



## 8. Desalination Scenarios

Eight scenarios have been developed to demonstrate the issues associated with and influencing the selection of desalination processes. The following 8 scenarios have been selected to represent the various water qualities and requirements faced by Queensland communities.

**Table 8-1 Queensland Desalination Scenarios**

No.	Feedwater Source	TDS Concentration mg/L	Desalination Plant Capacity	
			Equivalent Population (EP)	kL/d (Technology)
1	Seawater	37,800 mg/L	800	200 (RO)
2	Seawater	35,000 mg/L	30,000	Alternative A: 20,000 (RO) Alternative B: 9,000 (RO) Alternative C: 20,000 (MED)
3	Ground Water	2,000 mg/L	5,000	Alternative A: 1,700 (RO) Alternative B: 1,700 (EDR)
4	Ground Water	3,000 mg/L	1,500	Alternative A: 1,500 (RO) Alternative B: 450 (RO) Alternative C: 1,500 (EDR)
5	Bore Water	3,400 mg/L	Alternative A: 100 Alternative B: 100 Alternative C: 2.5	Alternative A: 100 (RO) Alternative B: 30 (RO) Alternative C: 1.5 (RO)
6	Artesian Water	1,045 mg/L	3,250	Alternative A: 3,900 (RO) Alternative B: 975 (RO) Alternative C: 3,900 (EDR)
7	Brackish Water	2,900 mg/L	10,000	Alternative A: 10,000 (RO) Alternative B: 3,000 (RO)
8	Coal Seam Methane	3,880 mg/L	800	Alternative A: 400 (RO) Alternative B: 400 (TVC)

Lacking reliable water quality data and other site specific information, the cost estimates presented in this section have been developed solely for the purpose of comparing and evaluating options for various locations and types of feed water. They are sufficiently accurate to serve this purpose. They cannot be used directly for budget-setting purposes as common elements between options may have been omitted and/or the works not fully scoped. A functional design is recommended if a budget estimate is required.



Explanations on how the various capital and operating costs have been developed are provided below. In developing the cost estimates it should be noted that no attempt has been made to optimise the systems. Careful design and monitoring of the desalination plant, whilst operational, may in fact reduce both capital and operating costs.

### **8.1 Capital Cost explanations:**

- ▶ The total capital costs developed for each scenario provide allowance for all process, civil, mechanical and electrical works, with additional allowance for on-costs such as engineering, planning and design, and contingency. These costs also include ancillary capital costs associated with desalination plants such as pre- and post-treatment, brine disposal, and delivery of the water to and from the plant. Excluded are the land costs for the desalination plant (if required) and brine disposal infrastructure (such as evaporation lagoons and ocean disposal structures).
- ▶ The allowance for engineering, planning and design is assumed to be 15% of the process, civil, mechanical and electrical capital costs. This allowance would cover such costs as planning reports, environmental studies and approvals; geotechnical studies; detailed design and/or tender document preparation; pilot plant trials (in the case of larger capacity plants); and water quality testing.
- ▶ Given the generic nature of these scenarios a 25% contingency has been assumed.
- ▶ Capital costs reported in these scenarios are based on figure 4.2 in Section 4.1.1.

### **8.2 Operating and Maintenance Costs explanations:**

For each scenario the following operating and maintenance costs have been itemised:

#### ***Power costs***

In viewing the operating and maintenance costs, in general no attempt has been made to optimise the power requirements.

- ▶ For RO facilities, the high pressure RO delivery pumps represent the highest energy consumption. The RO feed pumps have been estimated using an RO sizing program. An allowance has been made for the energy requirements of ancillary equipment associated with RO facilities. For seawater an allowance of approximately 7% of the RO power requirements has been assumed, and for brackish water an allowance of approximately 40% of the RO power requirements has been assumed. The cost of electricity has been assumed as \$0.10/kWh. For RO units using power generators (Gen sets) the cost of power is assumed to be \$0.30/kWh based on a 3 kWh/L (assumed diesel cost of \$0.90/L).
- ▶ For EDR technologies the allowance for power consumption has been assumed as 1 kWh/kL at 1,500 mg/L TDS. For every 1,000 mg/L TDS thereafter, 0.5 kWh has been added to the total power consumption. The same allowance has been assumed for ancillary equipment as for RO plants.
- ▶ Thermal technologies such as MED and TVC use gas or steam energy respectively as the main power source. The cost of gas has been assumed as \$5/GJ and the cost of steam assumed as \$2/GJ.



**Chemical costs**

Actual chemical dosage rates (thus costs) would depend on the desalination process selected, the raw water quality and the processes tolerance to various contaminants.

- ▶ These have been assumed as 0.6% of the process, civil, mechanical and electrical costs for RO plants treating seawater. For RO plants treating brackish water chemical costs have been assumed as 1% of the civil, mechanical and electrical costs.
- ▶ For MED, VC and EDR desalination facilities the chemical cost allowance has been assumed as 0.5% of the process, civil, mechanical and electrical costs.

**Labour costs**

For the purposes of these scenarios, labour costs have been calculated based on the plant capacity. The cost of operator time has been assumed as \$40/hour.

Depending on the level of optimisation required, it may be necessary to have access to a process engineer (or equivalent) to perform trouble-shooter exercises and provide general operational advise. An allowance has been made in the cost estimates for each scenario. The cost of a process engineer (or equivalent) undertaking a troubleshooting role has been estimated as \$120/hour. For remote communities the travel costs associated with transferring skilled technicians to site are not included in this section.

For desalination plants less than 5 ML/d an allowance for 5 hours per week for the first 3 months, and 8 hours per month for the remainder of the year (9 months) has been made. For every year thereafter 1 day per month has been allowed for in the cost estimates. For plants greater than 5 ML/d the hours are doubled. Refer to Table 8-3 for troubleshooter time requirements.

It should be noted that the operator/troubleshooter hours have been used for comparative purposes only. In reality some plants may prefer to devote less attention on the desalination system and pay a premium in other operating and maintenance costs.

- ▶ Refer to Table 8-2 for operator time requirements for RO plants.
- ▶ For EDR plants less than 1 ML/d, it has been assumed that approximately 15 hours of operator time will be required every week to perform general day to day operation activities. For larger plants this value has been increased to 20 hours per week.
- ▶ For MED facilities an allowance of 40 hours per week for larger plants has been assumed. For a small TVC plant, it has been assumed that 15 hours per week of operator time will be required.

**Table 8-2 Operator Labour Requirements for RO Desalination Facilities**

<b>Plant Capacity (ML/d)</b>	<b>Operator Man-hours Required (hr/wk)</b>
0 – 0.5	3
0.5 – 2	6
2 – 5	20
5 – 10	30
10 – 20	40



**Table 8-3 Troubleshooter Labour Requirements for RO Desalination Facilities**

<b>Plant Capacity (ML/d)</b>	<b>Troubleshooter Man-hours Required (hr/year)</b>
0 – 5	132 (first year) 96 hours (every year thereafter)
5 – 20	264 (first year) 192 (every year thereafter)

**Membrane Replacement Costs (RO and EDR)**

- For RO plants the membranes require replacement every 3 to 5 years. On plants where no optimisation is undertaken the membrane replacement frequency will be approximately 3 years. This replacement frequency is extended to 5 years when the plant is optimised. We have assumed that the membranes will cost approximately 10% of the civil, electrical and mechanical works to replace. On large plants (typically greater than 1.5 ML/d) it has been assumed that the membranes will be replaced every 5 years.
- EDR membranes typically have a slightly longer lifespan than RO membrane, being 5 to 10 years. Anecdotal evidence suggests that the life span of these membranes can be increased to greater than 10 years. For the purposes of these scenarios it has been assumed that the membranes will be replaced every 5 years, assuming a low level of maintenance is performed on the system. With careful operation and maintenance the lifespan of the membranes may be increased to 10 years. It has been assumed that the cost to replace these membranes will be approximately 1% of the process, civil, electrical and mechanical costs.

EDR systems will also require the electrodes to be replaced every one to two years depending on the design of the system. An allowance for electrode replacement has been incorporated into the membrane replacement cost allowance.

**Maintenance Costs**

An allowance of 1.5% of the process, civil, electrical and mechanical costs has been assumed for general maintenance activities. For RO unit using gen sets an additional \$0.30/kWh has been allowed for maintenance of the generator.



## Scenario 1 – 200 kL/d Seawater Source

### Background Information

This scenario is based on a small coastal community of approximately 800 people, with an average potable water demand of 200 kL/d. The town currently sources its potable water from a ground water supply. The ground water source however is rapidly diminishing as a result of the recent drought conditions.

As the town is located less than 3 km from the coast, seawater has been identified as an alternate water supply. This scenario therefore addresses the feasibility of using desalination technology to treat seawater to a standard acceptable for potable water consumption by the community. Council have also shown an interest in a portable unit that can be shared between several small towns.

### Source Water Details

#### Location

Water is currently extracted from a ground water source located approximately 3 km inland from the coast. This site would be preferred for locating the desalination facility as:

- ▶ It is within close proximity of a suitable seawater intake location.
- ▶ Mains power is available to the site.
- ▶ Site currently owned by Council.
- ▶ Provides close connection into existing water reticulation system.

The actual intake location would depend on the results of coastal and hydrographic surveys. Seasonal variation on water quality and water depth may also influence final intake location selection.

#### Quality

Water quality is not currently available for the proposed intake structure location. In the absence of site specific information, seawater quality results from the Gladstone area have been used. The adopted seawater quality is provided below.

Water Quality Parameter	Unit	Value
pH	-	8.3
Temperature (max)	°C	30
TDS	mg/L	37,800
Ba	mg/L	0.01
Ca	mg/L	402
K	mg/L	616
Mg	mg/L	1320
Na	mg/L	11700
Sr	mg/L	11.1
Cl	mg/L	20800
F	mg/L	1.10
HCO <sub>3</sub>	mg/L	147.51
SO <sub>4</sub>	mg/L	2880
Si	mg/L	4
CO <sub>3</sub>	mg/L	8.63
CO <sub>2</sub>	mg/L	0.72

It is recommended that site specific water quality data is collected and analysed



## Scenario 1 – 200 kL/d Seawater Source

prior to detail design. It is recommended that the sampling program covers seasonal variations in seawater quality, including impacts of storm activity and fresh water input on suspended solids and temperature variations. More details on sampling requirements for pre-treatment can be found in Appendix C.

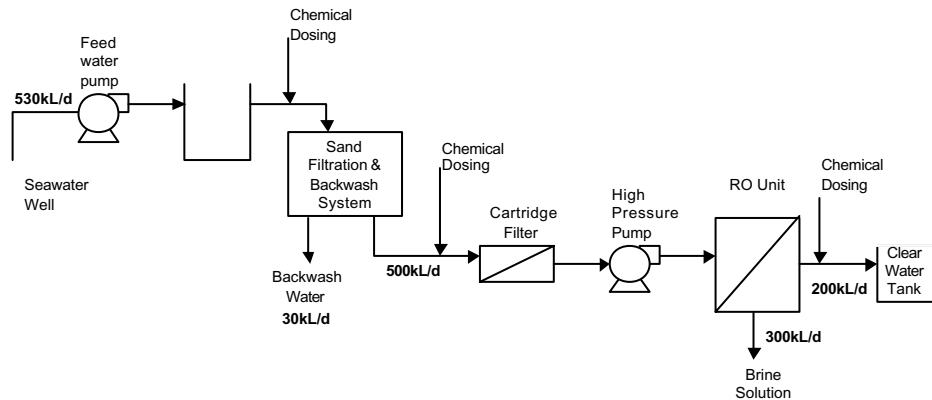
### Product Water Details

<b>Location</b>	The desalination facility would be located at the existing water treatment plant. Treated water would be fed directly into the existing clear water tanks, where the treated water would undergo pH correction and disinfection using existing infrastructure.
<b>Quality</b>	The product water would be suitable for potable use, with a target TDS concentration below 500 mg/L.
<b>Quantity</b>	In order to meet peak summer demands the desalination facility would need to be capable of producing 200 kL/d. The desalination facility would meet the entire water supply demand of 250 L/P/d.

### Desalination Technology

<b>Selection</b>	<p><b>Energy Considerations:</b> The desalination facility would be located at an existing water treatment plant therefore mains energy would be available. There is no economical waste heat source in the vicinity of the plant. This limits the technology choices to processes that use electrical energy, such as membrane technologies and mechanical vapour compression technologies.</p> <p><b>Feed water considerations:</b> The raw water source is seawater, with a correspondingly high TDS level.</p> <p><b>Selection using Decision Tree (Section 5)</b></p> <p>Since the source water has an elevated TDS and the existing water supply is diminishing, a higher quality/quantity of fresh water is required. Mains electricity is available, however there is no waste heat source available at the selected site. The feed water TDS is less than 44,000 mg/L and greater than 12,000 mg/L. The decision tree shows that seawater reverse osmosis (SWRO) would be the most appropriate technology to use in this scenario. RO is therefore considered further.</p> <p>An RO system can also be built and packaged as a containerised unit. This would allow the unit to be portable. The intake brine disposal structures however would need to be permanent for each site.</p>
<b>Technology Description</b>	<p>The RO system would include pre-treatment, cartridge filters, high pressure feed pumps, high pressure vessels containing RO membrane, brine recovery system and permeate recovery system.</p> <p>The following diagram schematically describes the RO system. A feed water flow rate of 530 kL/d would be required to produce 200 kL/d of product water (based on 95% efficiency for the sand filter and 40% recovery from the RO unit).</p>

## Scenario 1 – 200 kL/d Seawater Source



### Pre-treatment Requirements

Pre-treatment to remove particulate matter, scalants and condition the seawater prior to the RO unit is necessary. The following pre-treatment steps would be required:

- ▶ Chemical dosing to coagulate colloidal material that may be present in the water and improve the pre-filtration process.
- ▶ Sand filtration to reduce the turbidity levels
- ▶ Acid dosing for pH correction. Acid dosing is typically undertaken using sulphuric acid and helps to keep scale forming chemicals in solution thereby reducing scaling of the RO membranes.
- ▶ Anti-scalant dosing may also be required to improve the membrane performance and life. There are a number of proprietary anti-scalants on the market and the selection of the right chemical is best carried out by the RO supplier or during detail design phase.

### Post Treatment Requirements

The RO system described above would produce a high quality permeate. The permeate however may require the following post-treatment steps to ensure its suitability for potable water purposes:

- ▶ Chemical dosing for pH correction and alkalinity recovery
- ▶ Chemical dosing for water conditioning
- ▶ Disinfection.

### Waste Management

The RO process produces two main waste streams:

- ▶ A highly saline brine stream.
- ▶ Backwash waters from the pre-treatment processes.

In addition to contaminants removed from the feedwater, the brine and backwash waters will also contain chemicals used in pre-treatment and cleaning. For a plant producing approximately 200 kL/d of product water, approximately 330 kL/d of waste product will be produced. This waste would have a TDS concentration of over 60,000 mg/L.

It is recommended that the brine and backwash waters be returned to the ocean. This is the most commonly adopted brine disposal option for seawater desalination facilities. A coastal study would be required to best select the brine disposal



## Scenario 1 – 200 kL/d Seawater Source

location to ensure short-circuiting of the brine solution to the feed intake location does not occur. Environmental Protection Authority (EPA) approval would be required for ocean disposal of the brine.

### Environmental Factors

Environmental factors that would require further investigation include:

- ▶ Impact of the water extraction and brine disposal on the coastal environment.
- ▶ Noise emissions associated with the high-pressure pumps. Acoustic housing may be required.
- ▶ On-site chemical storage.

EPA approvals under Environmental Relevant Activity (ERA) 16 (Municipal water treatment plant) would be required. The disposal of brine into ocean would fall under a separate ERA. It is recommended that the EPA be consulted regarding the approvals required.

### Operational and Maintenance Requirements

#### Labour

The day to day operations (daily visual inspection and meter reading) and general maintenance (including changing membranes) would be carried out by existing Water Treatment Plant (WTP) personnel. It is not envisaged that additional personnel would be required to operate and maintain the RO plant, however access to a process engineer (or equivalent) may be required to perform troubleshooting exercises and provide general advise regarding operation. For a plant of this capacity approximately 3 hours/week of operator time would be required.

An allowance to seek advice from a troubleshooter should be made. This allowance may vary depending on the level of optimisation Council wish to achieve. The first year of operation will require significantly more troubleshooter time. For this scenario an allowance of 5 hours per week for 3 months, then 8 hours per month for the remainder of the year (9 months) has been made. Troubleshooting requirements are expected to decrease with time.

Suitable training from the RO supplier would be recommended to increase the skill level of the operators to cover RO technology. The 'trouble-shooter' personnel would require slightly more training and it is recommended that this person be experienced in operating desalination facilities.

The intake structures would also require regular inspections and maintenance, particularly after storm activity and rough conditions.

#### Chemical Requirements

Chemical requirements would include:

- ▶ Acid dosing and/or anti-scalant dosing for pre-treatment.
- ▶ Chemical dosing (eg lime, soda ash etc) for product water conditioning/pH correction (post treatment).
- ▶ Disinfection (post treatment).



## Scenario 1 – 200 kL/d Seawater Source

**Energy Requirements** The RO energy requirements would be dominated by the high pressure RO feed pumps and the seawater delivery pumps. It is estimated that the daily energy requirement would be in the order of 1.6 MWh/day.

The energy requirements of the RO plant would be met by mains supply. It may be necessary to upgrade the electrical supply into the existing WTP. It may also be necessary to supply power to the seawater extraction pumps or upgrade existing supplies. Discussions would need to be held with the relevant energy company to determine the scope and cost of any upgrade.

**Membrane Replacement** RO membranes require replacement every 3 to 5 years due to the deterioration of the membrane, thus decreasing the efficiency of the RO process. In the case of this scenario, it has been assumed that the membranes will be replaced every 3 years. The increased costs associated with membrane replacement are offset by lower man-hours and chemical consumption.

### Costs

**Capital** The capital costs (including civil, mechanical and electrical costs) associated with providing an RO system are in the order of \$1.8M (including 15% engineering/design and 25% contingency). This cost estimate is based on the following assumptions:

- ▶ Land cost is negligible (the RO facility would be located at the existing WTP).
- ▶ Brine can be discharged back to the ocean (via a discharge 3 km pipeline).
- ▶ A seawater intake structure and 3 km rising main will be developed and costs associated with the intake structure would be additional to the RO costs provided in this scenario.
- ▶ The product water can be fed directly into the existing WTP clear water tanks.

The above costs are indicative only, a pilot plant is recommended to confirm design feasibility and refine pre and post treatment requirements.



## Scenario 1 – 200 kL/d Seawater Source

**Operational & Maintenance** The annual O&M costs for this system have been estimated at approximately \$151,200 (first year of operation only).

A breakdown of the O&M costs are provided in the following table:

Annual allowance for membrane replacement:	\$ 43,400
Calculated based on 10% of the capital (excluding contingencies) and to be replaced once every 3 years.	
Power usage:	\$ 58,300
Based on 10c/kWh.	
Chemical consumption:	\$ 7,800
Based on 0.6% of capital (excluding contingencies).	
Labour	
Operator Costs	\$ 6,300
\$40/hour, 3 hours/week.	
Trouble shooter Costs (first year only)	\$ 15,900
\$120/hour as required	
Maintenance:	\$ 19,500
Based on 1.5% of the capital (excluding contingencies).	



---

## Scenario 2 – 20 ML/d Seawater Water Source

---

### Background Information

This scenario is based on a coastal community who is experiencing increases in their potable demands. Raw water is currently drawn from a local dam and pumped to the community's Water Treatment Plant (WTP). An additional effective population (EP) of 30,000 will raise the potable flow by 20 ML/d during the peak summer period.

Environmental restrictions inhibit any increases to the capacity of the local dam and the current WTP has reached its output capacity.

This scenario therefore addresses the feasibility of using a desalination technology to treat seawater to a standard acceptable for potable water consumption by the community. For comparative purposes this scenario investigates two scenarios:

- The desalination plant would cater for the peak summer potable water demand of 20 ML/d (670 L/P/d).
  - Using water conservation techniques and limiting water usage to in-house use only, the potable water demand would be reduced to 300 L/P/d (9 ML/d).
- 

### Source Water Details

---

#### Location

The raw water intake point would be located along the ocean floor, 2.0 metres offshore from a marina's constructed groyne. The intake structure would consist of screens, seawater pumps, manifolds and valves. This structure would be located within the groin minimising the aesthetic impact to the coastal community and providing a stable base for the intake structure.

#### Quality

Seawater sampling has been undertaken from this location following the development of the marina. Average water quality parameters are described below:

Water Quality Parameter	Unit	Value
NaCl	mg/L	29300
NaHCO <sub>3</sub>	mg/L	200
Mg SO <sub>4</sub>	mg/L	9400
TDS	mg/L	35000

Further seawater sampling would be required to fully determine pre-treatment requirements. It is recommended that raw water quality sampling is carried out over the course of year, to ensure seasonal variations and water quality variations are captured, as the performance of a desalination system is dependant on the raw water quality. Further details regarding the sampling monitoring requirements is provided in Appendix C.

---

### Product Water Details

---

#### Location

The desalination facility would be located within council designated land, about 200 metres from the seawater intake structure and 2 km away from a point where a connection into the potable reticulation system is possible. Treated water would undergo pH correction and disinfection prior to its distribution to the network.

#### Quality

The product water would be suitable for potable use, with a target TDS concentration below 500 mg/L.

---



---

## Scenario 2 – 20 ML/d Seawater Water Source

---

**Quantity** In order to meet peak summer demands the desalination facility would need to be capable of producing 20 ML/d. By using water conservation techniques and limiting water usage to in-house use only the potable water demand could be reduced to 9 ML/d. For the purpose of this scenario both the 20 ML/d and 9 ML/d flows have been assessed.

---

### Desalination Technology

---

**Selection** **Energy Considerations:** The desalination facility would be located within an area where mains energy would be available. There is no economical waste heat source in the vicinity of the plant.

**Feed water considerations:** The feed water is seawater and has a high TDS concentration.

**Selection using Decision Tree (Section 5)**

A higher quality/quantity of fresh water is required for this scenario. Mains electricity is available, however there is no waste heat source available at the selected site. The feed water TDS is slightly less than 44,000 mg/L and greater than 12,000 mg/L. Seawater reverse osmosis (SWRO) would therefore be suitable for treating this water. Considering the TDS is only slightly less than 44,000 mg/L, multiple effect distillation (MED) has also been investigated.

Three alternative scenarios are therefore discussed from this point onward, being:

*Alternative A: An RO facility would be installed to treat the total peak water demand of 20 ML/d.*

*Alternative B: An RO facility would be installed to treat 9 ML/d, whilst applying water conservation principles to reduce water consumption.*

*Alternative C: An MED facility would be installed to treat the total peak water demand of 20 ML/d.*

---

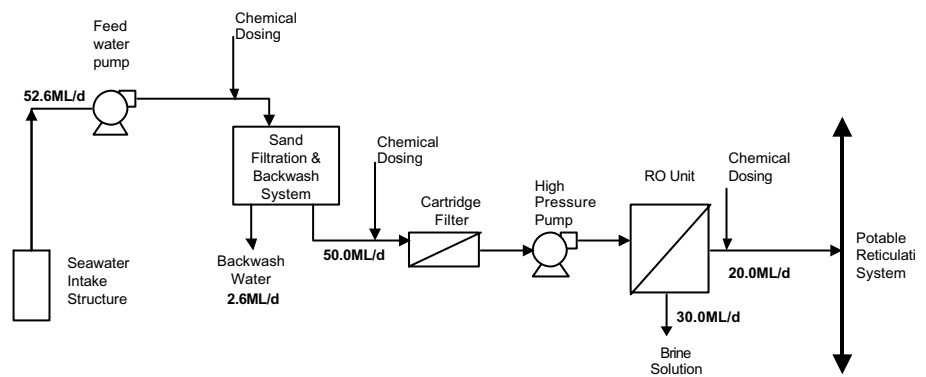
## Scenario 2 – 20 ML/d Seawater Water Source

### Technology Description

#### Alternative A: 20 ML/d RO facility

The RO unit would require a sand filtration pre-treatment system, cartridge filters, high pressure feed pumps, high pressure vessels containing the RO membrane, a brine and permeate recovery system.

The following diagram schematically describes the RO system. Approximately 53 ML/d of feed water would be required to produce 20 ML/d product water, based on a 40% recovery rate in the RO unit and a 95% recovery in the sand filtration system.

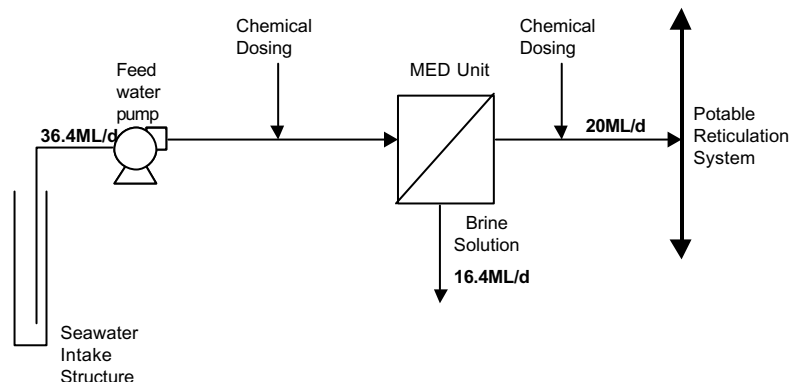


#### Alternative B: 9 ML/d RO facility

The system would be configured the same as Alternative A, however the size/capacity of units within the process would be reduced. Assuming the same recovery rate as in Alternative A, approximately 24 ML/d feed water would be required to produce 9 ML/d product water.

#### Alternative C: 20 ML/d MED facility

The MED facility requires no pre-filtration, however chemical dosing would still be required to prevent scale forming in the MED unit. A feed flow rate of approximately 36.4 ML/d would be required to produce 20 ML/d of product water, assuming a 55% recovery in the MED unit.





---

## Scenario 2 – 20 ML/d Seawater Water Source

---

### Pre-treatment Requirements

*Alternative A & B (RO facilities treating 20 and 9 ML/d respectively)*

It would be necessary to undertake the following pre-treatment of the seawater:

- ▶ Chemical dosing to coagulate colloidal material that may be present in the water and improve the pre-filtration process.
- ▶ Sand filtration to reduce the turbidity levels and particulate matter.
- ▶ Acid dosing for pH correction. Acid dosing is typically undertaken using sulphuric acid and helps to keep scale forming chemicals in solution thereby reducing scaling of the RO membranes.
- ▶ Anti-scalant dosing may also be required to improve the membrane performance and life. There are a number of proprietary anti-scalants on the market and the selection of the right chemical is best carried out by the RO supplier or during detail design phase.

Pilot plant testing is also recommended to assist with identifying pre-treatment requirements, ensuring the full-scale plant adequately meets the needs of the community.

*Alternative C: 20 ML/d MED facility*

The MED process will require the following pre-treatment:

- ▶ Anti-scalant dosing to reduce scale formation in MED process.

### Post Treatment Requirements

*Alternative A & B (RO facilities treating 20 and 9 ML/d respectively)*

A preliminary investigation of the RO system indicates a high quality permeate would be produced. Through the RO process the pH level of the water is substantially reduced and in addition to reducing salinity levels, the water is also stripped of many constituents that contribute to “normal” water taste. The permeate will therefore require the following post-treatment steps:

- ▶ Chemical dosing for pH correction (this can be achieved through lime dosing)
- ▶ Chemical dosing for water conditioning (replace some of the lost salts and alkalinity and strip off excess CO<sub>2</sub>)
- ▶ Disinfection.

Due to the high cost in desalinating waters, blending with traditionally treated waters or raw source water is often carried out. The advantages include:

- ▶ Reduced capital and operating costs of the RO unit as smaller unit are required.
- ▶ Maintains operation of traditional treatment plant (important when desalination is only carried out for a few months of the year).
- ▶ Reduces the post-treatment requirements, as some chemical constituents will be available in the traditionally treated water, thereby reducing chemical consumption.

*Alternative C: 20 ML/d MED facility*

The post-treatment requirements for an MED facility will be similar to those discussed for Alternative A and B. Blending of traditional treated water with the

---



---

## Scenario 2 – 20 ML/d Seawater Water Source

---

desalinated water may be required to improve the aesthetic qualities of the water and reduce corrosion potential.

The post-treatment requirements listed above and costed below do not make allowance for benefits to be gained from blending. Owing to the large volume of permeate produced, further studies would be required at the detailed design phase to quantify blending benefits.

---

### Waste Management

The RO process produces two main waste streams:

- A highly saline brine stream
- Backwash waters from the pre-treatment processes.

#### *Alternative A 20 ML/d RO facility*

In addition to contaminants removed from the feedwater, the brine and backwash waters will also contain concentrations of the chemicals added through the process. For a RO plant producing approximately 20.0 ML/d of product water, over 33 ML/d of waste product (filter backwash and brine) will be produced. The brine waste component would have a TDS concentration of over 75,000 mg/L.

Given the facilities close proximity to the ocean and the nearby wastewater treatment plant (WWTP), brine would be disposed of to sea via the WWTP ocean outfall.

#### *Alternative B 9 ML/d RO facility*

For a RO plant producing 9 ML/d product water, it is estimated that 15 ML/d of waste will be generated. The TDS of this brine waste would be in excess of 75,000 mg/L. As per Alternative A the brine would be disposed of via the WWTP ocean outfall.

#### *Alternative C 20 ML/d MED facility*

For a MED plant producing 20 ML/d product water, it is estimated that 16.4 ML/d of waste will be generated. The TDS of this brine waste would be in excess of 75,000 mg/L. As per Alternative A the brine would be disposed of via the WWTP ocean outfall.

Note that EPA approval will be required for ocean disposal of the brine waste for any of the above alternatives (see environmental factors below).

---

### Environmental Factors

Owing to the environmental sensitivity of the area, the importance of local tourism and the high percentage of residentially zoned land, the following factors must be taken in to consideration:

- Impact of brine disposal on the aquatic flora and fauna around the ocean outfall
- Impact on the community of any required easement development
- Aesthetic impact of the desalination facility

In addition to the above-mentioned issues, the MED plant will have the additional issue of elevated brine discharge temperature (approximately 70°C). Cooling of the brine waste stream may be required prior to discharge.

EPA approvals under ERA 16 (Municipal water treatment plant) would be required. The disposal of brine into ocean would fall under a separate ERA. It is recommended that the EPA be consulted regarding the approvals required.

---



---

## Scenario 2 – 20 ML/d Seawater Water Source

---

### Operational and Maintenance Requirements

---

#### Labour

It has been assumed that the day to day operations (daily visual inspection and meter reading) and general maintenance (including changing membranes) would be carried out by existing WTP personnel. Suitable training from the RO supplier is recommended to increase the skill level of the operators to cover RO technology.

An additional operator would be required to operate and maintain the desalination plant (RO or MED), and access to process engineer (or equivalent) may be required to perform troubleshooting exercises and provide general advise regarding operation. Due to the large capacity of the plants, the process will require optimisation. For all alternatives it is assumed during the first 3 months of operation the trouble shooter will be required for 10 hours per week. For the remainder of the first year an allowance of 16 hours per month for troubleshooter time has been made. Troubleshooting requirements should decrease with time.

#### *Alternative A & C:*

For a plant of this capacity approximately 40 hours/week of operator time would be required.

#### *Alternative B:*

For a plant of this capacity approximately 30 hours/week of operator time would be required.

#### Chemical Requirements

#### *Alternative A, B and C*

- ▶ Chemical requirements would include:
- ▶ Acid dosing for pH correction (sulphuric acid) – RO only.
- ▶ Coagulant dosing (alum) – RO only.
- ▶ Anti-scalant (RO suppliers typically recommend a preferred brand)
- ▶ Chemical dosing for product water conditioning (eg soda ash or lime etc)
- ▶ Disinfection

Estimates of chemical usage have been made for costing purposes only. Actual chemical dosage rates would depend on the membrane system selected and their tolerance to various contaminants.

---




---

## Scenario 2 – 20 ML/d Seawater Water Source

---

### Energy Requirements

#### *Alternative A: 20 ML/d RO facility*

The high pressure RO feed pumps and the seawater extraction pumps would dominate the RO energy requirements. It is estimated that the daily energy requirement would be in the order of 145 MWh/day. The energy requirements would be met by mains supply. Discussions would need to be held with the local electricity supplier to determine the scope and cost of any electrical supply.

#### *Alternative B: 9 ML/d RO facility*

The daily power consumption is estimated as 65 MWh/d. As per Alternative A discussion would need to be held with the local electricity supplier to determine electrical upgrade requirements (if any).

#### *Alternative C: 20 ML/d MED facility*

The power consumption for the MED facility will be approximately 17 MWh/d. MED uses gas as the main form of energy and would consume approximately 33000 GJ/d.

---

### Membrane Replacement

RO membranes require replacement every 3 to 5 years due to the deterioration of the membrane, thus decreasing the efficiency of the RO process. In the case of this scenario, it has been assumed that the membranes will be replaced every 5 years.

---

### Costs

#### Capital

The capital costs associated with providing an RO or MED system are summarised in the following table. These cost estimates are based on the following assumptions and include a 15% allowance for engineering/design and 25% contingency:

- ▶ Land costs are negligible as the RO facility would be located within existing council property.
- ▶ The site for the desalination facility is located around 200 meters from the seawater intake point.
- ▶ Access to an existing effluent disposal ocean outfall to utilise for brine disposal
- ▶ No electrical upgrades would be necessary to meet the required daily power consumption.

---

Alternative A: 20 ML/d RO facility	\$ 60 M
Alternative B: 9 ML/d RO facility	\$ 33 M
Alternative C: 20 ML/d MED facility:	\$ 84 M

---

It should be noted that making use of existing water treatment infrastructure, thereby reducing the pre-treatment capital costs, might reduce the above capital costs. A detailed investigation would be required to determine the feasibility of this option.

---




---

## Scenario 2 – 20 ML/d Seawater Water Source

---

### Operational & Maintenance

A breakdown of the O&M costs for each alternative are provided in the following table:

	Alternative A 20 ML/d RO	Alternative B 9 ML/d RO	Alternative C 20 ML/d MED
<b>Total O&amp;M Cost</b>	<b>\$ 7,108,800</b>	<b>\$ 3,378,300</b>	<b>\$ 7,359,000</b>
Annual allowance for membrane replacement: Calculated based on 10% of the capital (excluding contingencies) and to be replaced once every 5 years.	\$ 840,000	\$ 458,000	N/A
Power usage:	\$ 5,271,600 (10c/kWh)	\$ 2,345,000 (10c/kWh)	\$ 6,044,060 (\$5/GJ)
Chemical consumption:	\$ 252,000 (0.6% of capital, excluding contingencies)	\$ 137,400 (0.6% of capital, excluding contingencies)	\$ 300,000 (0.5% of capital, excluding contingencies)
Labour			
Operator Costs \$40/hour	\$ 83,200 (40 hours/week)	\$ 62,400 (30 hours/week)	\$ 83,200 (40 hours/week)
Trouble shooter Costs (first year) \$120/hour as required	\$ 32,000	\$ 32,000	\$ 32,000
Maintenance: Based on 1.5% of the capital (excluding contingencies).	\$ 630,000	\$ 343,500	\$ 900,000

---



## Scenario 3 – 1.7 ML/d Shallow Inland Ground Water Source

### Background Information

This scenario is based on an inland community of approximately 10,000 people, with a base potable water demand of approximately 4 ML/d, average demand of 6 ML/d and a peak demand of 11 ML/d. The town currently sources its potable water from surface water and groundwater supplies.

Raw water drawn from a weir impoundment is treated at the town's water treatment plant. Here the water undergoes clarification, filtration and disinfection prior to being pumped approximately 5 km to the town's main reservoir.

With the exception of disinfection, the water drawn up from groundwater aquifers does not receive treatment. The ground water is pumped directly to the town's main reservoir.

Under the Council's water supply strategy, groundwater sources are required to provide approximately half the base load requirements. Flow monitoring data indicated that the initial groundwater bores were gradually being diminished at a rate of 10% per year. Additional bores were sunk in an attempt to secure additional groundwater sources. However the quality of water extracted from the new bores is too salty for potable use.

Council have therefore investigated the use of desalination to convert the currently unacceptable bore water to a potable standard. The desalination system would be sized to produce 1.7 ML/d (170 L/P/d) of water (which is approximately half the town's base load demand).

As the desalination equipment will represent significant capital investment, Council have spent 6 months operating a small pilot plant unit. The aim of the pilot plant unit has been to confirm raw water quality, pre-treatment requirements and ability of the RO process to meet the community's water supply demands in a cost effective manner.

### Source Water Details

#### Location

The existing bore fields are located in a strip approximately 5 km upstream and downstream of the water treatment plant. The desalination facility will be located at the existing water treatment plant. Groundwater will be pumped up to 5 km from the bore fields to the desalination plant through existing pipework.

#### Quality

The bore water has been sampled on a regular basis over the last couple of years, with the average water quality described below:

Water Quality Parameter	Unit	Value
pH	-	7.4
Temperature	°C	23
TDS	mg/L	2000
Turbidity	NTU	1
Ca	mg/L	90
K	mg/L	3
Mg	mg/L	60
Mn	mg/L	0.01



### Scenario 3 – 1.7 ML/d Shallow Inland Ground Water Source

Water Quality Parameter	Unit	Value
Na	mg/L	560
Fe	mg/L	0.05
Cl	mg/L	850
F	mg/L	0.1
HCO <sub>3</sub>	mg/L	400
NO <sub>3</sub>	mg/L	<0.1
SO <sub>4</sub>	mg/L	50
Si	mg/L	32
CO <sub>3</sub>	mg/L	1
CO <sub>2</sub>	mg/L	28

The above water quality indicates that the bore water is brackish.

#### Product Water Details

<b>Location</b>	The desalination facility would be located at the existing water treatment plant. Desalinated water would undergo stabilisation, by blending with treated surface water, and disinfection before being pumped to the Town's main reservoir.
<b>Quality</b>	The product water would be suitable for potable use, with a target TDS concentration below 500 mg/L.
<b>Quantity</b>	In order to meet half the base load demands, the desalination facility will be capable of producing 1.7 ML/d. It is planned to mix the desalinated water with traditionally treated surface water. The mixing ratio will depend on the town's water demand.

#### Desalination Technology

<b>Selection</b>	<p><b>Energy Considerations:</b> The desalination facility would be located at an existing water treatment plant therefore mains energy would be available. There is no economical waste heat source in the vicinity of the plant.</p> <p><b>Feed water considerations:</b> The raw water source is considered to be brackish, with a relatively low TDS concentration.</p> <p><b>Selection using Decision Tree (Section 5)</b></p> <p>A higher quality/quantity of fresh water is required for this scenario. Mains electricity is available, however there is no waste heat source available at the selected site. The feed water TDS is less than 44,000 mg/L and less than 12,000 mg/L. The water source has a high scaling potential and has a TDS less than 3,000 mg/L. Brackish water reverse osmosis (BWRO) or EDR would therefore be suitable for treating this water.</p> <p>Two alternative scenarios are discussed from this point onward, being:</p> <p><i>Alternative A: BWRO to produce 1.7 ML/d product water.</i></p> <p><i>Alternative B: EDR to produce 1.7 ML/d product water.</i></p>
------------------	--

## Scenario 3 – 1.7 ML/d Shallow Inland Ground Water Source

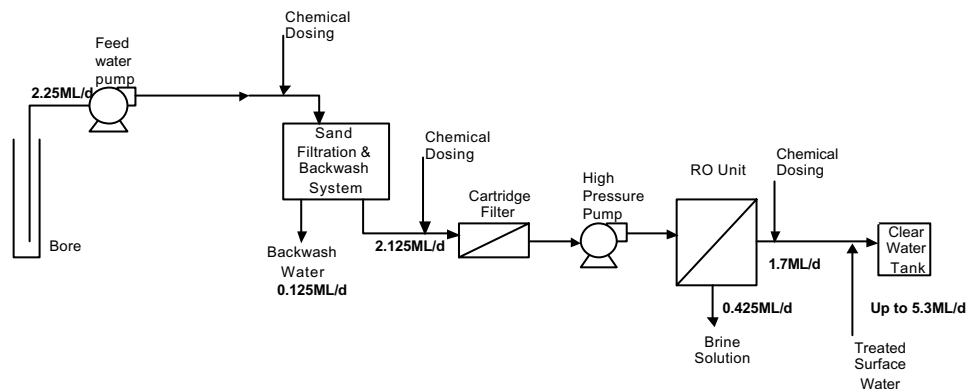
### Technology Description

For both systems the desalinated water will be blended with traditionally treated surface water, however the issues regarding this blending have not been discussed in any great detail.

#### Alternative A: 1.7 ML/d BWRO facility

The RO system would include pre-treatment, cartridge filters, high pressure feed pumps, high pressure vessels containing RO membrane, brine recovery system and permeate recovery system.

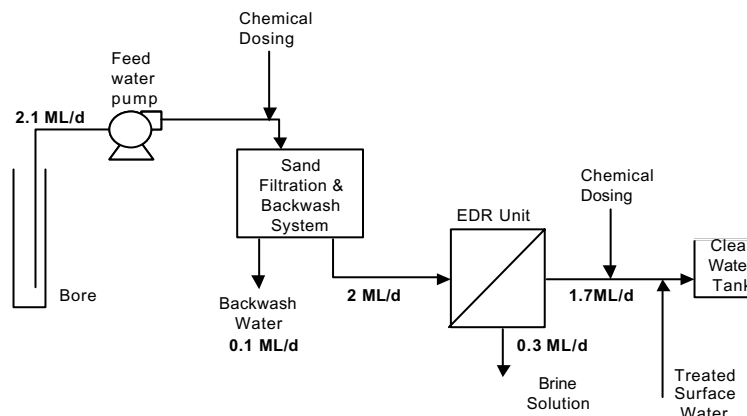
The following diagram schematically describes the RO system. A feed flow of approximately 2.25 ML/d would be required to produce 1.7 ML/d of product water, assuming the system is highly optimised and the resultant recovery rate is 80% for the RO unit and 95% efficiency for the pre-treatment component of the system.



#### Alternative B: 1.7 ML/d EDR facility

The EDR system would include pre-treatment, an EDR unit/membrane and brine and permeate recovery systems. As for the RO system, the product water will be blended with traditional treated water to supplement the towns' existing water supply.

The following diagram schematically describes the EDR system. A feed flow of 2.1 ML/d would be required to produce 1.7 ML/d product water, based on an 85% recovery from the EDR unit, and 95% efficiency of the pre-treatment unit.





## Scenario 3 – 1.7 ML/d Shallow Inland Ground Water Source

### Pre-treatment Requirements

#### *Alternative A and B*

Given the quality of the bore water, and the outcome of RO pilot plant trials it will be necessary to undertake the following pre-treatment:

- ▶ Sand filtration to reduce the turbidity levels
- ▶ Anti-scalant dosing to improve the membrane performance and life.

As extensive bore water sampling was undertaken prior to and during the pilot plant trials, sufficient information is available to assist the detail plant designer in nominating pre-treatment requirements and annual operating costs. Minor adjustments however would still be expected during the commissioning of the full-scale plant due to scale up effects.

It is expected that the pre-treatment requirements for the EDR system will be slightly less than that of the RO system, however the basic systems will still be required.

### Post Treatment Requirements

#### *Alternative A and B*

From the RO pilot plant trials, the following post-treatment steps will be required:

- ▶ Chemical dosing for pH correction (this can be achieved through lime or soda ash dosing)
- ▶ Degassing for alkalinity recovery.
- ▶ Disinfection (using existing infrastructure).

Blending with traditionally treated surface waters.

### Waste Management

Both the RO and EDR processes produce three main waste streams:

- ▶ A highly saline brine stream
- ▶ Backwash waters from the pre-treatment processes
- ▶ Wastes from cleaning processes.

In addition to contaminants removed from the feedwater, the brine and backwash waters will also contain concentrations of the chemicals added through the process.

Brine is typically disposed of in a number of ways, depending on prevailing conditions.

- ▶ Disposal of brine to sea is not considered appropriate given the distance to the ocean (200 km).
- ▶ Groundwater injection of the brine is adopted in a number of areas, however given a lack of hydro-geological information this option has not been considered further.
- ▶ Crystallisation requires expensive and sophisticated equipment and operational knowledge. Given the volume of brine produced each year and the location of the town it is not considered practical in this case.
- ▶ Aquaculture enterprises have been established elsewhere to make use of the brine waters. The feasibility of this option would depend on attracting a suitable business interest to make the venture profitable. There are also concerns of the potential impacts that RO and pre-treatment chemicals may have on the water quality.



## Scenario 3 – 1.7 ML/d Shallow Inland Ground Water Source

- Some livestock have a high level of tolerance to waters containing TDS levels up to 5,000 mg/L. The TDS levels are expected to exceed 10,000 mg/L for both alternatives, so this option is not suitable.

This scenario is located in a relatively dry area, where pan evaporation exceeds rainfall each month. Evaporative lagoons are therefore recommended at this site. EPA approval for the evaporative lagoons would be required. Every 10 years council will need to investigate options for disposal and removal of the salt. Based on available meteorological data, and assuming salt harvesting is carried out every ten years and a lagoon depth of 1m, the evaporative lagoons are sized as follows.

### *Alternative A:*

For a RO plant producing approximately 1.7 ML/d of product water, approximately 0.55 ML/d of waste product will be produced. This waste would have a TDS concentration of over 10,000 mg/L. The evaporative lagoons would cover an area of approximately 14 hectares. Approximately 20,000 tonnes of salt would accumulate in 10 years.

### *Alternative B:*

For an EDR plant, producing 1.7 ML/d of product water, approximately 0.4 ML/d of waste will be produced, with a TDS concentration greater than 10,000 mg/L. The evaporative lagoons would cover an area of approximately 10 hectares, and accumulate approximately 14,600 tonnes of salt every 10 years.

---

### **Environmental Factors**

Environmental factors that would require further investigation include:

- Operation and design of brine evaporation ponds
- Noise from high pressure pumps (acoustic housing will reduce impact)
- Aesthetic impacts of plant

EPA approvals under ERA 16 (Municipal water treatment plant) would be required. The disposal of brine into ocean would fall under a separate ERA. It is recommended that the EPA be consulted regarding the approvals required.

---

### **Operational and Maintenance Requirements**

#### **Labour**

#### *Alternative A and B*

It is recommended that as part of the desalination contract, process proving and training phases be included. The training component will ensure future operational staff receive hands on familiarisation of the equipment including operations and maintenance.

The existing water and wastewater treatment plants currently employ 3 people, with their work hours spread between water and sewerage infrastructure. With the RO process increasing the complexity of water treatment, it is envisaged that an additional resource will be employed, with the operators split between water and wastewater treatment. It is estimated that a total of 15 hours per week of operator time would be required. This estimate differs from those provided in Table 8-2 as the local council has decided to optimise the desalination facility and therefore a slightly higher operator input is expected.

Access to process engineer (or equivalent) may be required to perform troubleshooting exercises and provide general advise regarding operation. It has



## Scenario 3 – 1.7 ML/d Shallow Inland Ground Water Source

been assumed during the first 3 months of operation the troubleshooter will be required for approximately 5 hours per week. For the remainder of the first year an allowance of 8 hours per month for troubleshooter time has been made. Troubleshooting requirements should decrease with time.

### Chemical Requirements

*Alternative A and B*

Chemical requirements would include:

- ▶ Acid dosing for pH correction
- ▶ Anti-scalant (RO suppliers typically recommend a preferred brand)
- ▶ Chemical dosing for product water conditioning (eg lime or soda ash)
- ▶ Disinfection

### Energy Requirements

For all alternatives, the energy requirements would be met by mains supply. It will be necessary to upgrade the electrical supply into the existing WTP. Discussions will need to be held with the local electricity supplier to determine the scope and cost of the upgrades.

*Alternative A:*

The RO energy requirements would be dominated by the high pressure RO feed pumps and the bore water extraction pumps. It is estimated that the daily energy requirement would be in the order of 1.6 MWh/day.

It should be noted that this plant experiences relatively low energy consumption compared to other scenarios. Extensive pilot trials, careful design and the decision to have troubleshooting personnel and highly skilled operators available have led to power consumption reductions.

*Alternative B:*

The EDR energy requirements would be approximately 3 MWh/d. It maybe necessary to upgrade the electrical supply into the existing WTP. Discussions will need to be held with the local electricity supplier to determine the scope and cost of the upgrades.

It should be noted that no optimisation of the EDR process has been assumed in estimating these power requirements.

---

### Membrane Replacement

*Alternative A*

RO membranes require replacement every 3 to 5 years due to the deterioration of the membrane, thus decreasing the efficiency of the RO process. In the case of this scenario, it has been assumed that the membranes will be replaced every 5 years. The frequency assumes the plant is optimised.

*Alternative B*

EDR membranes require replacement every 5 to 10 years depending on the level of optimisation the plant receives. For this scenario it has been assumed that the membranes will require replacement every 5 years. The allowance for membrane replacement also includes the cost for electrode replacement. The electrodes will need to be replaced every one to two years.

---



## Scenario 3 – 1.7 ML/d Shallow Inland Ground Water Source

### Costs

#### Capital

The capital costs associated with providing an RO or EDR system are provided in the table below. These cost estimates are based on the following assumptions, and include a 15% allowance for engineering/design and 25% contingency:

- ▶ Land costs for the RO plant are negligible as the RO facility would be located at the existing WTP.
- ▶ Land costs for the evaporative lagoons are not included in the cost estimates.
- ▶ There are no costs associated with establishing the feedwater source further.
- ▶ The product water can be fed directly into the existing water distribution system.
- ▶ Brine and backwash waters are disposed of via evaporation ponds.

Alternative A: 1.7 ML/d BWRO facility	\$ 3.4 M
---------------------------------------	----------

Alternative B: 1.7 ML/d EDR facility	\$ 4.1 M
--------------------------------------	----------

#### Operational & Maintenance

The annual O&M costs for both alternatives are broken down as follows:

	Alternative A 1.7 ML/d RO	Alternative B 1.7 ML/d EDR
<b>Total O&amp;M Cost</b>	<b>\$ 216,100</b>	<b>\$ 229,900</b>
Annual allowance for membrane replacement:	\$ 48,500	\$ 5,800
Membranes to be replaced once every 5 years.	(10% of the capital, excluding contingencies)	(1% of the capital, excluding contingencies)
Power usage:	\$ 59,800	\$ 108,600
Assumed 10c/kWh.		
Chemical consumption:	\$ 24,300	\$ 14,500
	(1% of the capital, excluding contingencies)	(0.5% of the capital, excluding contingencies)
Labour		
Operator Costs \$40/hour.	\$ 31,200 (15 hours/week)	\$ 41,600 (20 hours/week)
Trouble shooter Costs (first year) \$120/hour as required	\$ 15,900	\$ 15,900
Maintenance:	\$ 36,400	\$ 43,500
Based on 1.5% of the capital (excluding contingencies).		



## Scenario 4 – 1.5 ML/d Saline Ground Water Source

### Background Information

This scenario is based on an inland community of approximately 1,500 people, with a peak summer potable water demand of 2 ML/d. The town currently sources its potable water from a surface water supply. Raw water is drawn from a weir impoundment and pumped via a 5 km rising main to the town's water treatment plant. Here the water undergoes aeration, chemical dosing, mixing, clarification, pre-chlorination, filtration, pH correction and disinfection before entering the town's reticulation system.

The raw water supply however experiences high levels of turbidity, iron and manganese (particularly in summer), which cause operational problems and customer complaints. During the early 1990s, a bore was sunk to provide an alternate water source during summer months. Subsequent testing of the bore water showed elevated levels of TDS, aluminium, fluoride, sodium and boron. As a result the bore water is unacceptable for potable water use without treatment.

This scenario therefore addresses the feasibility of using a desalination technology to treat the bore water supply to a standard acceptable for potable water consumption by the community. Initial studies suggest that the desalination facility should be sized for 1.5 ML/d (1,000 L/P/d) with peak summer demands being supplemented with traditional surface water supplies, however this water usage is very high and the community may benefit by reducing the water demand to 300 L/P/d (0.45 ML/d). This flow would only be suitable for supplying households with potable water for in-house use. By promoting water conservation the council has the potential to save a significant amount on capital investments.

### Source Water Details

#### Quality

The bore water has been sampled approximately twice a year for the last couple of years, with the average water quality described below:

Water Quality Parameter	Unit	Value
pH	-	8.35
Temperature	°C	52
TDS	mg/L	3000
Turbidity	NTU	2
Ca	mg/L	2.5
K	mg/L	4.5
Mg	mg/L	0.3
Mn	mg/L	0.03
Na	mg/L	873.43
Fe	mg/L	9.5
Cl	mg/L	155
F	mg/L	9.5
HCO <sub>3</sub>	mg/L	2000
NO <sub>3</sub>	mg/L	3.0
SO <sub>4</sub>	mg/L	10.0
Si	mg/L	19.0
CO <sub>3</sub>	mg/L	10.56
CO <sub>2</sub>	mg/L	45.27



---

## Scenario 4 – 1.5 ML/d Saline Ground Water Source

---

The above water quality indicates that the bore water is brackish.

It is recommended that raw and cooling pond water quality sampling is carried out over the course of year, to ensure seasonal variations and water quality variations are captured, as the performance of desalination processes typically depend on raw water quality. In addition to the water quality parameters currently being taken, it is also recommended that the following parameters be analysed: barium, reactive silica, ammonium, strontium and phosphate. Refer to Appendix C for further details regarding monitoring requirements.

The temperature of the bore water being extracted from the ground is approximately 52 °C. Typically the performance and life of membranes are only guaranteed where the feedwater temperature is below 40 °C. Scaling also become more problematic as the temperature increases. Cooling can be achieved by a number of methods, with the least sophisticated method being cooling ponds. The main problem with cooling ponds is that the feedwater quality often deteriorates, resulting in more costly pre-treatment steps. Heat exchangers can also be considered, they can be more expensive and add a degree of complexity to the system, however a higher feedwater quality can be sustained.

In this case, the town has an existing cooling pond, which will be utilised in the design of the desalination plant.

**Location** An existing bore is located adjacent to the existing water treatment plant. Any desalination facility therefore would be located at the existing water treatment plant. This reduces the need for any additional pumping, piping and extraction infrastructure, thereby reducing the ancillary costs associated with desalination.

---

### Product Water Details

---

**Location** The desalination facility would be located at the existing water treatment plant therefore treated water would be fed directly into the existing clear water tanks. Here the treated water would undergo pH correction and disinfection using existing infrastructure.

**Quality** The product water would be suitable for potable use, with a target TDS concentration below 500 mg/L.

**Quantity** In order to meet peak summer demands the desalination facility would need to be capable of producing 1.5 ML/d. It is planned to mix the desalinated water with traditionally treated surface water, to give a total plant capacity of 2 ML/d.

Using water conservation techniques, the water supply could be reduced to 300 L/P/d (0.45 ML/d). This alternative scenario is also discussed further in the following sections.

---



## Scenario 4 – 1.5 ML/d Saline Ground Water Source

### Desalination Technology

#### Selection

**Energy Considerations:** The desalination facility would be located at an existing water treatment plant therefore mains energy would be available. There is no economical waste heat source in the vicinity of the plant.

**Feed water considerations:** The raw water source is considered to be brackish. Given the relatively low TDS levels in the raw water.

#### Selection using Decision Tree (Section 5)

A higher quality/quantity of fresh water is required for this scenario. Mains electricity is available, however there is no waste heat source available at the selected site. The feed water TDS is less than 44,000 mg/L and less than 12,000 mg/L. The water source has a high scaling potential and has a TDS less than 3,000 mg/L (borderline TDS). Brackish water reverse osmosis (BWRO) or EDR would therefore be suitable for treating this water.

Three alternative scenarios are discussed from this point onward, being:

*Alternative A: BWRO to produce 1.5 ML/d product water.*

*Alternative B: BWRO to produce 0.45 ML/d product water.*

*Alternative C: EDR to produce 1.5 ML/d product water.*

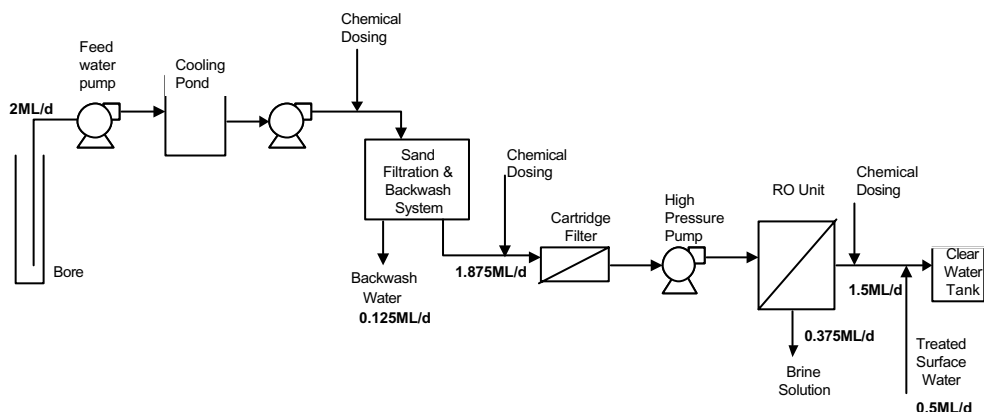
#### Technology Description

For the purposes of this scenario it has been assumed that the desalinated water will be blended with traditionally treated surface water at a ratio of 1.5ML/d:0.5ML/d. Further investigations (such as pilot trials) would be required to determine the most appropriate blending ratio and process configuration, to ensure community needs are met.

*Alternative A: BWRO to produce 1.5 ML/d product water*

The RO system would include cooling ponds, pre-treatment, cartridge filters, high pressure feed pumps, high pressure vessels containing RO membrane, brine recovery system and permeate recovery system.

The following diagram schematically describes the RO system. Approximately 2 ML/d feed water is required to product 1.5 ML/d product water, assuming a RO recovery rate of 80%, and a pre-treatment efficiency of 95%.



## Scenario 4 – 1.5 ML/d Saline Ground Water Source

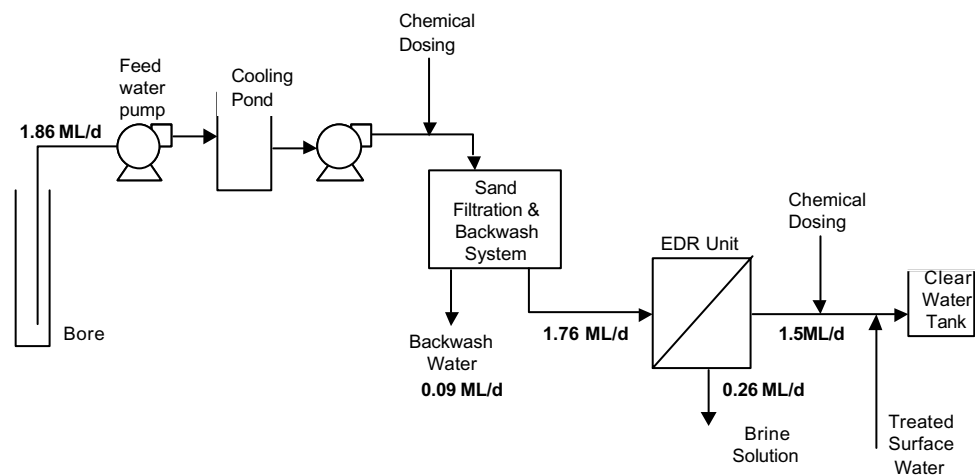
### *Alternative B: BWRO to produce 0.45 ML/d product water*

The system will be a similar configuration as Alternative A (see above), however the flow rates will be less. Approximately 0.6 ML/d of feed water will be required to produce 0.45 ML/d product water, based on 80% recovery rate for the RO unit, and a 95% recovery in the pre-treatment unit. Approximately 0.15 ML/d of brine and backwash waste will be generated.

### *Alternative C: EDR to produce 1.5 ML/d product water.*

The EDR system would include cooling ponds, pre-treatment, feed pumps, vessels containing EDR membranes, brine recovery system and permeate recovery system, similar to the RO systems described above.

The following diagram illustrates the process of the EDR desalination plant. To produce 1.5 ML/d product water, a feed water supply of 1.85 ML/d would be required, assuming a 85% recovery in the EDR unit, and 95% in the pre-treatment unit.



### **Pre-treatment Requirements**

#### *Alternatives A, B and C*

Given the quality of the bore water it may be necessary to undertake the following pre-treatment:

- ▶ Cooling via cooling ponds
- ▶ Sand filtration to reduce the turbidity levels
- ▶ Chemical dosing to coagulate colloidal material that may be present in the water and improve the pre-filtration process.
- ▶ Acid dosing for calcium carbonate scale control.
- ▶ Anti-scalant dosing may also be required to improve the membrane performance and life.

The pre-treatment requirements of the EDR system will be less than those for RO; however, the basic processes will most likely remain the same.



---

## Scenario 4 – 1.5 ML/d Saline Ground Water Source

---

### Post Treatment Requirements

*Alternatives A, B and C*

The permeate will require the following post-treatment steps:

- ▶ Chemical dosing for pH correction (lime dosing)
- ▶ Chemical dosing for water conditioning (lime dosing and strip off excess CO<sub>2</sub>)
- ▶ Disinfection.
- ▶ Blending with traditionally treated surface waters.

Due to the high cost in desalinating waters, blending with traditionally treated waters or raw source water is often carried out. The advantages include:

- ▶ Reduced capital and operating costs of the RO unit as smaller unit are required.
- ▶ Maintains operation of traditional treatment plant (important when desalination is only carried out for a few months of the year).
- ▶ Reduces the post-treatment requirements, as some chemical constituents will be available in the traditionally treated water, thereby reducing chemical consumption.

The post-treatment requirements provided above and costed below do not make allowance for benefits to be gained from blending. Further studies would be required at the detailed design phase to quantify blending benefits.

---

### Waste Management

The RO and EDR processes produce three main waste streams:

- ▶ A highly saline brine stream
- ▶ Backwash waters from the pre-treatment processes.
- ▶ Waste from membrane cleaning

In addition to contaminants removed from the feedwater, the brine and backwash waters will also contain concentrations of the chemicals added through the process.

Brine is typically disposed of in a number of ways, depending on prevailing conditions.

- ▶ Disposal of brine to sea is not considered appropriate given the distance to the ocean (300 km).
  - ▶ Groundwater injection of the brine is adopted in a number of areas, however given a lack of hydro-geological information this option has not been considered further.
  - ▶ Crystallisation requires expensive and sophisticated equipment and operational knowledge. Given the volume of brine produced each year and the location of the town it is not considered practical in this case.
  - ▶ Aquaculture enterprises have been established elsewhere to make use of the brine waters. The feasibility of this option would depend on attracting a suitable business interest to make the venture profitable.
  - ▶ Some livestock have a high level of tolerance to waters containing TDS levels up to 5,000 mg/L. The TDS levels are expected to exceed 10,000 mg/L,
-



---

## Scenario 4 – 1.5 ML/d Saline Ground Water Source

---

therefore stock watering is not considered feasible.

This scenario is located in a relatively dry area, where pan evaporation exceeds rainfall each month. Evaporative lagoons have therefore been considered for this site. Every 10 years council will need to investigate options for disposal and removal of the salt. Based on available meteorological data, and assuming salt harvesting is carried out every ten years and a lagoon depth of 1 m the following are applicable for each alternative.

### *Alternative A: 1.5 ML/d BWRO*

For a RO plant producing approximately 1.5 ML/d of product water, approximately 0.5 ML/d of waste product will be produced. This waste would have a TDS concentration of over 10,000 mg/L. The evaporative lagoons would cover an area of approximately 17 hectares and accumulate 18,300 tonnes of salt every 10 years.

### *Alternative B: 0.45 ML/d BWRO*

A RO plant producing 0.45 ML/d product water, will generate approximately 0.15 ML/d of waste. The TDS of the waste would be over 10,000 mg/L. The evaporative lagoons would cover an area of approximately 5 hectares. Approximately 5,500 tonnes of salt would accumulate in the lagoons every 10 years.

### *Alternative C: 1.5 ML/d EDR*

An EDR plant producing 1.5 ML/d product water would be expected to produce approximately 0.35 ML/d of waste. The TDS of the waste would be over 10,000 mg/L. Approximately 12,800 tonnes of salt would accumulate in the evaporative lagoons every ten years and the lagoons would cover an area of approximately 12 hectares.

---

### **Environmental Factors**

The following environmental factors will require consideration:

- ▶ Design and operation of brine evaporation ponds
- ▶ Noise from high pressure RO feed pump
- ▶ Aesthetic impacts of RO/EDR plant.

EPA approvals under ERA 16 (Municipal water treatment plant) would be required. The disposal of brine to evaporative lagoons would fall under a separate ERA. It is recommended that the EPA be consulted regarding the approvals required

---

### **Operational and Maintenance Requirements**

---

#### **Labour**

The existing WTP currently employs 3 people, with their work hours spread between water and sewerage infrastructure.

It has been assumed that the day to day operations (daily visual inspection, pH meter cleaning, chemical restocking and meter reading) and general maintenance (including changing membranes) would be carried out by existing WTP personnel (no additional personnel required). The equipment supplier would provide training.

For all alternatives, access to process engineer (or equivalent) may be required to perform troubleshooting exercises and provide general advise regarding operation. It has been assumed during the first 3 months of operation the troubleshooter will be required for approximately 5 hours per week. For the remainder of the first year an allowance of 8 hours per month for troubleshooter time has been made.

---



---

## Scenario 4 – 1.5 ML/d Saline Ground Water Source

---

Troubleshooting requirements should decrease with time.

*Alternative A: 1.5 ML/d BWRO*

For an RO facility of this capacity it is estimated that 6 hours per week of the operators time would be required. This assumes that the plant undergoes no optimisation.

*Alternative B: 0.45 ML/d BWRO*

The capacity of this RO plant is fairly small and therefore the operator requirements would be minimal (assuming no optimisation). It is estimated that 3 hours per week of the operators time would be required.

*Alternative C: 1.5 ML/d EDR*

For an EDR facility of this capacity it is estimated that 15 hours per week of the operators time would be required. This assumes that the plant undergoes no optimisation.

---

### Chemical Requirements

*Alternatives A, B and C*

Chemical requirements would include:

- ▶ Acid dosing for pH correction (sulphuric acid)
- ▶ Coagulant dosing ( $\text{FeCl}_3$ )
- ▶ Anti-scalant (RO suppliers typically recommend a preferred brand)
- ▶ Chemical dosing for product water conditioning (eg lime, soda ash etc)
- ▶ Disinfection

Estimates of chemical usage have been made for costing purposes only. Actual chemical dosage rates would depend on the membrane system selected and their tolerance to various contaminants.

### Energy Requirements

The energy requirements for all alternatives would be met by mains supply. It may be necessary to upgrade the electrical supply into the existing WTP. Discussions would need to be held with the local electricity supplier to determine the scope and cost of any upgrade.

*Alternative A: 1.5 ML/d BWRO*

The RO energy requirements would be dominated by the high pressure RO feed pumps and the bore water extraction pumps. It is estimated that the daily energy requirement would be in the order of 1.7 MWh/day.

*Alternative B: 0.45 ML/d BWRO*

The daily energy requirement for this alternative, including the extraction pumps, would be approximately 0.5 MWh/d.

*Alternative C: 1.5 ML/d EDR*

Daily energy requirements for the EDR process have been estimated as 3.1 MWh/d.

---



---

## Scenario 4 – 1.5 ML/d Saline Ground Water Source

---

### Membrane Replacement

#### *Alternative A and B*

RO membranes require replacement every 3 to 5 years due to the deterioration of the membrane, thus decreasing the efficiency of the RO process. In the case of this scenario, it has been assumed that the membranes will be replaced every 3 years. The increased costs associated with membrane replacement are offset by lower man-hours and chemical consumption.

#### *Alternative C*

EDR membranes require replacement every 5 to 10 years depending on the level of optimisation the plant receives. For this scenario it has been assumed that the membranes will require replacement every 5 years. The allowance for EDR membrane replacement also includes a provision for electrode replacement, which will occur every one to two years.

---

### Costs

---

#### Capital

The capital costs associated with providing a desalination plant for this scenario are provided in the table below. These cost estimates are based on the following assumptions and include a 15% allowance for engineering/design and 25% contingency:

- ▶ Land costs are negligible as the RO facility would be located at the existing WTP.
- ▶ There are no costs associated with establishing the feedwater source further.
- ▶ The product water can be fed directly into the existing WTP clear water tanks.
- ▶ Brine and backwash waters are disposed of via evaporation ponds.
- ▶ Land costs for evaporative lagoons are not included in these cost estimates.

---

Alternative A: 1.5 ML/d RO facility	\$ 3.1 M
Alternative B: 0.45 ML/d RO facility	\$ 1.4 M
Alternative C: 1.5 ML/d EDR facility:	\$ 3.7 M

---

It should be noted that the above capital costs may be reduced by making use of existing water treatment infrastructure, thereby reducing the pre-treatment capital costs. A detailed investigation would be required to determine the feasibility of this option.

---




---

## Scenario 4 – 1.5 ML/d Saline Ground Water Source

---

**Operational & Maintenance** The annual O&M can be broken down as follows:

	<b>Alternative A 1.5 ML/d RO</b>	<b>Alternative B 0.45 ML/d RO</b>	<b>Alternative C 1.5 ML/d EDR</b>
<b>Total O&amp;M Cost</b>	<b>\$ 219,400</b>	<b>\$ 99,000</b>	<b>\$ 217,100</b>
Annual allowance for membrane replacement:	\$ 74,700 (10% of the capital excluding contingencies, to be replaced once every 3 years)	\$ 32,700 (10% of the capital excluding contingencies, to be replaced once every 3 years)	\$ 5,200 (1% of the capital excluding contingencies, to be replaced once every 5 years)
Power usage: Based on 10c/kWh.	\$ 60,300	\$ 19,600	\$ 112,500
Chemical consumption:	\$ 22,400 (1% of capital, excluding contingencies)	\$ 9,800 (1% of capital, excluding contingencies)	\$ 13,100 (0.5% of capital, excluding contingencies)
Labour			
Operator Costs \$40/hour (6 hours/week)	\$ 12,500	\$ 6,300 (3 hours/week)	\$ 31,200 (15 hours/week)
Trouble shooter Costs (first year) \$120/hour as required	\$ 15,900	\$ 15,900	\$ 15,900
Maintenance: Based on 1.5% of the capital (excluding contingencies).	\$ 33,600	\$ 14,700	\$ 39,200

---



## Scenario 5 – 100 kL/d Saline Ground Water Source

### Background Information

This scenario is based on an inland community of approximately 100 people, with a peak summer potable water demand of 100 kL/d (1000 L/P/d). The town currently sources its potable water from a surface water supply. Raw water is drawn from a weir impoundment and pumped via a 3.5 km rising main to the town. The only treatment is disinfection before entering the town's reticulation system.

During summer, the surface water source becomes depleted and residents have to rely on bore water supply. Subsequent testing of the bore water showed elevated TDS. High silica concentrations in the ground water may cause problems with the desalination process.

This scenario therefore addresses the feasibility of using a desalination technology to treat the bore water supply to a standard acceptable for potable water consumption by the community. As part of this scenario, the feasibility of installing individual household desalination units has also been assessed.

By promoting water conservation techniques, the water demand can be reduced to 300 L/P/d (for in-house use only). Significant cost savings can be achieved by approaching water supply problems this way.

### Source Water Details

#### Location

An existing bore is located 0.5 km from the town. Any desalination facility would be located near the bore (council-owned land). Mains power is available at the site, however an upgrade of facilities may be required.

#### Quality

The bore water has been sampled approximately three times in the last few years, with the average water quality described below:

Water Quality Parameter	Unit	Value
pH	-	8
Temperature	°C	35
TDS	mg/L	3400
Turbidity	NTU	2
Ca	mg/L	165
K	mg/L	7
Mg	mg/L	66
Na	mg/L	954
Cl	mg/L	1519
F	mg/L	0.8
HCO <sub>3</sub>	mg/L	270
NO <sub>3</sub>	mg/L	1
SO <sub>4</sub>	mg/L	398
SiO <sub>2</sub>	mg/L	56
CO <sub>3</sub>	mg/L	0.33
CO <sub>2</sub>	mg/L	27

The above water quality indicates that the bore water is brackish. The bore water contains elevated levels of silica, which is a well known scale causing agent on RO membranes.



## Scenario 5 – 100 kL/d Saline Ground Water Source

It is recommended that raw water quality sampling is carried out over the course of a year, to ensure seasonal variations and water quality variations are captured, as the performance of the RO system is dependant on the raw water quality. Refer to Appendix C for details regarding monitoring requirements.

In addition to the water quality parameters currently being taken, it is also recommended that the following parameters be analysed: barium, reactive silica, ammonium, strontium and phosphate.

---

### Product Water Details

---

<b>Location</b>	<p>The desalination facility would be located at the existing bore. Minimal reticulation infrastructure is available at the site and will require upgrading for the transport of the treated water to the town's water supply network. Clear water storage tanks will be installed at the site after which desalinated water will undergo pH correction and disinfection prior to being fed into a new rising main connecting to the water supply network.</p> <p>An alternative scenario involves the desalination units located at the point of entry to individual households. No additional reticulation to the houses will be required.</p>
<b>Quality</b>	<p>The product water would be suitable for potable use, with a target TDS concentration below 500 mg/L.</p>
<b>Quantity</b>	<p>In order to meet peak summer demands the desalination facility would need to be capable of producing 100 kL/d. If water conservation principles are applied, the desalination facility would need to produce 30 kL/d.</p> <p>Individual household units would produce 1,500L/d as this is the minimum size recommended by suppliers. However, it is recommended that a detailed survey of households be undertaken to establish each houses potable water needs.</p>

---

### Desalination Technology

---

<b>Selection</b>	<p><b>Energy Considerations:</b></p> <p>The desalination facility would be located near an existing bore. The bore currently has an extraction pump and therefore mains energy would be available, however upgrade requirements of the electricity source will need to be identified. There is no economical waste heat source in the vicinity of the plant. Single-phase power is assumed available at individual households.</p> <p><b>Feed water considerations:</b></p> <p>The raw water source is considered to be brackish, with relatively high silica concentrations.</p> <p><b>Selection using Decision Tree (Section 5)</b></p> <p>A higher quality/quantity of fresh water is required for this scenario. Mains electricity is available, however there is no waste heat source available at the selected site. The feed water TDS is less than 44,000 mg/L and less than 12,000 mg/L. The water source has a high scaling potential and has a TDS greater than 3,000 mg/L (borderline TDS). Brackish water reverse osmosis (BWRO) would therefore be considered suitable for treating this water. Considering the TDS concentration is borderline, EDR may also be an appropriate technology for treating this bore water, however through discussions with an EDR supplier, it has</p>
------------------	---

## Scenario 5 – 100 kL/d Saline Ground Water Source

been determined that EDR is not economically feasible at such a low flow rate. Therefore EDR has not been considered in this scenario.

Three alternative strategies for supplying this community with desalinated water have been investigated:

*Alternative A: Plant to produce all community water requirements (100 kL/d).*

*Alternative B: Central plant of size to produce water only for internal potable use (300 L/P/d, 30 kL/d).*

*Alternative C: Individual household units fitted to main supply line into the house (1,500 L/d) (commonly known as 'point of entry' systems).*

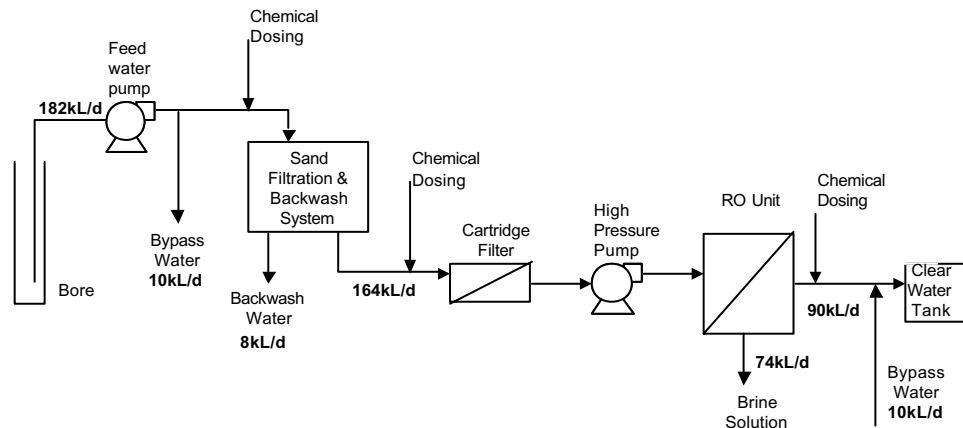
### Technology Description

*Alternative A: 100 kL/d RO facility*

The RO system would include pre-treatment, cartridge filters, high pressure feed pumps, high pressure vessels containing RO membrane, brine recovery system and permeate recovery system. 10 kL/d of raw untreated bore water will be blended with the desalinated water to reduce infrastructure and operating costs. Flow rates for individual streams are shown in the figure below.

Due to the high silica levels our preliminary calculations show that a 10% bypass and 55% recovery rate is required to ensure acceptable water quality. The RO process is shown schematically below. For a product water requirement of 100 kL per day, approximately 182 kL/d of feed water would be required.

Pilot plant trials would be required to determine the most appropriate design. Higher recovery rates may be achievable with high levels of pre-treatment and process optimisation.



*Alternative B: 30 kL/d RO facility*

The configuration of the RO plant producing 30 kL/d would be similar to that discussed above. For a recovery of 55% in the RO unit and 95% in the pre-treatment unit, it is expected that approximately 58 kL/d of feed water would be required to produce 30 kL/d of product water.

Pilot plant testing is also recommended to assist with identifying pre-treatment requirements and ensuring the full-scale plant adequately meets the needs of the community.



## Scenario 5 – 100 kL/d Saline Ground Water Source

*Alternative C: 40 Individual household units producing 1,500L/d.*

Small RO units will be installed at the water supply point of entry into the individual households. Suppliers have indicated that, depending on the water quality, the system would include pre-treatment media and cartridge filters, a RO membrane and a dosing pump for antiscalants as well as any other chemical addition that may be required.

The household unit can be considered a small-scale industrial treatment system, as illustrated above. To produce 1,500L/d product water the household units would need to be supplied with 2,871 L/d. This water would be fed via the main supply line to each house. A total of approximately 115 kL/d would be required to supply all households.

Bench scale pilot trials are recommended to determine the most appropriate design.

---

### Pre-treatment Requirements

*Alternative A and B*

Given the quality of the bore water it may be necessary to undertake the following pre-treatment:

- ▶ Sand filtration to reduce the turbidity levels.
- ▶ Coagulation prior to pre-filtration.
- ▶ Acid dosing for calcium carbonate scale control.
- ▶ Anti-scalant dosing will also be required to improve the membrane performance and life.
- ▶ Softening. This will help counter problems encountered due to high silica levels in the feed water. Other options commonly used to overcome high silica levels include increasing the feed water temperature (the solubility of silica reduces by 2 mg/L for every degree Centigrade increase), reducing the pH or anti-scalant dosing.

*Alternative C*

For small household units, it is recommended that the water undergo at a minimum the following pre-treatment:

- ▶ Sand filtration to reduce the turbidity levels
- ▶ Anti-scalant dosing will also be required to improve the membrane performance and life

Other pre-treatment options could be investigated, however the feasibility of these should be evaluated both economically and in terms of practicality.

### Post Treatment Requirements

*Alternative A and B*

The permeate will require the following post-treatment steps:

- ▶ Chemical dosing for pH correction (lime or soda ash dosing)
  - ▶ Chemical dosing for water conditioning (add lime and strip off excess CO<sub>2</sub>)
  - ▶ Disinfection.
-



## Scenario 5 – 100 kL/d Saline Ground Water Source

### *Alternative C*

It is recommended that water treated by individual household units undergo some form of disinfection. Small-scale UV disinfection units are available from suppliers. Bench scale pilot trials will establish the technical and economically feasibility of this treatment.

### **Waste Management**

The RO process produces three main waste streams:

- ▶ A highly saline brine stream
- ▶ Backwash waters from the pre-treatment processes.
- ▶ Cleaning waste stream

In addition to contaminants removed from the feedwater, the brine and backwash waters will also contain concentrations of the chemicals added through the process.

Brine is typically disposed of in a number of ways, depending on prevailing conditions.

- ▶ Disposal of brine to sea is not considered appropriate given the distance to the ocean (> 500 km).
- ▶ Groundwater injection of the brine is adopted in a number of areas, however given a lack of hydro-geological information this option has not been considered further.
- ▶ Crystallisation requires expensive and sophisticated equipment and operational knowledge. Given the volume of brine produced each year and the location of the town it is not considered practical in this case.
- ▶ Aquaculture enterprises have been established elsewhere to make use of the brine waters. The feasibility of this option would depend on attracting a suitable business interest to make the venture profitable.
- ▶ Some livestock have a high level of tolerance to waters containing TDS levels up to 5,000 mg/L. However in this case the TDS levels are expected to exceed 7,000 mg/L, and is therefore unsuitable

This scenario is located in a relatively dry area, where pan evaporation exceeds rainfall each month. Evaporative lagoons are therefore recommended at this site. The following brine disposal methods are proposed for each alternative and are based on the regions' meteorological data:

### *Alternative A:*

For a plant producing approximately 100 kL/d of product water, approximately 82 kL/d of waste product will be produced. This waste would have a TDS concentration of over 7,500 mg/L. A lagoon depth of 1 m would cover an area of approximately 1.1 hectares and accumulate 2,200 tonnes of salt every 10 years.

### *Alternative B:*

For a plant producing approximately 30 kL/d of product water, approximately 28 kL/d of waste product will be produced. This waste would have a TDS concentration of over 7,300 mg/L. Every 10 years to lagoons would accumulate approximately 750 tonnes of salt. A lagoon depth of 1 m would cover an area of approximately 0.4 hectares.



## Scenario 5 – 100 kL/d Saline Ground Water Source

### *Alternative C:*

The waste products would be disposed of via the households on-site wastewater treatment system (septic tanks in the case). Assuming the septic tanks have sufficient capacity, a total volume of 1,370 L/d of brine and backwash waste would be disposed of via the houses' existing wastewater system. This equates to a salt loading of 3.6 tonnes per years. A review of the septic tank and land disposal system capacity for each household in the community would identify those households that require larger capacity septic tanks/land disposal systems. The cost of this venture may not be economically feasible.

This option is not considered feasible and may be problematic because people rely on septic system to treat waste, which in turn rely on land based disposal of effluent. Applying high concentrations of salt to land may not be acceptable as a long-term solution.

Another possible option for disposing of the brine waste may be to install waste collection tanks at each household. These tanks would be emptied on a regular basis by a waste disposal service (operated by Council or private contractor). The waste could then be disposed of via an evaporation lagoon.

Note that careful design and consideration of the brine disposal method would therefore be required if this alternative was selected.

---

### **Environmental Factors**

#### *Alternatives A and B*

EPA approvals under ERA 16 (Municipal water treatment plant) would be required for all alternatives. It is recommended that the EPA be consulted regarding the approvals required.

Environmental factors that require consideration include:

- ▶ Type and quantity of chemicals, and how these are stored and disposed of in terms of environmental impacts.
- ▶ Brine disposal on-site. What is the potential environmental impact of on-site disposal? What impact will the design and operation evaporation pond have on the environment?
- ▶ Noise from the high-pressure pumps and other ancillary equipment.
- ▶ Aesthetics of the desalination plant. How does the plant appear to others?
- ▶ Backwash and cleaning stream disposal.

#### *Alternative C*

For this alternative the major environmental factor would be the impact of the brine waste on the existing wastewater treatment systems. The high TDS concentrations in the brine may be detrimental to the septic tank performance and thus the surrounding environment. It is recommended that a detailed investigation be undertaken to determine the feasibility of using septic tanks to treat the brine waste.



## Scenario 5 – 100 kL/d Saline Ground Water Source

### Operational and Maintenance Requirements

#### Labour

##### *Alternative A & B*

One operator maintains the existing disinfection facilities on a part time basis. It has been assumed that day-to-day operations (daily visual inspection and pH meter reading etc) and general maintenance of the RO plant (including changing membranes) would be carried out by the existing personnel. For plants of these capacities, approximately 3 hours/week of operator time would be required.

It is not envisaged that additional personnel would be required to operate and maintain the RO plant, however access to a process engineer (or equivalent) may be required to perform troubleshooting exercises and provide general advice regarding operation.

An allowance to seek advice from a troubleshooter should be made. This allowance may vary depending on the level of optimisation Council wish to achieve. The first year of operation will require significantly more troubleshooter time. For this scenario an allowance of 5 hours per week for 3 months, then 8 hour per month for the remainder of the year (9 months) has been made. Troubleshooting requirements are expected to decrease with time.

It is recommended that as part of the desalination contract, process proving and training phases be included. The training component will ensure future operational staff receive hands on familiarisation of the equipment including operations and maintenance. The 'trouble-shooter' personnel would require slightly more training and it is recommended that this person be experienced in operating desalination facilities.

##### *Alternative C*

The operation and maintenance of the household RO units is fairly minimal. Council will be responsible for the maintenance of the units, and existing personnel will be trained by the RO supplier to maintain the units suitably.

An allowance of 3 hours per house per year (total 120 hours per year) has been made for maintenance and servicing of the RO units. It is envisaged that the units will be serviced 6 monthly, and membranes be replaced approximately every 2 years.

It should be noted that the above service policy might not be best suited for all councils. Other councils may choose to transfer service responsibilities to the householder.

#### Chemical Requirements

##### *Alternative A and B*

The chemical requirements would include:

- ▶ Acid dosing for pH correction (sulphuric acid). Note that by lowering the pH, the problems caused by high silica concentrations can be reduced.
- ▶ Coagulant dosing (alum).
- ▶ Anti-scalant (RO suppliers typically recommend a preferred brand). Adding anti-scalant will also help minimise problems caused by high silica concentrations.
- ▶ Chemical dosing for product water conditioning (eg lime or soda ash).



## Scenario 5 – 100 kL/d Saline Ground Water Source

- Disinfection.

### *Alternative C*

The chemical requirements would include the anti-scalant and acid dosing. Dosing the water with both these chemicals will also help reduce the effects of high silica concentrations. Small-scale disinfection units for each household may also be considered, however these are not included in the cost estimate provided below.

### **Energy Requirements**

The RO energy requirements would be dominated by the high pressure RO feed pumps and the bore water extraction pumps. For all alternatives the energy requirements would be met by mains supply. It may be necessary to upgrade the electrical supply for Alternative A and B.

### *Alternative A*

Total energy requirements would be approximately 96 kWh/d

### *Alternative B*

Total energy requirements would be approximately 38 kWh/d

### *Alternative C*

Each household unit would consume approximately 0.9 kWh/d of energy. With an allowance for the pump requirements, the total energy consumption for the 40 RO units has been estimated as 49 kWh/d.

---

### **Membrane Replacement**

### *Alternative A and B*

RO membranes require replacement every 3 to 5 years due to the deterioration of the membrane, thus decreasing the efficiency of the RO process. In the case of this scenario, it has been assumed that the membranes will be replaced every 3 years. The increased costs associated with membrane replacement are offset by lower man-hours and chemical consumption.

### *Alternative C*

Small scale RO units will frequent membrane replacement as the level of optimisation and maintenance is reduced compared with large scale units. For the purposes of this scenario it has been assumed the membranes will be replaced every 2 years.

---

### **Costs**

#### **Capital**

The cost estimates are based on the following assumptions and include a 15% allowance for engineering/design and 25% contingency:

- Land costs are negligible as the RO facility would be located at the existing bore that is assumed to be on Council-owned land.
  - Land costs for evaporative lagoons are not included.
  - There are no costs associated with establishing the feedwater source further.
  - For Alternative C, no upgrades are required on the existing on-site wastewater treatment systems, and each household has a suitable septic tank (or equivalent) installed.
  - Costs do not include disinfection systems.
-



## Scenario 5 – 100 kL/d Saline Ground Water Source

Alternative A: 100 kL/d RO facility	\$ 0.48 M
Alternative B: 30 kL/d RO facility	\$ 0.24 M
Alternative C: 40 x 1,500 L/d RO units:	\$ 0.28 M

### Operational & Maintenance

The annual operating and maintenance costs for each alternative are listed in the table below. For Alternative C, the costs provided are for the entire community (ie 40 households), so that accurate comparisons can be made between alternatives.

	Alternative A 100 kL/d RO	Alternative B 30 kL/d RO	Alternative C 40 x 1,500 L/d RO
<b>Total O&amp;M Cost</b>	<b>\$ 45,700</b>	<b>\$ 33,700</b>	<b>\$ 19,600</b>
Annual allowance for membrane replacement: Calculated based on 10% of the capital for RO (excluding contingencies).	\$ 11,400 (Membrane replacement every 3 years)	\$ 5,800 (Membrane replacement every 3 years)	\$ 10,000 (Membrane replacement every 2 years)
Power usage: Based on 10c/kWh.	\$ 3,600	\$ 1,400	\$ 1,800
Chemical consumption: Based on 1% of capital (excluding contingencies).	\$ 3,400	\$ 1,700	\$ 1,000
<b>Labour</b>			
Operator Costs \$40/hour	\$ 6,300 (3 hours/week)	\$ 6,300 (3 hours/week)	\$ 4,800 (120 hours/year)
Trouble shooter Costs (first year) \$120/hour as required	\$ 15,900	\$ 15,900	N/A
Maintenance: Based on 1.5% of the capital (excluding contingencies).	\$ 5,100	\$ 2,600	\$ 2,000

Note on Alternative C: Smaller 'point of use' systems are available through the domestic water filter market. These units would be fitted to the kitchen tap and product water used for the purpose of cooking and drinking only (approximate capacity 20 L/d)



---

## Scenario 6 – 3.9 ML/d Saline Artesian Bore Water Source

---

### Background Information

This scenario is based on an inland community of approximately 3,250 people, with a peak summer potable water demand of 5.4 ML/d. It has been estimated from flow monitoring data that the average potable water demand is approximately 3.9 ML/d (1,200 L/P/d).

The town currently sources its potable water from a surface water supply. Raw water is drawn from a weir impoundment and pumped via a rising main to the town's water treatment plant. Here the water undergoes clarification, filtration, pH correction and disinfection before entering the town's reticulation system. As with many inland communities relying on surface water, the surface water supply is diminishing in terms of both quality and quantity.

Complaints have been received regarding the taste and odour of the surface water as well as discolouration of the water. Severe corrosion of the reticulation pipe work has also been reported. During periods of prolonged drought the town will rely on artesian bore water. The bore water is very hot and has a high pH. Testing of the bore water showed slightly elevated levels of TDS. The bore water is considered unacceptable for potable water use without treatment.

This scenario addresses the feasibility of using a desalination technology to treat the artesian bore water supply to a standard acceptable for potable water consumption by the community. The desalinated artesian bore water will be used as the town's potable water supply during drought periods. Demand management would most likely need to be used during drought periods to restrict the communities water demand to the supply provided by desalination (based on average supply of 3.9 ML/d). Using water conservation techniques, the in-house water supply could be reduced to 300 L/P/d (0.975 ML/d). This alternative is also investigated in this scenario.

It is envisaged that during non-drought periods that the desalination plant will continue to produce enough water to meet average water demands, and peak demands will be met by blending desalinated water with surface water. The reason for continuing to use the desalination plant is due to the economic and technical problems associated with operating a desalination plant intermittently.

---

### Source Water Details

---

#### Location

An existing bore is located approximately 5 km from the existing water treatment plant. Any desalination facility therefore would be located adjacent to the bore and desalinated water would be pumped to the existing treatment plant and from there into the town's reticulation network.

By locating the desalination plant near the bore, feedwater pumping and piping infrastructure requirements are reduced. The pipe and pump capacity would be sized based on the required product water flow rather than the required source water flow, which would be substantially cheaper.

---



---

## Scenario 6 – 3.9 ML/d Saline Artesian Bore Water Source

---

### Quality

The bore water has been sampled approximately three times in the last 15 years, with the average water quality described below:

Water Quality Parameter	Unit	Value
pH	-	8.7
Temperature	°C	90
TDS	mg/L	1045
Ca	mg/L	3
K	mg/L	3
Mg	mg/L	0.3
Na	mg/L	420
Cl	mg/L	115
F	mg/L	6
HCO <sub>3</sub>	mg/L	890
SO <sub>4</sub>	mg/L	4
Si	mg/L	32
CO <sub>3</sub>	mg/L	25
CO <sub>2</sub>	mg/L	5

The above water quality indicates that the bore water is brackish and high in silica.

It is recommended that:

- Samples are taken directly from the bore as well as from the cooling ponds, to establish the overall effectiveness of the cooling ponds as well as to characterise the feed water degradation in the cooling ponds. Should the cooling ponds be found to be ineffective at cooling the water to a temperature less than 40 °C other cooling methods such as heat exchangers will need to be investigated further.
- Raw water quality sampling is carried out over the course of year, to ensure seasonal variations and water quality variations are captured, as the performance of the RO system is dependant on the raw water quality. Refer to Appendix C for details regarding monitoring requirements.
- In addition to the water quality parameters currently being taken, it is also recommended that the following parameters be analysed: barium, reactive silica, ammonium, strontium and phosphate.

The temperature of the bore water being extracted from the ground is approximately 90 °C. Typically the performance and life of membranes are only guaranteed where the feedwater temperature is below 40 °C, and scaling is worse at higher temperatures.

Cooling can be achieved by a number of methods, with the least sophisticated method being cooling ponds. The main problem with cooling ponds is that the feedwater quality often deteriorates, resulting in more costly pre-treatment steps. Heat exchangers can also be considered, they can be more expensive and add a degree of complexity to the system, however a higher feedwater quality can be sustained.



---

## Scenario 6 – 3.9 ML/d Saline Artesian Bore Water Source

---

### Product Water Details

---

Pilot plant testing is also recommended to assist with identifying pre-treatment requirements (including various cooling options), ensuring the full-scale plant adequately meets the needs of the community.

---

**Location** Since the desalination plant will be located approximately 5 km from the existing treatment plant, additional reticulation (piping and pumps) will be required to transfer the treated bore water to the treatment plant for distribution to the community.

**Quality** The product water would be suitable for potable use, with a target TDS concentration below 500 mg/L.

**Quantity** In order to meet average summer demands the desalination facility would need to be capable of producing 3.9 ML/d. It is planned to mix the desalinated water with traditionally treated surface water, to meet a peak demand of 5.4 ML/d.

Reducing the water supply to 300 L/P/d the plant would only need to be sized for approximately 0.975 ML/d. Water would be for in-house use only. This water conservation alternative is investigated further in this scenario.

---

### Desalination Technology

---

**Selection** **Energy Considerations:** The desalination facility would be located at a bore. There is an electricity supply to the bore water drawing pumps. Although the water is 'hot', thermal options are not usually viable for this size plant and low feed water TDS concentrations.

**Feed water considerations:** The raw water source is considered to be brackish, with low TDS concentrations and high silica concentrations.

#### **Selection using Decision Tree (Section 5)**

A higher quality/quantity of fresh water is required for this scenario. Mains electricity is available, however there is no waste heat source available at the selected site. The feed water TDS is less than 44,000 mg/L and less than 12,000 mg/L. The water source has a high scaling potential and has a TDS less than 3,000 mg/L (borderline TDS). Brackish water reverse osmosis (BWRO) or EDR would therefore be suitable for treating this water. Three alternative scenarios are discussed from this point onward, being:

*Alternative A: BWRO to produce 3.9 ML/d product water.*

*Alternative B: BWRO to produce 0.975 ML/d product water.*

*Alternative C: EDR to produce 3.9 ML/d product water.*

**Technology Description** For all alternatives, cooling of the feed water will be necessary. The town has already constructed a cooling pond adjacent to the bore. The temperature of water from the cooling ponds is expected to experience seasonal fluctuations and therefore the RO system has been designed for a worst-case scenario (ie temperature of 35 °C). Variations in feedwater temperature result in increased rates of salt and water diffusion across the membrane, and therefore result in higher TDS concentrations in the product water.

---

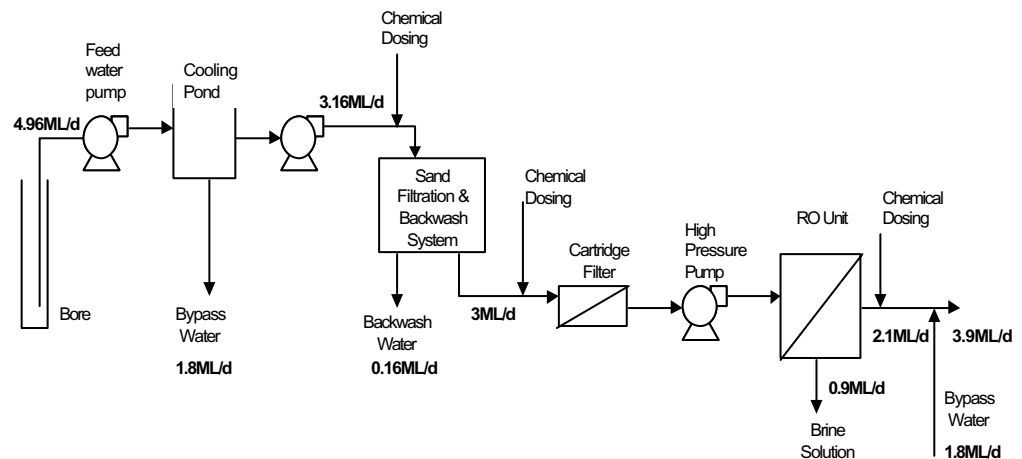
## Scenario 6 – 3.9 ML/d Saline Artesian Bore Water Source

### Alternative A

The RO system would include cooling ponds, pre-treatment, cartridge filters, high pressure feed pumps, high pressure vessels containing RO membrane, brine recovery system and permeate recovery system.

Preliminary calculations show that with a 1.8 ML/d bypass of untreated bore water and 70 % recovery rate acceptable water quality results are achieved. Water would be drawn from the bore at a rate of 4.96 ML/d and cooled in the cooling ponds. A total of 3.16 ML/d of bore would pass through the RO system producing 2.1 ML/d product water. 1.8 ML/d would bypass the RO system and be added to the treated water at the end of the process giving a total supply of 3.9 ML/d. With careful design and planning this ratio could be optimised further, thus capital, operating and maintenance costs could be reduced.

For the purposes of this scenario it has been assumed that the desalinated water will be blended with traditionally treated surface water at a ratio of 3.9ML/d:1.5ML/d to meet the peak summer demand. Further investigations would be required to determine the most appropriate blending ratio. The following diagram schematically describes the RO system.



### Alternative B

This alternative investigates the option of reducing the water supply to 300 L/P/d (0.975 ML/d). The RO system would include cooling ponds, pre-treatment, cartridge filters, high pressure feed pumps, high pressure vessels containing RO membrane, brine recovery system and permeate recovery system, as per Alternative A. The configuration would remain as for Alternative A, however the flow rates will be significantly lower.

The RO unit would be operated at 70% recovery, and the pre-treatment unit would recover approximately 95% of the water. Note that no attempt has been made to optimise this design and better recovery rates may be achievable with optimisation of the configuration and chemical dose rates.

Water would be drawn from the bore at a rate of 1.26 ML/d and cooled in the cooling ponds. A total of 0.86 ML/d of bore would pass through the RO system producing 0.575 ML/d product water. 0.4 ML/d would bypass the RO system and be added to the treated water at the end of the process giving a total supply of

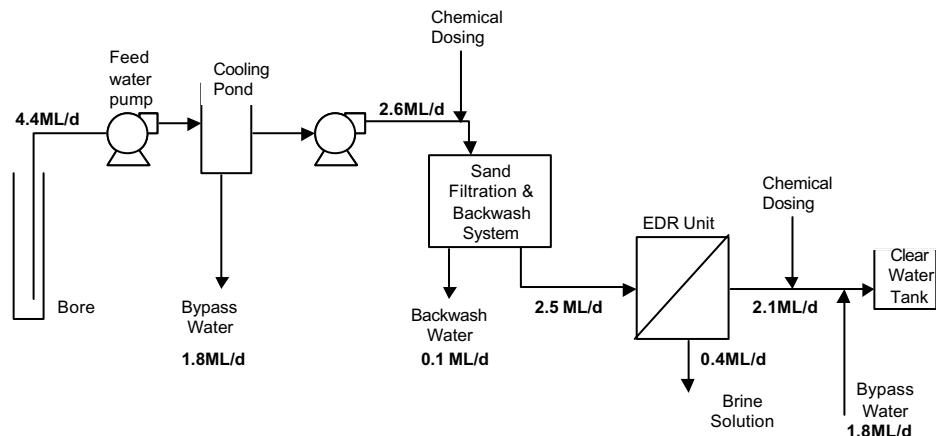
## Scenario 6 – 3.9 ML/d Saline Artesian Bore Water Source

0.975 ML/d. Further downsizing of the system could result from blending the desalinated water with traditionally treated water, however this has not been considered for this alternative.

### Alternative C

The EDR plant would comprise cooling ponds, pre-treatment, vessel containing EDR membranes, brine recovery system and a permeate recovery system. The configuration of the plant is shown schematically below. Assuming the EDR operates at approximately 85% recovery and the pre-treatment unit operates at 95% recovery, 4.4 ML/d feed water would need to be drawn from the bore and fed to the cooling ponds.

It has been assumed that a 1.8 ML/d bypass (as for Alternative A) would be possible, however pilot trials are recommended to confirm the technical feasibility of this option. Approximately 2.6 ML/d would be fed to the EDR system, yielding 2.1 ML/d product water. Combining the untreated bypass water with the desalinated water would give a total supply of 3.9 ML/d. This water could then be blended with traditionally treated water to make up the peak supply (as per Alternative A).



### Pre-treatment Requirements

#### Alternative A, B and C

It will be necessary to undertake the following pre-treatment:

- Cooling via cooling ponds (existing).
- Sand filtration to remove suspended solids.
- Coagulation to improve the pre-filtration.
- Acid dosing to reduce calcium carbonate scaling.
- Anti-scalant dosing may also be required to improve the membrane performance and life.

EDR processes do not require as much pre-treatment as RO process.



---

## Scenario 6 – 3.9 ML/d Saline Artesian Bore Water Source

---

### Post Treatment Requirements

*Alternative A, B and C*

The permeate may require the following post-treatment steps:

- ▶ Chemical dosing for pH correction (lime or soda ash dosing)
- ▶ Chemical dosing for water conditioning (add lime and strip off excess CO<sub>2</sub>)
- ▶ Disinfection.
- ▶ Blending with both untreated bore water and traditionally treated surface waters.

Given the fact that blending will not occur during drought periods, the post-treatment requirements provided above and costed below do not make allowance for benefits to be gained from blending. Further studies would be required at the detailed design phase to quantify blending benefits. Costs may be lower during non-drought periods.

---

### Waste Management

The RO and EDR processes produce three main waste streams:

- ▶ A highly saline brine stream.
- ▶ Backwash waters from the pre-treatment processes.
- ▶ Cleaning stream.

In addition to contaminants removed from the feedwater, the brine and backwash waters will also contain concentrations of the chemicals added through the process. Brine is typically disposed of in a number of ways, depending on prevailing conditions.

- ▶ Disposal of brine to sea is not considered appropriate given the distance to the ocean.
- ▶ Groundwater injection of the brine is adopted in a number of areas, however given a lack of hydro-geological information this option has not been considered further.
- ▶ Crystallisation requires expensive and sophisticated equipment and operational knowledge. Given the volume of brine produced each year and the location of the town it is not considered practical in this case.
- ▶ Aquaculture enterprises have been established elsewhere to make use of the brine waters. The feasibility of this option would depend on attracting a suitable business interest to make the venture profitable.
- ▶ Some livestock have a high level of tolerance to waters containing TDS levels up to 5,000 mg/L. Brine waters in some instances may provide an alternate livestock drinking water source. This option should be further investigated since the TDS concentration of the waste stream is expected to be less than 5,000 mg/L.

This scenario is located in a relatively dry area, where pan evaporation exceeds rainfall each month. Evaporative lagoons have therefore been considered for this site. Every 10 years council will need to investigate options for disposal and removal of the salt. Based on available meteorological data, and assuming salt harvesting is carried out every ten years and a lagoon depth of 1 m the following are applicable for each alternative.

---



---

## Scenario 6 – 3.9 ML/d Saline Artesian Bore Water Source

---

### *Alternative A*

For a RO plant producing 2.1 ML/d desalinated water, 1 ML/d of waste product will be generated. This waste would have a TDS concentration of 4,000 mg/L, and approximately 15,000 tonnes of salt will accumulate every 10 years. The evaporative lagoons would cover an area of approximately 10 hectares.

### *Alternative B*

For a RO plant producing 0.575 ML/d desalinated water, 0.285 ML/d of waste product will be generated. This waste would have a TDS concentration of 4,000 mg/L, and approximately 4,300 tonnes of salt will accumulate every 10 years. The evaporative lagoons would cover an area of approximately 3 hectares.

### *Alternative C*

For an EDR plant producing 2.1 ML/d desalinated water, 0.5 ML/d of waste product will be generated. This waste would have a TDS concentration of approximately 4,000 mg/L, and approximately 7,500 tonnes of salt will accumulate every 10 years. The evaporative lagoons would cover an area of approximately 5 hectares.

---

### **Environmental Factors**

#### *Alternative A, B and C*

Factors that require consideration include:

- ▶ Type and quantity of chemicals, and how these are stored and disposed of in terms of environmental impacts.
- ▶ Brine disposal on-site. What is the potential environmental impact of on-site disposal? What impact will the design and operation evaporation pond have on the environment?
- ▶ Noise from the high-pressure pumps and other ancillary equipment.
- ▶ Aesthetics of the desalination plant. How does the plant appear to others?
- ▶ Backwash and cleaning stream disposal.

EPA approvals under ERA 16 (Municipal water treatment plant) would be required for all alternatives. The disposal of brine into evaporative lagoons would fall under a separate ERA. It is recommended that the EPA be consulted regarding the approvals required.

---

### **Operational and Maintenance Requirements**

---

#### **Labour**

It is recommended that as part of the desalination contract, process proving and training phases be included. This allows the plant to undergo trouble shooting without diverting Council resources from existing work. The training component will ensure future operational staff receive hands on familiarisation of the equipment including operations and maintenance.

The existing WTP currently employs 4 people, with their work hours spread between water and sewerage infrastructure. It has been assumed that the day-to-day operations (daily visual inspection, pH meter reading and cleaning etc) and general maintenance (including changing membranes) would be carried out by existing WTP personnel.

For all alternatives, access to process engineer (or equivalent) may be required to perform troubleshooting exercises and provide general advise regarding operation.

---



---

## Scenario 6 – 3.9 ML/d Saline Artesian Bore Water Source

---

It has been assumed during the first 3 months of operation the troubleshooter will be required for approximately 5 hours per week. For the remainder of the first year an allowance of 8 hours per month for troubleshooter time has been made. Troubleshooting requirements should decrease with time.

### *Alternative A*

It is estimated that for a plant of this capacity the operators will need to devote 20 hours per week to the desalination plant.

### *Alternative B*

For a plant of this capacity, it is estimated that the operators will be required for 6 hours per week.

### *Alternative C*

The EDR facility will require approximately 20 hours per week of the operators time.

---

## **Chemical Requirements**

### *Alternative A, B and C*

Chemical requirements would include:

- ▶ Acid dosing for pH correction (sulphuric acid)
- ▶ Coagulant dosing (alum)
- ▶ Anti-scalant (RO suppliers typically recommend a preferred brand)
- ▶ Lime dosing for product water conditioning
- ▶ Disinfection

Estimates of chemical usage have been made for costing purposes only. Actual chemical dosage rates would depend on the membrane system selected and their tolerance to various contaminants. Note that the pre-treatment chemical requirements for EDR systems are less than for RO systems.

## **Energy Requirements**

For all alternatives, the energy requirements would be met by mains supply. It may be necessary to upgrade the electrical supply into the bore.

### *Alternative A*

The RO energy requirements would be dominated by the high pressure RO feed pumps and the bore water extraction pumps. It is estimated that the daily energy requirement would be in the order of 1.9 MWh/day.

### *Alternative B*

It is estimated that the daily energy requirement for an RO system of this capacity would be 0.4 MWh/d.

### *Alternative C*

The energy requirements for the EDR has been estimated as 4.7 MWh/d.

---



---

## Scenario 6 – 3.9 ML/d Saline Artesian Bore Water Source

---

### Membrane Replacement

#### *Alternative A and B*

RO membranes require replacement every 3 to 5 years due to the deterioration of the membrane, thus decreasing the efficiency of the RO process. In the case of this scenario, it has been assumed that the membranes will be replaced every 5 years.

#### *Alternative C*

EDR membranes require replacement every 5 to 10 years depending on the level of optimisation the plant receives. For this scenario it has been assumed that the membranes will require replacement every 5 years. The membrane replacement allowance for the EDR system in this scenario includes a provision for electrode replacement. The electrodes will require replacement every one to two years.

---

### Costs

---

#### Capital

The following cost estimates are based on the following assumptions and include a 15% allowance for engineering/design and 25% contingency:

- ▶ Land costs are negligible as the RO facility would be located at the existing WTP.
- ▶ Land costs for evaporative lagoons have not been included.
- ▶ There are no costs associated with establishing the feedwater source further.
- ▶ The treated bore water will need to be pumped 5 km to the existing treatment plant. Disinfection is assumed to occur prior to being transferred.
- ▶ Brine and backwash waters are disposed of via evaporation ponds.

---

Alternative A: 3.9 ML/d RO facility	\$ 5.9 M
Alternative B: 0.975 ML/d RO facility	\$ 2.2 M
Alternative C: 3.9 ML/d EDR facility:	\$ 8.9 M

---

It should be noted that making use of existing water treatment infrastructure, could reduce the above capital costs. A detailed investigation would be required to determine the feasibility of this option.

---




---

## Scenario 6 – 3.9 ML/d Saline Artesian Bore Water Source

---

**Operational & Maintenance** The annual O&M costs for this system have been estimated and can be broken down as follows:

	<b>Alternative A 3.9 ML/d RO</b>	<b>Alternative B 0.975 ML/d RO</b>	<b>Alternative C 3.9 ML/d EDR</b>
<b>Total O&amp;M Cost</b>	<b>\$ 314,700</b>	<b>\$ 113,200</b>	<b>\$ 367,800</b>
Annual allowance for membrane replacement:	\$ 84,000 (10% of the capital, excluding contingencies and to be replaced once every 5 years)	\$ 31,500 (10% of the capital, excluding contingencies and to be replaced once every 5 years)	\$ 12,700 (1% of capital, excluding contingencies, and 5 yearly replacement)
Power usage: Based on 10c/kWh.	\$ 68,200	\$ 13,800	\$ 170,500
Chemical consumption:	\$ 42,000 (1% of capital, excluding contingencies)	\$ 15,800 (1% of capital, excluding contingencies)	\$ 31,800 (0.5% of capital, excluding contingencies)
<b>Labour</b>			
Operator Costs \$40/hour (20 hours/week)	\$ 41,600	\$ 12,500 (6 hours/week)	\$ 41,600 (20 hours/week)
Trouble shooter Costs (first year) \$120/hour as required	\$ 15,900	\$ 15,900	\$ 15,900
Maintenance: Based on 1.5% of the capital (excluding contingencies).	\$ 63,000	\$ 23,700	\$ 95,300

---



## Scenario 7 – 10 ML/d Ground Water Source Affected by Salt Water Intrusion

### Background Information

This scenario is based on a coastal community of approximately 10,000 people, with a peak summer potable water demand of 10 ML/d (1,000 L/P/d). The town relies on groundwater for its potable supply. A system of bores exists south of the town and west of the existing Water Treatment Plant (WTP).

Issues arise when groundwater is pumped from aquifers that are in hydraulic connection with the sea, resulting in the migration of salt-water from the sea toward the freshwater aquifer. The key to controlling this problem is to maintain a proper balance between water being pumped from the aquifer and the amount of water recharging it.

Historical data from ground water extraction processes indicates a 5-10 percent depletion of the aquifer. In a coastal environment this depletion is recharged with saltwater. In keeping with water conservation principles, an alternative water supply of 300 L/P/d (3 ML/d) is also investigated as part of this scenario.

Monitoring of the groundwater stores indicates that the water source had been impacted by saltwater infiltration resulting in an increase in the salinity of the raw water.

This scenario addresses the feasibility of using a desalination technology to treat water sourced from a coastal aquifer that is susceptible to saltwater intrusions.

### Source Water Details

#### Location

Groundwater would be sourced from the established system of bores located 2 km south of the coastal community and 3 km west of the existing WTP.

#### Quality

Bore water sampling has been undertaken as part of the current potable water supply. Current mean water quality parameters are described below:

Water Quality Parameter	Units	Mean
Temperature	°C	21
pH	-	6.1
TDS	mg/L	2900
Colour	HU	0.3
Alkalinity (as CaCO <sub>3</sub> )	mg/L	267
Calcium	mg/L	9
Iron (Total)	mg/L	0.09
Magnesium	mg/L	28
Hardness (as CaCO <sub>3</sub> )	mg/L	36
Chloride	mg/L	312
Nitrite as N	mg/L	0.01

The elevated TDS levels indicate that the bore water is brackish. These results are characteristic of groundwater stores impacted by seawater infiltration. It is assumed that the water is low in scalant forming compounds.



## Scenario 7 – 10 ML/d Ground Water Source Affected by Salt Water Intrusion

It is recommended that raw water quality sampling is carried out over the course of year, to ensure seasonal variations and water quality variations are captured, as the performance of the RO system is dependant on the raw water quality. Refer to Appendix C for details regarding monitoring requirements.

### Product Water Details

<b>Location</b>	The desalination facility would be located alongside of the existing WTP, allowing for treated water to be fed directly into the existing clear water tanks. Here the treated water would undergo pH correction and disinfection using existing infrastructure.
<b>Quality</b>	The product water would be suitable for potable use, with a target TDS concentration below 500 mg/L.
<b>Quantity</b>	In order to meet peak summer demands the desalination facility would be capable of producing 10 ML/d. An alternative water conservative flow rate of 3 ML/d (300 L/P/d), which would supply water for in-house use only, is also considered.

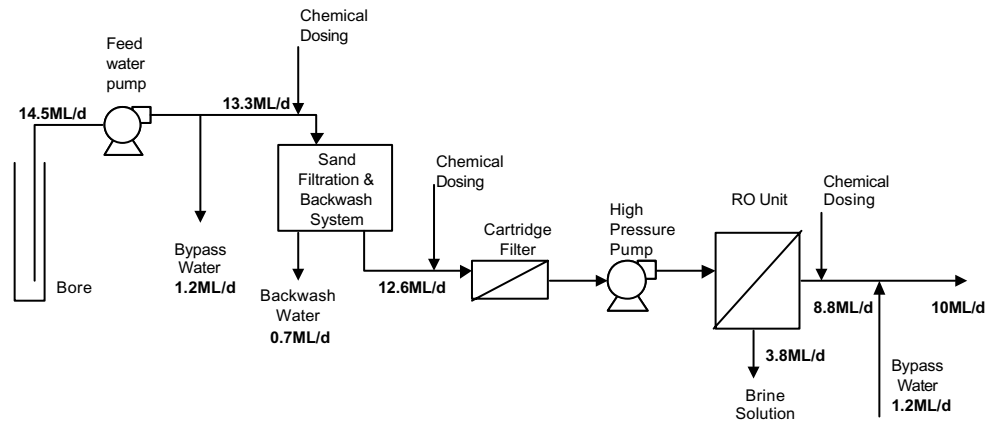
### Desalination Technology

<b>Selection</b>	<p><b>Energy Considerations:</b> The desalination facility would be located at an existing WTP therefore mains energy would be available. There is no economical waste heat source in the vicinity of the plant.</p> <p><b>Feed water considerations:</b> The raw water source is considered to be brackish.</p> <p><b>Selection using Decision Tree (Section 5)</b></p> <p>A higher quality/quantity of fresh water is required for this scenario. Mains electricity is available, however there is no waste heat source available at the selected site. The feed water TDS is less than 44,000 mg/L and less than 12,000 mg/L. The water source does not have a high scaling potential. Brackish water reverse osmosis (BWRO) would therefore be considered suitable for treating this water.</p> <p>Two alternatives are discussed in this scenario:</p> <p><i>Alternative A: BWRO to produce 10 ML/d product water.</i></p> <p><i>Alternative B: BWRO to produce 3 ML/d product water.</i></p>
<b>Technology Description</b>	<p>For both alternatives, the RO unit would require a sand filtration pre-treatment system, cartridge filters, high pressure feed pumps, high pressure vessels containing the RO membrane, a brine and permeate recovery system.</p> <p>Pilot plant testing is recommended to assist with identifying pre-treatment requirements, ensuring the full-scale plant adequately meets the needs of the community.</p> <p><i>Alternative A: BWRO to produce 10 ML/d product water</i></p> <p>Preliminary calculations show that with a 1.2 ML/d bypass of untreated bore water and 70 % recovery rate acceptable water quality is achieved. Water would be drawn from the bore at a rate of 14.5 ML/d. A total of 13.3 ML/d of bore would pass through the RO system producing 8.8 ML/d product water. 1.2 ML/d would bypass the RO system and be added to the treated water at the end of the process giving a total supply of 10 ML/d. With careful design and planning this</p>

## Scenario 7 – 10 ML/d Ground Water Source Affected by Salt Water Intrusion

ratio could be optimised further, thus capital, operating and maintenance costs could be reduced.

The following diagram schematically describes the RO system for Alternative A.



### Alternative B: BWRO to produce 3 ML/d product water

The configuration of the RO system for this alternative would be similar to that illustrated for Alternative A.

Water would be drawn from the bore at a rate of 4.35 ML/d. A total of 4.1 ML/d of bore would pass through the RO system producing 2.75 ML/d product water. 0.25 ML/d would bypass the RO system and be added to the desalinated water at the end of the process giving a total supply of 3 ML/d. Further downsizing of the system could result from optimisation of this configuration.

### Pre-treatment Requirements

#### Alternative A and B

For both alternatives it may be necessary to undertake the following pre-treatment:

- ▶ Sand filtration to remove any particulate matter
- ▶ Acid dosing for pH correction. Acid dosing is typically undertaken using sulphuric acid and helps to reduce calcium carbonate scaling of the RO membranes.
- ▶ Anti-scalant dosing may also be required to improve the membrane performance and life.

### Post Treatment Requirements

#### Alternative A and B

The permeate will require the following post-treatment steps:

- ▶ Chemical dosing for pH correction (lime or soda ash dosing)
- ▶ Chemical dosing for water conditioning (lime dosing and strip off excess CO<sub>2</sub>)
- ▶ Disinfection.



## Scenario 7 – 10 ML/d Ground Water Source Affected by Salt Water Intrusion

### Waste Management

The RO process produces three main waste streams:

- ▶ A highly saline brine stream
- ▶ Backwash waters from the pre-treatment processes
- ▶ Cleaning wastes from membranes.

In addition to contaminants removed from the feedwater, the brine and backwash waters will also contain concentrations of the chemicals added through the process. Given the close proximity to the ocean brine would be disposed of to sea via an ocean outfall.

#### *Alternative A*

For a plant producing approximately 10 ML/d of product water, approximately 4.5 ML/d of waste product will be produced. This waste would have a TDS concentration of around 12,000 mg/L.

#### *Alternative B*

An RO plant with a capacity of 3 ML/d would produce approximately 1.35 ML/d of waste product with a TDS concentration in the order of 12,000 mg/L.

### Environmental Factors

#### *Alternative A and B*

EPA approvals under ERA 16 (Municipal water treatment plant) would be required for all alternatives. The disposal of brine into ocean would fall under a separate ERA. It is recommended that the EPA be consulted regarding the approvals required.

The coastal community is listed as an environmental sensitive area and requires the following factors to be taken in to consideration:

- ▶ Impact of brine disposal on the oceans flora and fauna around the ocean outfall
- ▶ Impact on the community of any required easement development
- ▶ Aesthetic impact of the desalination facility

Periods of low rainfall during the summer months and the utilisation of groundwater as a raw water source will impact the regional hydrology.

Groundwater utilisation may cause the salt-water interface to move inland and closer to the ground surface. Methods to minimise this impact are listed below:

- ▶ Mapping the hydraulic head (potentiometric surface) may be required to determine the direction of groundwater flow within the aquifer. Development of a high potentiometric surface may control the influx of salt water to the aquifer.
- ▶ Groundwater monitoring and management would be required to keep salt-water intrusion under control.



## Scenario 7 – 10 ML/d Ground Water Source Affected by Salt Water Intrusion

### Operational and Maintenance Requirements

#### Labour

It is recommended that as part of the desalination contract, process proving and training phases be included. The training component will ensure future operational staff receive hands on familiarisation of the equipment including operations and maintenance.

The existing WTP currently employs 2 people. It has been assumed that the day to day operations (daily visual inspection, pH meter cleaning, chemical restocking and meter reading) and general maintenance (including changing membranes) would be carried out by additional or existing personnel. Access to process engineer (or equivalent) may be required to perform troubleshooting exercises and provide general advise regarding operation.

#### *Alternative A*

Given the large capacity of the plant it is estimated that 40 hours per week of operator time would be required to monitor and maintain the RO facility. Additional personnel will be required. It has been assumed during the first 3 months of operation the troubleshooter will be required for approximately 10 hours per week. For the remainder of the first year an allowance of 16 hours per month for troubleshooter time has been made. Troubleshooting requirements should decrease with time.

#### *Alternative B*

The operators would be required to attend the RO facility for approximately 20 hours per week. The existing WTP personnel would carry out the monitoring/maintaining role. It has been assumed during the first 3 months of operation the troubleshooter will be required for approximately 5 hours per week. For the remainder of the first year an allowance of 8 hours per month for troubleshooter time has been made. Troubleshooting requirements should decrease with time.

#### Chemical Requirements

#### *Alternative A and B*

Chemical requirements would include:

- ▶ Acid dosing for pH correction (sulphuric acid)
- ▶ Anti-scalant (RO suppliers typically recommend a preferred brand)
- ▶ Chemical dosing for product water conditioning (eg lime or soda ash)
- ▶ Disinfection

Estimates of chemical usage have been made for costing purposes only. Actual chemical dosage rates would depend on the membrane system selected and their tolerance to various contaminants.

#### Energy Requirements

The high pressure RO feed pumps and the bore water extraction pumps would dominate the RO energy requirements. The energy requirements would be met by mains supply. It may be necessary to upgrade the electrical supply into the existing WTP. Discussions would need to be held with the local electricity supplier to determine the scope and cost of any upgrade.

#### *Alternative A*



## Scenario 7 – 10 ML/d Ground Water Source Affected by Salt Water Intrusion

It is estimated that the daily energy requirement would be in the order of 12.6 MWh/day.

### *Alternative B*

It is estimated that the daily energy requirements of this facility will be 2.6 MWh/d.

---

### **Membrane Replacement**

#### *Alternative A and B*

RO membranes require replacement every 3 to 5 years due to the deterioration of the membrane, thus decreasing the efficiency of the RO process. In the case of this scenario, it has been assumed that the membranes will be replaced every 5 years.

---

### **Costs**

#### **Capital**

The capital costs associated with providing an RO systems of the capacities described previously are shown in the following table. These cost estimates are based on the following assumptions and include a 15% allowance for engineering/design and 25% contingency:

- ▶ Land costs are negligible as the RO facility would be located at the existing WTP.
- ▶ There are no costs associated with establishing the feedwater source further.
- ▶ The product water can be fed directly into the existing WTP clear water tanks.
- ▶ Brine can be disposed of to the ocean. Costs for brine disposal infrastructure not included.

---

Alternative A: 10 ML/d BWRO facility	\$ 11.2 M
Alternative B: 3 ML/d BWRO facility	\$ 4.6 M

---

It should be noted that the above capital costs may be reduced by making further use of existing water treatment infrastructure, thereby reducing the pre-treatment capital costs. A detailed investigation would be required to determine the feasibility of this option.

---



## Scenario 7 – 10 ML/d Ground Water Source Affected by Salt Water Intrusion

### Operational & Maintenance

The annual O&M costs for both alternatives are broken down as follows:

	Alternative A 10 ML/d RO	Alternative B 3 ML/d RO
<b>Total O&amp;M Cost</b>	<b>\$ 933,700</b>	<b>\$ 300,000</b>
Annual allowance for membrane replacement: Calculated based on 10% of the capital (excluding contingencies) and to be replaced once every 5 years.	\$ 160,000	\$ 66,000
Power usage: Assumed 10c/kWh.	\$ 458,800	\$ 94,000
Chemical consumption: Based on 1% of capital (excluding contingencies).	\$ 80,000	\$ 33,000
Labour		
Operator Costs \$40/hour	\$ 83,200 (40 hours/week)	\$ 41,600 (20 hours/week)
Trouble shooter Costs (first year) \$120/hour as required	\$ 31,700	\$ 15,900
Maintenance: Based on 1.5% of the capital (excluding contingencies).	\$ 120,000	\$ 49,500



---

## Scenario 8 – 0.5 ML/d Coal Seam Methane Water Source

---

### Background Information

This scenario is based on an inland mining community of approximately 800 people where the peak summer potable water demand of 0.8 ML/d (1000 L/person/d). The mines Water Treatment Plant (WTP) currently supplies the community's potable demands where its raw water is obtained from an artesian basin and surface water body. Treated water is pumped 4.0 km to the town. The potable demand is increasing due to mining expansion and concerns exist as to the ability of the WTP to meet future requirements.

Proposals for extensions to the existing mine will include the harvesting of methane gas. The methane extraction process involves pumping large volumes of water from the ground to the surface. The water pressure that is trapping the gas in the coal must be lowered in order to release significant amounts of methane. Coal Seam Methane (CSM) water produced can be either reinjected into the coal seam or disposed of to land. The reuse of this resource is a more viable option than reinjection or disposal.

It is likely that the population of the mining community will increase by 20% within the year and up to 60% over the following five years.

This scenario therefore addresses the feasibility of using a desalination technology to treat CSM produced water to a standard acceptable for potable water consumption by the mining community.

---

### Source Water Details

---

#### Location

The proposed CSM Plant is to be located 1.0 km east of the existing mine. The desalination facility therefore would be located adjacent to the CSM Plant, reducing the need for any additional pumping, piping and extraction infrastructure, thereby minimising the ancillary costs associated with desalination.

#### Quality

CSM water quality analysis results are shown in the table below:

Water Quality Parameter	Units	Mean
pH	-	7.9
Temperature	°C	29
TDS	mg/L	3880
Turbidity	NTU	3.2
Calcium	mg/L	134
K	mg/L	6.5
Mg	mg/L	57
Na	mg/L	867.2
Cl	mg/L	1312.4
F	mg/L	0.4
HCO <sub>3</sub>	mg/L	267
NO <sub>3</sub>	mg/L	0.09

---



## Scenario 8 – 0.5 ML/d Coal Seam Methane Water Source

Water Quality Parameter	Units	Mean
SO <sub>4</sub>	mg/L	344
SiO <sub>2</sub>	mg/L	38
CO <sub>3</sub>	mg/L	0.28
CO <sub>2</sub>	mg/L	23.4

Results indicate that the product water is brackish. Appropriate pre-treatment should maximise the efficiency and minimise scaling impact on the desalination unit. It is recommended that more detailed raw water quality sampling be carried out to ensure that desalination system needs are satisfied (refer to Appendix C for further details).

High molecular weight hydrocarbons will be removed during pre-treatment processes. Polyamide based membranes have shown susceptibility to low molecular weight hydrocarbons where cellulose triacetate based membranes appear to be more resilient. (Owadally, 2002)

Periodic hydrocarbon analysis should be undertaken on both the raw and product water to ensure that organic membrane fouling is minimised and that no health risks exist.

### Product Water Details

<b>Location</b>	Permeate would undergo post-treatment and then be pumped 2.1 km to the communities potable reticulation system.
<b>Quality</b>	The product water would be suitable for potable use, with a target TDS concentration below 500 mg/L.
<b>Quantity</b>	In order to meet peak summer demands the desalination facility would need to be capable of producing 0.4 ML/d. Desalinated water would be blended with traditionally treated water. As desalination facilities are modular in design, any additional potable demands could be met by attaching an additional unit to the plant.

### Desalination Technology (Include Site specifics)

<b>Selection</b>	<p><b>Energy Considerations:</b> The desalination facility would be located adjacent to the CSM Plant in order to utilise methane gas as an energy source. The relatively lower yield of carbon dioxide per unit of energy produced when burning methane compared with oil and coal would help minimise the facilities environmental impact. Mains energy is difficult to access at the proposed site.</p> <p><b>Feed water considerations:</b> The raw water source is considered to be brackish with high metal, nutrient and TDS concentrations.</p> <p><b>Selection using Decision Tree (Section 5)</b></p> <p>A higher quantity of water is required than currently being delivered by the WTP. No mains energy is available, however waste heat is available. The feedwater TDS concentration is less than 10,000 mg/L, therefore brackish water reverse osmosis (BWRO) is recommended.</p> <p>In order to compare thermal and membrane technologies, thermal vapour</p>
------------------	--



---

## Scenario 8 – 0.5 ML/d Coal Seam Methane Water Source

---

compression (TVC) has been evaluated as an alternative. TVC is not recommended for systems with low TDS and is discussed for comparative purposes only.

Two alternatives are therefore discussed as part of this scenario:

*Alternative A: BWRO to produce 0.4 ML/d product water.*

*Alternative B: TVC to produce 0.4 ML/d product water.*

---

### Technology Description

For the purposes of this scenario it has been assumed that the mining communities potable demand would be shared equally between the existing WTP and the desalination plant. Desalinated water will be blended with traditionally treated water from the WTP at a ratio of 0.4 ML/d:0.4 ML/d.

Additional CSM water produced could be reinjected into the coal seam or treated to a higher level and utilised somewhere within the mines boundaries (coal wash plant, land irrigation, evaporation ponds).

Pilot plant testing is recommended to assist with identifying pre-treatment requirements, ensuring the full-scale plant adequately meets the needs of the community.

#### *Alternative A*

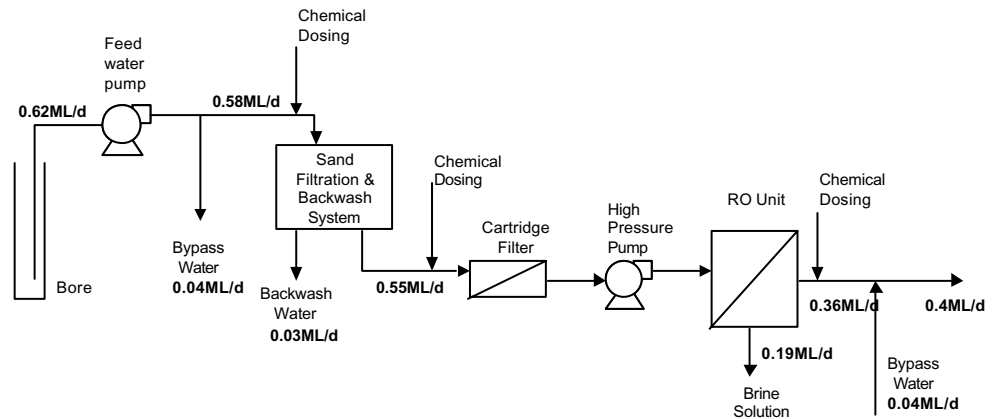
The RO unit would require a sand filtration pre-treatment system, cartridge filters, high pressure feed pumps, high pressure vessels containing the RO membrane, a brine and permeate recovery system.

The following diagram schematically describes the RO system. A feed flow of approximately 0.62 ML/d would be required to produce 0.4 ML/d of product water, assuming the system is not optimised and the resultant recovery rate is 65% for the RO unit and 95% efficiency for the pre-treatment component of the system. A total of 0.58 ML/d of bore would pass through the RO system producing 0.36 ML/d product water. 0.04 ML/d would bypass the RO system and be added to the treated water at the end of the process giving a total supply of 0.4 ML/d. With careful design and planning this ratio could be optimised further, thus capital, operating and maintenance costs could be reduced.

It has been assumed that high molecular weight hydrocarbons will be removed by the pre-treatment phase. Membrane selection will be particularly critical as some membranes are more efficient than others at treating water with low molecular weight hydrocarbons present. Careful design and consultation with membrane suppliers is highly recommended.

---

## Scenario 8 – 0.5 ML/d Coal Seam Methane Water Source

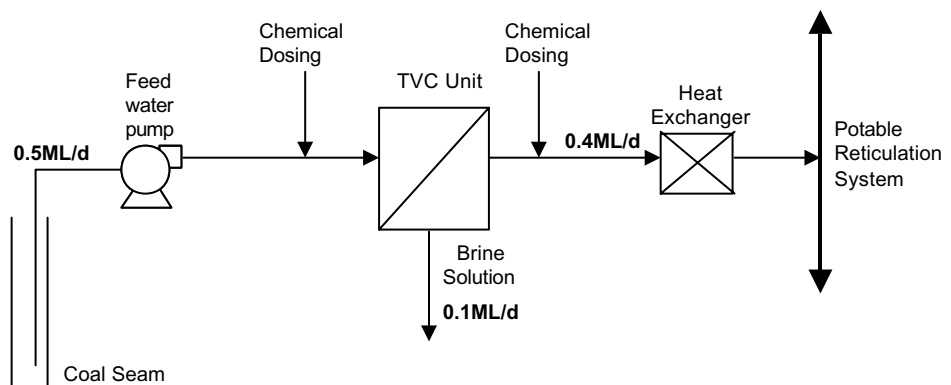


### Alternative B

For TVC the inlet feed is initially undergoes chemical dosing to lessen the effects of scale forming compounds. In the TVC unit the feed is pre-heated by the brine and product streams and may be further warmed by thermal rejection from the compressor. Then it is evaporated and passed to the compressor where its pressure is raised and condenses.

Permeate would under go post-treatment chemical dosing ensuring the water quality is maintained throughout the reticulation system. The product water may be at a slightly elevated temperature and therefore will need to be cooled via a heat exchanger prior to be released to the potable reticulation system.

The following diagram schematically describes the TVC system. It is assumed that the recovery rate in the TVC unit will be approximately 80%, hence 0.5 ML/d of feed water will be required to produce 0.4 ML/d product water.



### Pre-treatment Requirements

#### Alternative A

It may be necessary to undertake the following pre-treatment in the RO system:

- ▶ Sand filtration to reduce the turbidity levels



---

## Scenario 8 – 0.5 ML/d Coal Seam Methane Water Source

---

- ▶ Chemical dosing to coagulate colloidal material that may be present in the water and improve the pre-filtration process.
- ▶ Acid dosing for calcium carbonate scale control.
- ▶ Anti-scalant dosing to improve the membrane performance and life.

### *Alternative B*

It may be necessary to undertake the following pre-treatment for the TVC system:

- ▶ Anti-scalant dosing to reduce issues associated with scaling of the TVC unit.
- 

### **Post Treatment Requirements**

#### *Alternative A and B*

The permeate will require the following post-treatment steps:

- ▶ Heat exchanger or Cooling pond to reduce permeate temperature (TVC alternative only)
- ▶ Chemical dosing for pH correction (lime or soda ash dosing)
- ▶ Chemical dosing for water conditioning (add lime and strip off excess CO<sub>2</sub>)
- ▶ Disinfection.
- ▶ Blending with WTP product water.

The post-treatment requirements provided above do not make allowance for benefits to be gained from blending WTP product water with the RO or TVC permeate. Further studies would be required at the detailed design phase to quantify blending benefits.

---

### **Waste Management**

Both the RO and TVC systems will produce a brine waste stream. Brine is typically disposed of in a number of ways, depending on prevailing conditions.

- ▶ Disposal of brine to sea is not considered appropriate given the distance to the ocean (300 km).
- ▶ Groundwater injection of the brine is adopted in a number of areas, however given that CSM water is the source for the desalination process this option has not been considered further.
- ▶ Crystallisation requires expensive and sophisticated equipment and operational knowledge. Given the volume of brine produced each year and the location of the town it is not considered practical in this case.
- ▶ Aquaculture enterprises have been established elsewhere to make use of the brine waters. The feasibility of this option would depend on attracting a suitable business interest to make the venture profitable.

This scenario is located in a relatively dry area, where pan evaporation exceeds rainfall each month. Evaporative lagoons are therefore recommended at this site. Every 10 years council will need to investigate options for disposal and removal of the salt. Based on available meteorological data, and assuming salt harvesting is carried out every ten years and a lagoon depth of 1 m the following are applicable for each alternative.

#### *Alternative A*

The RO process produces three main waste streams:

---



---

## Scenario 8 – 0.5 ML/d Coal Seam Methane Water Source

---

- ▶ A highly saline brine stream.
- ▶ Backwash waters from the pre-treatment processes.
- ▶ Cleaning stream.

In addition to contaminants removed from the feedwater, the brine and backwash waters will also contain concentrations of the chemicals added through the process.

For a RO plant producing 0.4 ML/d desalinated water, 0.22 ML/d of waste product will be generated. This waste would have a TDS concentration of 10,000 mg/L, and approximately 5,700 tonnes of salt will accumulate every 10 years. The evaporative lagoons would cover an area of approximately 6 hectares.

### *Alternative B*

The TVC process produces two main waste streams:

- ▶ A highly saline brine stream
- ▶ Acid clean wastes every 10,000 hours.

In addition to contaminants removed from the feedwater, the brine and backwash waters will also contain concentrations of the chemicals added through the process. For a TVC plant producing 0.4 ML/d desalinated water, 0.1 ML/d of waste product will be generated. This waste would have a TDS concentration greater than 15,000 mg/L, and approximately 3,700 tonnes of salt will accumulate every 10 years. The evaporative lagoons would cover an area of approximately 3 hectares.

---

### **Environmental Factors** *Alternative A and B*

A number of aspects of this desalination process must be taken into consideration to ensure that all environmental impact are minimised:

- ▶ Ensure high-efficiency, low-emission methane combustion techniques are utilised.
- ▶ Manage wastes from annual organic/inorganic chemical cleans of the desalination unit are treated and disposed of appropriately.
- ▶ Ensure that all excess CSM water produced is reinjected (recycled) into the same coal seam restoring and preserving the hydrostatic balance in the coal bed aquifers.

EPA approvals under ERA 16 (Municipal water treatment plant) would be required for all alternatives. The disposal of brine into evaporative lagoons would fall under a separate ERA. It is recommended that the EPA be consulted regarding the approvals required.

---

### **Operational and Maintenance Requirements**

---

#### **Labour**

As with all new plants and technologies the initial operator input can be high. It is therefore recommended that as part of the desalination contract, process proving and training phases be included. The training component will ensure future operational staff receive hands on familiarisation of the equipment including operations and maintenance.

The existing WTP currently employs 3 people, with their work hours spread between the WTP and other mining operations. It has been assumed that the day

---



---

## Scenario 8 – 0.5 ML/d Coal Seam Methane Water Source

---

to day operations (daily visual inspection and meter reading) and general maintenance would be carried out by existing WTP personnel.

For all alternatives, access to process engineer (or equivalent) may be required to perform troubleshooting exercises and provide general advise regarding operation. It has been assumed during the first 3 months of operation the troubleshooter will be required for approximately 5 hours per week. For the remainder of the first year an allowance of 8 hours per month for troubleshooter time has been made. Troubleshooting requirements should decrease with time.

### *Alternative A*

Estimated operator hours for an RO facility of this capacity would be 6 hours per week.

### *Alternative B*

The operators would be required to spend approximately 15 hours per week monitoring and maintaining the TVC plant.

---

### **Chemical Requirements**

Chemical requirements would include:

- ▶ Acid dosing for pH correction (sulphuric acid)
- ▶ Anti-scalant (Desalination suppliers typically recommend a preferred brand)
- ▶ Chemical dosing for product water conditioning (eg lime or soda ash)
- ▶ Disinfection

Estimates of chemical usage have been made for costing purposes only. Actual chemical dosage rates would depend on the thermal system selected and its tolerance to various contaminants.

### **Energy Requirements**

#### *Alternative A*

The high pressure RO feed pumps and the bore water extraction pumps would dominate the RO energy requirements. The energy requirements would be met by a gen set. It is estimated that the daily energy requirement would be in the order of 0.39 MWh/day. Note that there are additional maintenance costs for using a gen set to power the RO unit. An allowance of 30c/kWh has been made.

#### *Alternative B*

The TVC energy requirements will be dominated by the production of high temperature, high-pressure vapours and permeate reticulation pumps. It is estimated that the daily energy requirement would be in the order of 4.6 MWh/day (16.56 GJ/d). The energy requirements would be met by gas produced from the CSM Plant.

### **Membrane Replacement**

#### *Alternative A only*

RO membranes require replacement every 3 to 5 years due to the deterioration of the membrane, thus decreasing the efficiency of the RO process. In the case of this scenario, it has been assumed that the membranes will be replaced every 3 years. The increased costs associated with membrane replacement are offset by lower man-hours and chemical consumption.

---

### **Costs**

---



## Scenario 8 – 0.5 ML/d Coal Seam Methane Water Source

### Capital

The capital costs associated with providing the two alternative systems are provided. These cost estimates are based on the following assumptions and include a 15% allowance for engineering/design and 25% contingency:

- ▶ Power costs are minimal as methane gas obtained from the coal seam will provide all energy required to run the thermal facility (TVC only)
- ▶ Land costs are negligible as the TVC/RO Plant would be located within the boundaries on the existing mine site.
- ▶ There are no costs associated with establishing the feedwater source further (TVC or RO).
- ▶ Additional costs will be required for the transportation of permeate to the existing potable reticulation system (TVC or RO).
- ▶ Additional costs are required for land and infrastructure associated with the brine evaporation ponds (TVC or RO), as these have not been included.

Alternative A: 0.4 ML/d BWRO facility with Gen Set	\$ 1.4 M
--	----------

Alternative B: 0.4 ML/d TVC facility	\$ 3.2 M
--------------------------------------	----------

This assessment has been based on a blending ratio of 0.4 ML/d desalinated water to 0.4 ML/d WTP product water. Other blending ratios should be further investigated to ensure an optimum is reached between cost and acceptable water quality.

### Operational & Maintenance

The annual O&M costs for the two alternatives can be broken down as follows:

	Alternative A 0.4 ML/d RO	Alternative B 0.4 ML/d TVC
<b>Total O&amp;M Cost</b>	<b>\$ 136,800</b>	<b>\$ 105,600</b>
Annual allowance for membrane replacement: Calculated based on 10% of the capital (excluding contingencies) and to be replaced once every 3 years.	\$ 33,000	N/A
Power usage: Assumed 10c/kWh.	\$ 28,800	\$ 12,100
Chemical consumption:	\$ 9,800 (1% of capital, excluding contingencies)	\$ 11,600 (0.5% of capital, excluding contingencies)
Labour		
Operator Costs \$40/hour	\$ 12,500 (6 hours/week)	\$ 31,200 (15 hours/week)
Trouble shooter Costs (first year) \$120/hour as required	\$ 15,900	\$ 15,900



---

### Scenario 8 – 0.5 ML/d Coal Seam Methane Water Source

---

Maintenance:	\$ 36,800	\$ 34,800
Based on 1.5% of the capital (excluding contingencies).	(also includes 30c/kWh for gen set maintenance)	

---



## 9. Desalination Technology Suppliers

From GHD experience, internet searches and DNR&M information 24 possible desalination equipment suppliers were identified. Of these only 17 companies were successfully contacted and a questionnaire completed over the phone.

The questionnaire developed by GHD covered questions relating to the:

- ▶ Type of desalination technology supplied (eg reverse osmosis, thermal processes).
- ▶ Capacity of units offered.
- ▶ Service packages available and whether training is offered to clients.
- ▶ Ability to supply mobile units and/or units capable of operating in an intermittent fashion.

The information gathered was entered directly into a database.

A summary of contact details for each company successfully contacted is provided in Appendix C. The companies are listed in order of type of technology supplied in Table 9-1.

**Table 9-1 Summary of companies supplying desalination technology**

<b>Company</b>	<b>Range of Equipment Supplied</b>
<b>Electrodialysis (ED)</b>	
Ionics Watertec	From 1ML/d
Osmoflo	0.05 to 20ML/d
PEX Industries	Not reported
QED OCCTECH	Not reported
<b>Multi Effect Distillation (MED)</b>	
PEX Industries	1.5 to 48ML/d
Thames Water Projects	Not reported
VA Tech WABAG	1 to 25ML/d
<b>Multistage Flash Distillation (MSF)</b>	
Inteleco	0.005 to 0.05ML/d
Thames Water Projects	Not reported
VA Tech WABAG	1 to 25ML/d



---

**Reverse Osmosis**

---

CRS Industrial Wastewater Treatment Systems	0.0005 to 1ML/d
ICES	0.001 to 4.8ML/d
Ionics Watertec	From 1ML/d
Normach	0.0018 to 2ML/d
O'Donnel Griffin	0.04 to 12ML/d
Osmoflo	0.05 to 20ML/d
PEX Industries	10 to 330ML/d
QED OCCTECH	1 to 8ML/d
Sharplift Marine and Industrial Equipment	0.0007 to 0.1ML/d
Surewater Australia	0.001 to 1ML/d
Thames Water Projects	2 to 36ML/d
VA Tech WABAG	5 to 150ML/d
Wendouree Water Treatment	0.0015 to 1.7ML/d

---

**Vapour Compression Distillation (VC)**

---

AquaDyne	From 0.5ML/d
Inteleco	0.0001 to 0.0005ML/d
KBA (Karla Bell & Associates)	0.0005 to 5 ML/d
PEX Industries	0.5 to 17ML/d
Thames Water Projects	1 to 25ML/d
VA Tech WABAG	Unknown

---

**Sal-Proc Process (Brine Value Adding)**

---

Geo-Processors Pty Ltd	NA
------------------------	----

---



## 10. Conclusions

### 10.1 Available Technologies

There are currently five main desalination technologies being used in commercial applications around the world:

<b>Thermal Technologies</b>	<b>Membrane Technologies</b>
Multistage Flash Distillation (MSF)	Reverse Osmosis (RO)
Multi Effect Distillation (MED)	(Reverse) Electrodialysis (ED(R))
Vapour Compression Distillation (VCD)	

In addition there are a number of emerging or alternate technologies available, though in many instances the commercial viability of these technologies is yet to be proven.

Of the five main desalination technologies, thermal processes are generally used in the following applications:

- ▶ To treat highly saline waters (predominantly seawater)
- ▶ Where large volumes of product water are required.
- ▶ In locations where energy costs are low or where a waste heat source is available.

Reverse Osmosis processes on the other hand are more favourable for treating brackish waters (under most conditions) or highly saline wastes where energy costs are high or the flow rates are low. ED(R) technologies are viable options when feed water contains low TDS and high scalant concentrations.

### 10.2 Queensland Installations

Within Queensland 27 desalination installations were identified and of these discussions were held with the owners/operators of 21 facilities. Reverse osmosis was the most popular technology, with 17 of the facilities using RO (including two mobile unit), 3 plants using VCD and 1 using resin exchangers.

Desalination was used for a variety of purposes including:

- ▶ Providing potable water requirements of island communities.
- ▶ Treating water to a high standard for industrial and processing applications.
- ▶ Providing alternate water sources for inland communities.

Desalination is becoming more popular in situations where existing surface water supplies are diminishing and the quality of available groundwater sources are deteriorating. Within Queensland there is anecdotal evidence that suggests existing groundwater aquifers are not being recharged at rates meeting the current extraction rates. As a result the groundwater sources are becoming more concentrated in salts and producing waters that are acceptable to inland communities. Desalination technologies allow the use of poor quality groundwater sources.



### 10.3 Equipment Suppliers

There are currently 24 desalination equipment suppliers within Australia, offering a range of technologies and product water capacities.

The trend within Australia is to provide desalination projects under EPCM or D&C contracts. However the project delivery option will depend on the ultimate asset owner.

### 10.4 Scenarios

Scenarios were developed for 8 communities covering a range of salinity issues and water demand requirements. The results of these scenarios are presented in Table 10-1. Capital costs include the desalination plant and where applicable the cost for an evaporative lagoon. Costs for land and reticulation systems are not included. Operating and maintenance costs include membrane replacement (for RO and EDR), electrode replacement (EDR only), power usage, chemical consumption, labour (including operator and troubleshooter expenses), and maintenance.

It should be noted that the cost estimates developed for the scenarios are based on several assumptions, which are listed in previous sections of this report. The costs have been developed for the purposes of comparing scenarios and should not be used for budgeting purposes. A functional design, taking into account site-specific issues, would be required for budgeting purposes.

The scenarios demonstrate:

- ▶ Desalination needs to be considered on a case by case basis. Issues such as availability of power, raw water quality, waste disposal and local conditions all need to be carefully considered and accounted for in a desalination system design. These factors are particularly important in selection of the most appropriate desalination technology.
- ▶ The cost of desalinating seawater is significantly higher than for brackish waters. This is due to the higher pressures required to overcome the osmotic pressure exerted by more saline solutions. This translates to higher pumping costs. The recovery rates in seawater installations are also lower resulting in the need for higher feedwater extraction, pumping and treatment costs.
- ▶ Pre and post treatment are important components of desalination, and will depend largely on raw water quality and final application.
- ▶ For the scenarios investigated the most common desalination technology selected was reverse osmosis. This was due to the lack of low cost energy and/or waste heat sources and source water quality available at the scenario locations.
- ▶ For three scenarios EDR was evaluated and compared with RO systems. EDR systems tend to be more expensive, in terms of dollars per volume product water, than RO systems. Additionally suppliers in general do not recommend EDR for low flow systems (eg < 100 kL/d).
- ▶ MED was investigated for one scenario however it was found that the costs were less than RO (in terms of dollars per volume product water). MED tends to be feasible when the TDS is very high (seawater), and under high flows (20 ML/d in this particular scenario).
- ▶ TVC was compared to RO in one scenario. At low flow rates (400 kL/d), TVC does not seem to be a cost effective technology, since total TVC cost (\$/kL/d) was more than double the RO total cost. TVC may become more financially feasible for feed waters containing higher TDS levels (e.g. seawater).
- ▶ Larger plants generally have lower production costs, demonstrating the effects of economy of scales.



**Table 10-1 Summary of Scenarios**

Scenario Number	TDS mg/L	Raw Water Source	Population		Flow		Process	Capital Cost*		Annual O&M Cost*	Total Cost +	
			EP	EP	Total kL/d	Water consumption allowance L/EP/d		Total \$M	per Flow \$/kL/d			Total (Year 1 only) \$/yr
1	37800	Seawater	800	800	200	250	SWRO	1.82	9100	151,200	2.07	4.56
2 A	45000	Seawater	30000	30000	20000	670	SWRO	59.00	3000	7,108,500	0.97	1.78
2 B	45000	Seawater	30000	30000	9000	300	SWRO	33.00	3700	3,377,900	1.03	2.03
2 C	45000	Seawater	30000	30000	20000	670	MED	84.00	4200	7,359,000	0.48	2.16
3 A	2000	Groundwater	5000	5000	1700	170	BWRO	3.40	2000	200,200	0.32	0.87
3 B	2000	Groundwater	5000	5000	1700	170	EDR	4.06	2400	214,000	0.34	1.00
4 A	3000	Groundwater	1500	1500	450	300	BWRO	3.14	2100	219,400	0.40	0.97
4 B	3000	Groundwater	1500	1500	450	300	BWRO	1.37	3000	99,000	0.60	1.44
4 C	3000	Groundwater	1500	1500	1500	1000	EDR	3.65	2400	217,000	0.40	1.06
5 A	3400	Groundwater	100	100	100	1000	BWRO	0.48	4800	45,700	1.25	2.55
5 B	3400	Groundwater	100	100	30	300	BWRO	0.24	8100	33,700	3.08	5.29
5 C	3400	Groundwater	2.5 people/house	2.5 people/house	60	1500 L per household	RO x 40 houses	0.28	4700	19,600	0.89	2.17
6 A	1045	Artesian (T = 90°C)	3250	3250	3900	1200	BWRO	5.88	1500	314,700	0.22	0.63
6 B	1045	Artesian (T = 90°C)	3250	3250	975	300	BWRO	2.21	2300	113,100	0.32	0.94
6 C	1045	Artesian (T = 90°C)	3250	3250	3900	1200	EDR	8.89	2300	367,700	0.26	0.88
7 A	2900	Groundwater (Coastal)	10000	10000	10000	1000	BWRO	11.20	1100	933,700	0.26	0.56
7 B	2900	Groundwater (Coastal)	10000	10000	3000	300	BWRO	4.62	1500	300,000	0.27	0.70
8 A	3880	Coal Seam Methane	800	800	400	1000	BWRO (+gen set)	1.38	3500	105,600	0.72	1.67
8 B	3880	Coal Seam Methane	800	800	400	1000	TVC	3.25	8100	136,800	0.94	3.16

# Desalination plant costs only. Does not include reticulation/distribution systems, waste disposal, land costs etc.

\* First operational year costs only.

+ Calculated based on 1/10 capital costs plus annual O&M costs (first year only). Cost estimates are comparative only and should not to be used for budgeting purposes.