

REPORT

Review of Literature on the Effects of Desalination Plant Brine Discharge Upon Cetaceans



Prepared for
Western Australian Water Corporation

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URS

R E P O R T

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1. INTRODUCTION

1.1 BACKGROUND

The Western Australian Water Corporation (WAWC) has proposed the installation of a desalination plant at Binningup, Western Australia as part of the Southern Seawater Desalination Project (SSDP). The seawater desalination plant will produce potable water by the seawater reverse osmosis (RO) process. The RO process involves gravitating seawater in through the seawater intake structure to the seawater pump station, pre-treating it (using filtration and/or coagulation) and then pressurising it over a membrane so that freshwater is driven through and higher salinity seawater (brine) is left behind. The brine, which is approximately twice as saline as seawater, passes through energy recovery devices before being discharged via the brine discharge pipeline and diffuser at high velocity and rapidly mixes with the surrounding seawater.

1.2 THIS REVIEW

The purpose of this review is to identify the potential environmental issues associated with brine discharge at the proposed SSDP and discuss their possible effects on cetaceans. Primary literature has been sourced for review where possible. However, little information is available on the potential effects upon cetaceans of the discharge of brine from desalination plants into nearshore waters. While a wide range of the potential environmental impacts of discharge from desalination plants has been identified, few studies have been published in scientific literature that examined the actual effects of discharge from desalination plants on large marine fauna. Secondary literature and anecdotal information, with appropriate qualification, have been used where gaps in knowledge exist.

1.3 BINNINGUP AREA

1.3.1 Binningup discharge area

During operation the SSDP will discharge brine through the ocean outfall diffuser(s) located between 600 m and 1100 m offshore with a total diffuser length of up to 450 m. The brine will be discharged at high velocity through angled nozzles and will mix rapidly with the surrounding seawater. The diffuser will consist of up to four outlet pipes, each to 3 m in diameter. The outlet pipes will be no more than 1 m, or 10% of the water column depth above the seabed.

The proposed discharge area and mixing zone is located in a Low Ecological Protection Area (LEPA). Based on measurements of the Perth Seawater Desalination Plant (PSDP) diffuser discharge, the near field (i.e. the mixing zone) extends around 100 m either side of the diffuser. For this reason the LEPA is proposed to be a rectangular zone that extends 100 m in all directions around the diffuser with an area of approximately 12.5 ha.

1.3.2 Water conditions

Local water temperature and salinity concentrations vary on a seasonal basis. Salinity has a peak of around 36.5 ppt in summer-autumn and a minimum of around 34.5 ppt in winter-spring. During rainfall events, freshwater outflow from the Harvey diversion drain (located approximately 2 km north of the proposed desalination plant) mixing into the Binningup marine waters can result in salinities as low as 30 ppt (WAWC 2008).

Water temperature reaches a peak of around 24°C in summer-autumn and a minimum of around 15°C in winter-spring. Analysis of temperature data shows that the site experiences well mixed conditions the majority of the time. A regular diurnal stratification / de-stratification cycle was observed where solar heating stratified the water column in temperature, which was then well mixed by wind and overnight cooling (WAWC 2008).

Dissolved oxygen (DO) concentrations in the Binningup area show diurnal fluctuations due to naturally occurring biological activity (photosynthesis and respiration). DO concentrations are generally between 6.5 and 8.5 mg/L. There are only a few instances in isolated locations where the instantaneous DO dropped to around 5 mg/L (Water Corporation 2008).

1.3.3 Characteristics of the brine discharge

The first stage of the plant will have a nominal production of 50 GL/yr of potable water. This will require approximately 120 GL/yr of seawater to be brought into the desalination plant and 70 GL/yr of brine discharge to be returned to the ocean. These flows will double when the second stage of the plant is completed. The brine discharge rate will be at a peak of 240 ML/d during the first stage and 480 ML/d during the second stage. The actual production rate varies somewhat from season to season, with higher production on days with higher seawater temperatures and clear water, and lower production in winter when the seawater is cooler and more turbid.

The potential impacts on the marine environment associated with the brine discharge (WAWC 2008) are:

- reduction in light
- reduction in pH
- increase in nutrients
- increase in salinity
- chemicals in the brine
- lower DO levels.

WAWC (2008) also identifies that brine discharge temperature will be up to 2°C above that of ambient seawater.

1.3.4 Cetaceans

Western Whale Research (2008) has identified that the cetaceans most likely to occur at Binningup are dolphins (bottlenose) and southern right whales. According to

WAWC (2008) species of cetaceans with the possibility of occurring in the Binningup marine environment include:

- humpback whale (*Megaptera novaeangliae*)
- southern right whale (*Eubalaena australis*)
- blue whale (*Balaenoptera musculus*)
- Bryde's whale (*Balaenoptera edeni*)
- pygmy right whale (*Caperea marginata*)
- southern right whale (*Eubalaena australis*)
- bottlenose dolphin (*Tursiops sp.*)
- killer whale, Orca (*Orcinus orca*).

2. ASPECTS AND IMPACTS

The following section discusses each of the potential environmental impacts associated with brine discharge in respect to potential impact on cetaceans.

2.1 LIGHT

The water entering the SSDP will be filtered through dual media filters prior to the RO process, thereby removing suspended marine material such as silt, sand and algae. It is this suspended material that reduces light penetration into water. As a result, the discharge of the SSDP will have less suspended particles and therefore may increase light penetration into marine waters (WAWC 2008). A slight increase in water clarity and hence light penetration is not expected to affect cetaceans.

The Ecology Lab (2005) undertook a marine ecology assessment for the intake and outlet pipelines for an RO desalination plant in Sydney, Australia. The Ecology Lab (2005) noted that greater light penetration may increase the growth of seagrass. Seagrass beds support a variety of fishes and invertebrates, some of which may provide prey for some species of cetaceans, or at least support production at lower trophic levels of the cetacean food pyramid.

2.2 pH

Seawater (such as occurs naturally at Binningup) typically has a pH of approximately 8. The discharge will range from pH 6 to 8. The buffering capacity of seawater (i.e. the ability to neutralise pH) coupled with the high level of dilution of the desalination discharge means that pH of any desalination discharge will be rapidly converted to ambient levels (WAWC 2008). No information was available from WAWC (2008) on the expected distance it would take from the diffuser before ambient levels are reached. However, ambient levels are expected to be reached well within the mixing zone (Lattemann & Hopner 2003). The Ecology Lab (2005) discussed the possible impacts of brine output on the marine environment. This report did not specifically discuss the effects of slightly reduced pH on the marine environment as impacts were expected to be negligible.

2.3 NUTRIENTS

Nitrogen can be a nutrient of concern in marine environments with regard to stimulating primary productivity (Morris et al. 2007). Morris et al. (2007) linked an increase of bioavailable nitrogen in the marine environment to a loss of sea grass (*Zostera muelleria*) in Western Point, Victoria, Australia. An increase in nitrogen may stimulate algal growth on seagrass, limiting the amount of sunlight that it receives for photosynthesis. A number of process chemicals that contain nitrogen (polyelectrolytes, biocides and acid detergents) are used in the reverse osmosis process. Measurements on the PSDP show that any nitrogen added in the RO process is equal to that removed in the filter backwash cake (i.e. sludge that is taken away to landfill).

It can be concluded that the operation of the SSDP is unlikely to increase nitrogen levels in marine waters. Therefore nutrients derived from the operation of the SSDP are unlikely to impact upon cetaceans, either directly or indirectly.

2.4 SALINITY

Salinity of the brine at the discharge point of the diffuser will be up to 65 ppt. The brine will rapidly mix with the surrounding seawater due to turbulence caused by the velocity of the output. The WAWC has committed to the SSDP desalination discharge not causing an increase in salinity at the boundary of LEPA that is:

1. greater than 1 part per thousand (ppt) 95% of the time
2. greater than 1.3 ppt at any time.

The brine is heavier than the surrounding seawater due to its higher salinity. The region where the brine settles to the seafloor is termed the nearfield and is predicted to be fully contained within the LEPA. Once the diluted brine reaches the seabed it will continue to dilute due to natural mixing processes. It will also be advected by currents and move down slope (i.e. offshore) due to being slightly denser than the surrounding seawater (WAWC 2008).

There is no potential for long-term build-up of salinity due to the discharge being sited on an open coastline. The brine discharge is predicted to increase the average density stratification by no more than 0.1 kg/m³ at 0.5 km from the diffuser. This stratification reduces with distance away from the diffuser and there is only a minor change to the duration of stratification 2 km and more from the diffuser (WAWC 2008).

Claims have been made that hypersaline water can harm whales. This is largely based upon a 1999 incident where at least 65 gray whales (*Eschrichtius robustus*) were reported to have washed up on Mexico's Baja Peninsula, where the animals migrate each winter to bear their young. Additional whale corpses were also discovered along California shores in March and April during the migration of the whales north to their feeding grounds (CNN 1999).

The apparent higher-than-average mortality rate generated widespread speculation in the media and amongst conservation activists on the cause of the deaths. One of the more popular explanations reported in the media was that the whales were being killed by cyanide in a fluorescent dye used by drug smugglers to mark the sea during air drops of illegal narcotics.

Another of the many explanations proliferated was pollution or changes to seawater conditions caused by a salt production facility in Guerro Negro lagoon, although there is no evidence of either occurring. The industrial salt production facility, ESSA, is a company jointly owned by the Mitsubishi Corporation and the Mexican government. The company, which has been operating in the area for over 40 years, produces approximately seven million tons of salt a year, making it the largest producer of salt in the world. The salt is produced by drawing seawater into large shallow evaporation ponds. Solar and wind energy then evaporate the water leaving the salt ready to harvest (Gustafson et al. 1998).

Weng (1997) of the University of California speculated that warm, salty water that was being removed from Guerro Negro lagoon by the salt-evaporation plant was being replaced with colder, less saline water from the open ocean. Weng (1997) stated that whales were less buoyant in cooler, less saline waters and thus would expend more energy while in the bay, causing more stress on the animals. However, there has been no evidence to support this claim.

According to CNN (1999), Dr Bruce Mate, a marine mammal specialist at Oregon State University, stated the most likely cause could be massive changes to animal communities in the Bering Sea where the whales spend their summers feeding and rearing their young. Mate also commented that, although it was the highest number of fatalities seen in the 24 years that people had kept records, it may just have been that more were recorded in that particular season.

To date there has not been further research done on the cause of the whales' deaths in 1999, nor have there been repeated high mortality rates.

Information for this review was also sought regarding physiological effects of hypersaline or hypertonic solutions on cetaceans and on parasites that use cetaceans as a host. No information could be found regarding these effects.

Anecdotal evidence of cetaceans' ability to live in hypersaline environments is provided in the Red Sea and the Arabian Gulf. Swenson (2005) reports that the salinity in the Red Sea can reach up to 40 ppt and in the Arabian Gulf can reach up to 41 ppt (Swift & Bower 2003). These waters support a number of cetaceans (Culik 2004) including:

- Risso's dolphin (*Grampus griseus*)
- Blainville's beaked whale (*Mesoplodon densirostris*)
- ginkgo-toothed Whale (*Mesoplodon gingodens*)
- false killer whale (*Pseudorca crassidens*)
- killer whale (*Orcinus orca*)
- Indian humpback whale (*Sousa plumbea*)
- pantropical spotted dolphin (*Stenella attenuata*)
- striped dolphin (*Stenella coeruleoalba*)
- rough-toothed dolphin (*Steno bredanensis*)
- bottlenose dolphin (*Tursiops truncatus*)
- sei whale (*Balaenoptera borealis*)
- Bryde's whale (*Balaenoptera sp.*)
- blue whales (*Balaenoptera musculus*).

According to de Silva Samarasinghe et al. (2003), water in Gulf St Vincent, South Australia, can exceed 42 ppt in summer when evaporation is at a maximum and the rainfall is minimal. According to Shepherd et al. (2008) the gulf is an environment commonly used by many species of dolphins and whales, including the bottlenose dolphin and the southern right whale.

Tomczak (2003) notes that when sea ice is formed in polar regions during winter hypersaline brine is ejected during the freezing process. It is known that these polar habitats support marine mammals such as whales. This observation provides further support that whales can tolerate areas of elevated salinity.

Bays et al. (1992) undertook a study to measure the toxic effects of increased salinity on marine species and determine the toxic effects of waste brine and the interactions between waste brine and sewage on toxicity. The study tested the effects of increased salinities on spores of giant kelp (*Macrocystis pyrifera*), an amphipod (*Rhepoxynius abronius*) and sea urchin embryos (*Strongylocentrotus purpuratus*). Sea urchin embryos were used in the experiment as they are among one of the most sensitive marine species. The salinities were based on the predictions from plume models for the Santa Barbara reverse osmosis desalination plant.

The study concluded that desalination plant brine and elevated salinity did not produce toxic effects on amphipods, kelp spores or sea urchin embryos at concentrations expected in the field. However, the combined effect of increased salinity and sewage effluent had a significant effect on sea urchin development. As the brine output in the SSDP will not be mixed with effluent it is unlikely that the brine plume will have any effects on sensitive marine species. Thus secondary effects of brine plumes on cetaceans are not likely to be seen in the Binningup area.

WAWC (2008) states that marine mammals such as whales and dolphins are unlikely to be affected by the saline discharge as they are able to sense changes in salinity and avoid if necessary (Western Whale Research 2008). It can be concluded that the operation of the SSDP Plant is unlikely to increase salinity to a level that will affect flora and fauna outside of the LEPA (WAWC 2008).

In the environmental assessment of the proposed Sydney seawater desalination plant, The Ecology Lab (2005) highlighted the possible impacts of increased salinity on the marine ecosystem. They state that increased salinity may impact upon small sessile organism and that mobile biota such as fish were likely to be able to avoid the zone of higher salinity in the immediate area of the discharge.

2.5 CHEMICALS

A number of chemicals are required for the efficient and effective operation of a desalination plant. These may include sulfuric acid, ferric sulphate/chloride, polyelectrolyte, antiscalants, sodium hypochlorite and sodium bisulphate. The actual chemical dosing regimes for the SSDP will be determined following pilot testing and will be refined during commissioning. All of the treatment chemicals to be used are either non-hazardous, form harmless byproducts or biodegrade relatively rapidly (WAWC 2008). Accordingly, it is unlikely that there will be any bioaccumulation of substances associated with the SSDP.

The seawater drawn into the seawater plant naturally contains metals whose concentrations will be approximately doubled before being discharged in the brine stream. Dilutions of 28 to 50 times within the LEPA would result in these substances being around 4% to 2% higher in concentration at the LEPA boundary compared to background seawater. Additional dilution beyond the LEPA will reduce this increase in concentration even further. Hence, it is only if a substance is added during the treatment process, as opposed to being present in the seawater intake stream, that there is the potential for any measurable environmental impact (WAWC 2008).

Given the potential toxicity of some metals, monitoring of the desalination discharge stream for metals will be carried out as part of the Discharge Water Quality

Monitoring Management Plan (WAWC 2008). The results of this monitoring should be reviewed in regards to potential effects on cetaceans.

2.6 DISSOLVED OXYGEN

The WAWC (2008) reported, as a worst case estimate, the brine from the SSDP could be up to 2 to 2.5 mg/L lower in DO than the ambient seawater. Following dilution with seawater, the largest decreases in dissolved oxygen that could occur are 0.09 mg/L (1.3 % sat) and 0.14 mg/L (2 % sat) at the LEPA boundary and within the LEPA respectively. Such changes, if they were to occur, would not be discernable against background variations in DO concentrations. The Ecology Lab (2005) did not specifically discuss the effects of slightly reduced DO levels on the marine environment as impacts were expected to be negligible.

Centre for Water Research (2007) concluded that there is not likely to be any significant change in DO, beyond natural variation, in any ecological or biological indicators that are affected by poorly oxygenated water in deeper waters. Thus as cetaceans are air breathing, and there is not likely to be any significant reduction of DO in the receiving environment, no tangible effect is contemplated.

2.7 TEMPERATURE

The temperature of the brine at the discharge diffuser will be within 2°C of the ambient seawater temperature. According to Silva (2004) cetaceans are the only homeotherms that spend their entire life in the open sea, subject to water temperatures ranging from -2°C to about 30°C. Because of this cetaceans have a highly developed thermoregulation system. Thus the temperature differences caused by the brine discharge are most likely to be within their tolerance range.

The Ecology Lab (2005) suggested that a change in seawater temperature in the order of 1—2°C above ambient conditions may attract biota more suited to warm conditions, which could affect the structure of animal assemblages in a very small area around the outlet. This is unlikely to affect the feeding behavior of cetaceans.

3. CONCLUSION

Despite the large number of desalination plants operating around the world, there are many knowledge gaps and uncertainties regarding the impacts of desalination projects on the marine environment, as monitoring results of operating plants are only available to a limited extent. Even less information is available on the effects that RO desalination plants have on large marine fauna.

The environmental effects of brine discharge on cetaceans have not been studied at other RO desalination plants. However, there is no information available that suggests brine discharge will have a negative effect on cetacean health. In the case of the ESSA saltworks in Mexico there was no evidence to suggest that hypersaline brine discharge was the cause of gray whale deaths in 1999 and there has been no apparent recurrence of this episode. There are, however, many examples of cetaceans living in sea areas with elevated salinities.

Cetaceans are large, highly mobile organisms in relation to the size of the brine mixing zone proposed at the SSDP. Because of their mobility, it is expected that exposure to environmental conditions within the mixing zone, even if they were to be adverse, will be minimal. Hence it is considered highly unlikely that there will be adverse impacts on cetaceans due to brine discharge from the SSDP.

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5. LIMITATIONS OF REPORT

URS Australia Pty Ltd (URS) has prepared this report in accordance with the usual care and thoroughness of the consulting profession for the use of Western Australian Water Corporation and only those third parties who have been authorised in writing by URS to rely on the report. It is based on generally accepted practices and standards at the time it was prepared. No other warranty, expressed or implied, is made as to the professional advice included in this report. It is prepared in accordance with the scope of work and for the purpose outlined in the Proposal dated 23 June 2008.

The methodology adopted and sources of information used by URS are outlined in this report. URS has made no independent verification of this information beyond the agreed scope of works, and URS assumes no responsibility for any inaccuracies or omissions. No indications were found during our investigations that information contained in this report as provided to URS was false.

This report was prepared between 23 June and 8 July 2008, and is based on the conditions encountered and information reviewed at the time of preparation. URS disclaims responsibility for any changes that may have occurred after this time.

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