

**Preliminary Feasibility Study  
of Ocean Cooling for  
Munmorah Power Station  
MM Units 3&4 Rehabilitation  
Delta Electricity**

**Report ref:**  
41442  
25 February 2010  
Revision 2

Document prepared by:

Aurecon Australia Pty Ltd  
ABN 54 005 139 873  
116 Military Road  
Neutral Bay  
New South Wales 2089 Australia

T: +61 2 9465 5599  
F: +61 2 9465 5598  
E: sydney@ap.aurecongroup.com  
W: aurecongroup.com

## Document control



Document ID: MM Power Station Ocean discharge feasibility Final 20100225

Rev No	Date	Revision details	Typist	Author	Verifier	Approver
0	15/02/2010	Prelim Draft	HT	Various	PF	LK
1	23/02/2010	Draft to Delta	HT	Various	PF	LK
2	25/02/2010	Final to Delta	HT	Various	PF	LK

A person using Aurecon documents or data accepts the risk of:

- a) Using the documents or data in electronic form without requesting and checking them for accuracy against the original hard copy version.
- b) Using the documents or data for any purpose not agreed to in writing by Aurecon.

## Contents

<b>1.</b>	<b>Introduction</b>	<b>1</b>
<b>2.</b>	<b>Methodology</b>	<b>1</b>
<b>3.</b>	<b>Description of Options</b>	<b>2</b>
3.1	Option 1	2
3.2	Option 2	2
3.3	Option 3	2
3.4	Option 4	2
3.5	Option 5	3
<b>4.</b>	<b>Environmental Aspects</b>	<b>3</b>
4.1	Thermal effects	3
4.2	Salinity	3
4.3	Water flows	4
4.4	Changes in Lake Water Levels	4
4.5	Marine and Estuarine Ecology	4
4.6	Terrestrial Ecology	5
4.7	Socio – Economic Impacts	5
<b>5.</b>	<b>Greenhouse gas assessment</b>	<b>6</b>
<b>6.</b>	<b>Community Consultation</b>	<b>7</b>
<b>7.</b>	<b>Summary of Options, Aspects and Issues</b>	<b>8</b>
<b>8.</b>	<b>Engineering, Geotechnical and Environmental Studies</b>	<b>15</b>
<b>9.</b>	<b>Discussion</b>	<b>16</b>
<b>10.</b>	<b>References</b>	<b>18</b>

## 1. Introduction

One of the draft Consent Conditions proposed by the Department of Planning (DOP) in connection with the proposed Munmorah Power Station Rehabilitation project requires that:

*“the Proponent shall investigate all practical measures that could be taken to reduce the thermal impacts of the project on Lake Budgewoi. The investigation shall include consideration of the feasibility of constructing a pipeline between the project and the ocean for the supply and/or discharge of cooling water, and an investigation into alternative tempering arrangements. The Proponent shall submit a report detailing the outcomes of the investigation to the DECCW within 12 months of the date of this approval, unless otherwise agreed by the DECCW.”*

In order to inform its consideration of the proposed condition, Delta Electricity engaged Aurecon to undertake a high level concept feasibility study of the various issues associated with providing some form of ocean cooling for Munmorah Power Station. This report provides a summary of the findings of this investigation.

## 2. Methodology

An initial “options identification” phase involving a team of relevant specialists was undertaken to identify technically feasible options for using one or more connections to the ocean for power station cooling. This exercise identified five possible options:

- Option 1:** A pipeline from Munmorah Power Station to discharge warm water to the ocean and using the existing inlet system from Lake Munmorah
- Option 2:** A pipeline from the ocean to supply cooling water to Munmorah Power Station and retaining the existing discharge to Lake Budgewoi
- Option 3:** A pipeline from Munmorah Power Station to discharge warm water to the ocean and another pipeline from the ocean to Munmorah Power Station to supply cooling water
- Option 4:** An inlet pipeline from the ocean to Lake Munmorah
- Option 5:** An inlet pipeline from the ocean to Lake Munmorah and a discharge connection from Lake Budgewoi to the ocean

The following reviews were undertaken for each of the above options:

- technical aspects in relation to water flows, pipeline/tunnel designs, along with associated civil and electrical engineering aspects
- ecological implications of additional flows and salinity changes on the lake system
- ballpark costing of feasible options including, where possible, appropriate calibration against the costing and scale of the Kurnell Desalination Facility pipeline works.
- strategic review of greenhouse and community issues

### 3. Description of Options

This section briefly describes the options studied. It is supported by Figures 1 to 5, which show conceptual arrangements of the options. Additional civil, structural, electrical and cost details are provided in Section 7.

#### 3.1 Option 1

Option 1 includes a pipeline from Munmorah Power Station to discharge warm water to the ocean while continuing to use the existing inlet system from Lake Munmorah (See Figure 1).

Cooling water from both Units would be pumped out to the ocean via an additional pumping station to be provided at the outfall canal within the grounds of Munmorah Power Station. Three large pumps, each of 9,000 L/s capacity, would operate in parallel to pump the water to the ocean. Some additional attemperation could possibly be required at the end of the ocean discharge during extreme summer conditions in the lake to meet discharge limit requirements; however this would need to be verified. If additional attemperation is required, an additional two pumps of a similar capacity would be required to increase pumping capacity up to 40 m<sup>3</sup>/sec.

Twin pipes of 2,400 mm diameter would be constructed from Munmorah Power Station to Colongra Point. From Colongra Point to the ocean a 3,500 mm diameter tunnel would be constructed underneath Lake Munmorah. The outlet would extend about 1,000 m out to sea to the 20 m water depth point. Because the tunnel passes through areas known for mining, it would need to be constructed with a reinforced concrete lining.

#### 3.2 Option 2

This option requires a pipeline from the ocean to supply cooling water to Munmorah Power Station while retaining the existing discharge to Lake Budgewoi (See Figure 2).

A pumping station would be provided to draw water from Birdie Beach from a dredged intake. Three large pumps, similar to those in Option 1, would be used to pump the water to the Power Station. A de-sanding chamber would be required prior to the tunnel inlet.

#### 3.3 Option 3

This option requires a pipeline from Munmorah Power Station to discharge warm water to the ocean and another pipeline from the ocean to Munmorah Power Station to bring in cold sea water at the inlet of Munmorah's circulating water intake canal (See Figure 3). The discharge would initially be in pipework, and then a tunnel passing under Lake Munmorah.

As for option 2, a pumping station would be provided to draw water from Birdie Beach from a dredged intake. A de-sanding chamber would be required prior to the tunnel inlet.

Option 3 includes the pumping station, pipework and tunnels as described for Options 1 and 2 above

#### 3.4 Option 4

This option involves an inlet pipeline from the ocean to Lake Munmorah. It would use the existing inlet system from Lake Munmorah to the power station and retain the existing discharge to Lake Budgewoi (See Figure 4).

A pumping station would draw seawater from the ocean at Birdie Beach, and transfer it into Lake Munmorah, where the water would make its way to the power station inlet canal. The discharge for this pumping station would be by an open channel or canal to be constructed into Lake Munmorah.

The pumping station would use eight submersible pumps each of 3,500 L/s capacity.

Some additional attemperation make-up water could possibly be required during extreme summer conditions in the lake to meet discharge limit requirements. However this would need to be verified. Up to an additional 14,000 L/s of pumping would be required to increase pumping capacity up to 40 m<sup>3</sup>/sec.

### 3.5 Option 5

This option includes an inlet connection (pipeline) from the ocean to Lake Munmorah and a discharge connection from Lake Budgewoi to the ocean (See Figure 5)

A pumping station at Slade Park would be required to draw water from Lake Budgewoi and to discharge it via a deep outlet into the ocean.

A second pumping station would draw seawater from the ocean at Birdie Beach, and transfer it into Lake Munmorah, where the water would make its way to the power station inlet canal. The discharge for this pumping station would be by an open channel or canal to be constructed into Lake Munmorah.

Both pumping stations would be based on using eight submersible pumps each of 3,500 L/s capacity.

Some additional input to allow for additional attemperation flows could possibly be required for this during extreme summer conditions in the lake to meet discharge limit requirements; however this would need to be verified. Up to an additional 14,000 L/s of pumping would be required to increase cooling water flows, with attemperation, up to 40 m<sup>3</sup>/sec.

## 4. Environmental Aspects

The following environmental aspects have been identified as requiring consideration, as appropriate, to the various options under consideration.

### 4.1 Thermal effects

It is noted that there are differences in the ambient temperatures of the Lakes and the ocean waters, with the ocean waters experiencing a narrower range of temperatures. During the summer, the lakes are generally warmer than the ocean and during the winter the ocean is generally warmer than the lakes. The normal ambient temperature range in the ocean is from 17.6°C to 22.6°C, compared to a normal range in the lakes of 10.5°C to 28°C. The following thermal effects require consideration:

- Discharging warmed cooling water up to 37.5°C into cooler ocean environment, for options proposing ocean discharge of cooling waters
- Increases in the amount of ocean water (at a potentially significant different temperature) entering into Tuggerah lakes, for options importing water from the ocean to the lakes system

### 4.2 Salinity

The Tuggerah lakes have estuarine salinities in a normal range of 17‰ to 39‰ (parts per thousand) and can be brackish under high catchment rainfall runoff events. The salinity of sea water is 35.5‰. Potential effects on the ecological communities of the lakes and/or ocean are required in relation to:

- Discharge of less saline water from Tuggerah lakes to the ocean, for options discharging to the ocean
- Importation of higher salinity ocean water, into the Tuggerah Lakes system, for options that import additional cooling water from the ocean

### 4.3 Water flows

Significant changes to water flows would occur for options that import or export lake water to the or from the ocean. Normal flows at full load are 27 m<sup>3</sup>/sec, but can increase to 40 m<sup>3</sup>/sec for the fully attemperated system under current operations. To put these flows in to perspective, the Kurnell Desalination Project draws water at a rate of around 5 m<sup>3</sup>/sec. Potential effects to be considered are

- Increased flows in through the Entrance for options that import or discharge cooling water in one direction only
- Increased scouring of lake channels due to increased flows where increased flows occur, with potential consequent changes to tidal flows through the Entrance
- Increased sedimentation and blockages as a result of changes flow regimes
- Changes in coastal current flows, for options that interact with the coastal environment

### 4.4 Changes in Lake Water Levels

Changes to the dynamics of water movement may also result in changes to lake water levels, including:

- Possible flooding due to water flow changes
- Changes to the lake tidal range

To put this in perspective, the normal cooling water flow for the proposal at full load is 27 m<sup>3</sup>/sec (2,350 ML/day). This is about twice the normal total daily tidal exchange in Tuggerah Lakes (about 1,230 ML/day). In the event that volumes including attemperation flows up to 40 m<sup>3</sup>/sec (3,550 ML/day) are required to pass through the Entrance, flows would be nearly four times an average exchange per tide.

There is a significant potential for flows of this magnitude to affect normal flow patterns and resulting flood levels as well as tidal ranges in the lakes. This is most relevant for options that involve one way exchanges of water used for cooling with the ocean.

### 4.5 Marine and Estuarine Ecology

The Tuggerah Lakes estuary is a major NSW fish nursery area that is important to the fisheries along the NSW coastline. The following potential ecological effects of changes to the Tuggerah Lakes system as a result of the options considered in relation to ocean cooling of Munmorah Power station cooling water discharges require consideration:

- Potential changes to NSW fish stocks
- lower temperature tolerances of marine species compared to estuarine adapted species, for options that discharge cooling water to the ocean
- Coastal ecological communities have intolerance to reduced salinity
- Movement of fish and larvae, for options that change flow rates into and/ or out of the lakes
- Impacts on fish and prawn larvae transport
- Changes to the lake nursery areas
- Changes to the species composition and total numbers in the lakes
- Impingement of species on screens
- Indirect impacts on Bird Island Nature Reserve through changed ocean conditions in adjacent waters

- Changes to the volume of fish and prawns passed through the cooling water system, for options that increase the retention of fish and prawns in the lake, or options that might attract fish and prawns to the cooling water system due to changed flow regimes in the Lakes
- Possible effects of changed flow and temperature regimes on seagrass communities
- Potential increase of import of exotic marine species in to the lake system for options that change flows or salinity regimes
- Ocean floor impacts for options involving discharges or intakes from the ocean
- Impacts on seagrass communities due to changes in lake characteristics due to altered flows, temperatures and water levels
- Effects of disturbance to lake sediments and consequent release of turbidity, acidity, trace elements into the lake from mechanical disturbance or altered flow regimes, from scouring and actions such as trenching on lakebed for piping installation, should this be required
- Effects of disturbing acid sulphate soils through new facility developments and pipeline installation

#### **4.6 Terrestrial Ecology**

Options that require new facilities, such as pumping stations and associated infrastructure and tunnels etc require new developments that will potentially affect terrestrial ecological communities. Potential effects include:

- Clearing for new facilities, access and 11 kV power lines
- Erosion and sedimentation
- Spoil disposal for options requiring construction of tunnels etc.
- Impacts on threatened species and endangered ecological communities

#### **4.7 Socio – Economic Impacts**

The Tuggerah Lakes region has important many values that are important to the community that are sensitive to changes that might occur to the lakes systems. These include

- commercial and recreational fishing
- effects of changed flows and water levels on recreation use of the lake
- visual impacts from new facilities, such as pumping stations and 11 kV power supply connections
- noise impacts from new facilities
- loss of amenity in and around the lakes and on beaches affected by various options
- impacts of construction activities associated with these options on the community and the environment

## 5. Greenhouse gas assessment

The Scope 1 and 2 greenhouse gas (GHG) emissions resulting from the operation of pumping stations for each circulating water option have been calculated and are summarised in Table 1 below.

For each option, it has been assumed that all electricity for pumping has been sourced from the NSW electricity grid and that there are no direct GHG emissions (Scope 1). The National Greenhouse and Energy Reporting (NGER) (Measurement) Technical Guidelines provides an emission factor of 0.89 kgCO<sub>2e</sub>/kWh for Scope 2 emissions for the purchase of electricity from the NSW grid.

**Table 1 – Estimated Scope 2 greenhouse emissions for options 1 to 5**

Option No.	Total Pumping Station Power (MW)	Pumping Operation	Hours/year	Scope 2 GHG Emissions (tCO <sub>2e</sub> /year)
1	8	Summer months only. Assume 6 months/year.	4,380	31,200
2	8			31,200
3	16			62,400
4	1.6			6,200
5	3.2			12,500

For each option, pumping is only carried out in summer as the winter temperature of the ocean is warmer than the lakes (both Munmorah and Budgewoi). Therefore, it has been assumed that pumping will only occur for six months of the year. Estimates show that options 1, 2 and 3 would cause the emission of substantially more GHG than options 4 and 5.

An additional benefit of reducing the inlet circulating water temperature during summer is a possible reduction in plant GHG emissions from increased unit efficiency. This effect is most significant for options 2 and 3. While quantification of reduction in plant GHG emissions is beyond the scope of this report, a rough estimate has indicated the reduction in emissions due for these options is in order of 10,000 to 20,000 tCO<sub>2e</sub>/year.

## 6. Community Consultation

Extensive community consultation would be required for all of the options due to the following reasons:

- Construction of pipelines for options 1-3 would require tunnels being constructed under Lake Munmorah
- Impacts of tunnels on coal mining in the region would need to be considered
- Construction of pumping stations would occur in the Munmorah State recreation area and construction of all options would have associated noise, air quality, ecological, soil and sedimentation impacts.
- New pumping stations, once operational these would have a visual impact and potential noise impact impacts on the local community.
- All options, except Option 1, would require dredging to be undertaken at Birdie Beach, with the associated impacts on the beaches and local environment.
- All options would require additional pumping stations which would have visual impacts in the area as well as additional power requirements. Where this power comes from would need to be finalised but could come from power station auxiliaries or be sourced via the local power supply network
- Impacts associated with the ecology of the lakes as well as the coastline and ocean could be significant, with possible consequent impacts on recreational and commercial fishing.
- Possible increase flooding impacts and impacts on the recreational activities within the lakes and particularly at the Entrance would need to be examined, identified and quantified where possible.
- Power supplies to remote pumping stations requires the construction of new 11 kV power lines with associated environmental and community impacts

## 7. Summary of Options, Aspects and Issues

A brief summary of each of the 5 options considered, together with their key aspects and issues are presented in Table 2. The estimated costs for the various options are based on up front capital costs at the level of consideration available for this study and rely on expert opinion. While the costs include allowance for attemperation in relevant options, they do not include ongoing operation and maintenance costs or the costs associated with obtaining environmental approvals or any resultant environmental offset requirements.

**Table 2: Summary of financial, technical and ecological implications of the five pipeline options**

	Option 1	Option 2	Option 3	Option 4	Option 5
<b>Estimated Costs Excluding GST</b>					
<b>Estimated Costs</b>	<b>AU\$230 million</b>	<b>AU\$140 million</b>	<b>AU\$320 million</b>	<b>AU\$60 million</b>	<b>AU\$110 million</b>
<b>Civil / structural</b>					
inlet	<ul style="list-style-type: none"> <li>Inlet structure near outfall canal with coffer dam and pumping station</li> </ul>	<ul style="list-style-type: none"> <li>dredged ocean inlet approach channel located at 5 m ocean depth</li> </ul>	As described for options 1 and 2	<ul style="list-style-type: none"> <li>dredged ocean inlet approach channel located at 5 m ocean depth</li> </ul>	<ul style="list-style-type: none"> <li>dredged approach channel to the pump station from Lake Budgewoi and dredged approach from ocean</li> </ul>
Tunnels / pipelines	<ul style="list-style-type: none"> <li>2.6 km 3.3 m diameter underground pipeline</li> <li>4 km 3.5 m diameter tunnel from the western edge of Lake Munmorah to the ocean outlet structure located at 20 m deep sea bed.</li> </ul>	<ul style="list-style-type: none"> <li>3.8 km 3.5 m diameter tunnel to the intake canal</li> </ul>	As described for options 1 and 2	<ul style="list-style-type: none"> <li>Discharge channel into Lake Munmorah</li> </ul>	<ul style="list-style-type: none"> <li>1.5 km length of tunnel with a 3.5 m diameter from Lake Budgewoi to an ocean outlet at 20 m depth including tunnel head works</li> </ul>

**Preliminary Feasibility Study of Ocean Cooling for Munmorah Power Station**

	<b>Option 1</b>	<b>Option 2</b>	<b>Option 3</b>	<b>Option 4</b>	<b>Option 5</b>
Other	<ul style="list-style-type: none"> <li>Civil and structural works associated with the pump station</li> <li>pump Station at western edge of Lake Munmorah</li> </ul>	<ul style="list-style-type: none"> <li>Civil and structural works associated with the pump station</li> <li>inlet shaft to tunnel</li> <li>Mains to de-sanding chamber</li> <li>de-sanding chamber</li> </ul>	As described for options 1 and 2	<ul style="list-style-type: none"> <li>Civil and structural works associated with the pump station</li> <li>inlet shaft to tunnel</li> <li>Mains to de-sanding chamber</li> <li>de-sanding chamber</li> </ul>	<ul style="list-style-type: none"> <li>Civil and structural works associated with both pump stations</li> <li>Mains to de-sanding chamber for intakes from Lake Budgewoi (to ocean) and ocean (to Lake Munmorah)</li> <li>De-sanding chamber for both intakes</li> </ul>
Outlet	<ul style="list-style-type: none"> <li>1,000 m into the ocean and located at the 20 m water depth.</li> </ul>	<ul style="list-style-type: none"> <li>outlet riser shaft from tunnel</li> </ul>	As described for options 1 and 2		<ul style="list-style-type: none"> <li>water from Lake Budgewoi, discharges via a deep outlet into the ocean at ~1,000 m at the 20 m water depth.</li> <li>discharge into Lake Munmorah would be by a dredged open channel or canal</li> </ul>
<b>Electrical</b>					
Pumping station(s)	<ul style="list-style-type: none"> <li>One pumping station with three 2.6 MW pumps (total 8 MW)</li> <li>with direct on line (DOL) starters, switchgear, earth grid and Miscellaneous Power &amp; Lighting (MP&amp;L) requirements</li> </ul>	<ul style="list-style-type: none"> <li>One pumping station with three 2.6 MW pumps (total 8 MW)</li> <li>with DOL starters, switchgear, earth grid and MP&amp;L requirements</li> </ul>	<ul style="list-style-type: none"> <li>Two pumping stations, each with three 2.6 MW pumps (total 16 MW)</li> <li>with DOL starters, switchgear, earth grid and MP&amp;L requirements</li> </ul>	<ul style="list-style-type: none"> <li>One pumping station with eight submersible 200 kW pumps (total 1.6 MW)</li> <li>with DOL starters, switchgear, earth grid and MP&amp;L requirements</li> </ul>	<ul style="list-style-type: none"> <li>Two pumping stations each with eight submersible 200 kW pumps (total 3.2 MW).</li> <li>with DOL starters, switchgear, earth grid and MP&amp;L requirements</li> </ul>

Preliminary Feasibility Study of Ocean Cooling for Munmorah Power Station

	Option 1	Option 2	Option 3	Option 4	Option 5
Control and power	<ul style="list-style-type: none"> <li>Control from ICMS</li> <li>All interfacing, instrumentation and cabling</li> <li>Power could be supplied from Station 11kV board.</li> </ul>	<ul style="list-style-type: none"> <li>Control from ICMS</li> <li>All interfacing, instrumentation and cabling</li> <li>Additional 11 kV power supply required to remote pumping station from local Council power supply</li> </ul>	<ul style="list-style-type: none"> <li>Control from ICMS</li> <li>All interfacing, instrumentation and cabling</li> <li>Power could be supplied from Station 11kV board.</li> <li>Additional power supply required to remote pumping stations from local Council power supply</li> </ul>	<ul style="list-style-type: none"> <li>Control from ICMS</li> <li>All interfacing, instrumentation and cabling</li> <li>Additional 11 kV power supply required to remote pumping station from local Council power supply</li> </ul>	<ul style="list-style-type: none"> <li>Control from ICMS</li> <li>All interfacing, instrumentation and cabling</li> <li>Additional 11 kV power supply required to remote pumping station from local Council power supply</li> </ul>
<b>Environmental</b>					
Flows	<ul style="list-style-type: none"> <li>All cooling water heated by the power station would be pumped to the Ocean. The 27 m<sup>3</sup>/s would be replenished by an additional flow of 27 m<sup>3</sup>/s flowing inwards at The Entrance.</li> <li>cooling water discharge rate to coastal waters would be about 27 m<sup>3</sup>/sec (2,350 ML/day) about twice the total daily tidal exchange in Tuggerah Lakes (about 1,230 ML/day)</li> <li>if required, up to 40 m<sup>3</sup>/sec (3,550 ML/day) during summer attemperation flows nearly four times an average exchange per tide.</li> </ul>	<ul style="list-style-type: none"> <li>cooling water intake would be 27 m<sup>3</sup>/sec (2,350 ML/day) about twice the total daily tidal exchange in Tuggerah Lakes (about 1,230 ML/day)</li> </ul>	<ul style="list-style-type: none"> <li>Installation of two equal capacity pumping stations, one for ocean inflows and one for outflows would avoid excessive exchanges at The Entrance and a lager tidal range in the lakes resulting from options 1 and 2.</li> <li>27 m<sup>3</sup>/sec intake and discharge</li> </ul>	<ul style="list-style-type: none"> <li>27 m<sup>3</sup>/s is drawn from the ocean into Lake Munmorah</li> <li>if required, up to 40 m<sup>3</sup>/sec (3,550 ML/day) during summer attemperation flows could be required</li> </ul>	<ul style="list-style-type: none"> <li>27 m<sup>3</sup>/s is drawn from the ocean into Lake Munmorah</li> <li>27 m<sup>3</sup>/s is drawn from the ocean into Lake Munmorah</li> <li>if required, up to 40 m<sup>3</sup>/sec (3,550 ML/day) during summer attemperation flows could be required</li> </ul>

Preliminary Feasibility Study of Ocean Cooling for Munmorah Power Station

	Option 1	Option 2	Option 3	Option 4	Option 5
Thermal impacts	<ul style="list-style-type: none"> <li>Acceptable temperature range for the ocean is 17.6-22.6°C. Cooling water discharge temperatures could be as high as 37.5°C – effect of high temperatures on ocean ecology would need to be investigated</li> <li>increased inflow of cold seawater into Tuggerah Lakes in summer (due to increased flows). Effect of cooler lake temperatures on lake productivity would need to be investigated. Possible cold water pollution effect.</li> </ul>	<ul style="list-style-type: none"> <li>Supply of colder seawater in summer (maximum 22°C) would be supplied into the inlet CW canal of the power station.</li> <li>Heated outlet water from the power station will pass through Lakes Budgewoi and Tuggerah, and finally discharge at The Entrance</li> </ul>	<ul style="list-style-type: none"> <li>All cooling water for the power station would come from, and be returned to, the Ocean, having little or no impact on the lake systems</li> <li>Acceptable temperature range for the ocean is 17.6-22.6°C. Cooling water discharge temperatures could be as high as 37.5°C. This would require the development of an attemperating system to avoid ocean environmental consequences.</li> </ul>	<ul style="list-style-type: none"> <li>Fresh cooler seawater is drawn into Lake Munmorah.</li> <li>Heated outlet water from the power station will pass through Tuggerah Lakes and finally discharge at The Entrance, as in Option 2.</li> </ul>	<ul style="list-style-type: none"> <li>Water drawn from Lake Budgewoi is partially heated and will be ~2°C above the average lake temperature.</li> <li>Sea water supply would be 2°C cooler than the water currently drawn through Budgewoi Creek from Lake Budgewoi.</li> </ul>
Salinity	<ul style="list-style-type: none"> <li>Tuggerah lakes have estuarine salinities in a normal range of 17‰ to 39‰. Salinities may be affected by increased inflow of seawater through the Entrance, which in turn could affect lake ecology</li> <li>Coastal ecological communities (35.5‰) have intolerance to the reduced salinity that would be discharged from the lakes, particularly when freshwater inputs are elevated. This would require detailed investigation.</li> </ul>	<ul style="list-style-type: none"> <li>Increase salinity due to intake of seawater directly into cooling water system with potential impacts on lake ecology.</li> </ul>	<ul style="list-style-type: none"> <li>All cooling water for the power station would come from, and be returned to the ocean.</li> <li>Should be no impacts on salinity in the ocean.</li> </ul>	<ul style="list-style-type: none"> <li>Increase salinity due to intake of seawater directly into Lake Munmorah and into the cooling water system</li> </ul>	<ul style="list-style-type: none"> <li>Increase salinity due to intake of seawater directly into Lake Munmorah and into the cooling water system</li> <li>Discharge of estuarine waters from Lake Budgewoi into the coastal zone</li> </ul>

Preliminary Feasibility Study of Ocean Cooling for Munmorah Power Station

	Option 1	Option 2	Option 3	Option 4	Option 5
Ecology	<ul style="list-style-type: none"> <li>Impacts on coastal ecological communities at discharges – hot water in summer and cold water in winter</li> <li>increased marine populations in lakes drawn in by increased flows through entrance,</li> <li>possible increase in exotic pest species due to increased flows and salinity changes</li> <li>increase fish and prawn larvae transport to the lakes from the coastal waters</li> <li>Reduction in movement of juveniles and adults back to the ocean for spawning.</li> <li>exposure of mudflats due to changed tidal range could reduce the seagrass communities and result in ecological changes</li> <li>changes in lake productivity due to reduced temperatures</li> <li>impact on seagrass, sediments and lake ecology should trenching for pipes under lake be required</li> </ul>	<ul style="list-style-type: none"> <li>a reduction in spring/summer seagrass growth in same part of the lake due to reduced temperatures</li> <li>Tuggerah Lakes fish nursery areas likely to be impacted</li> <li>fish larvae transport to the lakes would be greatly reduced</li> <li>increased fish mortality due to fish being drawn into pumps and cooling water system</li> <li>possible increase in exotic pest species due to increased flows and salinity changes</li> <li>impact on seagrass, sediments and lake ecology should trenching for pipes under lake be required</li> </ul>	<ul style="list-style-type: none"> <li>potential beneficial impact on lakes ecosystems, however extent of effect depends on the other contributing factors associated with the urbanised catchment and other uses of the lakes</li> <li>detailed modelling and investigation for the effects on changes in the ocean would be required</li> <li>impact on seagrass, sediments and lake ecology should trenching for pipes under lake be required</li> </ul>	<ul style="list-style-type: none"> <li>impacts of increased salinity on ecology of the lakes</li> <li>intake of marine organisms into the lakes</li> <li>effects on fish larvae and migration would need to be investigated</li> <li>possible increase in exotic pest species due to increased flows and salinity changes</li> </ul>	<ul style="list-style-type: none"> <li>impacts of increased salinity on ecology of the lakes</li> <li>intake of marine organisms into the lakes</li> <li>effects on fish larvae and migration would need to be investigated</li> <li>possible increase in exotic pest species due to increased flows and salinity changes</li> </ul>

Preliminary Feasibility Study of Ocean Cooling for Munmorah Power Station

	Option 1	Option 2	Option 3	Option 4	Option 5
Other	<ul style="list-style-type: none"> <li>increase scouring at the Entrance</li> <li>introduction of larger tidal range in the lakes</li> <li>storm events may increase local flooding</li> <li>construction impacts in environmentally sensitive locality</li> <li>potential impacts on Bird island Nature Reserve</li> <li>Pumping station visual and noise effects</li> <li>Coastal could be impacted by discharge facilities</li> </ul>	<ul style="list-style-type: none"> <li>increase scouring at the Entrance</li> <li>Pumping of coastal water into the lake via the cooling water system would cause the tidal flows to be mostly directed out of the lake at The Entrance.</li> <li>Potential increased sedimentation and increased blockage at some locations in Lakes</li> <li>Pumping station and associated infrastructure visual and noise effects</li> <li>construction impacts in environmentally sensitive locality</li> <li>Coastal could be impacted by intake facilities</li> <li>Environmental and community impacts of new transmission lines to supply remote pumping stations</li> </ul>	<ul style="list-style-type: none"> <li>Installation of two equal capacity pumping stations, one for ocean inflows and one for outflows will avoid excessive exchanges at The Entrance and larger tidal range in the lakes.</li> <li>Pumping station and associated infrastructure visual and noise effects</li> <li>Coastal could be impacted by discharge and intake facilities</li> <li>Environmental and community impacts of new transmission lines to supply remote pumping stations</li> </ul>	<ul style="list-style-type: none"> <li>Pumping of coastal water into the lake would cause the tidal flows to be mostly directed out of the lake at The Entrance.</li> <li>Pumping station and associated infrastructure visual and noise effects</li> <li>Coastal could be impacted by intake facilities</li> <li>Environmental and community impacts of new transmission lines to supply remote pumping stations</li> </ul>	<ul style="list-style-type: none"> <li>Effects of pumping of coastal water into the lake</li> <li>Effects on tidal flows</li> <li>Pumping station and associated infrastructure visual and noise effects</li> <li>Coastal could be impacted by discharge and intake facilities</li> <li>Environmental and community impacts of new transmission lines to supply remote pumping stations</li> </ul>

**Preliminary Feasibility Study of Ocean Cooling for Munmorah Power Station**

	<b>Option 1</b>	<b>Option 2</b>	<b>Option 3</b>	<b>Option 4</b>	<b>Option 5</b>
Recreational	<ul style="list-style-type: none"> <li>Affect on commercial and recreational fishery unknown</li> <li>Recreational activity at entrance impacted by increased flows</li> </ul>	<ul style="list-style-type: none"> <li>Reduction in commercial and recreation fishery due to reduced number of fish</li> <li>Recreational activity at entrance impacted by increased flows</li> <li>Recreational and conservation values of Munmorah SRA and Birdie Beach impacted by pumping stations and intake flows</li> </ul>	<ul style="list-style-type: none"> <li>Recreational and conservation values of Munmorah SRA and Birdie Beach impacted by pumping stations and intake and discharge flows</li> <li>Potential localised impacts on commercial and recreational fishing</li> </ul>	<ul style="list-style-type: none"> <li>Affect on commercial and recreational fishery unknown</li> <li>Recreational activity at entrance impacted by increased flows</li> <li>Recreational and conservation values of Munmorah SRA and Birdie Beach impacted by pumping stations and intake flows</li> <li>Potential localised impacts on commercial and recreational fishing</li> </ul>	<ul style="list-style-type: none"> <li>Affect on commercial and recreational fishery unknown</li> <li>Recreational and conservation values of Munmorah SRA and Birdie Beach impacted by pumping stations and intake flows</li> <li>Potential localised impacts on commercial and recreational fishing</li> </ul>
<b>Scope 2 greenhouse gas emissions (tCO<sub>2</sub>e/year)</b>					
Estimated Scope 2 GHG emissions	31,200	31,200	62,400	6,200	12,500

## 8. Engineering, Geotechnical and Environmental Studies

Due to the scope and complexity of the five options considered, extensive engineering, geotechnical and environmental investigations and studies would be required prior to finalisation of any plans. These studies, which are likely to cost several millions of dollars, have not been included in any of the costings included in Table 2.

It should also be noted that the necessary investigations would need to be conducted in conjunction with a comprehensive community involvement program, which would have both time and cost implications.

## 9. Discussion

The main engineering features, other aspects and potential environmental impacts for the five options have been summarised in Table 2. Consideration of the options has shown that, while ocean cooling configurations could reduce the thermal loads on the lakes, the consequences of an ocean discharge and/or supply of cooling water could well have a far larger effect on the environment, ecosystems and the community than the existing system and would require considerable engineering works to minimise effects on the coastal environment.

It is also important to note that the environment of the Tuggerah Lakes system is subject to a variety of influences, particularly those related to urbanisation. Accordingly, the extent of any potential environmental improvements which may result from removal or reduction of the power station's thermal discharge may be minor. In this context, it is noted that the environmental assessment for the proposed rehabilitation works at Munmorah Power Station has predicted that impacts of the rehabilitation are negligible and acceptable.

While it would be possible to construct tunnels to the ocean, this would require long, expensive tunnels through coal-bearing areas and the installation of expensive offshore outlet structures on an exposed coastline. Alternative pipeline installation using trenching methods due to constraints from previous mining would result in significant disturbance to lake sediments, seagrasses and lake ecosystems.

The supply and/or discharge of ocean cooling water may result in varying tidal levels in the Lakes and at the power station cooling water outlet in Lake Budgewoi. This would require major modifications to the existing cooling water systems at the power station.

The implications of the options considered are discussed below.

Option 1 has an estimated cost of \$230 million. The discharge of cooling water from the power station to the ocean via a pipeline would require the make-up of an equivalent volume of water to the lake. While this could possibly be achieved through the existing entrance to the Tuggerah Lakes at The Entrance, the resulting flows would likely have significant environmental, social and economic impacts on the Tuggerah Lakes system.

A one way augmentation of the cooling water system is likely to have significant impacts on lake levels, flooding impacts and tidal exchanges within the lakes. Negative impacts on NSW fisheries resulting from changes to the Tuggerah lakes system are also potentially significant.

Potential impacts in the ocean outfall locality could be anticipated and these would require detailed investigation and, possibly, ameliorative measures. Attenuation, of discharges to the ocean is still likely to be required under extreme summer conditions.

While Option 2, at an estimated cost of \$140 million is unlikely to require attenuation of cooling water during extreme summer events, the additional flow into the Tuggerah Lakes system would still require the discharge of an equivalent volume of water from the Lake system, possibly via the Entrance, with the associated significant environmental, social and economic impacts on the Tuggerah Lakes system.

As for option 1, a one way augmentation of the cooling water system is likely to have significant impacts on lake levels, flooding impacts and tidal exchanges within the lakes. Negative impacts on NSW fisheries resulting from changes to the Tuggerah lakes system are also potentially significant.

Option 3, with an estimated cost of \$320 million would be designed to remove power station thermal impacts from the Tuggerah Lakes System. However, existing impacts have been shown to be acceptable and the actual additional environmental benefit realised would depend on the contribution of other factors, such as urbanisation within the lake catchment, to the current state of the lakes. Sourcing of cooling water from and returning it to the ocean would avoid reducing the lake level by

pumping the equivalent volume of water from the ocean to Lake Munmorah to maintain the water balance of the lakes.

Likely increased environmental and social impacts on the community and the ocean have been identified and would require significant investigation to quantify and devise appropriate ameliorative measures and safeguards. Impacts on the community from additional facilities in sensitive locations are also likely to be significant. Installation of piping systems between the power station and the ocean could have significant impacts on lake sediments, seagrasses and lake ecosystems. The additional greenhouse gas emissions resulting from this option have been estimated to be greater than all other options, even when efficiency savings from power station operations are considered.

Option 4, is the cheapest option at an estimated cost of \$60 million. However, it would require the make-up of an equivalent volume of water to the lake similar to Option 1, being sourced through the existing entrance to the Tuggerah Lakes at The Entrance, with likely significant environmental, social and economic impacts on the Tuggerah Lakes system.

Potential impacts in the ocean discharge locality could be anticipated and would require detailed investigation and ameliorative measures. Attemperation before discharge of cooling water is also likely to still be required under extreme summer conditions, as the water pumped into Lake Munmorah would only have a minor impact on cooling water inlet temperatures.

As for option 1, a one way augmentation of the cooling water system is likely to have significant impacts on lake levels, flooding impacts and tidal exchanges within the lakes. The potential negative impacts on NSW fisheries resulting from changes to the Tuggerah lakes fish nurseries from a one way cooling water flow to the ocean may also be significant.

Option 5, at a cost of \$110 million, could avoid impacts on the lake water levels by importing water from the ocean to Lake Munmorah and returning the equivalent volume of water from Lake Budgewoi to the ocean. However, a lack of impact on the lakes is not certain, without detailed investigation. Water level fluctuations in the Lake may still occur as a result of changed flow regimes. Likely increased impacts on the lake and ocean have been identified.

There are only a limited number of cases in Australia where cooling water is discharged directly into temperate coastal waters and these are at a smaller scale than would need to be considered for Munmorah.

While option 3 minimises the thermal impacts on the lake system it is the most expensive option and the proposed extensive piping installation and associated facilities has potentially greater environmental and social consequences than the proposed Munmorah Rehabilitation cooling system.

Options 1, 2 and 4 would introduce significant changes to water flow regimes in the lakes have been shown to have potential significant increased impacts in the lake system.

The preceding investigation has identified significant environmental, engineering, social and economic issues associated with introducing a cooling water ocean outfall and or supply, in order to obtain possible localised benefits from reducing the existing power station thermal impacts on the Tuggerah lakes. A large degree of uncertainty in relation to predicting the potential consequences of such a proposal has been identified.

## 10. References

Bureau of Meteorology – Sea Temperature Data – Norah Head

Delta Electricity – Munmorah Power Station Rehabilitation Environmental Assessment

National Greenhouse and Energy Reporting (NGER) (Measurement) Technical Guidelines

Sydney Water - Environmental Assessment of the Concept Plan for Sydney's Desalination Project



U:\GIS\Project-2\project\Munmorah\mmps\_ocean\_cooling\_option\_1.mxd\4144220-02-10\KAD\Rev 0



SCALE 1:30,000 @ A4  
 0 500 1,000m  
 Projection: MGA



U:\GIS\Project-2\project\Munmorah\hmps\_ocean\_cooling\_option\_2.mxd\4144220-02-10\KAD\Rev 0



SCALE 1:35,000 @ A4  
0 500 1,000m

Projection: MGA



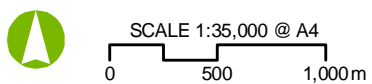
U:\GIS\Project-2\project\Mummorah\mmps\_ocean\_cooling\_option\_3.mxd\4144220-02-10\KAD\Rev 0

Mummorah Power Station Preliminary Feasibility Study for ocean cooling

FIGURE 3: Conceptual Option 3



U:\GIS\Project-2\project\Munmorah\mmps\_ocean\_cooling\_option\_5.mxd\4144220-02-10\KAD\Rev 0



Projection: MGA



U:\GIS\Project-2\project\Munmorah\mmps\_ocean\_cooling\_option\_4.mxd\4144220-02-10\KAD\Rev 0



SCALE 1:35,000 @ A4  
0 500 1,000m

Projection: MGA