50ML/day into the water distribution system from Kurnell will be via a pipeline or tunnel across Botany Bay. There would be no infrastructure in the National Park as any tunnels would be some 60-80 metres below the surface. Should the pipeline across the Bay be the preferred option then impacts on aquatic habitat such as seagrasses will need to be carefully managed.

Figure 7.3 Current Aerial View of Kurnell

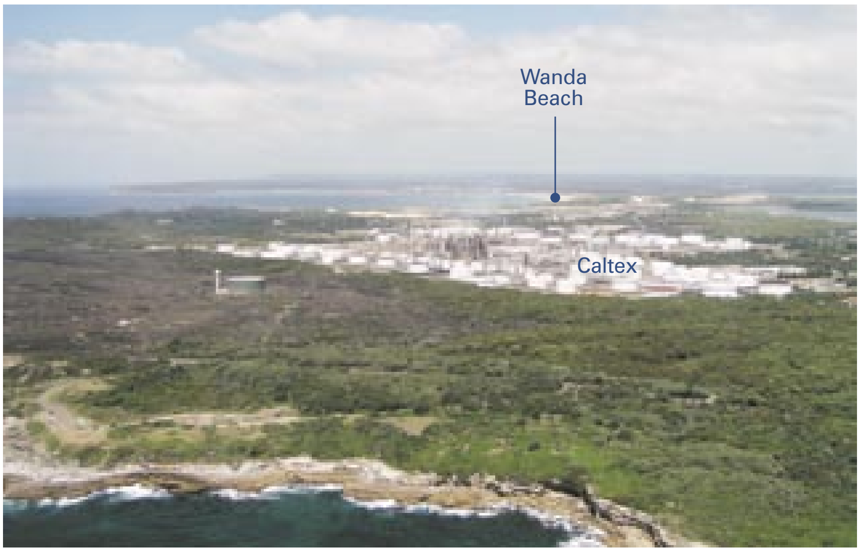


Figure 7.4 Aerial View of 500ML/Day Desalination Plant at Kurnell[20]

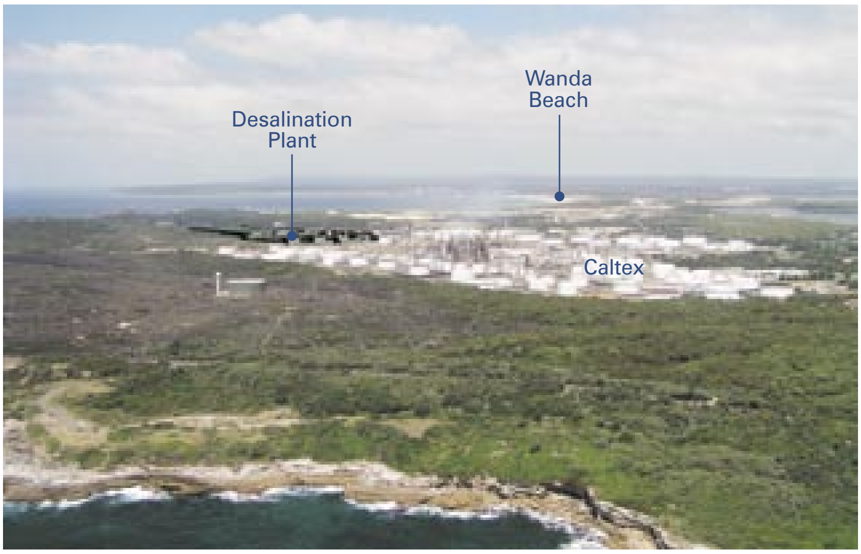
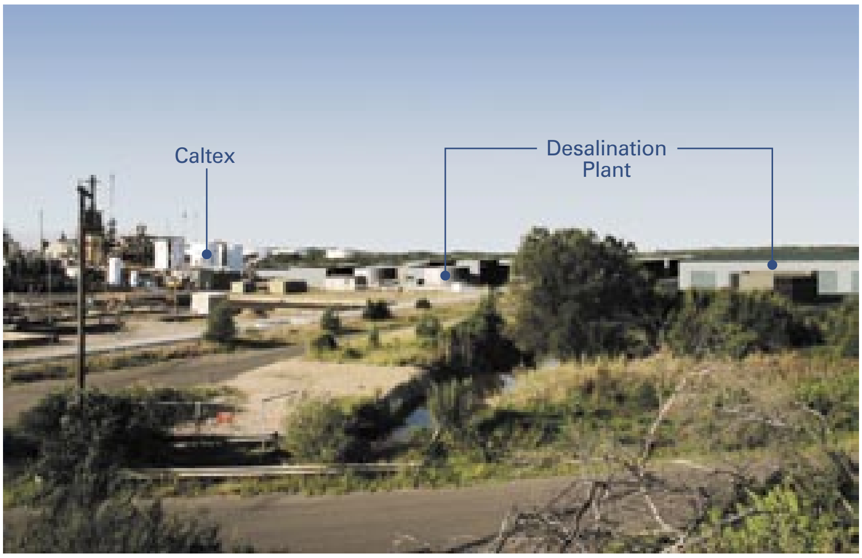


Figure 7.5 View of 500ML/Day Desalination Plant at Kurnell from Sir Joseph Banks Drive[20]



[20] There are three sites currently under consideration at Kurnell - this shows one possible site location.

7.3.4 Water Distribution

For a plant capacity of 50ML/day, the water can be distributed into the existing system about 11km to the west of Kurnell at Miranda. The water would be pumped from the plant through a new 750mm diameter pipeline and connect into the existing water network in Sutherland.

For a larger plant capacity from 100ML/day it would be necessary to convey the water to the north, for distribution. The water could be pumped through a pipe laid in a trench on Botany Bay and then conveyed via a tunnel to the Waterloo pumping station. Other options have been investigated including tunnelling under Botany Bay to Waterloo pumping station and horizontally directionally drilling under the bay. Horizontal directional drilling has been found not to be feasible.

There may be greater risks in tunnelling under Botany Bay due to the geological nature of the bay, which has the presence of glacial valleys (palaeochannels) and dykes with potential to delay construction. The pipe route across the bay is preferred as it provides greater certainty with respect to known risks and is able to be constructed in less time than the tunnel. The risk of delay is of particular importance for a drought response plant.

7.4 Malabar Configurations

7.4.1 General

Two sites were identified at Malabar that would be suitable for a desalination plant.

A 50ML/day plant could be constructed at Malabar on the Sydney Water site - visually the plant would blend in with the other facilities on-site. Drinking water delivery would be to the outlet main from Maroubra Reservoir, and could be constructed for a relatively low cost. A 100 to 200ML/day plant could be constructed at Malabar on the Anzac Rifle Range Site, and could also deliver water into the local water distribution system. A plant greater than 200ML/day could be constructed on the Anzac Rifle Range with construction of a large scale distribution tunnel to Waterloo.

Figure 7.6 shows a possible 500ML/day desalination plant on Malabar headland. Figure 7.7 shows one potential water distribution route for a 500ML/day desalination plant at Malabar. Figure 7.8 is a current aerial view of Malabar headland. Figure 7.9 shows what a 500ML/day desalination plant would look like at Malabar. Figure 7.10 shows a 500ML/day plant from Anzac Parade, Malabar. The plant would occupy less than 20% of the cleared area and would not encroach on the natural vegetation to the east or west.

7.4.2 Power Supply

The current electrical network capacity is capable of supplying a Malabar desalination plant up to 100ML/day. The energy needs of a 500ML/day plant at Malabar will require augmentation of the network to increase supply. Infrastructure planning indicates this would be completed by 2008.

21 Nominal site area selected.

Figure 7.6 Possible 500ML/day Desalination Plant at Malabar[21]

Figure 7.7 One Potential Water Distribution Route for a 500ML/day Desalination Plant at Malabar

Figure 7.8 Current Aerial View of Malabar

Figure 7.9 Aerial View of 500ML/day Desalination Plant at Malabar

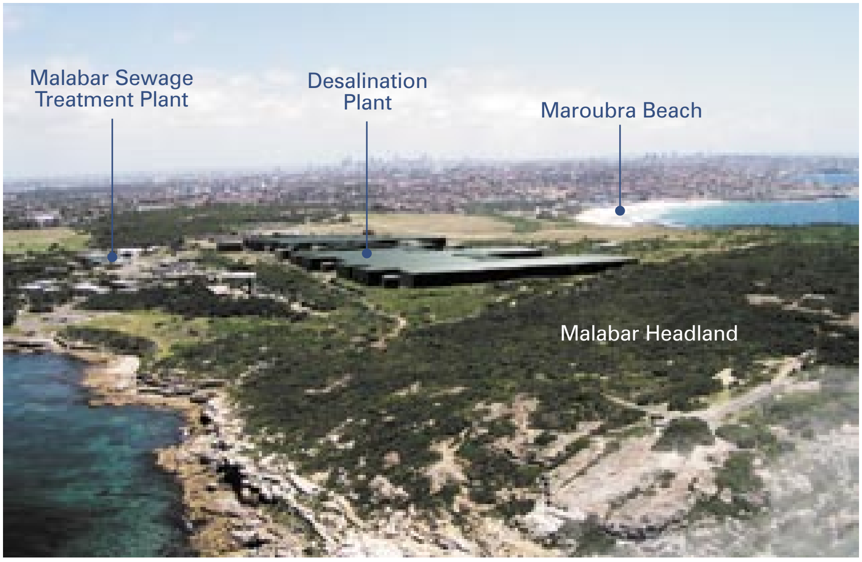
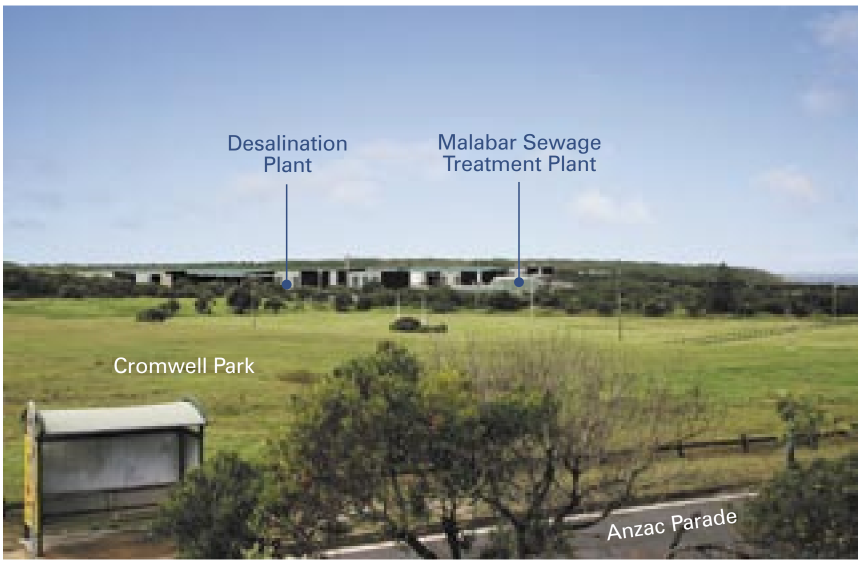


Figure 7.10 View of 500ML/day Desalination Plant at Malabar from Anzac Parade



A 500ML/day plant at Malabar would be very visible compared to a Kurnell plant and may require significant visual screening, which would impose a further cost.

7.4.3 Environmental Issues

At Malabar the site is in relatively close proximity to residential areas including schools, which increases the sensitivity of the locality to the potential operational impacts such as noise and traffic.

The Anzac Rifle Range site is an area of approximately 110 hectares and is bounded to the east and west by natural vegetation (total of 70 hectares) and to the south by Sydney Water's Sewage Treatment Plant site. A 500ML/day desalination plant would occupy 22 hectares (approximately 20%) of the cleared rifle range. The Anzac Rifle Range was formerly subject to uncontrolled filling with building and domestic waste and could potentially include some industrial waste. Due to its use as a functioning rifle range there is also heavy metal contamination.

In the context of a drought response plant the potential for time delays due to the unknown nature of the contamination would be significant and a further six to twelve months may be necessary to undertake remedial works.

A 500ML/day plant at Malabar would be very visible compared to a Kurnell plant and may require significant visual screening, which would impose a further cost.

As the Anzac Rifle Range is Commonwealth land, acquisition of a portion of the site would need to be agreed with the Commonwealth Government. In addition, approval from the Federal Minister for the Environment may be required if it is found that the Environmental Protection and Biodiversity Conservation Act 1999 applies. This approval would be in addition to any other approvals that may be required under NSW Environmental Planning & Assessment Act.

7.4.4 Water Distribution

The Malabar plant site is located within the Potts Hill Delivery System. For a plant capacity of 50-200ML/day the water could be conveyed into the local water distribution system without the need for construction of tunnel. A greater than 200ML/day plant would require construction of a large scale distribution tunnel to Waterloo. In terms of drought context it is preferable to plan for the full capacity required (500ML/day).

7.5 Port Kembla Configurations

7.5.1 General

A 50ML/day plant could be constructed at Port Kembla on a coastal industrial site. Visually the plant would blend in with the other adjacent facilities. Desalinated water could be pumped through a new pipeline from the plant to the Berkeley Reservoirs.

Water consumption in the Illawarra is approximately 100ML/day. It was assumed for the Planning Study that up to 50ML/day could be provided by a desalination plant and the existing water filtration plant would supply a baseload of 50 ML/day.

Figure 7.11 shows a possible 50ML/day desalination plant at Port Kembla. Figure 7.12 shows the potential water distribution route for a 50ML/day plant at Port Kembla. Figure 7.13 is a current ocean view at Port Kembla. Figure 7.14 shows what a 50ML/day desalination plant would look like at Port Kembla.

Figure 7.11 Possible 50ML/day plant at Port Kembla

Figure 7.12 Possible Distribution Route for a 50ML/day Desalination Plant at Port Kembla

7.5.2 Power Supply

The electrical network has capacity to supply a 50ML/day Port Kembla desalination plant and no network augmentation would be required.

7.5.3 Environmental Issues

The site is located in an existing industrial area that has been heavily modified by the development of Port Kembla and associated industries. There are no sensitive land uses, such as schools or residences, located in close proximity of the site, and this reduces the sensitivity of the locality to any operational impacts of the proposal.

Figure 7.13 Current Ocean View of Port Kembla

Figure 7.14 Ocean View of 50ML/day Desalination Plant at Port Kembla

7.5.4 Water Distribution

Desalinated water could be pumped through a new pipeline from the plant to the Berkeley Reservoirs, located about five kilometres to the west. From here the water could be distributed through the existing water supply systems to customers. The average demand in the entire Illawarra Delivery System is approximately 100ML/day under Level 2 restrictions, so a plant of 50ML/day capacity could supply approximately 50% of the demand in the system. There is land available for a 100ML/plant, if it were required.

It should be noted that as Sydney's water supply is integrated (refer figure 5.1), any reduction in the use of dam water by Sydney, through a supplementary supply such as desalination, would result in that amount of water being available for Illawarra.

7.5.5 Pumping from the Illawarra

The option of pumping desalinated water over the Illawarra escarpment to Lake Avon with a view to supplementing Sydney's supply was also considered. Pumping costs against the pumping head (approximately 350 metres) were calculated to be $2.5 million per annum for a 100ML/day plant or $12.4 million for a 500ML/day plant.

The increased energy required for pumping increased the greenhouse gas emissions by 25%. In addition the environmental impacts of transferring the water from Lake Avon via the Avon River were considered to be potentially significant and the option was thus ruled out.

7.6 Summary

As a drought response measure, Kurnell is the preferred location for constructing a plant up to 500ML/day in size. A pipeline laid across the bay would be required for connection of the water into the water distribution mains. The location of the plant would be in an industrial zoned area of Kurnell. Environmental impacts to be assessed and managed include the potential presence of threatened species at the site(s) and marine impacts associated with pipeline construction.

A 500ML/day plant could also be constructed at Malabar as a drought response measure. However, it presents higher risks of guaranteeing delivery to meet the water supply timeframe during continuing drought. The extent and nature of any contamination at the Malabar site is unknown, as the site has been used for uncontrolled filling. The complexities of managing land use issues, potential contamination and ease of construction issues could result in significant delays at the Malabar location.

As a drought response measure, Kurnell is the preferred location for constructing a plant up to 500ML/day in size.

Outside the context of drought, Port Kembla is suitable for a small baseload plant of 50ML/day. At Kurnell, a 50ML/day plant could be constructed and water distributed into the local distribution system. In a non drought context 200ML/day could be distributed locally at Malabar. At Kurnell and Malabar, further staging could occur as needed, including the construction of the major infrastructure to connect to the water distribution system at the next stage.

In the context of responsible planning it is prudent it keep options open which could meet both long-term water supply needs and respond to a drought if required. A site that enables a plant to be progressively sized larger, i.e. staged, would provide the most suitable vehicle to meet these needs.

8. Financial Analyses

Based on the options developed, cost estimates were generated for plants of various capacities. For the purposes of this comparison it was assumed that all plants were constructed in a single stage and that the plants used grid power. A fast-track process for delivery of a 500ML/day plant at Malabar or Kurnell has a minimum estimated time for construction of 26 months. This timeframe is based on a Malabar option with a manageable site acquisition and preparation scenario and a Kurnell option with a pipeline across Botany Bay.

The total capital expenditure and the levelised water cost for the Kurnell, Malabar and Port Kembla options are summarised in Table 8.1. It should be noted that all costs presented here and elsewhere in this chapter include both a desalination plant and the associated infrastructure such as intake, outfalls, delivery infrastructure and land.

Table 8.1 Desalination Cost Summary

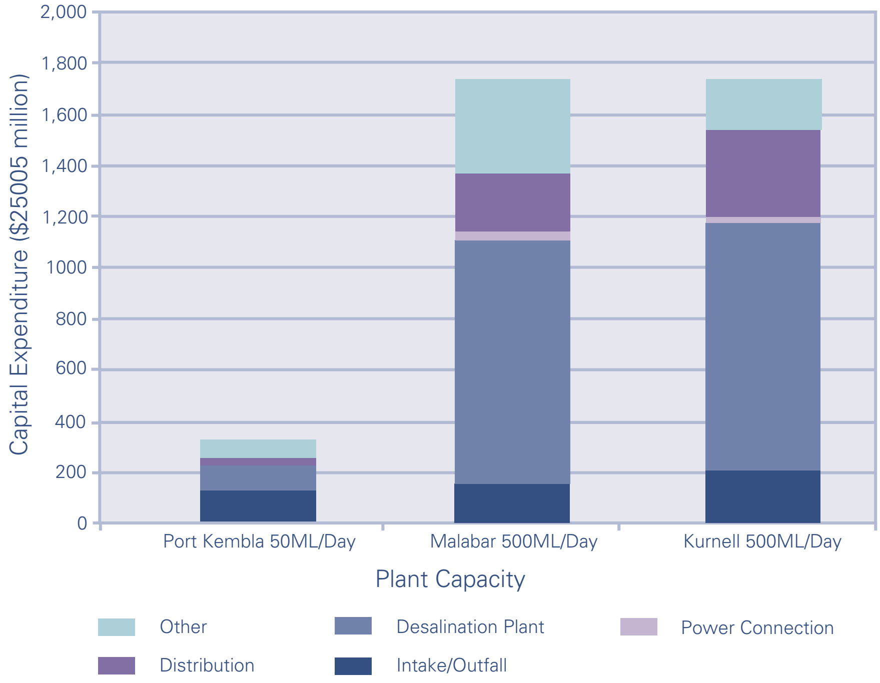
Option	Capacity (ML/day)	Total Capital Expen-diture ($2005 M)[22]	Total Levelised Water Cost ($2005/ kL)[23]	Minimum Con-struction Time (months)	Intake/ Outfall	Delivery Infra-structure
Kurnell Fast track 500ML/ day	500	1,750	1.44	26	Two separate tunnels	Local pipe, pipe across Botany Bay and tunnel to Waterloo
Malabar Fast track 500ML/ day	500	1,750	1.44	26	Two separate tunnels	Local pipe and tunnel to Waterloo,
Port Kembla 50ML/ day	50	330	2.30	24	Single tunnel	Local pipe

[22] Capital expenditure is presented as P80 (value with a 80% probability of not being exceeded), includes the required land area, in 2005 dollars.

[23] Greenhouse gas mitigation is not included.

Figure 8.1 shows the capital cost breakdown for the three locations.

Figure 8.1 Capital Cost Breakdown at Port Kembla, Malabar and Kurnell



Operating Costs

Operating cost estimates include, desalination plant, associated pumping, water treatment, chemical costs, waste disposal costs and maintenance.

Figures 8.2 and 8.3 show the breakdown of operating costs for 50ML/day and 500ML/day plants.

Figure 8.2 Operating Cost Breakdown for a 50ML/day Desalination Plant

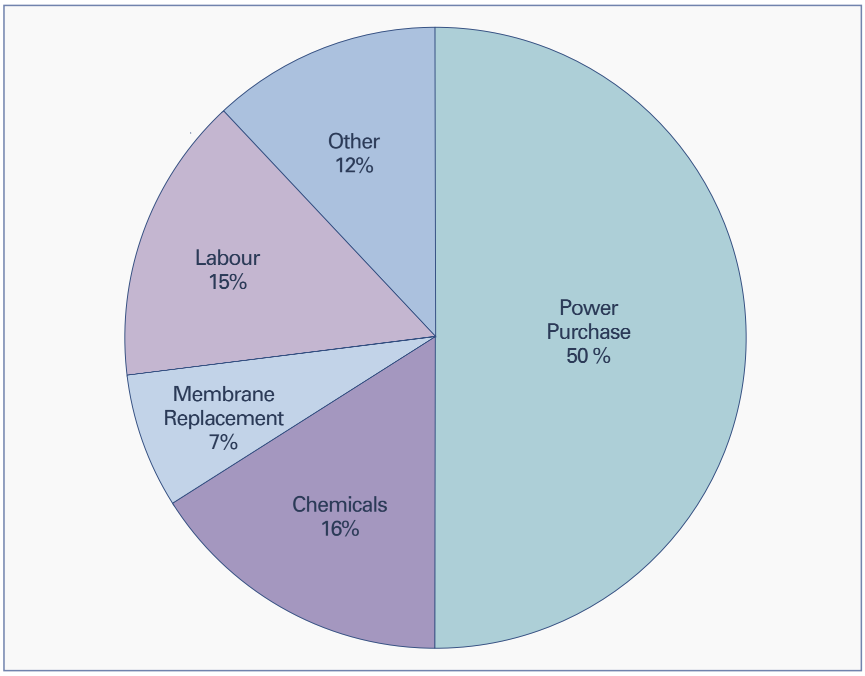
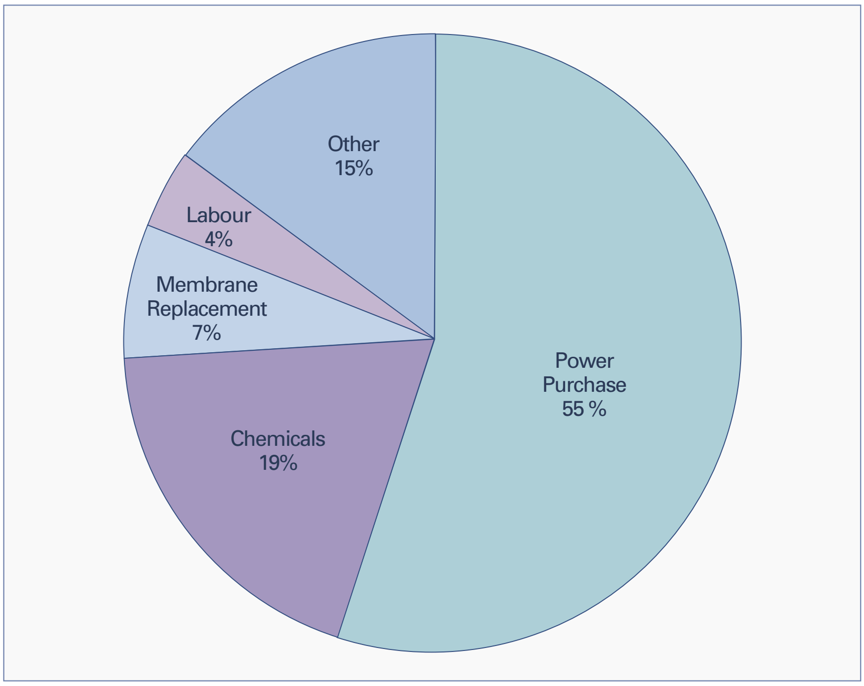


Figure 8.3 Operating Cost Breakdown for a 500ML/day Desalination Plant



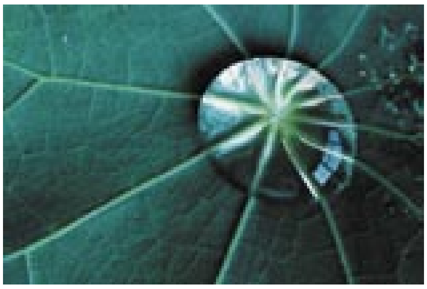
9. The Next Steps

The Planning Study has identified three potential locations of which only Malabar and Kurnell are suitable for staging a desalination plant up to 500ML/day.

Technical and environmental investigations on Malabar and Kurnell have shown that the costs to construct are similar for both sites. If the project is fast-tracked to respond to continuing drought, Kurnell is the preferred option. At Malabar, the time taken to purchase and prepare the land may potentially cause a significant delay. There may also be significant delays associated with remediation of the Malabar site.

An implementation program has been developed for construction of up to a 500ML/day desalination plant in the event of ongoing drought. This program includes the following:

- Environmental assessment and approvals including display and public comment;
- Commencement of the procurement process:



1. Seek expressions of interest from the private sector – end of June 2005;
2. Be in a position within 22 weeks to engage contractors in a competitive process to complete pre-construction testing, design and costing; and
3. Following a further 32 weeks be in a position to award a contract for construction, operations and maintenance if necessary.

Actual progress will be dependant on climatic conditions, success of other supply and demand measures such as groundwater investigations and demand management initiatives.