

DESALINATION ECOTOXICITY REVIEW

BRISBANE | PERTH | SINGAPORE | PAPUA NEW GUINEA

EYRE PENINSULA DESALINATION PLANT



B22030

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DECEMBER 2022

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EXECUTIVE SUMMARY

SA Water are proposing to build a 24 ML/day desalination plant in the vicinity of Port Lincoln on the Eyre Peninsula, to supplement the region's water supply which has historically been provided by the Uley South Basin bore field and the River Murray. As part of the approvals process an ecotoxicological assessment of the discharge from the proposed desalination plant needs to be undertaken. This report considers the available ecotoxicology information from other large scale seawater desalination plants built in Australia. Of particular interest is the now operating Adelaide Desalination Plant (ADP) and the proposed Olympic Dam Desalination Plant (ODDP) to supplement the data collection process for the Eyre Peninsula Desalination Plant (EPDP). The proposed EPDP intends to use the same chemicals that were assessed and approved for use by the ADP and will be designed to achieve a conservative 40:1 dilution of the discharge by the edge of the mixing zone.

All previous ecotoxicological assessments of discharges simulating operational desalination plant brine have indicated that salinity was the main driver of the observed toxicity, with a small effect being observed in some assessments from the addition of process chemicals such as antiscalant. The dilution required to protect the receiving environment from the effects of salinity was shown to be more than adequate to nullify this additional toxicity.

Ecotoxicity assessments indicated that some chemicals used to clean the membranes and other desalination infrastructure would require a higher rate of dilution than those achieved by the desalination plant under normal operating conditions. This is not unusual given that some of these chemicals are biological control agents that are used for antifouling purposes and are toxic by design. The toxicity associated with process and cleaning chemicals can be managed using standard procedures for their disposal into the waste stream at appropriate concentrations calculated as part of the ecotoxicology assessment. This can be achieved through appropriate plant design to ensure there is no effect on the receiving environment.

While there is a plethora of relevant ecotoxicology information available, it is recommended that a site-specific approach be taken. This approach uses a subset of regionally relevant organisms and intake water from the proposed site for chronic pre-operational ecotoxicity testing of the pilot plant saline concentrate. The results of this subset of tests can then be directly compared with the ADP results to ensure that any observed toxicity is within the bounds of that seen during the ADP assessment. This testing can also be supported by the results from the numerous tests undertaken on large seawater desalination plants around Australia for more toxicity context and robust results.

It is also recommended that a post operational ecotoxicity assessment of the brine discharge be undertaken as the plant is brought to operational capacity using the same subset of ecotoxicity tests employed in the pilot study, in a similar requirement to that placed upon the ADP (for example testing to be carried out at 50% of total production then 3 months and 6 months after full production has commenced).

Given the results of the ecotoxicological assessments for other large seawater desalination plants in Australia, the resultant discharge dilution ratios and the size and output volume of the proposed EPDP, it is expected that the proposed 40:1 dilution ratio to be achieved by the edge of the mixing zone will be adequate to protect the receiving environment. The recommended pre and post commissioning testing regime will ensure that this is achieved. The treatment of cleaning chemicals should be handled so that concentrations entering the discharge stream are low enough to present no risk to the receiving environment.

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1. INTRODUCTION

1.1 BACKGROUND

The Eyre Peninsula is a triangular peninsula in South Australia, bounded by the Spencer Gulf on the east, by the Great Australian Bight on the west, and by the Gawler Ranges on the north. Eyre Peninsula water sources have reduced over time due to the changing climate and salinisation and underground water resources are suffering from gradually increasing salinity. The Uley South Basin has provided water for drinking supply since 1976 and currently provides 75% of all water used on the Eyre Peninsula, with the majority of the balance coming from the River Murray. Presently, water is pumped several hundred kilometres from the Murray River to the town of Whyalla through the Morgan-Whyalla pipeline.

Working together with the Eyre Peninsula community, SA Water has investigated potential locations to establish seawater desalination plants to address Eyre Peninsula's future water security concerns. The desalination plant is required by 2025 to prevent permanent damage to Uley South Basin and the flow-on impacts to water availability across the Eyre Peninsula. The plant will provide a new reliable, climate-independent source of drinking water to supplement existing groundwater sources and water from the River Murray and is critical to maintaining a long term supply of safe, clean drinking water for around 35,000 people on the Eyre Peninsula. Four sites have now been shortlisted as possible locations for the Eyre Peninsula Desalination Plant: Sleaford West, Point Boston, Uley South Shoal Point, and Sleaford North.

1.2 ECOTOXICOLOGICAL ASSESSMENTS OF POTENTIAL DISCHARGES

Contaminants that enter the natural environment can affect the flora and fauna of the ecosystem into which they are released. The science of studying these effects is called ecotoxicology and it investigates the impacts of contaminants on individuals, populations, natural communities, and ecosystems, as well as determining what happens to the contaminant as it breaks down in the environment, typically referred to as its 'fate' (Newman & Unger, 2003). Ecotoxicology is a complex field of study and draws on a range of scientific disciplines including ecology, toxicology, physiology, analytical chemistry, molecular biology and mathematics.

An ecotoxicological assessment can be used to assess the potential impact of a complex mixture such as a proposed discharge, on the environment. This is usually done by exposing a number of organisms to a sample that best represents the potential discharge and recording the effects on the different species. The ecotoxicity assessments that have been carried out on the majority of large seawater desalination plants in Australia used this method. These studies typically obtain representative discharge samples for assessments by processing intake water from the proposed site through a small scale benchtop reverse osmosis plant or obtaining discharge from an already established desalination plant. The additional factors that determine the chemical composition of the discharge, including the level of recovery, (i.e. how much freshwater is to be extracted from the seawater), the process treatment chemicals and cleaning chemicals can all be managed to replicate those expected for the proposed desalination plant.

Several different species are required for toxicity testing, currently recommendations suggest five species from four trophic levels. However, it is strongly encouraged to increase the number of species tested where possible to eight in order to produce more reliable and robust results (ANZG, 2018; Warne et al., 2018). It is also ideal to use local species as part of the testing regime, but this needs to be weighed against the practicality of procuring the test species in adequate numbers and keeping them successfully in a laboratory setting for testing purposes as well as the potential for the application of standardised toxicity test methods.

The chosen species are exposed to a dilution series of the discharge to understand at what point the discharge negatively affects the organism(s), referred to as an 'endpoint'. A chronic endpoint is desired as the measure of toxicity for each species, i.e., a measurable non-lethal indicator such as number of brood, growth or successful germination. It is also often useful to understand the potential effects on acute endpoints such as immobilisation and death, which provide data for plant process disruptions where the receiving environment may experience short exposures of the discharge at higher concentrations.

Data collected during these experiments are used to statistically derive an 'effective concentration', the concentration at which a certain percentage of the test organisms are affected. An effective concentration of 10% is typically used in ecotoxicological assessments of this nature, i.e., the concentration at which 10% of the population experience the test endpoints, known as the EC10. A chronic EC10 value will be calculated for each test species based on the results of the ecotoxicology testing. These EC10 values for each species are then used to calculate a guidelines value based on a species sensitivity distribution (SSD), using BurrliOz 2.0 software (Barry and Henderson 2014). This is a statistical approach whereby the concentration of discharge that is hazardous to no more than a pre-defined percentage of organisms in the receiving environment is calculated. An SSD is a cumulative distribution function that describes the variation in sensitivity of species to a chemical or discharge. An example of an SSD is shown in Figure 4-1 for the Olympic Dam ecotoxicology assessment. While BurrliOz 2.0 does it have its limitations, it does allow for standardisation of distribution fitting across SSDs. From the SSD protective concentrations can be estimated for different levels of protection. For example, ANZG (2018) default guidelines are based on a slightly to moderately disturbed level or the concentration that will protect 95% of species in a receiving environment. This is also known as the PC95 and is the most common protective concentration used when assessing a discharge unless the discharge will occur into a high environmental value zone, where the PC99 would be adopted, or the receiving environment is considered highly disturbed where the PC90 or PC80 may be recommended.

The process of deriving site-specific guideline values and dilution ratios using the SSD method from a number of single-species toxicity tests is deliberately conservative. This ensures that the receiving environment will be adequately protected when taking into consideration the inherent associated single-species ecotoxicity testing and the many variables that exist when undertaking a testing regime based on a synthetic discharge under laboratory conditions.

1.3 STUDY OBJECTIVES

The following report has been prepared for SA Water to provide technical information relating to the ecotoxicity of seawater desalination discharges of the proposed Eyre Peninsula Desalination Plant (EPDP) as part of the development assessment process.

The objectives of this study are to:

- Review relevant available information on seawater desalination plant discharge ecotoxicology assessments with a particular focus on information generated as part of the Adelaide Desalination Plant (ADP) development process and the information available from the Olympic Dam Desalination Plant (ODDP) Environmental Impact Statement.
- Assess the applicability of the ADP ecotoxicity data and any other relevant information for the assessment of the potential ecotoxicity of the proposed EPDP discharge.
- Derive a protective concentration and corresponding safe dilution from the available ecotoxicity data deemed relevant to the EPDP discharge.

The following sections have been divided into:

- Salinity and its potential effects;
- Chemical additives used in both the desalination process and membrane cleaning;
- Utility and applicability of previous ecotoxicity assessments for the proposed EPDP;
- Literature review of relevant desalination ecotoxicity studies; and
- Recommendations.

2.SALINITY EFFECTS

It is generally accepted that salinity is the main driver of the observed toxicity of seawater desalination plant discharge. The importance of understanding the tolerance of species that may experience elevated salinity associated with the brine discharge is paramount to ensuring no significant impacts result from plant operations. Marine organisms have varying sensitivity in response to changes in salinity. Osmotic conformers are organisms that have no mechanism to control the salinity within their bodies and therefore their cells conform to the same salinity as their environment (Voutchkov, 2011). Large increases in salinity in the surrounding marine environment cause the water to flow out of the cells of these organisms, which could lead to cell dehydration and ultimately death. Organisms that can only survive in a narrow salinity range are referred to as “stenohaline”. On the contrary, osmotic regulators can control the salt content within their cells despite variations in external salinity (Voutchkov, 2011). Most marine fish, reptiles, birds and mammals are osmotic regulators. Salinity tolerances of marine organism vary, but some shellfish (scallops, clams, oysters, mussels or crabs) and reef building corals are able to tolerate very high salinities (Voutchkov, 2011). An additional factor when considering environmental impacts of concentrate discharges is the mobility of the organisms. Mobile organisms may simply move away from areas of higher salinity without adverse impacts. Sessile organisms (e.g. plants and corals) are more vulnerable to salinity changes (Missimer & Maliva, 2018). Many marine organisms are naturally adapted to the changes in seawater salinity that occur seasonally and are mostly driven by the evaporative rate from the ocean surface, by rain deposition and runoff events and by surface water discharges. Typically, the range of natural salinity fluctuation is at least $\pm 10\%$ of the average annual ambient seawater salinity concentration. The “10% increment above ambient ocean salinity” threshold is considered a conservative measure of aquatic life tolerance to elevated salinity. The actual salinity tolerance (the point at which organisms can survive) of most marine organisms is usually significantly higher than this level and often exceeds 40 ppt (Voutchkov, 2011).

The toxicity assessments undertaken on the large seawater desalination plants that have been built in Australia since the turn of the century have all indicated that the main driver of the observed toxicity was the salinity of the brines. Table 2-1 shows the characteristics of those plants and the dilution ratios calculated to ensure that the discharge would have little to no effect after diffusion.

Table 2-1 Australian desalination plants and calculated little to no effect dilution ratios

Study site	Treatment	Safe dilution/ protective factor	Note/comment
ADP pilot plant	Brine	PC 95: 21:1	
Penneshaw	Brine	PC 95: 12:1	Most relevant to EPDP
Olympic Dam	Brine with Nalco anti-scalant PC1020T at a dosing rate of 3.6 mg/L.	PC 99: 60:1 (60 x dilution, 1.66% effluent). Recalculated using NOEC: 26.3:1 (3.8% with a corresponding safe dilution of 26.3)	Second value uses recommended process when salinity is the main toxicity driver.
ADP post commissioning	Discharge effluent	3 months after fully operational: 15.1:1 6 months after fully operational: 27.4:1	
Adelaide Desalination Plant (ADP) Pilot plant saline concentrate study	Ambient saline concentrate without antiscalant	PC 95: 16:1 PC 99: 23:1	EC10 concentrations used but NOEC used when a gradual reduction in effect was not seen.
	Ambient saline concentrate with antiscalant	PC 95: 12:1 PC 99: 14:1	EC10 concentrations used but NOEC used when a gradual reduction in effect was not seen.
	pH adjusted saline concentrate without antiscalant	PC 95: 13:1 PC 99: 15:1	EC10 concentrations used but NOEC used when a gradual reduction in effect was not seen.
	pH adjusted saline concentrate with antiscalant	PC 95: 12:1 PC 99: 14:1	EC10 concentrations used but NOEC used when a gradual reduction in effect was not seen.
Olympic Dam desalination plant discharge	Return water for Point Lowly ^b	Best dataset PC 99: 45:1 PC 95: 30:1	A mixture of EC10 and NOEC concentrations used.
Sydney desalination plant	Concentrated seawater	Stream 1 PC 95: 27:1 PC 99: 20:1	Ecological trigger values calculated from EC10 data.

Study site	Treatment	Safe dilution/ protective factor	Note/comment
	Concentrated seawater with anti-scalent	Stream 4 PC 95: 13:1 PC 90: 12:1	Ecological trigger values calculated from EC10 data
Perth Seawater Desalination Plant	Seawater concentrate discharge	PC 95: 13:1	Based on EC10 toxicity data
Victorian Desalination Plant Round 1: April 2008	Salinity adjusted intake water from the Perth Seawater Desalination Plant.	PC 99 (ACR 2.5): 39:1	Calculated from EC10 based species sensitivity distributions.
	Case 2 brine concentrate and pre-treatment supernatant waste	PC 99 (ACR 2.5): 29:1	Calculated from EC10 based species sensitivity distributions.
Victorian Desalination Plant Round 2: June 2008	Case 1 Brine concentrate plus pre-treatment waste	PC 99 (ACR 2.5): 17.8	Calculated from EC10 based species sensitivity distributions.
	Case 2 Brine concentrate plus pre-treatment supernatant waste	PC 99 (ACR 2.5): 22.6	Calculated from EC10 based species sensitivity distributions
	Case 3 Brine concentrate	PC 99 (ACR 2.5): 18.3	Calculated from EC10 based species sensitivity distributions
	Salinity adjusted intake water	PC 99 (ACR 2.5): 16.7	Calculated from EC10 based species sensitivity distributions
Gold Coast Desalination Plant (GCDP)	Short-term concentrated effluent pulse exposure	<1 hour: salinity concentration up to 42.0 ppt Up to 4 hours: salinity concentration up to 41.9 ppt	

3. DESALINATION CHEMICAL EFFECTS

Reverse Osmosis Desalination is a method of water purification that uses a membrane to separate particles in solution and remove the salt. A number of processes typically occur in the desalination of seawater that may affect discharge characteristics. Table 3-1 provides a generic overview of these processes. There are a range of process chemicals available for use in the various stages of desalination, and the final selection of chemicals will be dependent upon desalination process design, environmental and engineering performance requirements, and regulatory requirements for the discharge of the final waste stream.

Information on water treatment chemicals used in desalination plant operation is often too broad to be useful in a toxicological assessment context. While the same broad class of chemical may be used to perform a particular function as part of the desalination process, the various products on the market that perform those functions can have subtly different chemical characteristics or recommended dosage rates; this, in turn, affects their potential toxicity. The following sections outline the broad chemical classes used as part of the desalination process, typical dosing rates used for each and their potential toxicity to organisms in receiving waters.

Table 3-1 Summary of processes in desalination, their purposes and the chemicals that are added

Process		Purpose	Approach
1	Chlorination	Control biological growth in intake and pre-treatment; Reduce rate of biofouling	Chlorine (NaOCl)
2	Dechlorination	Protect chlorine-sensitive RO membranes	Sodium metabisulfite
3	Antiscalant dosing	Minimise rate of scale formation on RO membranes.	Sequestering agent dispersants
4	pH adjustment	Minimise rate of scale formation in RO membranes. To achieve optimum pH for boron removal	Acid (H ₂ SO ₄) Base (NaOH)
5	Membrane cleaning	To periodically clean the membranes to restore RO performance	Acids, bases and surfactants

3.1 CHLORINATION

Intermittent chlorination is typically performed at the marine intake structures and at the seawater pump station to control marine growth. Chlorine, either as chlorine solution (generated using chlorine gas) or commercial liquid sodium hypochlorite is normally employed at concentrations below 10 mg/L as Cl₂ equivalent (active chlorine). The toxicity of sodium hypochlorite has been determined for a wide variety of aquatic organisms. Free chlorine and bromine will be removed in the process due to its potential to harm the reverse osmosis membranes and will therefore, not be part of the discharge and is not relevant from a toxicity perspective.

3.2 DECHLORINATION

As stated previously, feed seawater is chlorinated for marine biofoulant control. However, as chlorine can cause irreversible damage to RO membranes, the seawater must be dechlorinated prior to entering the RO membrane system. This is achieved by adding sodium metabisulfite when chlorine dosing is active.

As part of the process to ensure complete removal of free chlorine and free bromine, a slight overdose of sodium bisulfite is used. As sodium bisulfite is an oxygen scavenger, the discharge will have lower levels of dissolved oxygen associated with it. Dissolved oxygen could have a significant impact on the receiving environment and, therefore, tight control of the dechlorination process will be needed. The toxicity data available for sodium bisulfite is limited.

3.3 ANTISCALANT DOSING

Antiscalants are used to minimise or prevent the accumulation of sparingly soluble salts on the RO membrane surface, as the seawater is concentrated in the RO process. This ensures maximum performance (with respect to water quality and energy consumption) from the system. The following are some of the chemicals that are commonly used in the de-scaling process.

Sodium polyacrylate is used as an antiscalant – it prevents the deposition of calcium salts. As the purpose of dosing polycarboxylates into the waste stream is to bind calcium and inhibit scale formation, this process is likely to dominate the environmental fate of polycarboxylates, both within the desalination plant and the discharge receiving stream. The concentration of polycarboxylates expected in the desalination plant discharge is expected to be negligible.

Polyphosphates are also used as antiscalants in desalination plants. These compounds inhibit the formation of inorganic scale precipitates on the membranes. The main environmental risk associated with polyphosphates is the degradation of the compound to phosphate, a nutrient associated with eutrophication. Elevated concentrations of phosphate may lead to eutrophication and possible algal blooms, although it should be noted that it is generally considered that nitrogen is the limiting nutrient in marine water, while phosphorus is the limiting factor in freshwater.

Antiscalant active ingredients may include phosphonates, which are used to prevent metal hydroxides/oxides and compounds, such as calcium carbonate, calcium sulfate and silicates from precipitating onto the RO membranes and other equipment. As for the polyphosphates, the degradation products of the phosphonates include phosphate, which in high concentrations could lead to eutrophication.

3.4 MEMBRANE CLEANING

Over time, the permeability of the RO membranes declines due to fouling and scaling of the membrane surface, leading to higher feed pressures being required to maintain a constant permeate flux. RO performance is restored using various cleaning chemicals: high pH for biofilm and organics; low pH for inorganic precipitates. Chemical cleaning requires the shutdown of the RO train. Chemicals are batched to the correct strength, pH and temperature, prior to circulation through an RO train. The amount and type of chemicals required varies depending on the degree and nature of membrane fouling.

Acids such as citric and hydrochloric are often used to clean the alkaline scale and metal oxides from RO membranes. The acids are added to lower the pH to approximately 2-3 in RO systems. There are few marine toxicity data available for citric acid. However, it should be noted that often it is the amount of acidity that is more important than the type of acid. i.e. pH is most important. However, as the solutions used in membrane cleaning are neutralised before disposal these acids, providing the neutralisation is done correctly, will not contribute to toxicity.

Ethylenediamine tetraacetic acid (EDTA) is a chelating agent that is often used for sequestration of metals in freshwater. In the desalination process EDTA may be employed in acidic or alkaline chemical cleaning solutions to sequester metallic scale from the RO membranes and pipes. The toxicity of EDTA to organisms in seawater has not been widely investigated, although it is a common constituent of synthetic seawater mixes used in the aquarium industry.

Alkyl glucoside surfactants or alkyl polyglucosides are often used in household products like cleaning agents, dishwashing detergent and laundry detergents. They are composed of a linear fatty alcohol which is bound to the C-1 carbon of the glucose molecule by a glycosidic bond. The alkyl chain usually contains either 8-10 or 12-14 carbon atoms. Toxicity data for marine organisms could not be sourced for these products but data for freshwater organisms indicated low toxicity.

2,2-dibromo-3-nitrilopropionamide (DBNPA) is used as a non-oxidising biocide. Therefore, it is expected to exert toxic effects on aquatic organisms.

3.5 DESALINATION PLANT SPECIFIC CHEMICALS

Each desalination plant will have an approved set of chemicals that will be used in the desalination process and for membrane cleaning. The ecotoxicological assessments undertaken as part of the approval process in Australia has included an assessment for the proposed chemicals as part of the operational discharge and the membrane cleaning process. A summary of the dilution ratios required for discharges from the different desalination plants can be seen in Table 3-2.

Pre-treatment processes such as chlorination/dechlorination, pH adjustment and antiscalant addition tend to cancel each other out, as is their intention in the desalination process, or with regard to the antiscalant, be at concentrations low enough that they are contributing little or no toxicity in the discharge. It should be noted that where an antiscalant is thought to be contributing to the toxicity of a discharge, the required dilution for salinity as the main driver of the observed toxicity is more than adequate to meet the dilution requirements for the antiscalant.

Membrane cleaning chemicals have often been found to have a high level of toxicity, which is expected given that some of the chemicals used are intentionally toxic, such as biocide. Membrane cleaning is never undertaken when a desalination plant is operational and all material used in this process is collected and stored for appropriate disposal. For some sites, this has involved shipping the material off-site for treatment and disposal or slowly releasing safe concentrations into the operational waste stream at a concentration calculated to cause little to no environmental harm.

Table 3-2 Australian desalination plant-specific chemicals and calculated little to no effect dilution ratios

Study	Treatment	Safe dilution /protective factor	Note/comment
Adelaide Desalination Plant (ADP) Pilot plant backwash DTA	Backwash supernatant	PC 95: 5:1 PC 99: 12:1	EC10 values used to derive protective concentrations
	Dechlorinated membrane pre-treatment chemically enhanced backwash	PC 95: 6:1 PC 99: 14:1	EC10 values used to derive protective concentrations
Adelaide Desalination Plant Process chemicals DTA	Acidified and neutralised permeate	IC10 PC 95: 47 PC 99: 371 IC10 Best data ^a PC 95: 21 PC 99: 106	EC10 values used to derive protective concentrations

Study	Treatment	Safe dilution /protective factor	Note/comment
	DBNPA treated and neutralised permeate	IC10 PC 95: 13 PC 99: 23 IC10 Best data ^a PC 95: 11 PC 99: 19	EC10 values used to derive protective concentrations
	Permeate treated with NaOH/Na4-EDTA/neutralised	IC10 PC 95: 715 PC 99: 5000 IC10 Best data ^a PC 95: 770 PC 99: 5000	EC10 values used to derive protective concentrations
	Permeate treated with NaOH/sodium laurel sulphate/neutralised	IC10 PC 95: 2500 PC 99: 5000 IC10 Best data ^a PC 95: 2500 PC 99: 5000	EC10 values used to derive protective concentrations
	Polyelectrolyte treated feedwater	An environmental concern level of 10% sample concentration was calculated which would require at least a ten times dilution to protect the majority of species in the receiving environment.	EC10 values used to derive protective concentrations
Sydney desalination plant	Concentrated seawater with backwash liquid and antiscalent	Stream 2 PC 95: 40:1 PC 90: 31:1	Ecological trigger values calculated from EC10 data
	Concentrated seawater with antiscalent and membrane cleaning	Stream 5 PC 95: 14:1 PC 90: 13:1	Ecological trigger values calculated from EC10 data

Study	Treatment	Safe dilution /protective factor	Note/comment
	Concentrated seawater with antiscalent, backwash liquid and membrane cleaning	Stream 6 PC 95: 16:1 PC 90: 14:1	Ecological trigger values calculated from EC10 data

4. TOXICITY CONSIDERATIONS FOR EPDP

4.1 UTILITY OF AVAILABLE ECOTOXICITY DATA

There is a large amount of ecotoxicity information available on the potential toxicity of waste brines discharged to the ocean from large scale seawater desalination plants from a number of Australian states as well as internationally. However, as shown in the following literature review and discussed in earlier sections, the ecotoxicity data that was generated for the Adelaide Desalination Plant is highly relevant for the assessment of the proposed EPDP, as is the work that was undertaken for the proposed Olympic Dam seawater desalination plant that was to be located in the Upper Spencer Gulf.

The fundamental questions that are of importance with regards to the understanding of ecotoxicity data and defining a safe discharge dilution that will protect the receiving environment are:

1. Are the samples that are being tested appropriate with regards to their representativeness of the scenario in question?
2. Are the species that have been tested as part of the evaluation process relevant to the proposed discharge point?
3. Are the results from the testing adequate to understand the discharge characteristic that is the main driver of the observed toxicity?
4. Will the proposed discharge process offer an adequate level of dilution to ensure the protection of the receiving ecosystem?

4.2 UTILITY OF CURRENTLY AVAILABLE ECOTOXICITY DATA FOR EPDP ASSESSMENT

4.2.1 ADELAIDE DESALINATION PLANT ECOTOXICITY ASSESSMENT

As part of the ADP assessment, brine samples tested were generated using different reverse osmosis plants:

- Port Stanvac seawater processed through Kangaroo Islands Penneshaw desalination plant.
- Port Stanvac seawater processed through a benchtop pilot plant.
- Port Stanvac seawater processed through the pilot plant that was set up at the site of the proposed ADP.

The feed-in water was collected from Port Stanvac, the proposed site for the ADP, for each of the studies with a brine then generated for the ecotoxicity regime. The water quality characteristics of the Port Stanvac feed water is considered to have similar composition to that which will be used for the EPDP and can therefore be considered representative.

The species that were used as part of the ADP ecotoxicity assessment included a number that were relevant to the coast of the Gulf St Vincent, were generic with regard to their ubiquitous distribution or were the best available surrogate offered by the ecotoxicity testing laboratories. The species that were used during the ADP assessment included:

- *Pagrus auratus* (fish)
- *Seriola lalandi* (fish)
- *Allorchestes compressa* (amphipod)
- *Nitzschia closterium* (microalga)
- *Heliocidaris tuberculata* (sea urchin)
- *Mimacclamys asperrima* (scallop)
- *Ecklonia radiata* (macroalga)
- *Diopatra dentata* (polychaete)
- *Mytilus edulis* (mussel)

All these species would also be considered locally or regionally relevant regarding the assessment of the EPDP.

The results of the ecotoxicity assessment for the ADP indicated that salinity is the main driver of the observed toxicity for an operational brine discharge, which has been confirmed by other large seawater desalination plant discharge studies undertaken in Australia. As presented in the literature review, the chemicals that are potentially toxic to the receiving environment are either not discharged with the brines (due to needing a much greater dilution rate than could not be met) or are in such low concentrations that they have little to no toxic effect and are considered negligible given the required dilution to reduce the toxicity of the salinity to acceptable levels.

To derive the minimum dilution needed to protect the receiving environment from a brine discharge, the species sensitivity distribution (SSD) method is recommended as per the (ANZG, 2018). This method was used to derive the protective concentrations in the assessment of ADP brine. The outcomes of the ecotoxicity assessment using brine generated from Penneshaw and the ADP pilot plant indicated that dilutions of approximately 12:1 and 21:1 would be needed, respectively. The reason for the observed difference in the required dilution was the increased salinity of the brine produced by the ADP pilot plant which was operating at a greater recovery rate than the Penneshaw plant, which increased the salinity of the ADP's discharge and hence the toxicity.

Further testing undertaken for the ADP investigated two different proposed Clean in Place (CIP) chemicals mixtures:

1. Permeate sample with sodium hydroxide added to reach a pH of 12.5 with 0.35% Na₄-EDTA and then neutralised with sulphuric acid until a pH of 8.0 was reached;
2. Permeate sample with sodium hydroxide added to reach a pH of 12.5 with 0.01% laurel sulphate and then neutralised with sulphuric acid until a pH of 8.0 reached.

The same set of species were used in the assessment of the CIP chemicals that were used previously for the ADP ecotoxicity assessment.

The resulting safe dilution to protect 95% of receiving environment species from toxicity effects, CIP mixture 1 was calculated to need a 770:1 dilution and CIP mixture 2 would need a dilution of 2500:1.

It should be noted that the ecotoxicity assessment undertaken using the brines generated by the Penneshaw desalination plant as the most relevant for the assessment of the proposed EPDP. The brines assessed had a salinity of approximately 60 PSU, the same as the proposed salinity of the brine discharge from the EPDP. The pre-treatment chemicals are also those that were approved for use at the ADP. The safe dilution for this brine was derived to be 12:1, well within the proposed 40:1

4.2.2 OLYMPIC DAM DESALINATION PLANT ECOTOXICITY ASSESSMENT

As summarised in Section 2.3, tests were undertaken as part of the assessment of the discharge from the proposed Olympic Dam Desalination Plant (ODDP) during 2006, 2007 and 2008.

The samples that were tested as part of the ODDP assessment ranged from 35 ppt to 45 ppt salinity. The ecotoxicity testing that was undertaken in 2006 was at a salinity that would be comparable with that measured at the proposed EPDP discharge area, while tests done in 2007 and 2008 were undertaken at higher salinities to better match salinities in the Upper Spencer Gulf and would not be suitable for assessing the EPDP.

The brine generated for use in the ecotoxicity testing for ODDP used Nalco anti-scalant PC1020T at a dosing rate of 3.6 mg/L. This anti-scalant will be used in the EPDP and is therefore relevant to the EPDP ecotoxicity assessment.

The species tested in 2006 for the ODDP ecotoxicity assessment are presented in Table 4-1. Only three of the tested species, *Nitzschia closterium*, *Hormosira banksii* and *Seriola lalandi*, would be considered regionally relevant to the proposed EPDP.

Table 4-1 Species tested as part of the 2006 Olympic Dam Desalination Plant ecotoxicity assessment

Species	Regionally relevant to EPDP	Notes
<i>Nitzschia closterium</i> (microalga)	Yes	Widely distributed in Australian waters
<i>Hormosira banksii</i> (macroalga)	Yes	Widely distributed throughout SA waters
<i>Penaeus monodon</i> (crustacean)	No	
<i>Saccostrea commercialis</i> (bivalve)	No	
<i>Heliocidaris tuberculata</i> (sea urchin)	No	Distributed on rocky reefs from Southern Queensland to central New South Wales

Species	Regionally relevant to EPDP	Notes
<i>Seriola lalandi</i> (fish)	Yes	An important aquaculture species in the Spencer Gulf

The main toxicity observed in the ODDP ecotoxicity assessment was attributed to the increased salinity of the brine samples. The brines that were tested were approximately 78 PSU, which is higher than that tested for the APD (72 PSU) and higher than that proposed for the EPDP (~60 PSU). Toxicity not explained by salinity alone was observed for the microalga which was thought to be due to the added anti-scalant.

The protective levels calculated for the ODDP data generated in 2006 to protect 95% of species was a concentration of 1.66% effluent and 60 times dilution. Upon recalculation using chronic and sub-chronic no observed effect concentration (NOEC) values and chronic converted acute values using an acute to chronic ratio of 2 (recommended when salinity is considered the main driver of toxicity), the 95% protective dilution was calculated to be 3.8% with a corresponding safe dilution of 26.3. Percentage concentrations of discharge brines and values used in the recalculation are presented in Table 4-2 and the corresponding SSD is presented in Figure 4-1.

Table 4-2 Concentrations of 2006 ODDP brine discharge used in recalculation of protective concentration

Species	NOEC (% sample)	NOEC used (% sample)
<i>Nitzschia closterium</i> (microalga)	11	11
<i>Hormosira banksii</i> (macroalga)	16.5	16.5
<i>Penaeus monodon</i> (crustacean)	16.5	8.25
<i>Saccostrea commercialis</i> (bivalve)	8.3	8.3
<i>Heliocidaris tuberculata</i> (sea urchin)	4.1	4.1
<i>Seriola lalandi</i> (fish)	12.5	6.25

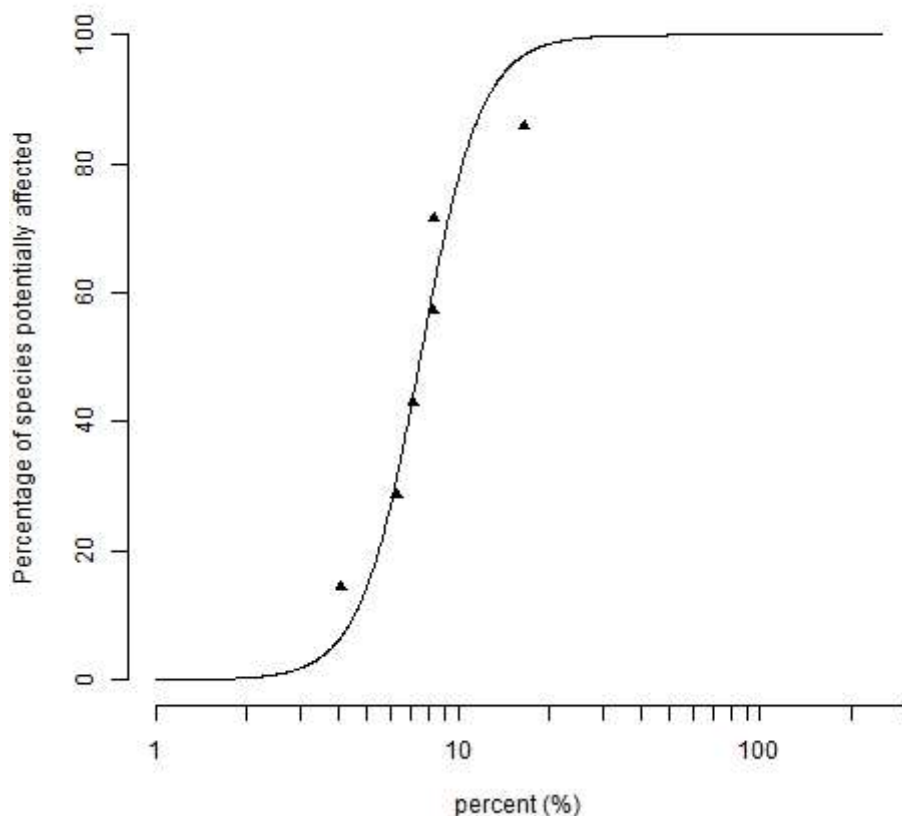


Figure 4-1 Species sensitivity distribution for 2006 ODDP brine discharge concentrations

4.2.3 ADP POST PLANT COMMISSIONING ASSESSMENT

As part of the Adelaide Desalination Plant EPA licence compliance conditions, post commissioning ecotoxicity testing was required to assess the performance of the plant regarding the toxicity of the discharge effluent. This licence condition was imposed after following the initial pre-commissioning ecotoxicity testing results, where a safe dilution to protect the receiving ecosystem was derived. The post-commissioning ecotoxicity testing involved the collection of discharge samples for ecotoxicity testing, as the plant increased its output from mid-2011 up to October 2013. Samples were collected at specific points as the plant increased output as per Table 4-3. Each of the five samples were submitted to a NATA accredited laboratory for ecotoxicity testing. Over the program, three species were used due to the unavailability of the polychaete, *Diopatra aciculata*, for testing of the 3-month after operation and 6-month after operation samples, where the sea urchin, *Helicidaris tuberculata*, was used instead. The regionally relevant mussel, *Mytilus galloprovincialis*, was the only species that was exposed to all five samples. Table 4-3 gives the 10% inhibition concentration (IC10) and the corresponding safe dilution needed to protect the receiving ecosystem. The safe dilutions were derived by dividing the chronic IC10 value by a safety factor of 2 (the safety factor used when salinity is the driver of the observed toxicity). The resultant safe dilution was then deemed to be acceptable if it was within the minimum 50-fold diffusion that occurs within the designated mixing zone.

Table 4-3 Plant production, date of sample collection and IC10/safe dilutions for each discharge scenario

Sample	Target value	10% of total production	20% of total production	30% of total production	3 months after fully operational	6 months after fully operational
Data of sample collection		12/10/2011	15/05/2012	17/05/2012	25/03/2013	19/08/2013
Plant production at the time		30ML/d	60ML/d	90ML/d	165ML/d	90ML/d
<i>Mytilus galloprovincialis</i> 48-h larval dev	IC10	12.9 (12.8-12.9)	10.9 (8.9-13.4)	12.5 (8.2-13.0)	6.4*	6.3*
	Safe Dilution	15.5	18.4	16	31.3	31.8
<i>Diopatra aciculata</i> 14-d growth	IC10	19.5 (2.4-76.3)	4.1^ (0.5-38.9)	2.1^ (0.6-11.9)	NA	NA
	Safe Dilution	10.3	48.8	95.3	NA	NA
<i>Heliocidaris tuberculata</i> 72-h larval dev	IC10	NA	NA	NA	12.9 (12.6-13.1)	7.3 (6.7-7.8)
	Safe Dilution	NA	NA	NA	15.5	27.4

* Confidence intervals not reliable

^ Below lowest test concentration (<6.3% sample concentration)

The results showed that the majority of the resultant safe dilutions were within the safe minimum diffusion that would be achieved in the mixing zone with the exception of the *D. aciculata* 14-d growth test when exposed to the sample collected at the 30% of total production stage of commissioning. Upon investigation of the results of the testing for both the 20% and 30% of total production discharge for this endpoint, it was observed the test results had high variability around each of the concentrations tested, including the control, with the overall result affected by the standard deviation oscillating above and below the level of significance for these tests. It was decided that these weight endpoint results would not be considered in the interpretation of the discharges. Results for the mussel, *M. galloprovincialis*, were the most complete set for the assessment of the discharges, given that it was the only species that was tested against all five samples. The levels of toxicity measured for this species were all below the level of dilution expected to be achieved within the mixing zone around the discharge point. This outcome was corroborated by the results for the sea urchin, *H. tuberculata*, for the 3 months and 6 months discharges where the level of toxicity measured was within the expected dilution of the mixing zone. These results indicated that the ADP was operating within the required performance criteria.

5. LITERATURE REVIEW

Hydrobiology has conducted several desalination plant ecotoxicity assessment projects in Australia, for example, Adelaide, Sydney, Melbourne, and Gold Coast large seawater desalination projects to assess ecotoxicity of seawater desalination discharges and its utility to assist in the calculation of dilution criteria. The outcomes of these studies have been provided in previous sections as summaries but we have included here a more in-depth review of those studies.

5.1 ECOTOXICITY EVALUATION FOR ADELAIDE DESALINATION PILOT PLANT SALINE CONCENTRATE AND BACKWASH

Hydrobiology was commissioned by SA Water in July 2008 to undertake an ecotoxicity program aimed to investigate the toxicity of a saline concentrate representative of the Adelaide Desalination Plant (ADP) to determine the protective concentrations necessary to minimise environmental harm and to calculate the corresponding dilutions to achieve this.

The testing of a pilot plant saline concentrate, and backwash products was undertaken in the second phase of ecotoxicity testing. The samples that were tested are listed below:

- Backwash supernatant, which may include small concentrations of insoluble iron and manganese (in the form of ferric hydroxide and manganese dioxide), as well as very low concentrations of unreacted polymer used in the solids clarification/thickening process. Contributing streams to the backwash supernatant include UF membrane pre-treatment backwash and conventional media filter backwash;
- Dechlorinated membrane pre-treatment chemically enhanced backwash: this involved dosing filtered seawater with approximately 200 mg/L of chlorine (in the form of sodium hypochlorite) and increasing the pH to 10 (using sodium hydroxide). This was followed by a low pH clean (pH 2, using sulphuric acid). The combined waste contained residual free chlorine (typically less than 20 mg/L) at a pH between 6.5 and 7.5. This solution was then batch dechlorinated using sodium metabisulphite;
- Reverse osmosis concentrate (45% recovery rate) with no added antiscalant at ambient pH;

- Reverse osmosis concentrate (45% recovery rate) with added antiscalant (the applied concentration at this pH was ~ 2.8 mg/L, corresponding to ~ 5 mg/L antiscalant in the saline concentrate) at ambient pH;
- Reverse osmosis concentrate (45%) with no added antiscalant at an adjusted pH of 7.1
- Reverse osmosis concentrate (45% recovery rate) with added antiscalant (the applied concentration at this pH was ~ 1.2 mg/L, corresponding to ~ 2.2 mg/L in the saline concentrate) at an adjusted pH of 7.1

Saline concentrate was pH adjusted by adding an amount of sulphuric acid to the feed water before the reverse osmosis process while the feedwater for the ambient concentrate did not receive any acidic pre-filtering treatment.

The following toxicity tests were selected - with the pilot plant saline concentrate and backwash samples:

Acute tests:

- 96-h fish imbalance test using *Pagrus auratus* (acute); and,
- 96-h amphipod survival test using *Allorchestes compressa* (acute).

Sub-chronic tests:

- 72-h microalga growth inhibition test using *Nitzschia closterium* (sub-chronic);
- 1-h sea urchin fertilisation success using *Heliocidaris tuberculata* (sub-chronic);
- 72-h sea urchin larval development test using *Heliocidaris tuberculata* (sub-chronic);
- 48-h scallop larval development test using *Mimamclamys asperima* (sub-chronic); and,
- 72-h macroalga germination assay using *Ecklonia radiata* (sub-chronic).

Chronic tests:

- 14-d macroalga gametophyte growth test using *Ecklonia radiata* (chronic);
- 14-d polychaete survival test using *Diopatra dentata* (chronic);
- 14-d polychaete biomass test using *Diopatra dentata* (chronic);
- 14-d amphipod survival test using *Allorchestes compressa* (chronic);
- 14-d amphipod biomass test using *Allorchestes compressa* (chronic); and,
- 7-d fish growth test using *Pagrus auratus* (chronic).
- 16-d sea urchin metamorphosis test using *Heliocidaris erthyrogramma* (chronic);

5.1.1.1 TOXICITY TESTING RESULTS

AMBIENT PILOT PLANT SALINE CONCENTRATE

Results of the direct toxicity assessment (DTA) testing of the ambient saline concentrate and ambient saline concentrate with added antiscalant are presented in Table 5-1. The most sensitive organism to the ambient saline concentrate both with and without the antiscalant added was the sea urchin and scallop while the least sensitive organism was the amphipod.

An EC10 was not calculable for a number of the tests due to the response of the organisms being all or nothing where a gradual reduction in effect was not seen between test concentrations. The TOXCALC (Tidepool Scientific Software) software used by the laboratory is unable to derive a point estimate for the EC10 in these circumstances but does indicate that the value was between the no observed effect concentration (NOEC) and the lowest observed effect concentration (LOEC). For the purposes of deriving trigger values (TVs) a conservative approach was taken and the NOEC value was used in the species sensitivity distributions. It should also be noted that some of the calculated EC/IC10 values were imprecise with 95% confidence intervals either large or not calculable.

The EC10/NOEC values used in species sensitivity distributions to derive ecological TVs for ambient saline concentrate both with and without antiscalant are greyed out in Table 5-1.

Table 5-1 Results of DTA of ambient pilot plant saline concentrate with and without antiscalant.

	QA/QC criteria met	EC10/NOEC values (% sample)	
		Ambient saline concentrate with antiscalant	Ambient saline concentrate without antiscalant
Microalgal Cell Yield	Yes	8.6	5.8
Sea Urchin Fertilisation Success (<i>H. tuberculata</i>)	Yes	22.1 (16.8 – 26.9)	20.6 (17.9 – 23.2)
Sea Urchin Larval Development (<i>H. tuberculata</i>)	Yes	13.3 (12.8 – 13.0)	13.5 (13.0 – 13.8)
Sea Urchin Metamorphosis (<i>H. erythrogramma</i>)	Yes	>12.5	>12.5
Scallop Larval Development	Yes	12.8 (12.3 – 13.0)	12.9 (12.7 – 13.0)
Macro-algal Germination	Yes	93.4	>100
Macroalgal Gametophyte Growth	Yes	27.2 (15.9 – 37.8)	59.2 (52.6 – 63.7)
Amphipod Survival (96-h)	Yes	54.1 (49.0 – 71.8)	65.2
Amphipod Survival ((14-d)	Yes	47.1 (27.6 – 56.4)	28.8 (9.4 – 38.6)
Amphipod biomass (14-d)	Yes	42.3 (0.0 – 62.6)	28.3 (0.0 – 33.7)
Polychaete Survival (14-d)	Yes	31.3 (21.2 – 51.7)	19.4 (2.1 – 36.6)
Polychaete Biomass (14-d)	Yes	>50	>50
Fish Growth (7-d)	Yes	13.8 (13.5 – 13.8)	13.8 (13.3 – 13.8)

* greyed out cells were used in calculation of species sensitivity distributions. Values in brackets are 95% confidence intervals

Figure 5-1 and Figure 5-2 display the Species sensitivity distributions (SSDs) derived from the EC10/NOEC data and the fit of the data by the BurrliOZ (ANZECC and ARMCANZ, 2000) software.

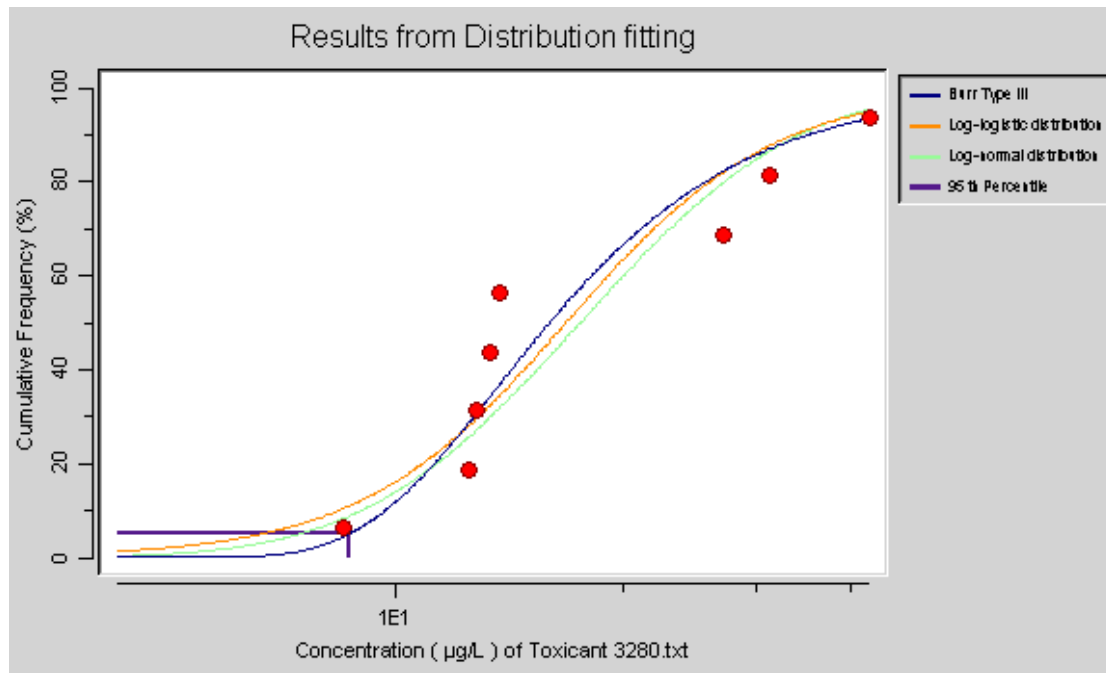


Figure 5-1 Species sensitivity distribution for pilot plant ambient saline concentrate with antiscalant

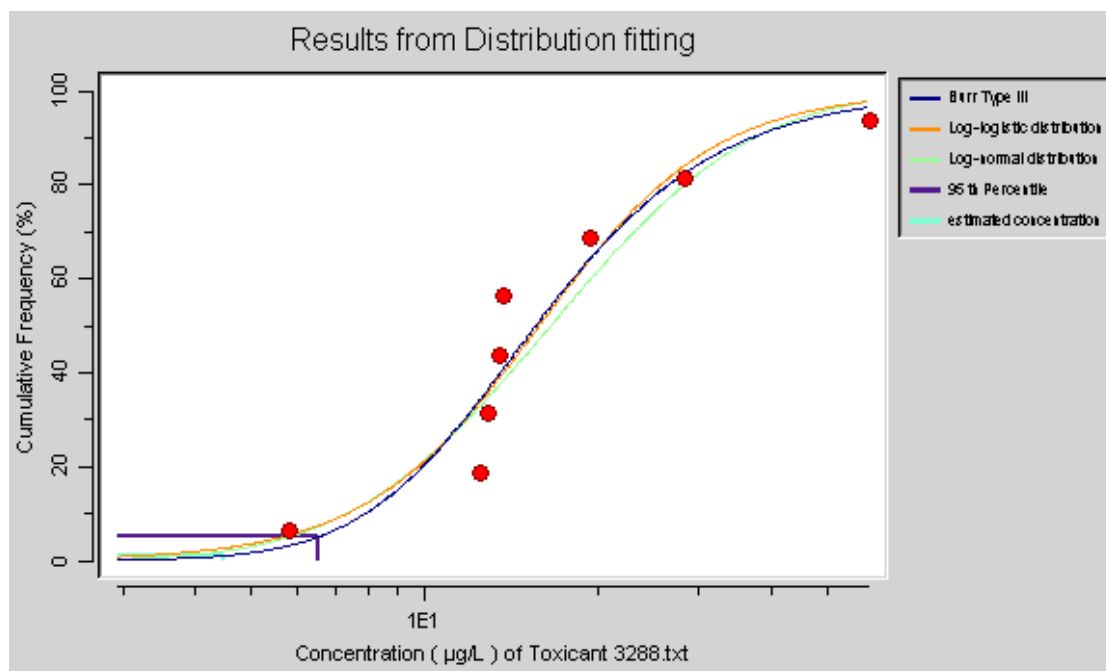


Figure 5-2 Species sensitivity distribution for pilot plant ambient saline concentrate without antiscalant

The fit of the Burr Type III distribution to each of the above sets of data was acceptable for the number of data points available for curve derivation with the goodness of fit values in the range of 20 to 25. The values obtained for the above SSDs were in the same range as those obtained for trigger values in the Australian and New Zealand water quality guidelines (ANZECC and ARMCANZ, 2000) that were based on a similar number of data points.

The concentrations of the ambient saline concentrate with and without antiscalant that must be achieved in order to protect 95% of species and corresponding safe dilution factors are presented in Table 5-2.

Table 5-2 Concentrations of the ambient pH saline concentrate that would need to be met to ensure the protection of 95% of species and their corresponding safe dilution factors

	PC95 (% sample) and safe dilution factor for ambient pH	
	Ambient saline concentrate with antiscalant	Ambient saline concentrate without antiscalant
PC 95	8.67	6.52
Safe Dilution Factor	12:1	16:1
PC 99	7.25	4.47
Safe Dilution Factor	14:1	23:1

The calculated safe dilutions indicate that the toxicity of the ambient saline concentrate without the added antiscalant was slightly more toxic than the saline concentrate with added antiscalant.

PH-ADJUSTED PILOT PLANT SALINE CONCENTRATE

Results of the DTA testing of the pH adjusted saline concentrate both with and without antiscalant are presented in Table 5-3. For the concentrate with the antiscalant the polychaete (biomass endpoint) was the most sensitive followed by the microalgae, sea urchin, fish and scallop, while the macroalgal germination endpoint was the least sensitive. The concentrate without the antiscalant was most toxic to the microalgae followed by the polychaete (survival endpoint), sea urchin and scallop, while the macroalgal germination test was the least sensitive.

The EC10/NOEC values used in species sensitivity distributions to derive ecological TVs for ambient saline concentrate both with and without antiscalant are highlighted in Table 5-3.

Table 5-3 Results of DTA of pH adjusted pilot plant saline concentrate with and without antiscalant

Direct Toxicity Assessment Test	QA/QC criteria met	EC10/NOEC values (% sample)	
		pH adjusted saline concentrate with antiscalant	pH adjusted saline concentrate without antiscalant
Microalgal Cell Yield	Yes	10.6	7.9
Sea Urchin Fertilisation Success (<i>H. tuberculata</i>)	Yes	22.5 (15.8 – 27.3)	21.1 (16.8 – 27.5)
Sea Urchin Larval Development (<i>H. tuberculata</i>)	Yes	13.6 (13.4 – 13.9)	13.3 (12.7 – 13.9)
Sea Urchin Metamorphosis (<i>H. erythrogramma</i>)	Yes	>12.5	>12.5

Scallop Larval Development	Yes	12.9 (12.6 – 13.0)	12.8 (12.5 – 12.9)
Macro-algal Germination	Yes	>100	>100
Macroalgal Gametophyte Growth	Yes	>12.5	53.5 (37.3 – 62.7)
Amphipod Survival (96-h)	Yes	78.1 (57.4 – 79.8)	52.2 (45.4 – 72.9)
Amphipod Survival ((14-d)	Yes	38.9 (0.0 – 58.9)	33.5 (0.0 – 42.8)
Amphipod Biomass (14-d)	Yes	50.0 (0.0 – 58.0)	28.5 (0.0 – 35.9)
Polychaete Survival (14-d)	Yes	41.1 (36.7 – 44.1)	11.4
Polychaete Biomass (14-d)	Yes	8.4	>50
Fish Growth (7-d)	Yes	13.8 (13.3 – 13.8)	13.8 (13.5 – 13.8)

* greyed out cells were used in calculation of species sensitivity distributions. Values in brackets are 95% confidence intervals

Figure 5-3 and Figure 5-4 display the SSDs derived from the EC10/NOEC data and the fit of the data by the BurrliOZ software.

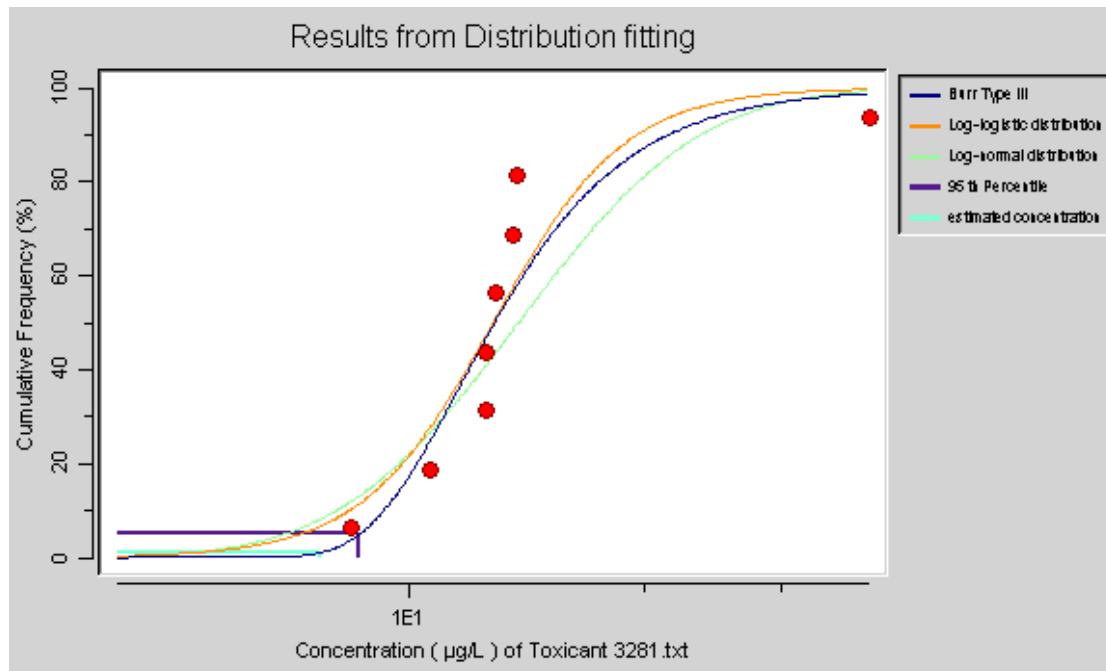


Figure 5-3 Species sensitivity distribution for pH adjusted pilot plant saline concentrate with antiscalant

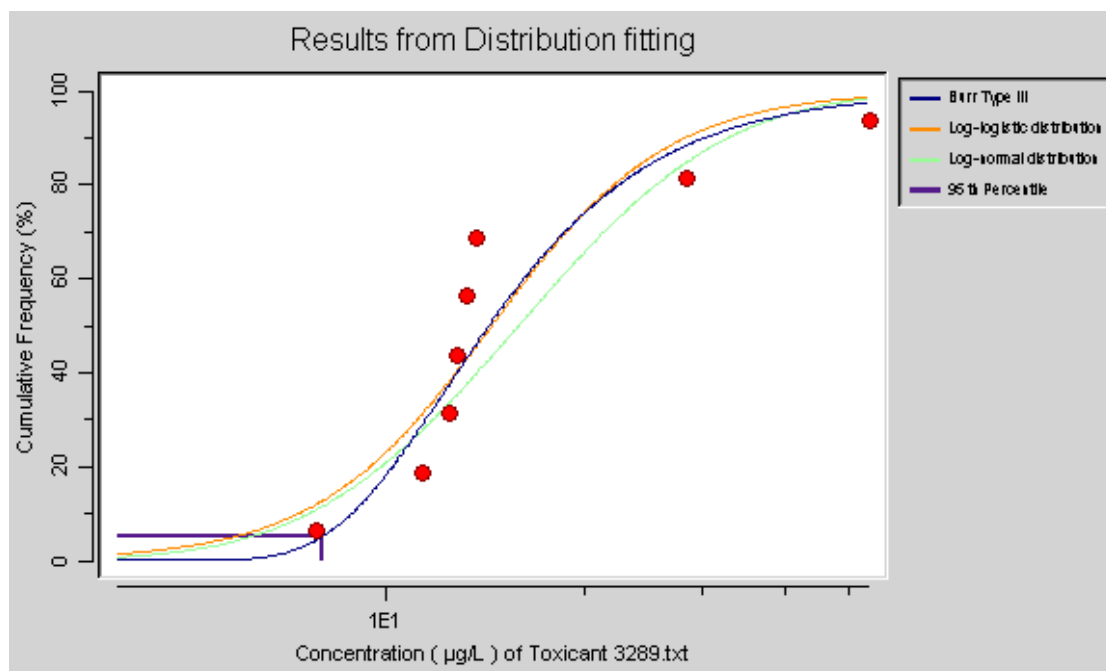


Figure 5-4 Species sensitivity distribution for pH adjusted pilot plant saline concentrate without antiscalant

The fit of the Burr Type III distribution to each of the above sets of data was acceptable for the number of data points available for curve derivation with the goodness of fit values in the range of 20 to 25. The values obtained for the above SSDs were similar to those obtained for trigger values in the Australian and New Zealand water quality guidelines (ANZECC and ARMCANZ, 2000) that were based on a similar number of data points.

The concentrations of the pH-adjusted saline concentrate with antiscalant and without antiscalant that must be achieved in order to protect 95% of species and corresponding safe dilution factors are presented in Table 5-4.

Table 5-4 Concentrations of the pH-adjusted discharge that would need to be met to ensure the protection of 95% of species and their corresponding safe dilution factors

PC95 (% sample) and safe dilution factor for pH-adjusted		
	pH adjusted saline concentrate with antiscalant	pH adjusted saline concentrate without antiscalant
PC 95	8.61	8.00
Safe Dilution Factor	12:1	13:1
PC 99	7.66	6.75
Safe Dilution Factor	14:1	15:1

The safe dilutions calculated indicate that the pH adjusted saline concentrate without antiscalant needs a higher rate of dilution, but the inherent assumptions involved with calculating protective concentrations and safe dilutions the difference can be considered negligible.

BACKWASH

Results of the DTA testing of the backwash supernatant and dechlorinated membrane pre-treatment chemically enhanced backwash are presented in Table 5-5. For the backwash supernatant the most sensitive organism was the microalga while the sea urchin fertilisation test, the macroalgal gametophyte growth test and the amphipod biomass test were the only other bioassays to detect toxicity. Similarly, the dechlorinated membrane pre-treatment chemically enhanced backwash caused the greatest toxicity in the microalgal test with toxicity also recorded in the sea urchin larval development test, the sea urchin fertilisation success test, the macroalgal gametophyte growth test and the scallop larval development test in order of decreasing sensitivity.

The EC10/NOEC values used in species sensitivity distributions to derive ecological TVs for both backwash samples are highlighted in Table 5-5.

Table 5-5 Results of DTA for pilot plant backwash supernatant and dechlorinated membrane pre-treatment chemically enhanced backwash

Direct Toxicity Assessment Test	QA/QC criteria met	EC10/NOEC values (% sample)	
		Backwash supernatant	Dechlorinated membrane pre-treatment chemically enhanced backwash
Microalgal Cell Yield	Yes	4.4 (1 – 24.9)	3.1 (0.9 – 12.5)
Sea Urchin Fertilisation Success (<i>H. tuberculata</i>)	Yes	51.6 (50.6 – 52.7)	60.4
Sea Urchin Larval Development (<i>H. tuberculata</i>)	Yes	>100	57.1 (52.4 – 60.3)
Sea Urchin Metamorphosis (<i>H. erythrogramma</i>)	Yes	>100	>100
Scallop Larval Development	Yes	>100	89.5
Macro-algal Germination	Yes	>100	>100
Macroalgal Gametophyte Growth	Yes	72.8 (55.4 – 79.1)	64.5 (11.0 – 84.9)
Amphipod Survival (96-h)	Yes	>100	>100
Amphipod Survival ((14-d)	Yes	>100	>100
Amphipod Biomass (14-d)	Yes	87.5	>100
Polychaete Survival (14-d)	Yes	>100	>100
Polychaete Biomass (14-d)	Yes	>100	>100
Fish Growth (7-d)	Yes	>100	>100

* greyed out cells were used in calculation of species sensitivity distributions. Values in brackets are 95% confidence intervals

Figure 5-5 and Figure 5-6 display the SSDs derived from the EC10 data and the fit of the data by the BurrliOZ software.

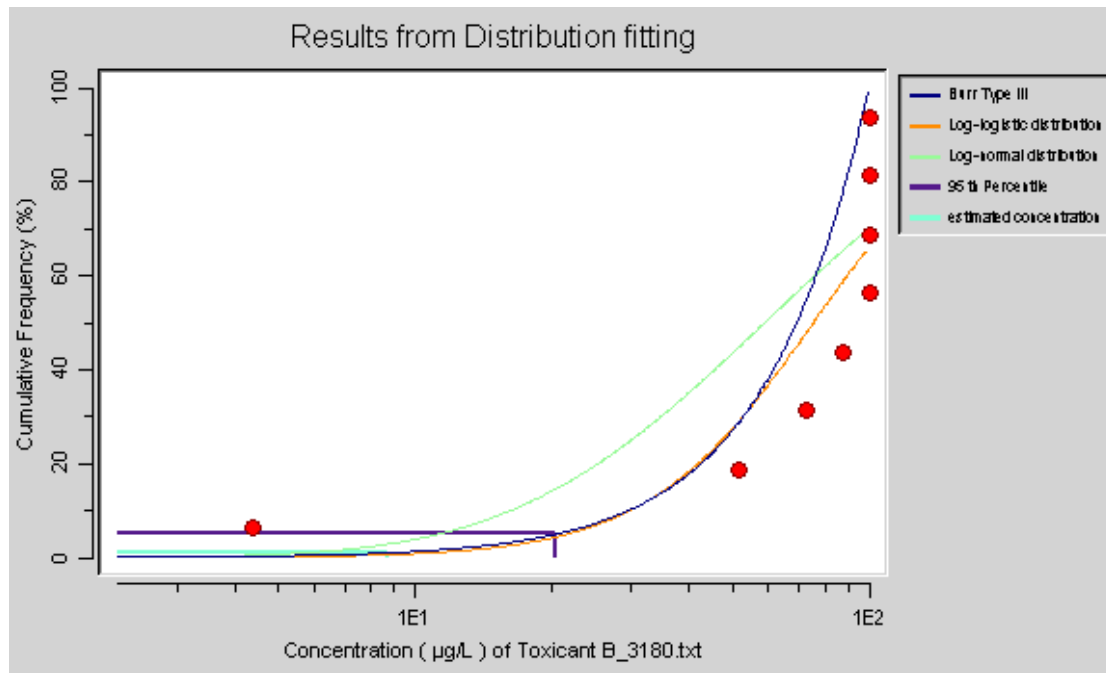


Figure 5-5 Species sensitivity distribution for pilot plant backwash supernatant

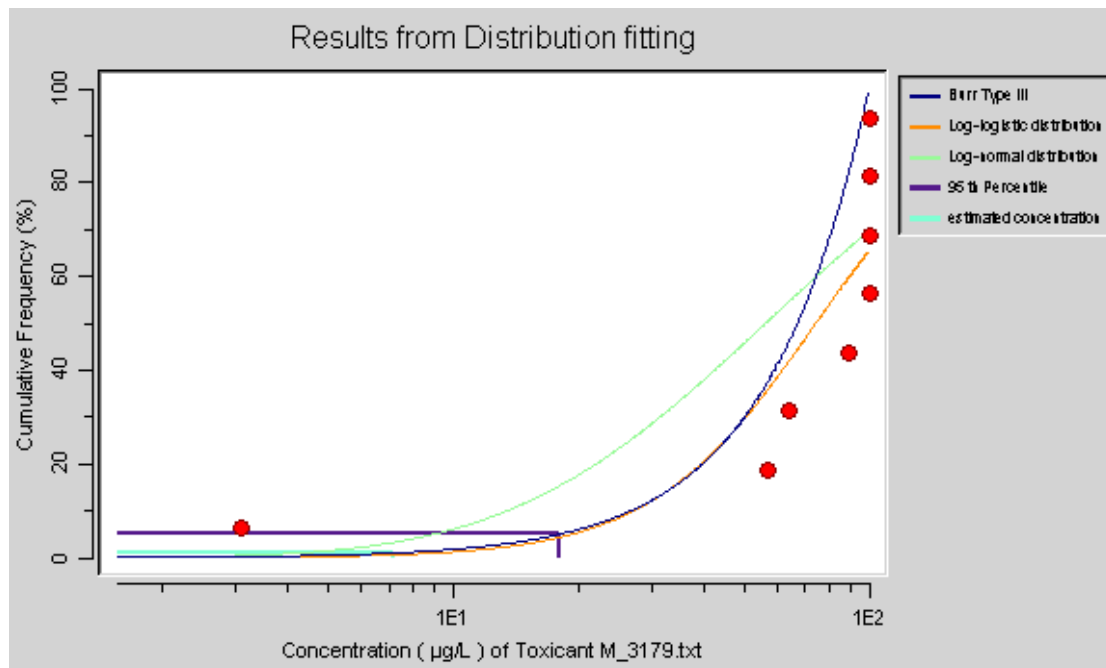


Figure 5-6 Species sensitivity distribution for dechlorinated membrane pre-treatment chemically enhanced backwash

The fit of the Burr Type III distribution to each of the above sets of data was acceptable for the number of data points available for curve derivation with the goodness of fit values in the range of 30 to 31. The values obtained for the above SSDs were similar to those obtained for trigger values in the Australian and New Zealand water quality guidelines (ANZECC and ARMCANZ, 2000) that were based on a similar number of data points.

The concentrations of the backwash supernatant and the dechlorinated membrane pre-treatment chemically enhanced backwash that must be achieved in order to protect 95% of species and corresponding safe dilution factors are presented in Table 5-6.

Table 5-6 Concentrations of the backwash supernatant and dechlorinated membrane pre-treatment chemically enhanced backwash that would need to be met to the protection of 95% of species and their corresponding safe dilution factors

	PC95 (% sample) and safe dilution factor for backwash	
	Backwash supernatant	Dechlorinated membrane pre-treatment chemically enhanced backwash
PC 95	20.47	17.97
Safe Dilution Factor	5:1	6:1
PC 99	8.73	7.15
Safe Dilution Factor	12:1	14:1

The toxicity of both backwash samples was low and would require low levels of dilution to achieve concentrations that will not harm 95% of the endemic marine species.

5.1.2 ECOTOXICITY EVALUATION OF ADELAIDE DESALINATION PLANT EFFLUENT AND PROCESS CHEMICALS

Hydrobiology was commissioned by Adelaide Aqua in year 2009 to undertake an ecotoxicological testing program on a range of possible effluents that may be part of the discharge from the Adelaide desalination plant to the marine environment at Port Stanvac. Samples were obtained from the pilot plant located at Port Stanvac. These samples included sea water obtained directly from the seawater pump, brine obtained from the operating reverse osmosis membranes at a recovery rate of 50% and the freshwater permeate obtained from the operating reverse osmosis membranes at a recovery rate of 50%.

Ecotoxicity testing was undertaken on samples derived from the operational pilot plant located at Port Stanvac and also on a poly-electrolyte. The samples tested were prepared by Adelaide Aqua personnel at ESA laboratories and were as follows:

- A brine sample that had not been treated chemically;
- A brine sample with 15 mg/l free chlorine produced by adding sodium hypochlorite to the brine. The free chlorine is then neutralised by adding 26 mg/L of sodium metabisulphite;
- A permeate sample that had been treated with 1 g/L of sulphuric acid and 2.5 g/L citric acid and then neutralised to pH 6.5 with caustic soda;
- A permeate sample with 30 mg/L of the biocide DBNPA (dibromonitripropionamide) added which was then neutralised with 29.5 mg/L sodium metabisulphite, ensuring that the dissolved oxygen levels were greater than 6.5 mg/L;
- There were two samples tested for sample 5:
 - permeate sample with sodium hydroxide added to reach a pH of 12.5 with 0.35% Na₄-EDTA and then neutralised with sulphuric acid until a pH of 8.0 was reached;
 - permeate sample with sodium hydroxide added to reach a pH of 12.5 with 0.01% laurel sulphate and then neutralised with sulphuric acid until a pH of 8.0 reached; and

- An intake seawater sample treated with a polyelectrolyte flocculent.

Permeate samples salinity was manipulated to approximately 35‰ using artificial sea salts before testing.

Below is a list of test species used in the DTA tests:

- 72-h *Nitzschia closterium* algal growth inhibition test (sub-chronic);
- 72-h sea urchin larval development test using *Heliocidaris tuberculata* (sub-chronic);
- 48-h larval development using the blue mussel *Mytilus edulis* (sub-chronic);
- 14-d macroalgal (*Ecklonia radiata*) gametophyte growth test (chronic);
- 14-d polychaete (*Diopatra dentata*) biomass test (chronic);
- 14-d amphipod (*Allorchestes compressa*) biomass test (chronic); and
- 7-d fish (*Seriola lalandi* and *Pagrus auratus*) growth and imbalance test (chronic).

5.1.2.1 TESTING RESULTS

BRINE RESULTS

Results of the DTA of the pilot plant brine are presented in Table 5-7

Table 5-7 Results of DTA of pilot plant brine

	% sample		Salinity (‰)		
	IC10	NOEC	Diluent	IC10	NOEC
Microalgal Cell Yield	12.7 (8.0-14.1)	12.5	37.6	43.1	43
Sea Urchin Larval Development	6.6 (6.4-6.7)	6.3	38.1	40.9	40.8
Mussel Larval Development	7.7 (7.2-8.7)	6.3	38.1	41.4	40.8
Macroalgal Gametophyte Growth	44.8 (27.7-55.0)	50	38.1	57.3	59.6
Amphipod Biomass (14-d)	20 (0-72.0)	50	37.6	46.3	59.3
Amphipod Survival (14-d)	11.8 (0-75.1)	50	37.6	42.7	59.3
Polychaete Biomass (14-d)	1.1 (0.04-43.3)	25	37.5	38	48.4
Polychaete Survival (14-d)	26.1 (4.3-36.5)	25	37.5	48.9	48.4
Snapper Growth (7-d)	0.4 (0.3-0.4)	<1.6	35	35.2	35.6
Snapper Imbalance (7-d)	0.7 (0.2-2.5)	<1.6	35	35.3	35.6
Kingfish Growth (7-d)	1.4 (0.4-9.6)	12.5	37.7	38.3	43.1
Kingfish Imbalance (7-d)	6.6 (0-9.0)	12.5	37.7	40.6	43.1

The larval fish tests were the most sensitive to the brine sample followed by the sea urchin and mussel larval development tests. The macroalgae proved to be the least sensitive of all the organisms tested. The corresponding salinity indicated that the snapper were very sensitive to an

increase in salinity with a 0.2 ‰ increase causing a 10% decrease in the growth of the larval snapper while a 0.3 ‰ increase caused an imbalance to 10% of the larval snapper. For the larval kingfish an increase in salinity of 0.5 ‰ saw a 10% reduced growth rate and 0.7 ‰ increase caused 10% of the larval kingfish to become imbalanced. A salinity of 57.3 ‰ was observed to cause a 10% reduction in gametophyte growth.

BRINE PROTECTIVE CONCENTRATIONS

Protective concentrations for the brine were derived using IC10 and NOEC data as well as an “IC10 Best Data” set. An IC10 result was included in the best data set if the upper and lower confidence limits were within 3 times the IC10 % sample concentration. Table 5-8 displays the data that have been used to calculate the protective concentrations for all three sets of data with those values shaded in the table.

Table 5-8 Values used for the derivation of protective concentrations for brine sample

	% sample		
	IC10	IC10 Best Data	NOEC
Microalgal Cell Yield	12.7 (8.0-14.1)	12.7 (8.0-14.1)	12.5
Sea Urchin Larval Development	6.6 (6.4-6.7)	6.6 (6.4-6.7)	6.3
Scallop Larval Development	7.7 (7.2-8.7)	7.7 (7.2-8.7)	6.3
Macroalgal Gametophyte Growth	44.8 (27.7-55.0)	44.8 (27.7-55.0)	50
Amphipod Biomass (14-d)	20 (0-72.0)	20 (0-72.0)	50
Amphipod Survival (14-d)	11.8 (0-75.1)	11.8 (0-75.1)	50
Polychaete Biomass (14-d)	1.1 (0.04-43.3)	1.1 (0.04-43.3)	25
Polychaete Survival (14-d)	26.1 (4.3-36.5)	26.1 (4.3-36.5)	25
Snapper Growth (7-d)	0.4 (0.3-0.4)	0.4 (0.3-0.4)	1.6
Snapper Imbalance (7-d)	0.7 (0.2-2.5)	0.7 (0.2-2.5)	1.6
Kingfish Growth (7-d)	1.4 (0.4-9.6)	1.4 (0.4-9.6)	12.5
Kingfish Imbalance (7-d)	6.6 (0-9.0)	6.6 (0-9.0)	12.5

Figure 5-7 and Figure 5-8 display the SSDs derived from the IC10, IC10 Best Data and NOEC data respectively, and the goodness of fit of the data by the BurrliOZ (ANZECC and ARMCANZ, 2000) software.

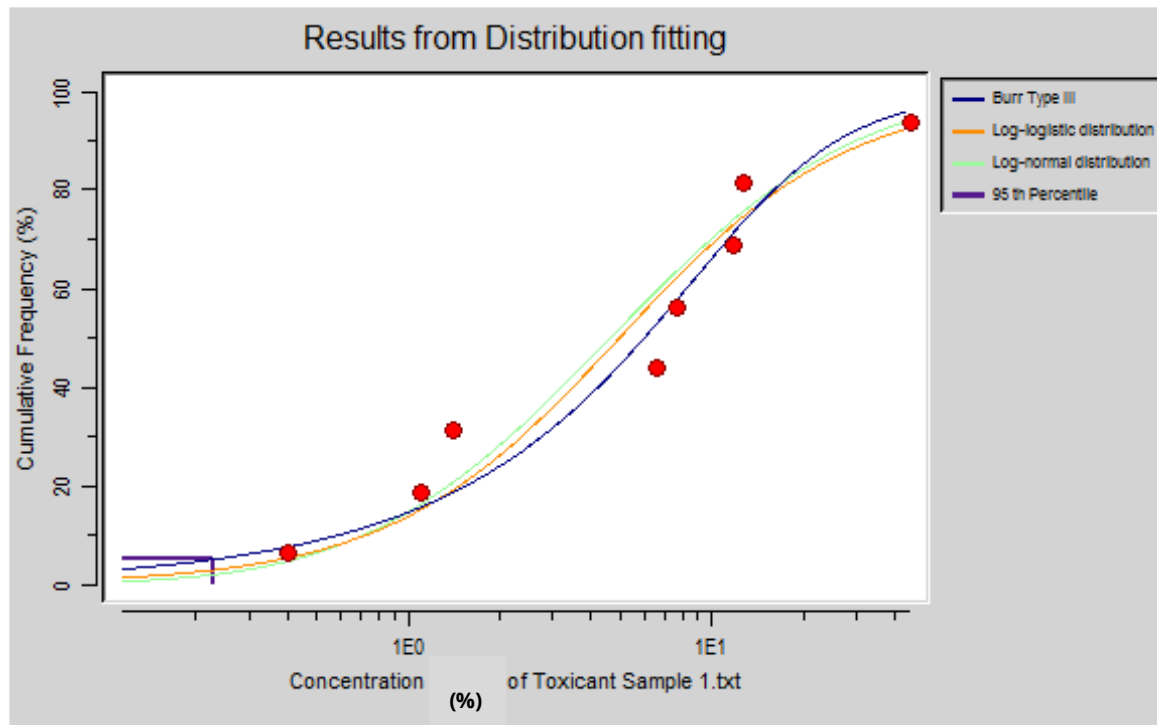


Figure 5-7 Species sensitivity distribution for pilot plant brine IC10 data

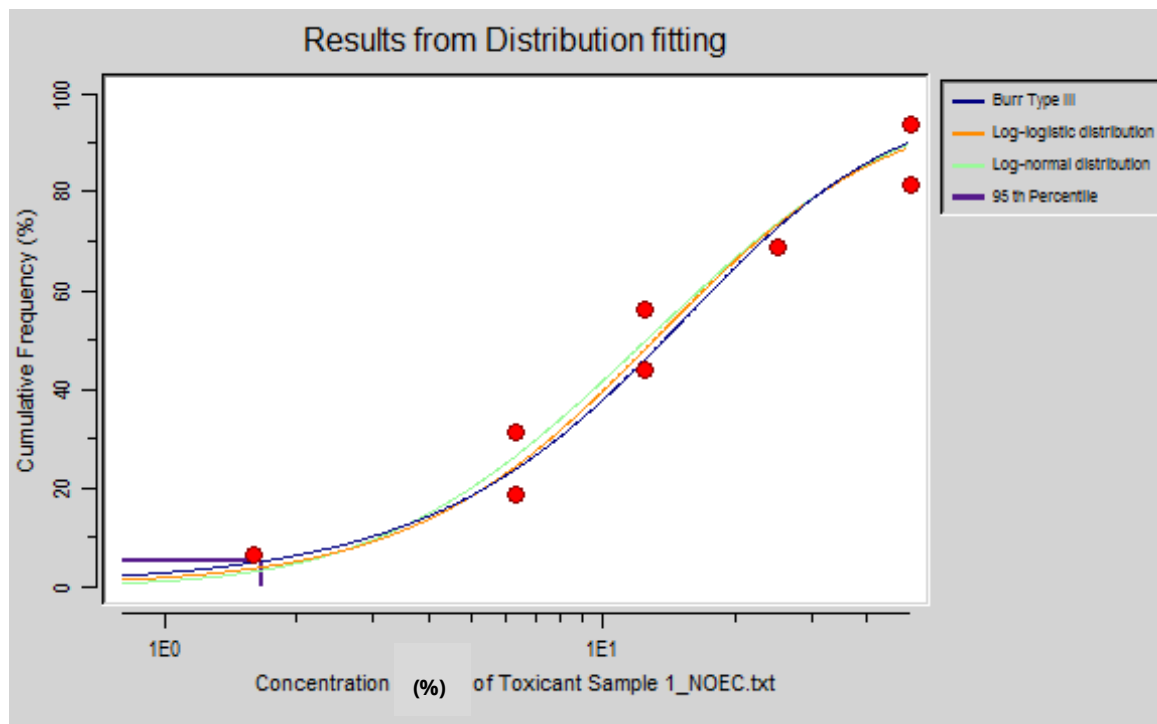


Figure 5-8 Species sensitivity distribution for pilot plant brine NOEC data

The resultant protective concentrations and safe dilutions for the three sets of brine data are presented in Table 5-9.

Table 5-9 Protective concentrations and safe dilutions for the brine sample (but see further discussion of IC10 Best Data set below).

	% sample		
PC	IC10	IC10 Best Data	NOEC
95%	0.23	0.55	1.66
Safe Dilution	435	182	61
99%	0.02	0.07	0.44
Safe Dilution	5000	1429	228
Goodness of Fit	26.7	21.3	32.5

CHLORINATED/DECHLORINATED BRINE RESULTS

Results of the DTA of the pilot plant brine that underwent a chlorination/dechlorination process prior to testing are presented in Table 5-10.

Table 5-10 Results of DTA of pilot plant chlorinated/dechlorinated brine

	% sample		Salinity (‰)		
	IC10	NOEC	Diluent	IC10	NOEC
Microalgal Cell Yield	13.1 (10.5-14.8)	12.5	37.6	43.3	43
Sea Urchin Larval Development	6.4 (6.2-6.6)	3.1	38.1	40.9	39.4
Mussel Larval Development	7.5 (6.4-8.3)	6.3	38.1	41.3	40.8
Macroalgal Gametophyte Growth	32.1 (31-33.0)	25	38.1	51.9	48.8
Amphipod Biomass (14-d)	24.0 (0.6-73.6)	50	37.6	48.0	59.3
Amphipod Survival (14-d)	50.1 (0-53.5)	50	37.6	59.3	59.3
Polychaete Biomass (14-d)	7.6 (0-38.3)	25	37.5	40.8	48.4
Polychaete Survival (14-d)	7.4 (0-36.3)	25	37.5	40.7	48.4
Snapper Growth (7-d)	0.4 (0.3-0.5)	<1.6	35	35.2	35.6
Snapper Imbalance (7-d)	0.9 (0.4-2.3)	<1.6	35	35.3	35.6
Kingfish Growth (7-d)	2.0 (0.2-12.1)	12.5	37.7	38.6	43.1
Kingfish Imbalance (7-d)	6.4 (0.4-9.7)	12.5	37.7	40.5	43.1

The larval fish were the most sensitive to the chlorinated/dechlorinated brine sample followed by the sea urchin and mussel larval development tests. As was seen with the brine sample an increase of 0.2‰ was enough to reduce the growth of the snapper by 10% and an increase of 0.3‰ cause 10% of the larval snapper to experience imbalance. For the larval kingfish an increase of 0.9‰ reduced growth by 10% and an increase of 1.2‰ caused 10% of the larval kingfish to experience imbalance. The macrophyte survival endpoint was the least sensitive of the organisms tested where a 10% reduction in gametophyte length was observed after salinity increase of 21.7‰.

CHLORINATED/DECHLORINATED BRINE PROTECTIVE CONCENTRATIONS

Protective concentrations for the chlorinated/dechlorinated brine were derived using IC10 and NOEC data as well as an "IC10 Best Data" set. An IC10 result was included in the best data set if the upper and lower confidence limits were within 3 times the IC10 % sample concentration. The snapper data was also excluded from the IC10 Best Data due to the unusual results of the testing. Table 5-11 displays the data that has been used to calculate the protective concentrations for all three sets of data with those values shaded in the table.

Table 5-11 Values used for the derivation of protective concentrations for the chlorinated/dechlorinated brine sample

	% sample		
	IC10	IC10 Best Data	NOEC
Microalgal Cell Yield	13.1 (10.5-14.8)	13.1 (10.5-14.8)	12.5
Sea Urchin Larval Development	6.4 (6.2-6.6)	6.4 (6.2-6.6)	3.1
Scallop Larval Development	7.5 (6.4-8.3)	7.5 (6.4-8.3)	6.3
Macroalgal Gametophyte Growth	32.1 (31-33.0)	32.1 (31-33.0)	25
Amphipod Biomass (14-d)	24.0 (0.6-73.6)	24.0 (0.6-73.6)	50
Amphipod Survival (14-d)	50.1 (0-53.5)	50.1 (0-53.5)	50
Polychaete Biomass (14-d)	7.6 (0-38.3)	7.6 (0-38.3)	25
Polychaete Survival (14-d)	7.4 (0-36.3)	7.4 (0-36.3)	25
Snapper Growth (7-d)	0.4 (0.3-0.5)	0.4 (0.3-0.5)	<1.6
Snapper Imbalance (7-d)	0.9 (0.4-2.3)	0.9 (0.4-2.3)	<1.6
Kingfish Growth (7-d)	2.0 (0.2-12.1)	2.0 (0.2-12.1)	12.5
Kingfish Imbalance (7-d)	6.4 (0.4-9.7)	6.4 (0.4-9.7)	12.5

Figure 5-9, Figure 5-10 and Figure 5-11 displays the SSDs derived from the IC10, IC10 Best Data and NOEC data respectively, and the fit of the data by the BurriIOZ (ANZECC and ARMCANZ 2000) software.

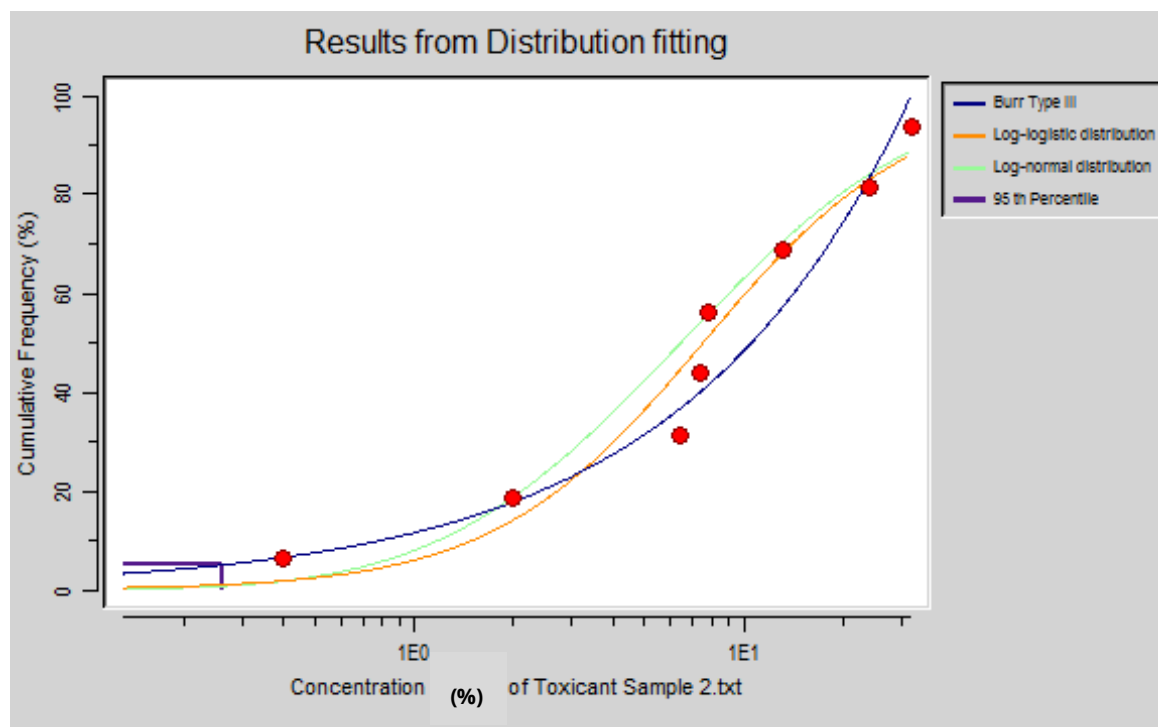


Figure 5-9 Species sensitivity distribution for pilot plant chlorinated/dechlorinated brine IC10 data

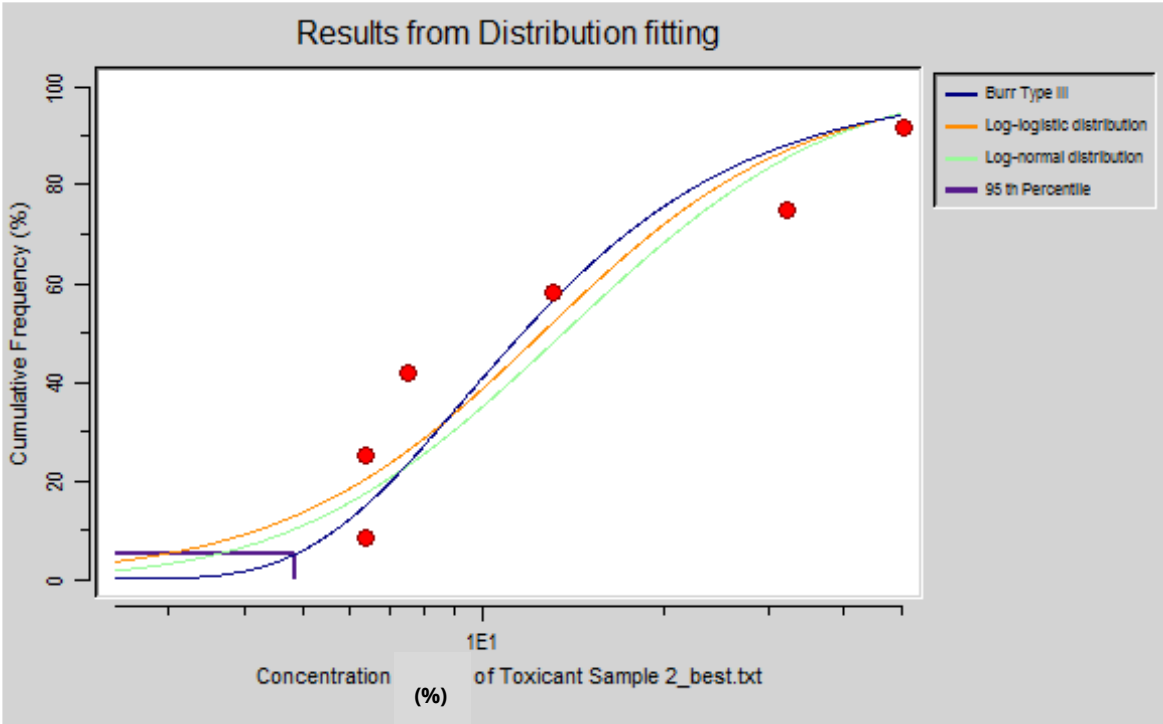


Figure 5-10 Species sensitivity distribution for pilot plant chlorinated/dechlorinated brine IC10 Best Data

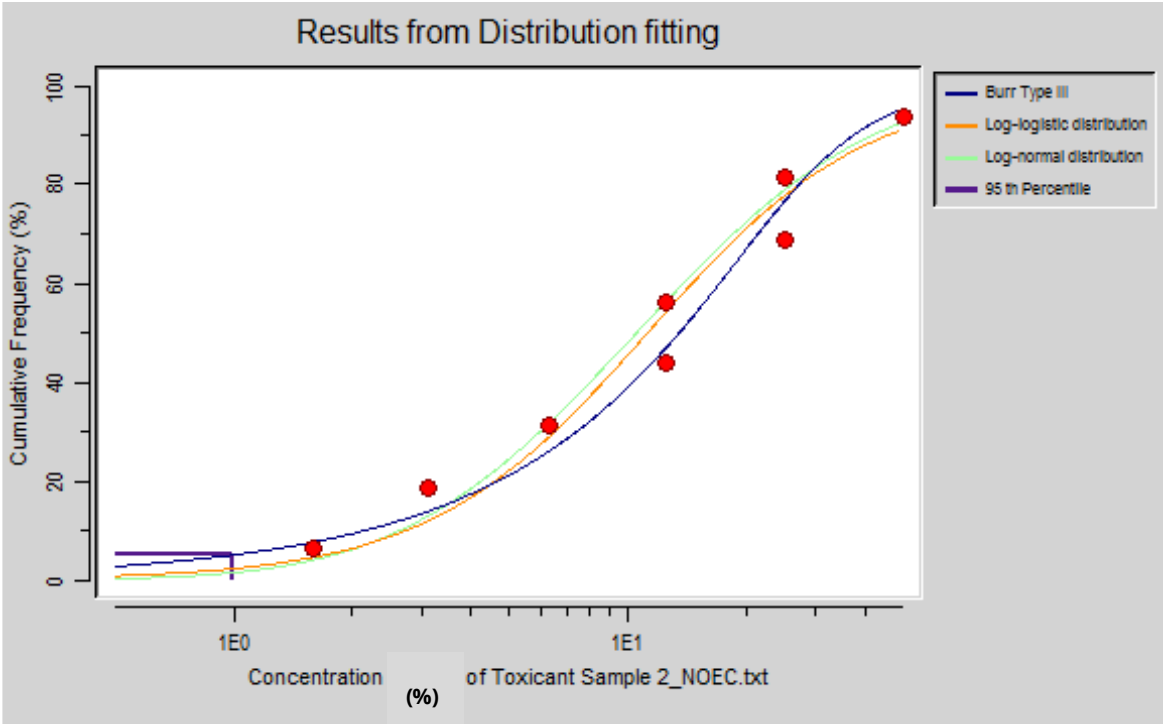


Figure 5-11 Species sensitivity distribution for pilot plant chlorinated/dechlorinated brine NOEC data

The resultant protective concentrations and safe dilutions for the three sets of chlorinated/dechlorinated brine data are presented in Table 5-12.

Table 5-12 Protective concentrations and safe dilutions for the chlorinated/dechlorinated brine sample

% sample

PC	IC10	IC10 Best Data	NOEC
95%	0.26	4.87	1
Safe Dilution	385	21	100
99%	0.02	3.77	0.16
Safe Dilution	5000	27	625
Goodness of Fit	26.7	26.8	27.2

ACIDIFIED/NEUTRALISED PERMEATE RESULTS

Results of the DTA of the pilot plant permeate that underwent acidification and neutralisation prior to testing are presented in Table 5-13.

Table 5-13 Results of DTA of pilot plant acidified and neutralised permeate

	% sample	
	IC10	NOEC
Microalgal Cell Yield	100	100
Sea Urchin Larval Development	25.5 (23.8-26.3)	25
Mussel Larval Development	25.7 (24.9-25.8)	25
Macroalgal Gametophyte Growth	62.6 (0-67.1)	50
Amphipod Biomass (14-d)	100	100
Amphipod Survival (14-d)	100	100
Polychaete Biomass (14-d)	4.2 (0-46.6)	50
Polychaete Survival (14-d)	14.3 (NC)	50
Snapper Growth (7-d)	55.4 (48.6-59.1)	50
Snapper Imbalance (7-d)	62.4 (45.1-71.8)	50
Kingfish Growth (7-d)	4.4 (0-9.7)	50
Kingfish Imbalance (7-d)	3.7 (0-11.5)	50

The sea urchin and mussel larval development tests proved to be the most sensitive of the routine tests used while the fish imbalance and polychaete biomass endpoints were also sensitive to the brine. The microalgae and the snapper proved to be the least sensitive of all the organisms tested.

ACIDIFIED/NEUTRALISED PERMEATE PROTECTIVE CONCENTRATIONS

Protective concentrations for the acidified/neutralised permeate were derived using IC10 estimates as well as an “IC10 Best Data” set. An IC10 result was included in the best data set if the upper and lower confidence limits were within 3 times the IC10 % sample concentration. Table 5-14 displays

the values that have been used to calculate the protective concentrations for the two sets of data with those values shaded in the table. The NOEC values were not used as only three of the test concentrations could be used to calculate the PC's.

Table 5-14 Values used for the derivation of protective concentrations for the acidified/neutralised permeate sample

	% sample	
	IC10	IC10 Best Data
Microalgal Cell Yield	100	100
Sea Urchin Larval Development	25.5 (23.8-26.3)	25.5 (23.8-26.3)
Scallop Larval Development	25.7 (24.9-25.8)	25.7 (24.9-25.8)
Macroalgal Gametophyte Growth	62.6 (0-67.1)	62.6 (0-67.1)
Amphipod Biomass (14-d)	100	100
Amphipod Survival (14-d)	100	100
Polychaete Biomass (14-d)	4.2 (0-46.6)	4.2 (0-46.6)
Polychaete Survival (14-d)	14.3 (NC)	14.3 (NC)
Snapper Growth (7-d)	55.4 (48.6-59.1)	55.4 (48.6-59.1)
Snapper Imbalance (7-d)	62.4 (45.1-71.8)	62.4 (45.1-71.8)
Kingfish Growth (7-d)	4.4 (0-9.7)	4.4 (0-9.7)
Kingfish Imbalance (7-d)	3.7 (0-11.5)	3.7 (0-11.5)

Figure 5-12 and Figure 5-13 display the SSDs derived from the IC10 and IC10 Best Data estimates respectively, and the goodness of fit of the data by the BurrliOZ (ANZECC and ARMCANZ, 2000) software.

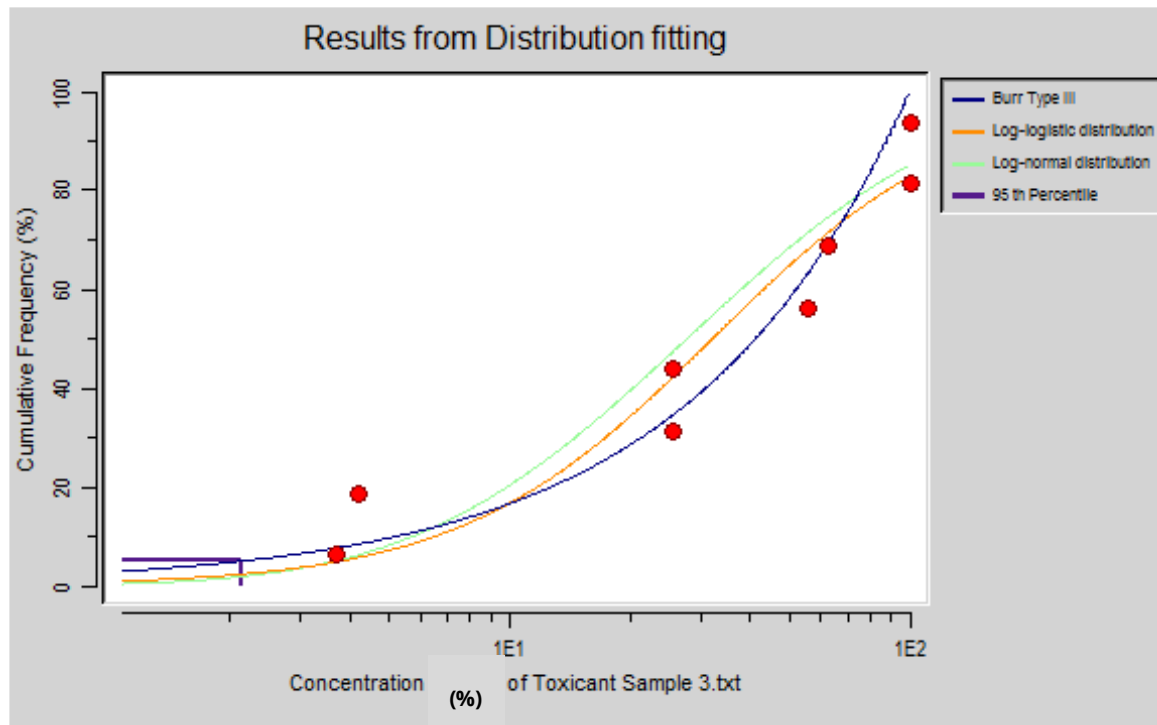


Figure 5-12 Species sensitivity distribution for pilot plant acidified/neutralised permeate IC10 data

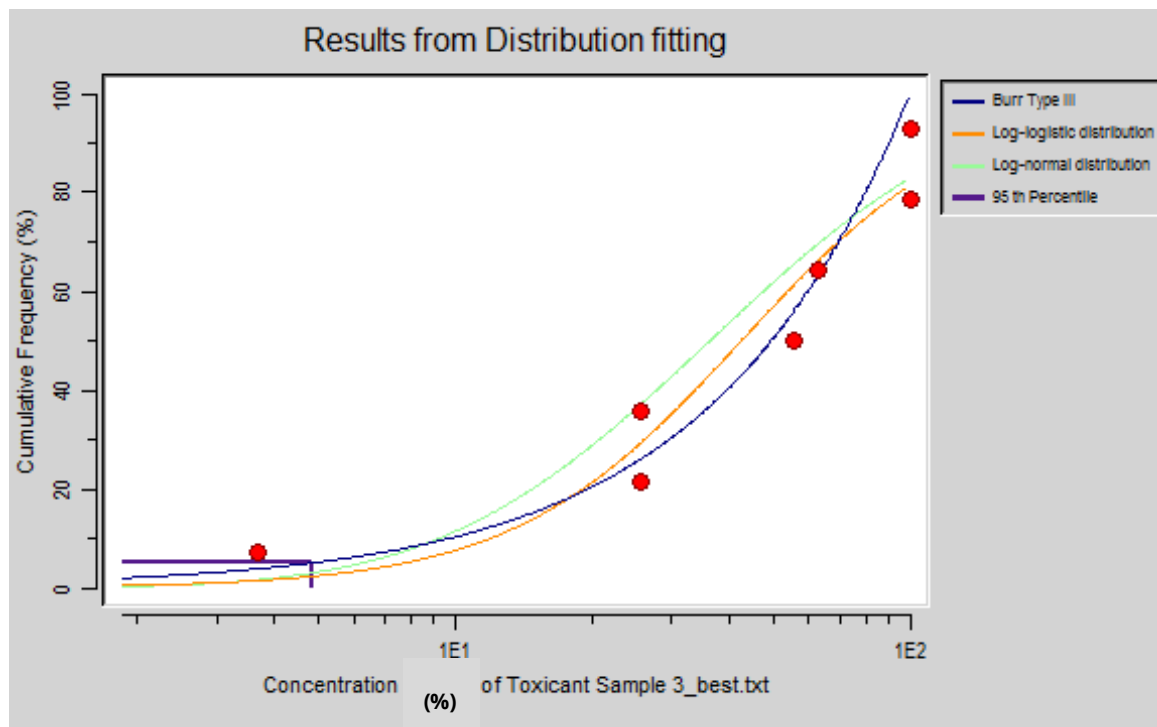


Figure 5-13 Species sensitivity distribution for pilot plant acidified/neutralised permeate IC10 Best Data

The resultant protective concentrations and safe dilutions for the three sets of chlorinated/dechlorinated brine data are presented in Table 5-15. The exclusion of the polychaete data from the calculation of the PC's in the IC10 Best Data reduced the required dilution by just over half for the 95% PC and by three times for the 99% PC. This indicates that the calculation of the PC's was sensitive to the inclusion of the polychaete data.

Table 5-15 Protective concentrations and safe dilutions for the acidified/neutralised permeate sample

	% sample	
PC	IC10	IC10 Best Data
95%	2.16	4.83
Safe Dilution	47	21
99%	0.27	0.95
Safe Dilution	371	106
Fit of Data	36.6	32.2

DBNPA TREATED/NEUTRALISED PERMEATE RESULTS

Results of the DTA of the pilot plant permeate that underwent DBNPA treatment and neutralisation prior to testing are presented in Table 5-16.

Table 5-16 Results of DTA of pilot plant DBNPA treated and neutralised permeate

	% sample	
	IC10	NOEC
Microalgal Cell Yield	18.0 (11.0-23.0))	25
Sea Urchin Larval Development	19.7 (17.1-25.6)	12.5
Mussel Larval Development	25.5 (24.8-25.8)	25
Macroalgal Gametophyte Growth	18.9 (14.4-31.5)	25
Amphipod Biomass (14-d)	20.1 (0-75.9)	50
Amphipod Survival (14-d)	9.1 (0-20.6)	12.5
Polychaete Biomass (14-d)	29 (NC)	100
Polychaete Survival (14-d)	27.6 (0-64.0)	50
Snapper Growth (7-d)	27.5 (25.4-28.8)	25
Snapper Imbalance (7-d)	40.8 (37.7-44.3)	25
Kingfish Growth (7-d)	28.8 (2.4-58.7)	50
Kingfish Imbalance (7-d)	11.6 (1.0-65.6)	50

The sea urchin and mussel larval development tests proved to be the most sensitive of the routine tests used while the fish imbalance and polychaete biomass endpoints were also sensitive to the brine. The microalgae proved to be the least sensitive of all the organisms tested.

DBNPA TREATED/NEUTRALISED PERMEATE PROTECTIVE CONCENTRATIONS

Protective concentrations for the DBNPA treated/neutralised permeate were derived using IC10 data as well as an “IC10 Best Data” set. An IC10 result was included in the best data set if the upper and lower confidence limits were within 3 times the IC10 % sample concentration. Table 5-17 displays the data that has been used to calculate the protective concentrations for the two sets of estimates with those values shaded in the table. PC’s for the NOEC data were not calculated due to only three concentrations being able to be used for the calculations.

Table 5-17 Values used for the derivation of protective concentrations for the DBNPA treated/neutralised permeate sample

	% sample	
	IC10	IC10 Best Data
Microalgal Cell Yield	18.0 (11.0-23.0))	18.0 (11.0-23.0))
Sea Urchin Larval Development	19.7 (17.1-25.6)	19.7 (17.1-25.6)
Scallop Larval Development	25.5 (24.8-25.8)	25.5 (24.8-25.8)
Macroalgal Gametophyte Growth	18.9 (14.4-31.5)	18.9 (14.4-31.5)
Amphipod Biomass (14-d)	20.1 (0-75.9)	20.1 (0-75.9)
Amphipod Survival (14-d)	9.1 (0-20.6)	9.1 (0-20.6)
Polychaete Biomass (14-d)	29 (NC)	29 (NC)
Polychaete Survival (14-d)	27.6 (0-64.0)	27.6 (0-64.0)
Snapper Growth (7-d)	27.5 (25.4-28.8)	27.5 (25.4-28.8)
Snapper Imbalance (7-d)	40.8 (37.7-44.3)	40.8 (37.7-44.3)
Kingfish Growth (7-d)	28.8 (2.4-58.7)	28.8 (2.4-58.7)
Kingfish Imbalance (7-d)	11.6 (1.0-65.6)	11.6 (1.0-65.6)

Figure 5-14 and Figure 5-15 display the SSDs derived from the IC10, and IC10 Best Data estimates respectively, and the goodness of fit of the data by the BurrliOZ (ANZECC and ARMCANZ, 2000) software.

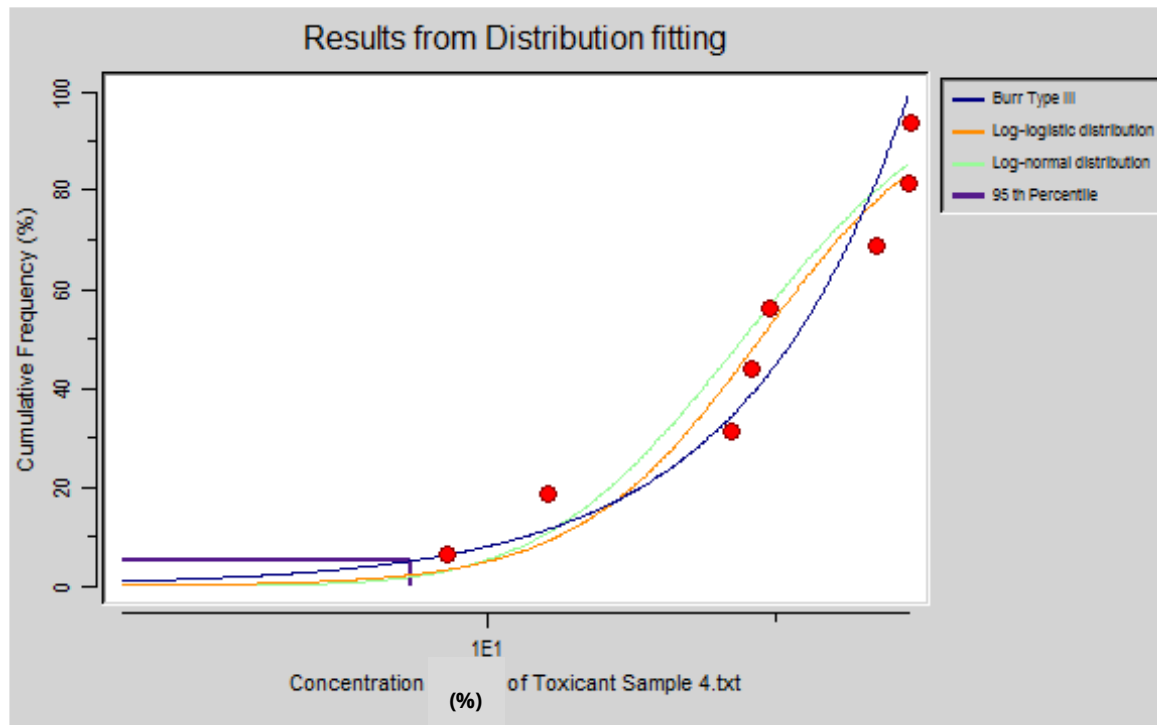


Figure 5-14 Species sensitivity distribution for pilot plant DBNPA treated/neutralised permeate IC10 data

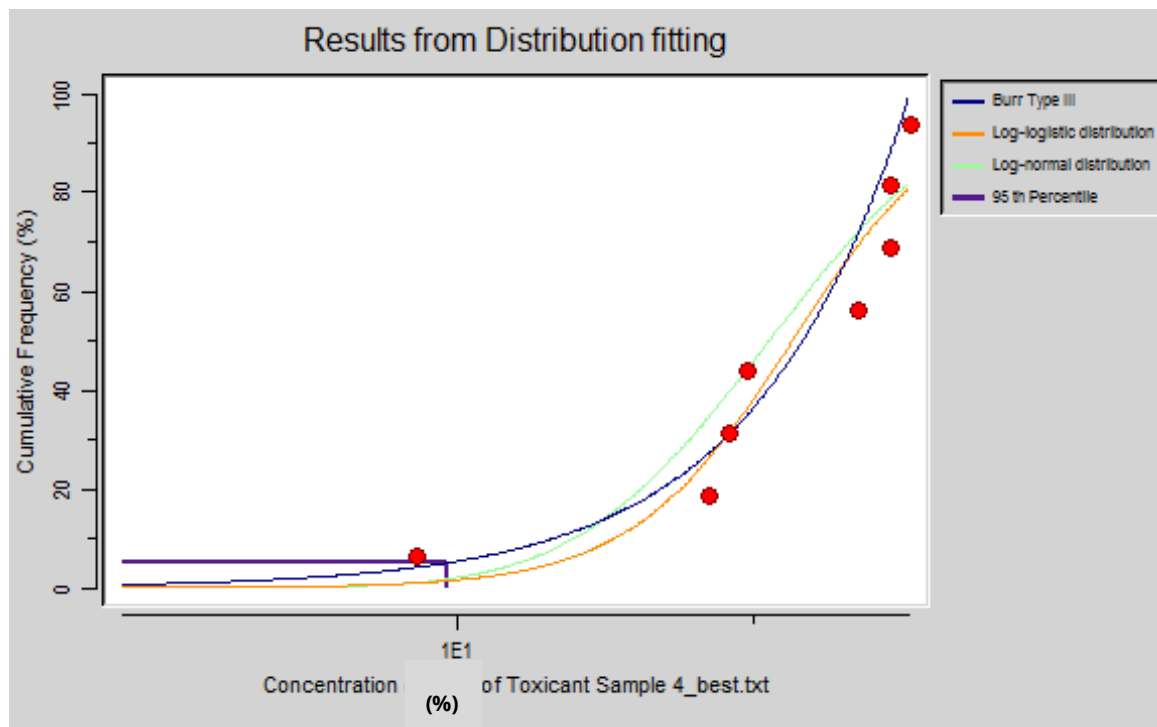


Figure 5-15 Species sensitivity distribution for pilot plant DBNPA treated/neutralised permeate IC10 Best Data

The resultant protective concentrations and safe dilutions for the three sets of DBNPA treated/neutralised permeate data are presented in Table 5-18. The use of the kingfish growth test data instead of the kingfish imbalance test for the IC10 Best Data PC's did not significantly alter the safe dilutions needed from those calculated using the IC10 data.

Table 5-18 Protective concentrations and safe dilutions for the DBNPA treated permeate sample

	% sample	
PC	IC10	IC10 Best Data
95%	8.32	9.73
Safe Dilution	13	11
99%	4.37	5.43
Safe Dilution	23	19
Goodness of Fit	24	23.4

NaOH/Na4-EDTA/NEUTRALISED PERMEATE RESULTS

Results of the DTA of the pilot plant permeate that underwent NaOH/Na4-EDTA treatment and neutralisation prior to testing are presented in Table 5-19.

Table 5-19 Results of DTA of pilot plant permeate treated with NaOH/Na4-EDTA/neutralised

	% sample	
	IC10	NOEC
Microalgal Cell Yield	0.9 (0.7-1.4)	<3.1
Sea Urchin Larval Development	4.0 (3.6-4.3)	3.1
Mussel Larval Development	4.5 (0.1-5.3)	3.1
Macroalgal Gametophyte Growth	26.0 (21.1-28.8)	25
Amphipod Biomass (14-d)	1.0 (0.5-10.1)	6.3
Amphipod Survival (14-d)	2.6 (1.1-3.4)	3.1
Polychaete Biomass (14-d)	4.5	100
Polychaete Survival (14-d)	100	100
Fish Imbalance (7-d)	0.15 (0-0.24)	<3.1

The microalgae test proved to be the most sensitive of the standard tests used while the fish imbalance endpoint was also sensitive to the treated permeate. The macroalgae proved to be the least sensitive of all the organisms tested.

PERMEATE TREATED WITH NaOH/Na4-EDTA/NEUTRALISED PROTECTIVE CONCENTRATIONS

Protective concentrations for the NaOH/Na4-EDTA/neutralised permeate were derived using IC10 and NOEC data as well as an “IC10 Best Data” set. An IC10 result was included in the best data set if the upper and lower confidence limits were within 3 times the IC10 % sample concentration. Table 5-20 displays the values that were used to calculate the protective concentrations for all three sets of data with those values shaded in the table. PC’s for the NOEC data were not calculated due to only four concentrations being able to be used for the calculations.

Table 5-20 Values used for the derivation of protective concentrations for the NaOH/Na₄-EDTA/neutralised permeate sample

	% sample		
	IC10	IC10 Best Data	NOEC
Microalgal Cell Yield	0.9 (0.7-1.4)	0.9 (0.7-1.4)	<3.1
Sea Urchin Larval Development	4.0 (3.6-4.3)	4.0 (3.6-4.3)	3.1
Scallop Larval Development	4.5 (0.1-5.3)	4.5 (0.1-5.3)	3.1
Macroalgal Gametophyte Growth	26.0 (21.1-28.8)	26.0 (21.1-28.8)	25
Amphipod Biomass (14-d)	1.0 (0.5-10.1)	1.0 (0.5-10.1)	6.3
Amphipod Survival (14-d)	2.6 (1.1-3.4)	2.6 (1.1-3.4)	3.1
Polychaete Biomass (14-d)	4.5	4.5	100
Polychaete Survival (14-d)	100	100	100
Fish Imbalance (7-d)	0.15 (0-0.24)	0.15 (0-0.24)	<3.1

Figure 5-16 and Figure 5-17 display the SSDs derived from the IC10 and IC10 Best Data estimates respectively, and the goodness of fit of the data by the BurrliOZ (ANZECC and ARMCANZ, 2000) software.

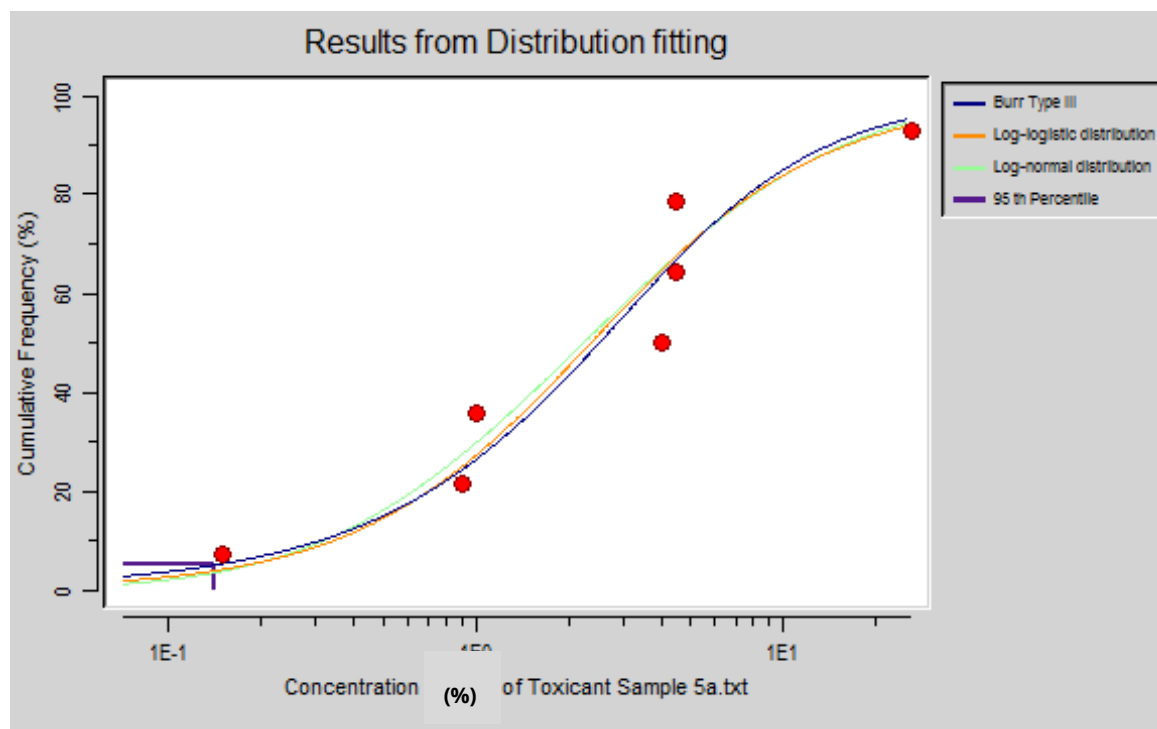


Figure 5-16 Species sensitivity distribution for pilotplant NaOH/Na₄-EDTA/neutralised permeate IC10 data

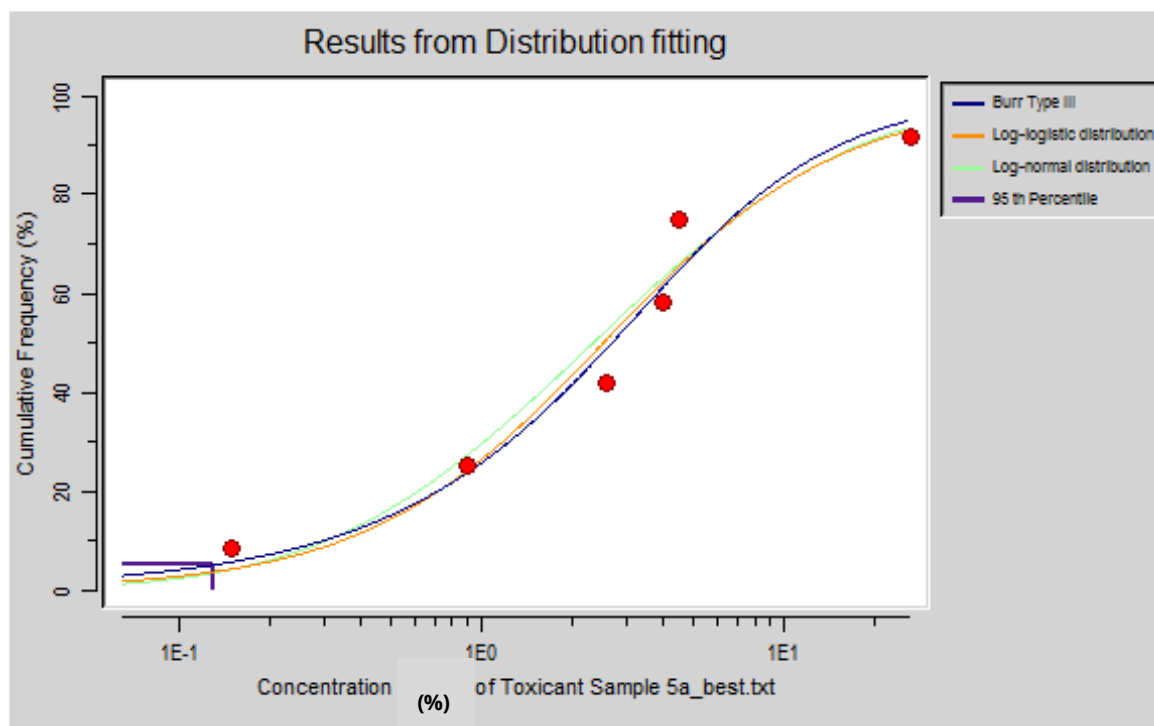


Figure 5-17 Species sensitivity distribution for pilot plant NaOH/Na4-EDTA/neutralised permeate IC10 Best Data

The resultant protective concentrations and safe dilutions for the two sets of NaOH/Na4-EDTA/neutralised permeate data are presented in Table 5-21. The exclusion of the polychaete data and the use of the amphipod survival data instead of the biomass data did not significantly alter the calculated PC's.

Table 5-21 Protective concentrations and safe dilutions for the NaOH/Na4-EDTA/neutralised permeate sample

PC	% sample	
	IC10	IC10 Best Data
95%	0.14	0.13
Safe Dilution	715	770
99%	0.02	0.02
Safe Dilution	5000	5000
Goodness of Fit	18.3	16.4

NaOH/SODIUM LAUREL SULPHATE/NEUTRALISED PERMEATE RESULTS

Results of the DTA of the pilot plant permeate that underwent NaOH/sodium laurel sulphate/neutralisation prior to testing are presented in Table 5-22.

Table 5-22 Results of DTA of pilot plant permeate treated with NaOH/sodium laurel sulphate/neutralised

	% sample	
	IC10	NOEC
Microalgal Cell Yield	0.3 (0.32-0.35)	<3.1
Sea Urchin Larval Development	0.2 (0.1-0.2)	<3.1
Mussel Larval Development	0.08 (0.07-0.08)	<3.1
Macroalgal Gametophyte Growth	6.7 (2.5-7.4)	6.3
Amphipod Biomass (14-d)	6.8 (2.7-7.0)	6.3
Amphipod Survival (14-d)	6.0 (0.8-7.0)	6.3
Polychaete Biomass (14-d)	2.4 (0.4-9.7)	6.3
Polychaete Survival (14-d)	10.1 (7.1-12.2)	12.5
Fish Imbalance (7-d)	0.05 (0.04-0.06)	<3.1

The mussel larval development test proved to be the most sensitive of the routine tests used while the fish imbalance endpoint was also sensitive to the treated permeate. The macroalgae proved to be the least sensitive of all the organisms tested.

NAOH/SODIUM LAUREL SULPHATE/NEUTRALISED PERMEATE PROTECTIVE CONCENTRATIONS

Protective concentrations for the NaOH/sodium laurel sulphate/neutralised permeate were derived using IC10 data as well as an "IC10 Best Data" set. An IC10 result was included in the best data set if the upper and lower confidence limits were within 3 times the IC10 % sample concentration. Table 5-23 displays the values that were used to calculate the protective concentrations for the two sets of data with those values shaded in the table. As there NOEC results only included two concentrations the PC's were not calculated based on those values.

Table 5-23 Values used for the derivation of protective concentrations for the NaOH/sodium laurel sulphate/neutralised permeate sample

	% sample	
	IC10	IC10 Best Data
Microalgal Cell Yield	0.3 (0.32-0.35)	0.3 (0.32-0.35)
Sea Urchin Larval Development	0.2 (0.1-0.2)	0.2 (0.1-0.2)
Scallop Larval Development	0.08 (0.07-0.08)	0.08 (0.07-0.08)
Macroalgal Gametophyte Growth	6.7 (2.5-7.4)	6.7 (2.5-7.4)
Amphipod Biomass (14-d)	6.8 (2.7-7.0)	6.8 (2.7-7.0)
Amphipod Survival (14-d)	6.0 (0.8-7.0)	6.0 (0.8-7.0)
Polychaete Biomass (14-d)	2.4 (0.4-9.7)	2.4 (0.4-9.7)

Polychaete Survival (14-d)	10.1 (7.1-12.2)	10.1 (7.1-12.2)
Fish Imbalance (7-d)	0.05 (0.04-0.06)	0.05 (0.04-0.06)

Figure 5-18 and Figure 5-19 display the SSDs derived from the IC10 and IC10 Best Data estimates respectively, and the goodness of fit of the data by the BurrliOZ (ANZECC and ARMCANZ, 2000) software.

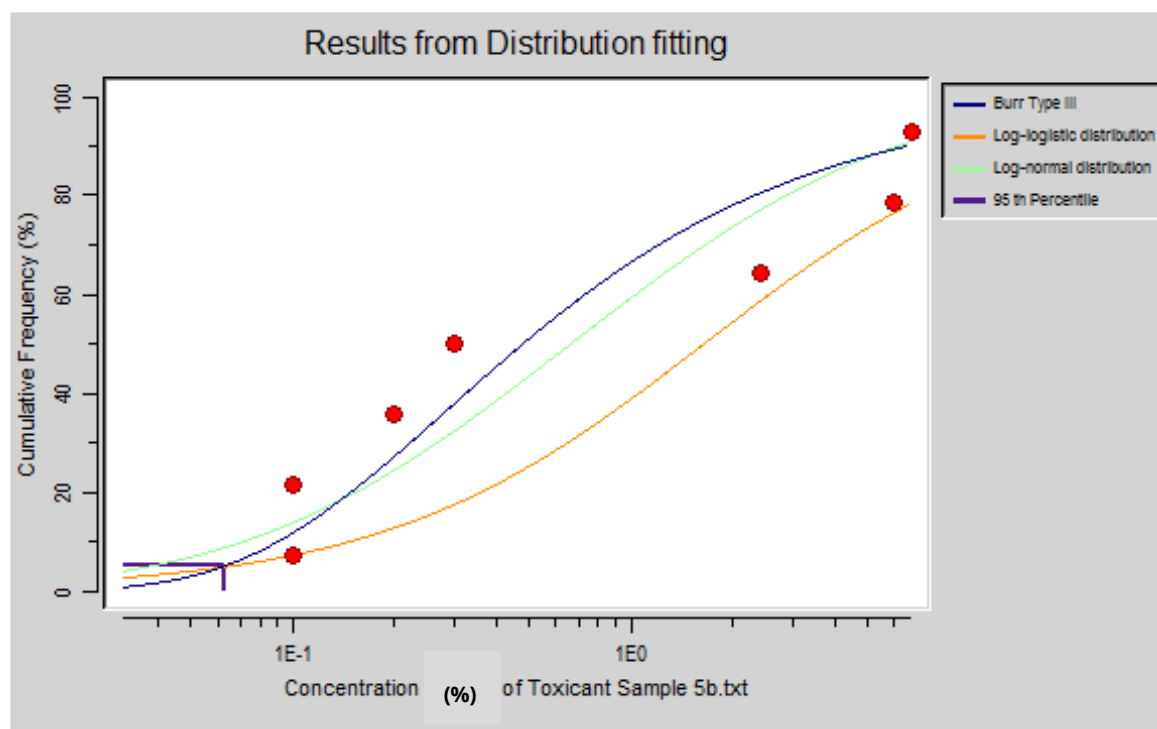


Figure 5-18 Species sensitivity distribution for pilot plant NaOH/sodium laurel sulphate/neutralised permeate IC10 data

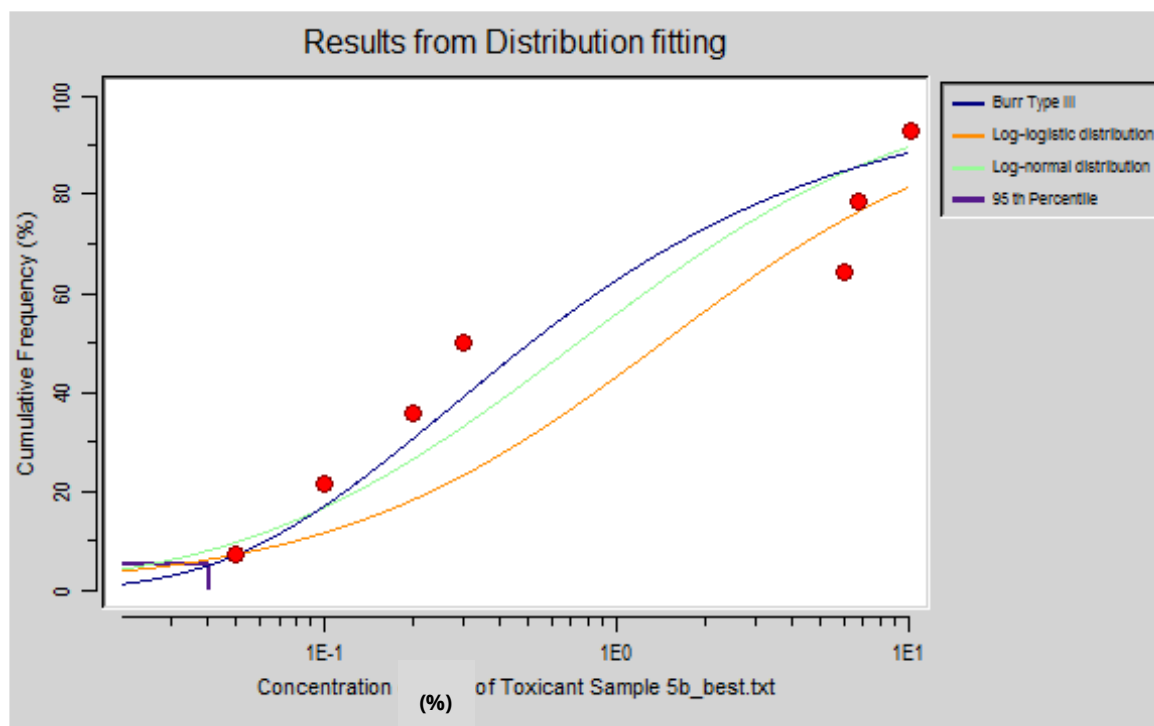


Figure 5-19 Species sensitivity distribution for pilot plant NaOH/sodium laurel sulphate/neutralised permeate IC10 Best Data

The resultant protective concentrations and safe dilutions for the two sets of NaOH/sodium laurel sulphate/neutralised permeate data are presented in Table 5-24. The use of the polychaete survival data instead of the biomass data in the IC10 Best Data set did not significantly alter the calculated PC's.

Table 5-24 Protective concentrations and safe dilutions for the NaOH/sodium laurel sulphate/neutralised permeate sample

PC	% sample	
	IC10	IC10 Best Data
95%	0.04	0.04
Safe Dilution	2500	2500
99%	0.02	0.02
Safe Dilution	5000	5000
Fit of Data	10.7	12.8

POLYELECTROLYTE TREATED FEEDWATER

Results of the DTA of the polyelectrolyte treated feedwater are presented in Table 5-25. The toxicity exhibited by the polyelectrolyte to the selected test organisms was low. From the results, the most sensitive organism to the sample was the macroalgae, while the amphipod indicating moderate toxicity and all other tests did not exhibit any sensitivity to the concentrations tested. By using the application factor approach recommended by ANZECC and ARMCANZ, (2000) (Section 8.3.3.2) for data sets that do not meet the requirements for calculating PCs using the SSD method, an

environmental concern level can be calculated by dividing the lowest chronic NOEC value by 10. For the polyelectrolyte treated feedwater a environmental concern level of 10% sample concentration was calculated which would require at least a ten times dilution to protect the majority of species in the receiving environment.

Table 5-25 Results of DTA of polyelectrolyte treated feedwater

	% sample	
	IC10	NOEC
Microalgal Cell Yield	>100	100
Macroalgal Gametophyte Growth	14.4	100
Amphipod Biomass (14-d)	18.3	100
Amphipod Survival (14-d)	61.7	100
Polychaete Biomass (14-d)	>100	100
Polychaete Survival (14-d)	>100	100

5.2 OLYMPIC DAM DESALINATION PLANT DISCHARGE ECOLOGICAL TRIGGER VALUE DERIVATION

5.2.1 A REFINED ASSESSMENT OF THE SELECTION OF SPECIES AND OTHER FACTORS THAT AFFECT DILUTION FACTORS FOR THE PROPOSED DESALINATION PLANT AT POINT LOWLY, SOUTH AUSTRALIA

In 2006 BHP Billiton planned to put a 280 million litre a day, Reverse Osmosis desalination plant, onto the Point Lowly peninsula, South Australia. Dr Warne (CSIRO) reviewed two years of studies undertaken as part of the Draft Environmental Impact Statement (EIS) for the proposed desalination plant at Point Lowly and provided his expert opinion on a number of issues related to the toxicity tests.

Sixteen organisms were tested and evaluated as part of the Environmental Impact Statement for the proposed desalination plant at Point Lowly for their appropriateness to calculate dilution factors for the return water. The ambient salinity at Point Lowly (40-43 g/L) is greater than the majority of Australian marine waters (34- 37 g/L), with the return water salinity approximating 78 g/L. Dr Warne's report provided an assessment of all the direct toxicity assessment (DTA) results, and the species protection values presented use the most appropriate dataset available and superseded all previous calculated values.

5.2.1.1 DIRECT TOXICITY ASSESSMENT (DTA)

There are two different approaches that can be used to conduct direct toxicity assessment (DTA) which is also called whole effluent toxicity testing (WET).

- to use generic species that occur in that environmental media. For example, a DTA test at Point Lowly would use species that occur within Australian marine waters. This is also called the Standard DTA approach (Van Dam and Chapman, 2001).
- to use endemic organisms that actually occur in the ecosystem that is being assessed. For example, a DTA test at Point Lowly would use species that are found in the marine waters

around Point Lowly or closely related organisms. This is also called the Site-specific DTA approach (Van Dam and Chapman, 2001).

The initial toxicity testing undertaken to assess the toxicity of the return water for Point Lowly followed the generic species approach with the exception of the Giant Australian Cuttlefish, *Sepia apama*. The species used were *S. apama* - cephalopod, *Penaeus monodon* – crustacean; *Seriola lalandi* – fish; *Nitzschia closterium* – diatom; *Hormosira banksii* – brown macroalga; *Heliocidaris tuberculata* – echinoid; and *Saccostrea commercialis* – bivalve. The use of these generic organisms caused some problems mainly as they were acclimated to normal salinity marine water (i.e. 35 – 36 ppt), while the salinity of the Point Lowly region varies between 40 and 43 ppt. At the salinities that naturally occur at Point Lowly, two of the tested species (i.e. the oyster and the sea urchin) died – thus highlighting their unsuitability as test organisms. Also, neither of these species was endemic to the Point Lowly region. Given the above, Dr Warne recommended that it would be desirable to (1) conduct further toxicity tests, preferably using species found in Upper Spencer Gulf, (2) increase the number of species for which there are toxicity data and (3) increase the relevance of the resulting dilution factors.

As a result of Dr Warne's previous recommendation subsequent toxicity testing was undertaken to follow the endemic species approach. A list of all the species that have been used to determine the toxicity of return water and whether they are endemic to Upper Spencer Gulf (USG) (where Point Lowly is located) is presented in Table 5-26.

Table 5-26 Information on the test organisms used in the direct toxicity assessment of return water for the proposed Point Lowly desalination plant

Species	Present in USG	Notes	Phase ^a
Microalga - <i>Nitzschia closterium</i>	Yes	Widely distributed in Australian waters	1
Microalga - <i>Isochrysis galbana</i>	Genus yes, species unknown		2
Microalga - <i>Ecklonia radiata</i>	No	Widely distributed throughout SA waters, but not recorded to occur north of Arno Bay (which is to the south of Point Lowly)	2
Macroalga - <i>Hormosira banksii</i>	Yes	Widely distributed throughout SA waters	1
Copepod - <i>Gladioferens imparipes</i>	Unknown		2
Tiger Prawn - <i>Penaeus monodon</i>	No		1
Western King Prawn - <i>Melicertus latisulcatus</i>	Yes		2
Blue Swimmer Crab - <i>Portunus armatus</i>	Yes		2
Pacific Oyster - <i>Crassostrea gigas</i>	Yes	In aquaculture	2

Sydney Rock Oyster - <i>Saccostrea commercialis</i>	No		1
Sea urchin - <i>Heliocidaris tuberculata</i>	No	Distributed on rocky reefs from Southern Queensland to central New South Wales	1
Yellowtail Kingfish - <i>Seriola lalandi</i>	Yes	Also an important aquaculture species	1, 2 & 3
Snapper - <i>Chrysophrys auratus</i>	Yes		2
Mulloway - <i>Argyrosomus japonicus</i>	Yes		2
Giant Australian Cuttlefish - <i>Sepia apama</i>	Yes	Important breeding habitat at Point Lowly	1 & 2
Sponge - <i>Aplysina</i> sp.	Yes	This is a newly developed toxicity test.	3

^aPhases 1, 2 and 3 refer to testing conducted in 2006, 2007 and 2008 respectively.

5.2.1.2 RECOMMENDED SPECIES FOR THE CALCULATION OF DILUTION FACTORS AND THE RATIONALE

Some of the DTA tests were conducted using diluent water with salinity outside the range found at Point Lowly, that some of the DTA tests only use acute exposure and QAQC issues. According to Dr Warne's opinion, the most internally consistent dataset which permits the largest number of species should be used to derive the dilution factors. By internally consistent it is meant that:

- toxicity data for only one type of exposure (i.e. chronic or acute or pulse) and
- data determined using diluent water with a single salinity within the range of Point Lowly (i.e. 40 – 43 ppt).

Based on these criteria, the best dataset was that using chronic toxicity data measured in diluent water with a salinity of 41.2 ppt (Table 5-27). An a priori decision was made to use, whenever possible, the concentration that causes a 10 % effect (EC10) rather than no observed effect concentration (NOEC) data to derive the PC99 and safe dilution factors. For the Giant Australian Cuttlefish there were limitations associated with the toxicity data for both phases I and II. Given the selection criteria the toxicity data from phase II were used to calculate the safe dilution factors.

The second-best dataset was considered to be that which permitted the most species to be used to derive the dilution factors even if some acute, chronic, and pulse values measured in different salinity diluent water were combined (Table 5-27). In addition to the chronic toxicity values measured at 41.2 ppt the best toxicity values for *H. banksii*, *G. imparipes* and *S. lalandi* were included in the second-best dataset. In the case of *S. lalandi* the toxicity values from phases I, II and III were deemed not ideal (see previous explanation). The lowest EC10 value was 1.48 % return water however, this was determined in diluent water with a salinity of 44.3 ppt which is higher than the highest reliably measured salinity at Point Lowly (i.e. 43 ppt). The EC10 and NOEC values from phases I (conducted using diluent water with a salinity of 41.2 ppt) and II (where the diluent water had a salinity of 35 ppt) were 12.5 (10.6% when recalculated by the author) and 11.1 % return water, respectively. The close agreement of the EC10 values from phase I and II tends to indicate that the phase III result was atypical and therefore as the recalculated phase II EC10 of 10.6% return water was the lower of the two value it was adopted.

The best dataset contains toxicity data for seven species that belong to six taxonomic groups of organisms. The second-best dataset contains toxicity data for ten species that belong to six taxonomic groups of organisms. Both datasets exceed the minimum data requirements of the BurrliOZ method (Campbell et al., 2000) and the Australian and New Zealand water quality guidelines (ANZECC and ARMCANZ, 2000) to derive site-specific trigger values (i.e. at least five species that belong to at least four taxonomic groups of organisms).

Table 5-27 The species and the toxicity values for the two preferred datasets used to derive the dilution factors.

Test species	Taxonomic group	EC10 and NOEC values (% return water)	
		Best dataset	2 nd best dataset
<i>H. banksii</i>	Macroalga		16 ^a
<i>I. galbana</i>	Diatom	84.4	84.4
<i>E. radiata</i>	Macroalga	27.6	27.6
<i>C. gigas</i>	Bivalve	3.3	3.3
<i>G. imparipes</i>	Crustacean		10.9 ^b
<i>C. auratus</i>	Fish	22.2	22.2
<i>S. lalandi</i>	Fish		10.6 ^c
<i>A. japonicus</i>	Fish	11.0 ^d	11.0 ^d
<i>M. latisulcatus</i>	Crustacean	7.5 ^e	7.5 ^e
<i>S. apama</i>	Cephalopod	6.3	6.3

^athe NOEC for *H. banksii* was measured in diluent water with a salinity of 37 ppt. ^bthe EC10 for *G. imparipes* is an acute toxicity value. ^cthe EC10 value for *S. lalandi* was measured in diluent water with a salinity of 35 ppt and calculated by the author using data generated by Geotechnical Services (2008) (Appendix O10.4 of the Draft EIS, BHP Billiton, 2009). The method used fits a log-logistic distribution to the data (Barnes et al., 2003). ^din Warne (2008a) the reported value was 11.6 % return water. The reason for the change is discussed in the text on this species that following this table. ^ethe EC10 value for *M. latisulcatus* was calculated by the author using data generated by Geotechnical Services (2008) (Appendix O10.4 of the Draft EIS, BHP Billiton, 2009). The method of Barnes et al (2003) was used.

5.2.1.3 DERIVATION OF PROTECTIVE CONCENTRATION VALUES AND SAFE DILUTION FACTORS

The suite of organisms tested as part of the Draft Environmental Impact Statement for the proposed desalination plant at Point Lowly were evaluated for their appropriateness to calculate safe dilution factors for the return water.

The PC99 and safe dilution factor for the best dataset were 2.35 % return water and 45 (rounded up from 42.6) respectively. The PC95 and safe dilution factor for the best dataset were 3.37 % return water and 30 (rounded up from 29.6) respectively. The PC99 value and dilution factor for the second-best dataset were 2.51 % return water and 40 (rounded up from 39.8) respectively. The PC95 value and dilution factor for the second-best dataset were 3.91 % return water and 26 (rounded up from 25.6) respectively. The SSD plots used to generate these PC values and safe dilution factors for the best and second-best datasets are presented in Figures 1 and 2 respectively.

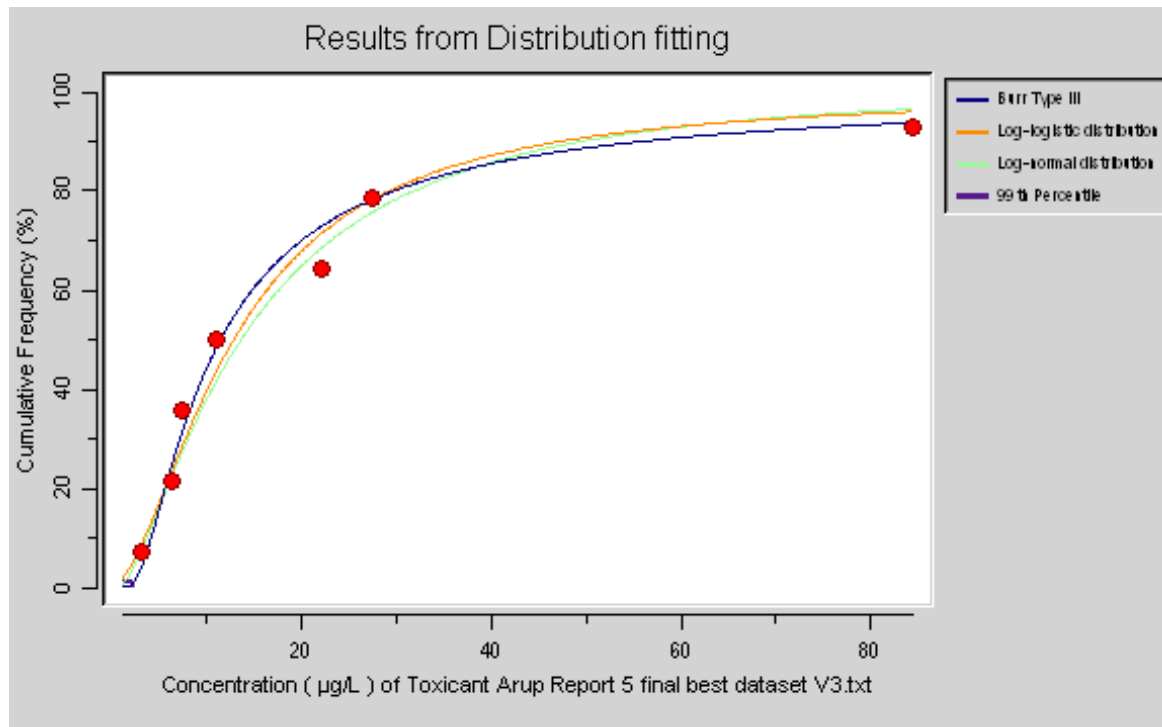


Figure 5-20 The species sensitivity distribution plot of the concentrations of return water that cause a 10% effect (EC10) for the best dataset

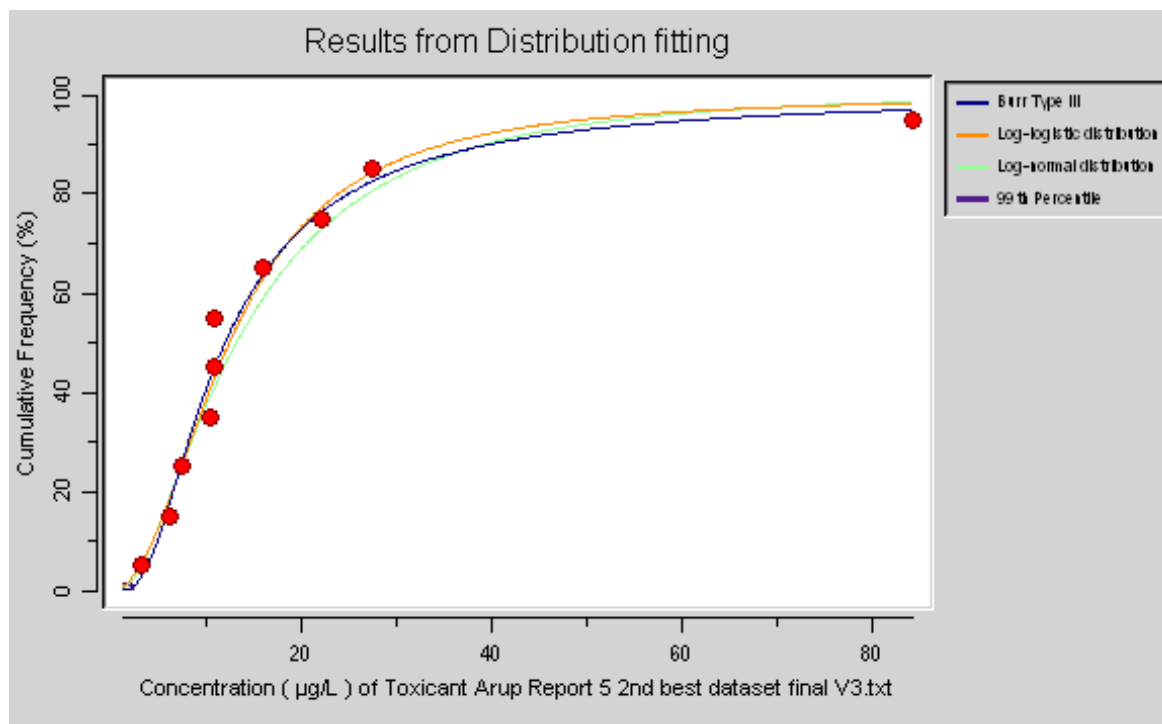


Figure 5-21 The species sensitivity distribution plot of the concentrations of return water that cause a 10% effect (EC10) for the second best dataset

It is worth noting that the PC99 and safe dilution factors derived using the best dataset (even though they are based on toxicity data for fewer species) are more conservative (i.e. requiring a greater

dilution of the return water) than those derived using the second best dataset. Therefore, in order to be conservative, the PC99 and safe dilution factor of the best dataset are preferred. The close agreement of the PC99 and safe dilution factors generated by the two datasets increases the confidence associated with using the values from the best dataset.

If the PC99 and dilution factor for the best dataset are achieved, then theoretically 99% of marine organisms typical of Upper Spencer Gulf should be protected from experiencing sub- chronic or chronic toxic effects of greater than 10% magnitude caused by the discharge of return water into water with a salinity of 41.2 ppt. It is important to note however, that the salinity of the diluent water used in the preceding calculations (41.2 ppt) is slightly below the mean of the range of salinities experienced at Point Lowly. Therefore, it is likely that the PC99 and safe dilution factor underestimate those that would be derived using toxicity data generated using diluent water with a salinity of 43 ppt (the maximum salinity reached at Point Lowly).

5.3 ECOLOGICAL TRIGGER VALUE DERIVATION OF SYDNEY WATER DESALINATION PLANT EFFLUENT

Hydrobiology was commissioned by Sydney Water in 2007 to undertake an ecotoxicity program aimed to investigate the toxicity of a saline concentrate representative of the Sydney Desalination Plant to derive ecological trigger values for each stream of desalination plant effluent using direct toxicity assessment (DTA) data and ANZECC/ARMCANZ (2000) methods necessary to minimise environmental harm and derive 'safe' dilutions for each stream of desalination plant effluent to achieve this. Samples of seawater concentrate were collected from the pilot desalination plant at Kurnell on a number of occasions in the period mid-May to late June 2007. The following seawater concentrate streams were sampled by Sydney Water from the desalination plant:

- Stream 1 – Concentrated seawater
- Stream 2 – Concentrated seawater with backwash liquid and antiscalent
- Stream 4 – Concentrated seawater with antiscalent
- Stream 5 – Concentrated seawater with antiscalent and membrane cleaning
- Stream 6 – Concentrated seawater with antiscalent, backwash liquid and membrane cleaning
- Stream 8 – Concentrated Seawater with Antiscalent, Backwash Liquid and Membrane Cleaning with Biocide

Samples for each of the above streams were collected from the pilot plant on three separate days to ensure independence of the samples and to capture any variations in plant operations that could result in alterations in properties of the test streams. It should be noted that Stream 8 results were discarded due to ambiguity in the original method and dosage of its neutralisation.

The effluent from each stream was then subjected to direct toxicity assessment using a suite of organisms including:

- The sea urchin, *Haliocidaris tuberculata*;
- The oyster, *Saccostrea commercialis*;
- The macro-algae, *Hormisira banksii*;
- The fish, *Lateolabrax lineatus* (Striped Trumpeter), *Lates calcarifer* (Barramundi) or *Macquaria novaeemaculeata* (Australian Bass) depending on availability; and,
- The prawn, *Penaeus monodon*.

5.3.1.1 DIRECT TOXICITY RESULTS

Results for direct toxicity assessment of effluent from Streams 1, 2, 4, 5 and 6 of the desalination process are presented in Table 5-28. It should be noted that the availability of fish resulted in three different species being used for the fish imbalance testing of the effluent streams. The three fish species used for the testing will have differing tolerances to salinity as the Barramundi and Bass both have life stages in estuarine and freshwater ecosystems while the striped trumpeter spends its life cycle in marine conditions. Whilst using fish with differing salinity tolerances is not ideal and will affect the results to some degree the overall outcome after calculation of the trigger values and dilution factors will not be overly different due to the fish only representing one data point in the species sensitivity distribution.

Table 5-28 Results of direct toxicity assessment of effluent collected from streams 1, 2, 4, 5 and 6 of the desalination process

Test		Stream 1 (% effluent)				Stream 2 (% effluent)				Stream 4 (% effluent)				Stream 5 (% effluent)				Stream 6 (% effluent)			
Sample		NOEC	LOEC	EC ₅₀	EC ₁₀	NOEC	LOEC	EC ₅₀	EC ₁₀	NOEC	LOEC	EC ₅₀	EC ₁₀	NOEC	LOEC	EC ₅₀	EC ₁₀	NOEC	LOEC	EC ₅₀	EC ₁₀
Sea Urchin Fertilisation	1	2.5	5	6.4	4.4	1.25	2.5	3.1	2	10	50	54.1	22.3	10	50	28	14.2	10	50	22.7	11.7
	2	5	10	16.7	7.1	1.25	2.5	6.6	1.8	10	50	55.5	26.7	10	50	26.7	12.8	10	50	48	19.5
	3	2.5	5	12	5.3	5	10	8.7	4.7	5	10	16.7	6.7	10	50	22.4	11.3	10	50	22.4	11.2
Sea Urchin Larval Development	1	10	50	22.1	11.6	2.5	5	6.3	3.7	10	50	21.6	11.5	5	10	20.8	10.8	10	50	21.5	5
	2	5	10	7.9	5.8	5	10	17.2	8.4	10	50	21.6	11.4	5	10	20.8	5	10	50	21.5	9.7
	3	5	10	13.3	6.5	5	10	19.2	10	10	50	21.1	12.4	2.5	5	19.8	10.4	5	10	20.4	11.2
Rock Oyster Larval Development	1	10	50	22.4	10.7	5	100	10.7	9.9	10	50	21.2	10.2	10	50	20.7	18.1	10	50	20.1	11.5
	2	5	10	6.9	5.1	5	100	16.9	6.8	10	50	21.7	10	10	50	19.8	10.8	10	50	21	10.3
	3	5	10	16.1	6.6	5	100	16.9	10	10	50	21.9	10.5	5	10	17.4	10	10	50	20.6	10.7
Macro-algal germination	1	10	50	35.4	18.5	50	100	>100	108.4	10	50	61.6	40.8	5	10	26.8	11.6	50	100	69.3	52.9
	2	10	50	40.5	15.8	50	100	>100	69.5	10	50	34.6	16.6	10	50	55.1	26.7	50	100	77.2	64.9
	3	10	50	22.4	10.7	50	100	>100	98.6	10	50	45.4	20.2	10	50	58.2	32.5	10	50	>100	50.9
Fish Imbalance	1	10	50	38.1	14.5	10	50	21.3	10.9	10	50	53	40.4	50	100	63.8	52.2	50	100	66.8	54.1
	2	10	50	39.6	15	5	10	10	5.6	10	50	50.1	38.8	50	100	63.8	52.2	50	100	70.7	65.2
	3	10	50	30.8	9.5	10	50	32.1	13.8	10	50	17	6.1	50	100	78.5	55.7	50	100	90	14.5
Prawn Survival	1	10	50	38.4	19.1	10	50	34	15.1	10	50	18.6	8.5	10	50	19.9	9.6	10	50	21	11.3
	2	10	50	31.7	15	10	50	26.1	15.6	10	50	16.6	7.5	10	50	19.5	10.7	10	50	17.6	8.8
	3	10	50	19.4	13.5	10	50	20.5	14.9	10	50	21.1	11.1	10	50	18.8	9.6	10	50	15.8	9

ECOLOGICAL TRIGGER VALUES

The main component of the toxicity seen in desalination plant discharges is salinity and with this in mind it was decided to derive trigger values and dilution factors as a measure of salinity above the background salinity of the discharge area. This involves calculating the salinity that was tested at each dilution series and calibrating this to salinity above that of the background salinity. A background salinity of 35.54 ppt was calculated from data collected by Sydney Water at the site of the proposed intake pipe between January and September 2006. The difference between the actual salinity and the background salinity of the discharge area along with the % effluent was then used to develop SSDs and derive trigger values. The values used to derive the ecological trigger values in terms of salinity (ppt) above background and % effluent of each stream using EC10 data and NOEC data are presented in Table 5-29 and Table 5-30 respectively.

Table 5-29 EC10 data used in SSDs for derivation of ecological trigger values

Effluent Stream	Stream 1		Stream 2		Stream 4		Stream 5		Stream 6	
	% eff	ppt ↑ ambient	% eff	ppt ↑ ambient	% eff	ppt ↑ ambient	% eff	ppt ↑ ambient	% eff	ppt ↑ ambient
Sea Urchin Fertilisation	5.49	2	2.57	1.03	-	-	-	-	-	-
Sea Urchin Larval	-	-	-	-	11.76	3.64	8.25	2.06	8.15	2.69
Rock Oyster Larval	7.12	2.43	8.76	2.15	10.23	3.24	12.5	2.84	10.82	3.39
Macro-algal Germination	14.62	4.39	90.57	17.04	23.92	6.83	21.6	4.49	55.91	15.21
Fish Imbalance	12.74	3.9	9.44	2.28	21.23	6.12	53.34	10.27	37.12	10.29
Prawn Survival	15.7	4.67	15.2	3.33	8.91	2.89	9.95	2.37	9.64	3.09

Table 5-30 NOEC data used in SSDs for derivation of ecological trigger values

Effluent Stream	Stream 1		Stream 2		Stream 4		Stream 5		Stream 6	
	% eff	ppt ↑ ambient	% eff	ppt ↑ ambient	% eff	ppt ↑ ambient	% eff	ppt ↑ ambient	% eff	ppt ↑ ambient
Sea Urchin Fertilisation	3.2	1.4	1.98	0.92	7.94	2.64	-	-	-	-
Sea Urchin Larval	-	-	-	-	-	-	3.97	1.28	7.94	2.64
Rock Oyster Larval	6.3	2.21	5	1.47	10	3.18	7.94	2.01	10	3.18
Macro-algal Germination	10	3.18	50	9.66	10	3.18	7.94	2.01	29.24	8.22
Fish Imbalance	10	3.18	7.94	2.01	10	3.18	50	9.66	50	13.66
Prawn Survival	10	3.18	10	2.38	10	3.18	10	2.38	10	3.18

The concentrations for each stream effluent to protect 95 and 90% of species, derived from the Burr type III distribution, are presented in Table 5-31 for EC10 data and Table 5-32 for NOEC data along with their corresponding 'safe' dilutions.

As the salinity for both the desalination discharge and the diluents water was different for each stream the direct comparison of trigger values cannot be done. But with the derivation of the safe dilutions, which standardises the toxicity of the sample to the background salinity, we can see that Stream 2 was the most toxic to the suite of organisms using both EC10 and NOEC data. This stream would require a dilution of 40:1 to reduce toxicity to the 95% protective concentration while a dilution of 31:1 would be needed to reduce the toxicity to the 90% protective concentration when using EC10 data and 53:1 to reduce toxicity to 95% protective concentration while a dilution of 42:1 would be needed to reduce toxicity to the 90% protective concentration when using NOEC data. Stream 1, 4, 5 and 6 was calculated to require dilutions of between 27:1 and 13:1 to reduce the toxicity to the 95% protective concentration and 20:1 to 12:1 to reduce the toxicity to 90% protective concentration with stream 4 being the least toxic and needing the least dilution to achieve the desired 95% protective concentration when using EC10 data. Stream 1, 4, 5 and 6 were calculated to require dilutions of between 30:1 and 12:1 to reduce the toxicity to the 95% protective concentration and 24:1 to 12:1 to reduce the toxicity to 90% protective concentration with stream 4 being the least toxic and needing the least dilution to achieve the desired 95% protective concentration when using NOEC data.

Table 5-31 Ecological trigger values calculated from EC₁₀ data for each desalination plant effluent stream with corresponding safe dilutions.

Effluent Stream	Stream 1		Stream 2		Stream 4		Stream 5		Stream 6	
	% eff	ppt ↑ ambient	% eff	ppt ↑ ambient	% eff	ppt ↑ ambient	% eff	ppt ↑ ambient	% eff	ppt ↑ ambient
PC95 50	3.78	1.55	2.49	1.01	8.21	2.71	7.15	1.86	6.48	2.26
Safe Dilution	27:1		40:1		13:1		14:1		16:1	
PC90 50	5.26	1.94	3.21	1.14	8.92	2.9	8.11	2.04	7.55	2.54
Safe Dilution	20:1		31:1		12:1		13:1		14:1	

Table 5-32 Ecological trigger values calculated from NOEC data for each desalination plant effluent stream with corresponding safe dilutions.

Effluent Stream	Stream 1		Stream 2		Stream 4		Stream 5		Stream 6	
	% eff	ppt ↑ ambient	% eff	ppt ↑ ambient	% eff	ppt ↑ ambient	% eff	ppt ↑ ambient	% eff	ppt ↑ ambient
PC95 50	3.34	1.44	1.9	0.91	8.71	2.84	3.71	1.24	6.54	2.27
Safe Dilution	30:1		53:1		12:1		27:1		16:1	
PC90 50	4.31	1.69	2.4	1	8.99	2.92	4.35	1.35	7.52	2.53
Safe Dilution	24:1		42:1		12:1		23:1		14:1	

From the trigger values for each stream the percentage of species that are protected could be calculated for desired dilution factor of 30:1 and are presented in

Table 5-33. When using the EC₁₀ data Stream 2 is the only stream that will not offer a level of protection for 95% of species after 30 times dilution. All other streams offered a level of protection for more than 95% of species with stream 4 predicted to display no toxicity to any species in the ecosystem. The same is true when using NOEC data, where the only stream that does not offer 95% of species protection is Stream 2.

Table 5-33 Percentage of species protected for each stream after 30 times dilution calculated from both EC₁₀ and NOEC data.

Effluent Stream	Stream 1	Stream 2	Stream 4	Stream 5	Stream 6
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	NOEC	EC ₁₀	NOEC	EC ₁₀	NOEC	EC ₁₀	NOEC	EC ₁₀	NOEC	EC ₁₀
% Species Protected	95.05	96.17	79.64	89.13	100	100	97.21	100	100	99.99

5.4 PERTH SEAWATER DESALINATION PLANT

The PSDP is owned by the Western Australian Water Corporation and has been in operation since late 2006. Twelve months after being commissioned, a DTA study was undertaken by Geotechnical Services to determine the toxicity of the seawater concentrate discharge, as required under the Ministerial conditions of the operation licence. The report (Geotechnical Services 2008) was made publicly available in April 2008.

The species selected by Geotechnical Services for the toxicity assessment of the seawater concentrate were mostly endemic to the marine ecosystem surrounding the discharge of the PSDP. The species selected and the tests undertaken were:

- 72-h *Isochrysis galbana* microalgal growth test;
- 72-h *Ecklonia radiata* macroalgal germination test;
- 48-h *Mytilus edulis* mussel larval development test;
- 24-h pulse exposure *Gladioferens imparipes* copepod reproduction test; and
- 7-day *Pagrus auratus* larval fish growth test.

All of these tests were undertaken at Geotechnical Services ecotoxicology laboratories. The dilutions that were used for assessing the sensitivity of each organism to the seawater concentrate are presented in Table 5-34.

Table 5-34 Concentrations of the PSDP RO saline concentrate used in the 2007 direct toxicity assessment

Test	Conc 1 (% saline concentr ate)	Conc 2 (% saline concentr ate)	Conc 3 (% saline concentr ate)	Conc 4 (% saline concentr ate)	Conc 5 (% saline concentr ate)	Conc 6 (% saline concentr ate)	Conc 7 (% saline concentr ate)	Conc 8 (% saline concentr ate)
Microal gae	0.7	1.3	2.6	5.2	10.4	20.8	41.6	83.3
Macroal gae	0.8	1.6	3.1	6.3	12.5	25	50	100
Mussel	0.8	1.6	2.6	6.3	12.5	25	50	100
Copepo d	0.7	3.1	6.3	12.5	25	50		
Fish	1.5	1.6	3.1	6.3	12.5	25	50	100

From the dilution data, Geotechnical Services calculated the Protective Concentration (PC) for each species. Protective concentrations were separately derived by Geotechnical Services using Australian and New Zealand Water Quality Guidelines (ANZECC and ARM CANZ 2000) methods, with assessments of the concentrations that caused a 10% effect (i.e. EC10) and the no observed effect concentration (NOEC). Safe dilution factors were then determined. PC values (PC99, PC95, PC90 and PC80) and corresponding safe dilution factors derived for samples collected in 2007 from the PSDP are presented in Table 5-35.

Table 5-35 The protective concentrations for 99, 95, 90 and 80% of species based on EC10 and NOEC toxicity data and the corresponding safe dilution factors for the PSDP RO saline concentrate in the 2007 direct toxicity assessments.

Test	EC10 (% saline concentrate)	NOEC (% saline concentrate)
PC 99	6.6	7.9
Safe dilution factor	16:1	13:1
PC 95	8.2	9.0
Safe dilution factor	13:1	12:1
PC 90	9.2	9.8
Safe dilution factor	11:1	11:1
PC 80	10.9	10.9
Safe dilution factor	10:1	10:1

Values obtained from Geotechnical Services (2008).

Under the terms imposed by the Western Australian Government there were two zones to be considered, each with its own level of protection. The mixing zone was classed as a low environment protection area (LEPA) within which 80% of species must be protected (i.e. PC80 values applied). Outside the mixing zone was classed as a high environment protection area (HEPA) where 90% of species had to be protected (i.e. PC90 values applied). The results of the toxicity testing undertaken in 2007 indicated that the diffuser in use at the plant, which has been shown to achieve a minimum dilution of 45:1, provided a greater protection for more than 80% and 90% of marine species (Table 5-35).

5.5 TOXICITY ASSESSMENT FOR THE VICTORIAN DESALINATION PLANT

The Victorian Government proposed to construct a seawater desalination plant to supply water to the Melbourne Water supply system and possibly other regional supply systems. DTA testing program was undertaken for the Victorian Desalination Plant (VDP) project, using samples of salinity adjusted intake water and discharge samples of the Perth Seawater Desalination Plant. The samples were collected in two separate rounds (April and June 2008) and represented various waste discharge (or concentrate) scenarios including those available to the Project. Comparisons of the intake water quality, desalination processes and estimated concentrate characteristics indicated that the concentrate samples from the PSDP would be comparable to those for the VDP.

The DTA testing program consisted of exposing a suite of organisms that were either locally relevant to the southern coast of Victoria or generic species where a locally relevant species could not be used. The species and tests used are outlined below:

- Microalgal (*Nitzschia closterium*) 72-h growth rate test (chronic);
- Sea Urchin (*Heliocidaris tuberculata*) 1-h fertilisation success test (sub-chronic);
- Sea Urchin (*Heliocidaris tuberculata*) 72-h larval development test (sub-chronic);
- Scallop (*Mimacclamys asperima*) 72-h larval development test (sub-chronic);
- Macroalgal (*Hormosira banksii*) 72-h germination success test (sub-chronic);

- Amphipod (*Allorchestes compressa*) 96-h mortality test (acute); and
- Fish (the sand whiting *Sillago ciliata* for round one and the Australian bass *Macquaria novamaculeata* for round two samples) 96-h fish imbalance test (acute).

All the above tests were conducted using standardised published protocols and adhering to Ecotox Services Australasia and CSIRO internal procedure manuals. The sea urchin fertilisation and larval development tests, Doughboy scallop larval development test and the macroalgal germination test are NATA accredited. The aforementioned organisms were selected for testing because they were:

- representative of marine species of southern Australian waters;
- standardised toxicity protocols available; and
- available at the time of testing.

The selected species meet the minimum data requirements of the Australian and New Zealand Water Quality Guidelines (2000) necessary to conduct a DTA and to derive safe dilution factors. The safe dilution factors were calculated using the ANZECC/ARMCANZ (2000) methods.

Both acute (short) and chronic (long) toxicity tests conducted. The standard method used to derive safe dilution factors for discharges entails the use of chronic toxicity data. Therefore, acute to chronic ratios (ACR) are needed to convert acute toxicity data to estimates of chronic toxicity.

The relative toxicity of the desalination plant discharge and the salinity-adjusted intake samples indicated that the primary stressor was salinity. The other potential causative agents being chemicals added during the desalination process. DTA testing for the full suite of test organisms to the three waste discharge scenarios yielded safe dilution factors less than 29:1.

5.5.1.1 DIRECT TOXICITY ASSESSMENT RESULTS

ROUND ONE

In round one samples representing waste disposal Case 2 (concentrate plus pre-treatment supernatant) and intake water that had its salinity adjusted to that of the Case 2 sample were tested. The EC10 results for these samples are presented in Table 5-36.

Table 5-36 Results of the direct toxicity assessment of Perth Seawater Desalination Plant concentrate plus pre-treatment supernatant discharge (Case 2) and salinity adjusted intake water

Direct toxicity assessment test	EC10 values (% sample)	
	Case 2 discharge (concentrate + pre-treatment supernatant)	Salinity Adjusted Intake
	EC ₁₀	EC ₁₀
Microalgal yield	13 (0-25)	17 (0-17)
Sea urchin fertilisation	12.6 (11.9-13.1)	18.1 (8.4-23.2)
Sea urchin larval development	13.1 (12.5-13.4)	13.3 (12.7-13.5)
Doughboy Scallop larval development	12.6 (12.3-12.6)	12.3 (12-12.6)

Macroalgal germination	51.4 (44.3-57.1)	45.3 (40.7-49.7)
Amphipod survival	>100	>100
Fish imbalance	12.7 (4.7-13.9)	12.8 (4.7-13.9)

The EC10 results of the two samples for each species were not significantly different, indicating that salinity was the sole cause of the toxicity.

ROUND TWO

In round two samples representing waste disposal Cases 1, 2 and 3 and intake water that had its salinity adjusted to that of the Case 2 sample were tested. Results for the DTA testing of the samples are presented in Table 5-37.

Table 5-37 Results of the direct toxicity assessment of Perth Seawater Desalination Plant concentrate plus pre-treatment supernatant discharge and salinity adjusted intake water

Direct toxicity assessment test	EC10 values (% sample)			
	Waste disposal options			Salinity adjusted intake
	3	2	1	
Microalgal yield	15 (0 – 26)	12*	38*	20 (0 – 27)
Sea urchin fertilisation	39.0 (37.6 – 40.4)	47.4 (46.4 – 48.1)	16.6 (10.9 – 20.5)	39.6 (36.3– 42.6)
Sea urchin larval development	13.0 (12.5 – 13.4)	7.3 (6.3 – 8.0)	13.4 (12.9 – 13.6)	13.1 (12.8 – 13.3)
Doughboy Scallop larval development	12.4 (12.0 – 12.6)	12.5 (12.0 – 12.6)	14.3 (12.3 – 15.1)	12.4 (12.0 – 12.6)
Macroalgal germination	40.7 (39.3 – 41.7)	64.6 (57.2 – 73.0)	54.2 (39.8 – 63.3)	41.3 (39.7 – 41.9)
Amphipod survival	> 100	> 100	> 100	> 100
Fish imbalance	17.2 (0.0 – 20.9)	18.2 (0.0 – 20.7)	18.6 (0.0 – 20.1)	19.0 (0.0 – 26.7)

* These values are NOECs rather than EC10 values.

NOEC values and EC10 values that do not have 95% confidence limits or are greater than 100 % cannot be statistically compared. For waste disposal Case 3, there were no significant differences in the EC10 values compared to those for the salinity adjusted intake for six datasets and it could not be determined if there were differences for the amphipod. For waste disposal Case 2, there were no significant differences in the EC10 values compared to those for the salinity adjusted intake for three datasets, and significant increases and decreases in toxicity for two datasets and it could not be determined if there were differences for the microalga and amphipod. For Case 1 there were no significant differences in the EC10 values compared to those for the salinity adjusted intake for four datasets, one dataset where the toxicity changed significantly and it could not be determined if there were differences for the microalga and amphipod.

While there are significant differences in the toxicity of samples for the various options to individual species there was no clear evidence that Case 2 and 1 have different toxicity to Case 3.

Direct toxicity assessment tests were also conducted on the ferric-dosed and polymer-dosed samples. As these results were not central to the aims of the project the data are not presented. Overall, both of these samples were considerably less toxic than all three of the waste discharge cases (i.e. 1, 2 and 3).

5.5.1.2 PROTECTIVE CONCENTRATIONS

ROUND ONE

The EC10 values for the salinity adjusted intake water from the PSDP that were used to derive the PC99 and safe dilution factors are presented in Table 5-38.

Table 5-38 Concentrations of the salinity adjusted intake water from the Perth Seawater Desalination Plant that cause a 10% effect (EC10) that were used in BurrliOZ to derive protective concentrations for 99% of species and corresponding safe dilution factors. The acute to chronic ratios were only applied to the acute toxicity values (i.e. for the amphipod and fish).

DTA Test	EC10 values (% sample) for salinity adjusted intake water			
	ACR 1	ACR 2.5	ACR 5	ACR 10
Microalgal yield	17	17	17	17
Sea urchin fertilisation	13.3	13.3	13.3	13.3
Sea urchin larval development 1	-	-	-	-
Doughboy Scallop development	12.3	12.3	12.3	12.3
Macroalgal germination	45.3	45.3	45.3	45.3
Amphipod survival	100	40	20	10
Fish imbalance	12.7	5.1	2.5	1.3

Figure 5-22 to 5-23 display the SSDs derived from the EC10 data showing the fit of the data by the BurrliOZ software.

1 Sea urchin larval development data was not used as BurrliOZ only uses one toxicity value per species and the sea urchin fertilisation is the more conservative.

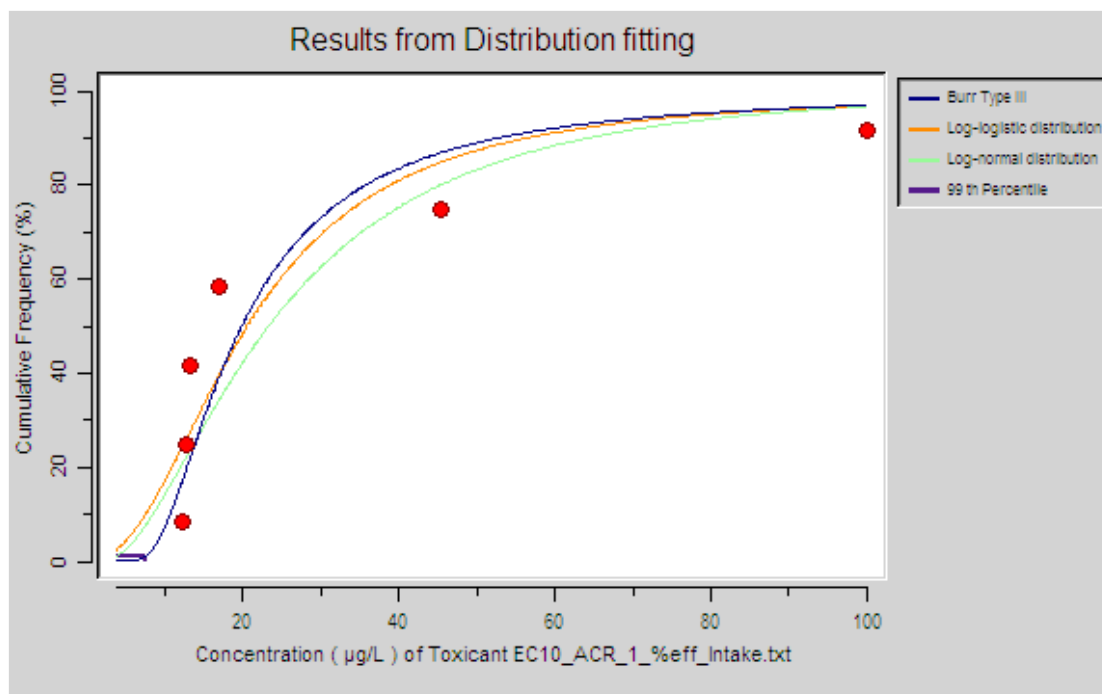


Figure 5-22 Species sensitivity distributions of EC10 values using an ACR of 1 for salinity adjusted intake water from the Perth Seawater Desalination Plant.

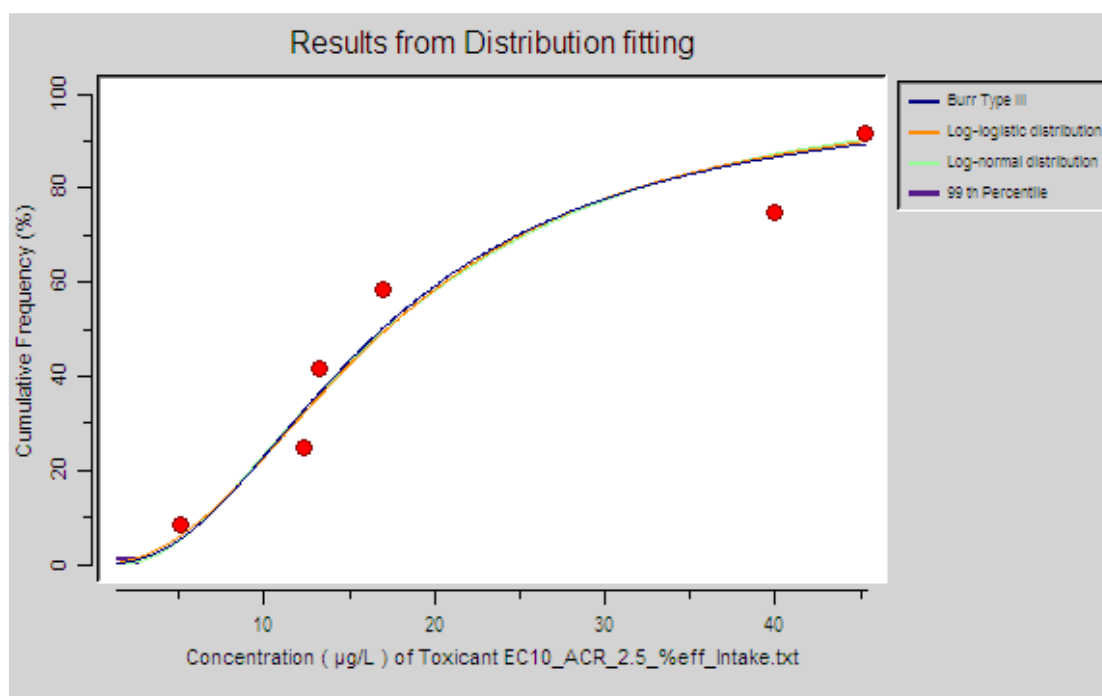


Figure 5-23 Species sensitivity distributions of EC10 values using an ACR of 2.5 for salinity adjusted intake water from the Perth Seawater Desalination Plant.

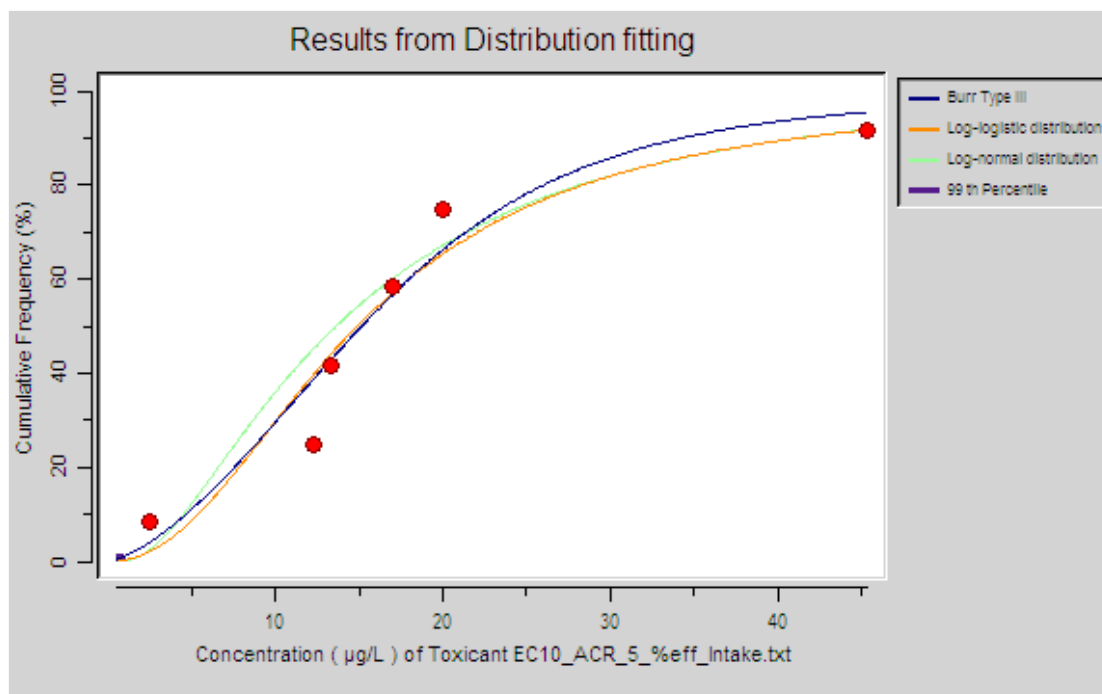


Figure 5-24 Species sensitivity distributions of EC10 values using an ACR of 5 for salinity adjusted intake water from the Perth Seawater Desalination Plant.

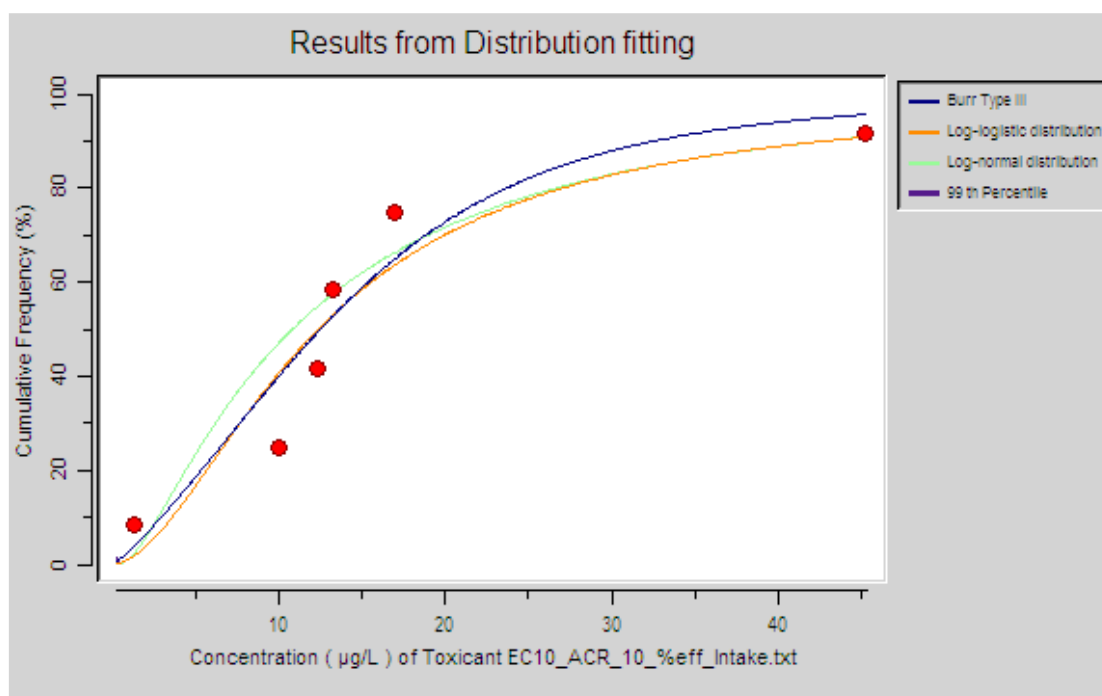


Figure 5-25 Species sensitivity distributions of EC10 values using an ACR of 10 for salinity adjusted intake water from the Perth Seawater Desalination Plant.

The fit of the Burr Type III distribution to each of the above sets of data was acceptable with the goodness of fit values ranging from 25 for the data with an ACR of 1 to 22.6 for the ACR of 10. The higher the goodness of fit values the better the fit. The values obtained for the above SSDs are similar to those obtained for trigger values in the Australian and New Zealand water quality guidelines (ANZECC and ARMCANZ, 2000) that are based on the same number of data.

The concentrations of the PSDP salinity adjusted intake water that must be achieved in order to protect 99% of species and corresponding safe dilution factors are presented in Table 5-39.

Table 5-39 Concentrations of the salinity adjusted intake water from the Perth Seawater Desalination Plant that should be met in order to protect 99% of species (PC99) and the corresponding safe dilution factors calculated from EC10 based species sensitivity distributions.

PC values and corresponding safety factors	PC99 (% sample) and safe dilution factors for salinity adjusted intake water			
	EC10 (ACR 1)	EC10 (ACR 2.5)	EC10 (ACR 5)	EC10 (ACR 10)
PC 99	7.44	2.62	0.95	0.40
Safe dilution factor	14:1	39:1	106:1	250:1

The safe dilution factors that must be achieved in order to protect 99% of endemic marine species ranged from 14:1 for an ACR of 1 to 220:1 for an ACR of 10 using EC10 data. By using the recommended ACR of 2.5, a safe dilution factor of 39:1 would be required to protect 99% of endemic marine species.

The EC10 values for the waste discharge Case 2 sample (concentrate plus pre-treatment supernatant) used to derive the PC99 and safe dilution factors are presented in Table 5-40.

Table 5-40 Concentrations of the Case 2 sample from the Perth Seawater Desalination Plant that cause a 10% effect (EC10) that were used in BurrliOZ to derive protective concentrations for 99% of species and corresponding safe dilution factors when acute to chronic ratios of 1, 2.5, 5 and 10 were used. 2

DTA Test	EC10 values (% sample) for Case 2 waste discharge			
	ACR 1	ACR 2.5	ACR 5	ACR 10
Microalgal yield	13	13	13	13
Sea urchin fertilisation	12.6	12.6	12.6	12.6
Sea urchin larval development³	-	-	-	-
Scallop larval development	12.6	12.6	12.6	12.6
Macroalgal germination	51.4	51.4	51.4	51.4
Amphipod survival	100	40	20	10
Fish imbalance	12.8	5.1	2.5	1.3

Figures 2-24 to 2-27 display the SSDs derived from the EC10 data showing the fit of the data by the BurrliOZ software.

2 ACR was only applied to acute toxicity data i.e. the fish and amphipod.

3 Sea urchin larval development data was not used as BurrliOZ only uses one toxicity value per species and the sea urchin fertilisation is the more conservative.

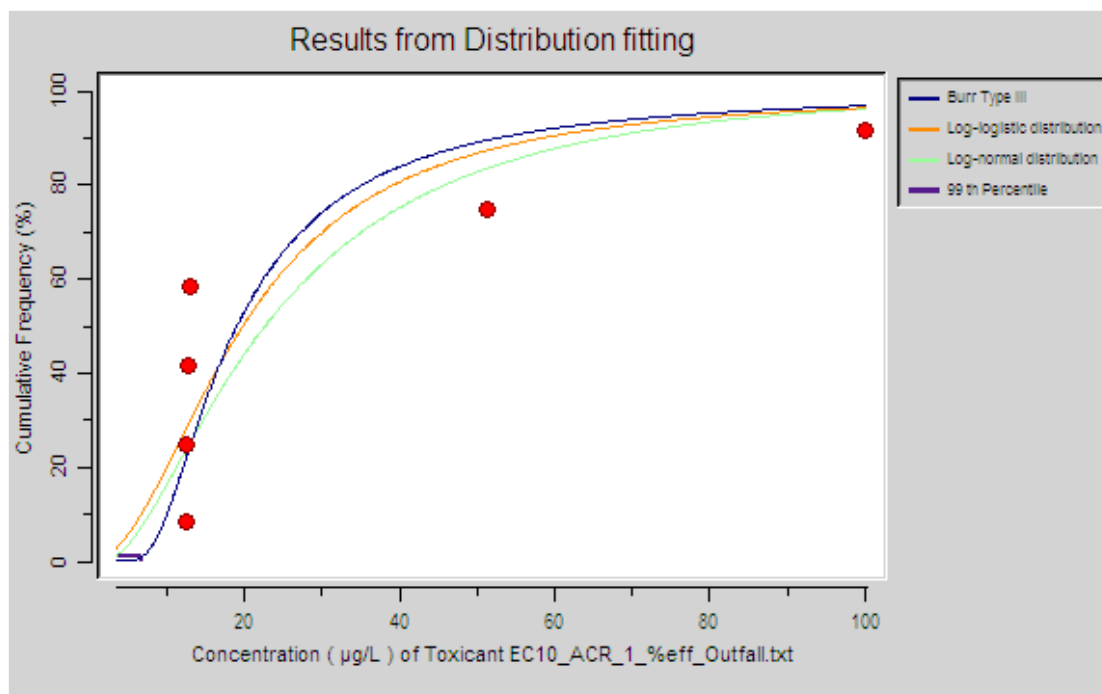


Figure 5-26 Species sensitivity distributions of EC10 values using an ACR of 1 for the Case 2 sample from the Perth Seawater Desalination Plant.

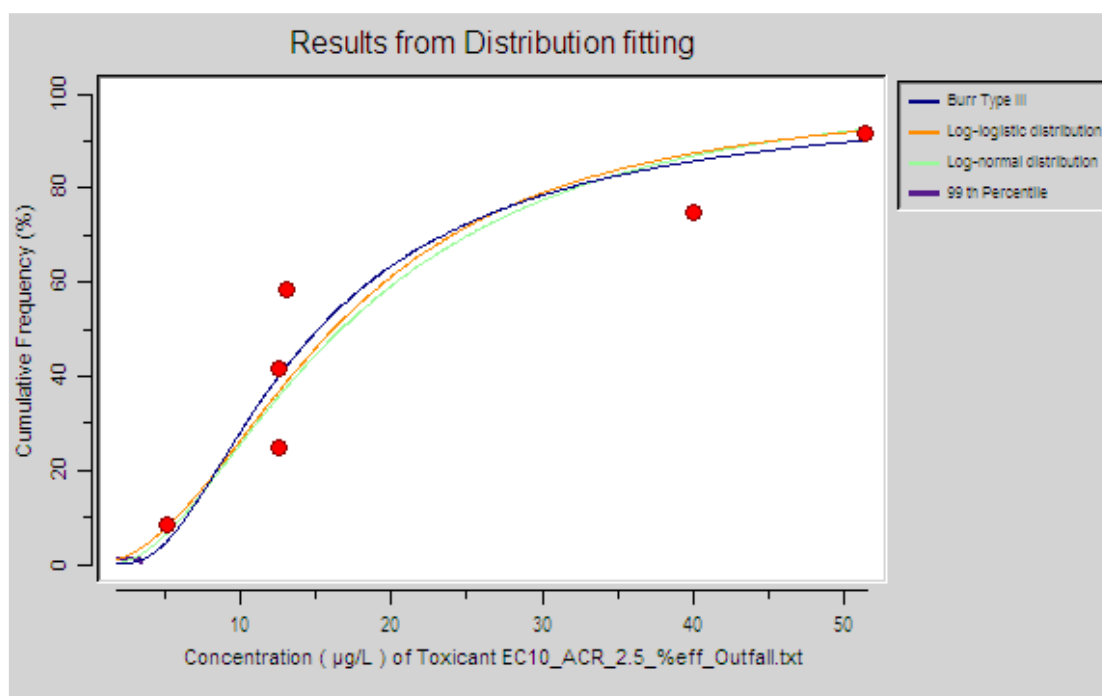


Figure 5-27 Species sensitivity distributions of EC10 values using an ACR of 2.5 for the Case 2 sample from the Perth Seawater Desalination Plant.

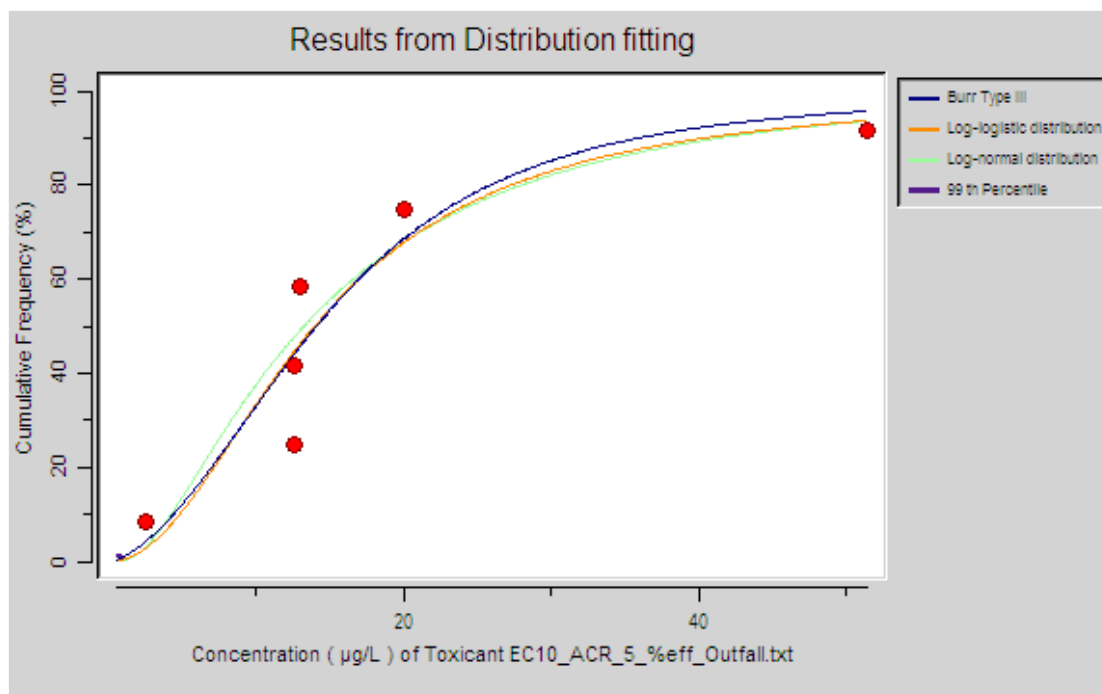


Figure 5-28 Species sensitivity distributions of EC10 values using an ACR of 5 for the Case 2 sample from the Perth Seawater Desalination Plant.

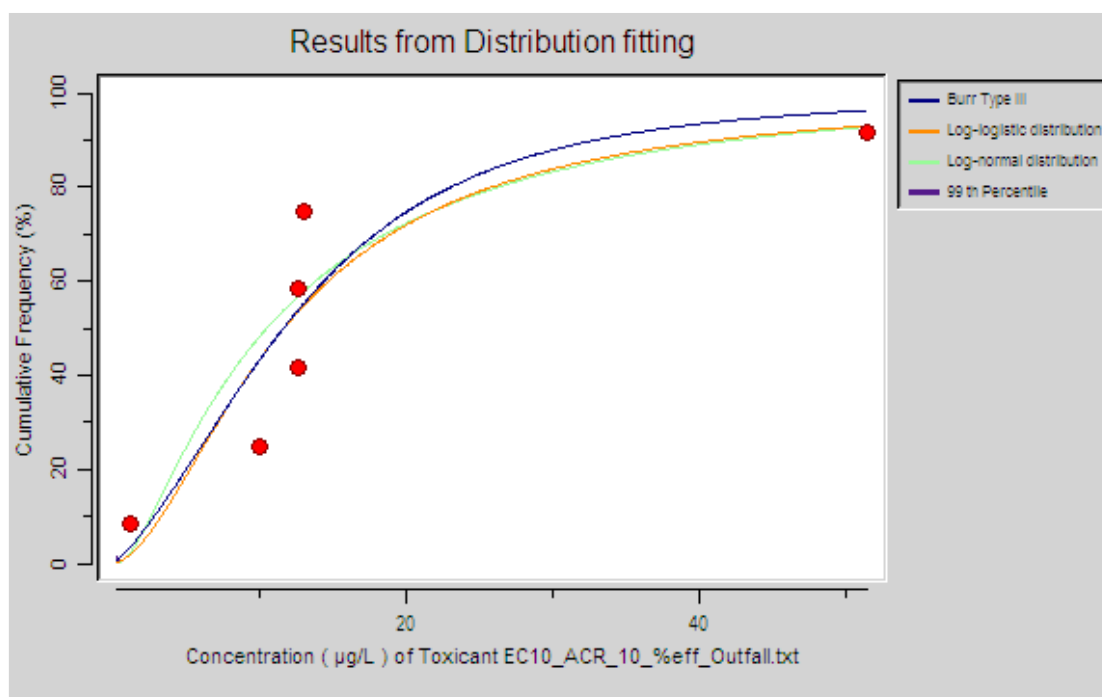


Figure 5-29 Species sensitivity distributions of EC10 values using an ACR of 10 for the Case 2 sample from the Perth Seawater Desalination Plant.

The fit of the Burr Type III distribution to each set of data was acceptable with the goodness of fit values ranging from 25.1 for the data with an ACR of 1 to 22.7 for the ACR of 10. The higher the goodness of fit values the better the fit. The values obtained for the above SSDs are similar to those obtained for trigger

values in the Australian and New Zealand water quality guidelines (ANZECC and ARMCANZ, 2000) that are based on the same number of data.

The concentrations of the Case 2 sample that must be achieved in order to protect 99% of endemic marine species and the corresponding safe dilution factors, derived from the Burr type III distribution, are presented in Table 5-41.

Table 5-41 Concentrations of the Case 2 discharge from the Perth Seawater Desalination Plant that should be met in order to protect 99% of species (PC99) and the corresponding safe dilution factors calculated from EC10 based species sensitivity distributions.

Type of value generated	PC99 (% sample) and safe dilution factors for waste discharge Case 2			
	EC10 (ACR 1)	EC10 (ACR 2.5)	EC10 (ACR 5)	EC10 (ACR 10)
PC 99	6.85	3.49	1.01	0.44
Safe dilution factor	15:1	29:1	100:1	228:1

Safe dilution factors calculated to protect 99% of species ranged from 15:1 for an ACR of 1 to 228:1 for an ACR of 10 using EC10 data. By using the ACR of 2.5, a safe dilution factor of 29:1 would be required to protect 99% of species.

ROUND TWO

The data used to calculate the PC99 and safe dilution factors for each of the three waste disposal options and the salinity adjusted intake sampled in round two are provided in

Table 5-42 to Table 5-45.

Table 5-42 Concentrations of the Case 1 discharge sample that cause a 10% effect (EC10) and were used in BurrliOZ to derive protective concentrations for 99% of species and safe dilution factors when acute to chronic ratio values of 1, 2.5, 5 and 10 were used to convert acute toxicity data to estimates of chronic toxicity. 4

DTA Test	EC10 values (% sample) for Case 1 waste discharge			
	EC ₁₀ (ACR 1)	EC ₁₀ (ACR 2.5)	EC ₁₀ (ACR 5)	EC ₁₀ (ACR 10)
Microalgal yield	38*	38	38	38
Sea urchin fertilisation	13.4	13.4	13.4	13.4
Sea urchin larval developments	-	-	-	-
Scallop larval development	14.3	14.3	14.3	14.3
Macroalgal germination	54.2	54.2	54.2	54.2

4 ACR was only applied to acute toxicity data i.e. the fish and amphipod.

5 Sea urchin larval development data was not used as BurrliOZ only uses one toxicity value per species and the sea urchin fertilisation is the more conservative.

Amphipod survival	100	40	20	10
Fish imbalance	18.6	7.4	3.7	1.9

Table 5-43 Concentrations of the Case 2 discharge sample that cause a 10% effect (EC₁₀) and were used in BurrliOZ to derive protective concentrations for 99% of species and safe dilution factors when acute to chronic ratio values of 1, 2.5, 5 and 10 were used to convert acute toxicity data to estimates of chronic toxicity.⁶

DTA Test	EC ₁₀ values (% sample) for Case 2 waste discharge			
	EC ₁₀ (ACR 1)	EC ₁₀ (ACR 2.5)	EC ₁₀ (ACR 5)	EC ₁₀ (ACR 10)
Microalgal yield	12*	12	12	12
Sea urchin fertilisation	7.3	7.3	7.3	7.3
Sea urchin larval development⁷	-	-	-	-
Scallop larval development	12.5	12.5	12.5	12.5
Macroalgal germination	64.6	64.6	64.6	64.6
Amphipod survival	100	40	20	10
Fish imbalance	18.2	7.3	3.6	1.8

Table 5-44 Concentrations of the Case 3 discharge sample that cause a 10% effect (EC₁₀) and were used in BurrliOZ to derive protective concentrations for 99% of species and safe dilution factors when acute to chronic ratio values of 1, 2.5, 5 and 10 were used to convert acute toxicity data to estimates of chronic toxicity.

DTA Test	EC ₁₀ values (% sample) for Case 3 waste discharge			
	EC ₁₀ (ACR 1)	EC ₁₀ (ACR 2.5)	EC ₁₀ (ACR 5)	EC ₁₀ (ACR 10)
Microalgal yield	15	15	15	15
Sea urchin fertilisation	13	13	13	13
Sea urchin larval development	-	-	-	-
Scallop larval development	12.4	12.4	12.4	12.4
Macroalgal germination	40.7	40.7	40.7	40.7

⁶ ACR was only applied to acute toxicity data i.e. the fish and amphipod.

⁷ Sea urchin larval development data was not used as BurrliOZ only uses one toxicity value per species and the sea urchin fertilisation is the more conservative.

Amphipod survival	100	40	20	10
Fish imbalance	17.2	6.9	3.4	1.7

Table 5-45 Concentrations of the salinity adjusted intake water sample that cause a 10% effect (EC10) and were used in BurrliOZ to derive protective concentrations for 99% of species and safe dilution factors when acute to chronic ratio values of 1, 2.5, 5 and 10 were used to convert acute toxicity data to estimates of chronic toxicity⁸.

DTA Test	EC10 values (% sample) for salinity adjusted intake			
	EC ₁₀ (ACR 1)	EC ₁₀ (ACR 2.5)	EC ₁₀ (ACR 5)	EC ₁₀ (ACR 10)
	% eff	% eff	% eff	% eff
Microalgal yield	20	20	20	20
Sea urchin fertilisation	13.1	13.1	13.1	13.1
Sea urchin larval development⁹	-	-	-	-
Scallop larval development	12.4	12.4	12.4	12.4
Macroalgal germination	41.3	41.3	41.3	41.3
Amphipod survival	100	40	20	10
Fish imbalance	19	7.6	3.8	1.9

Figure 5-30 to Figure 5-45 display the SSDs derived from the EC10 data showing the fit of the data by the BurrliOZ software.

⁸ ACR was only applied to acute toxicity data i.e. the fish and amphipod.

⁹ Sea urchin larval development data was not used as BurrliOZ only uses one toxicity value per species and the sea urchin fertilisation is the more conservative.

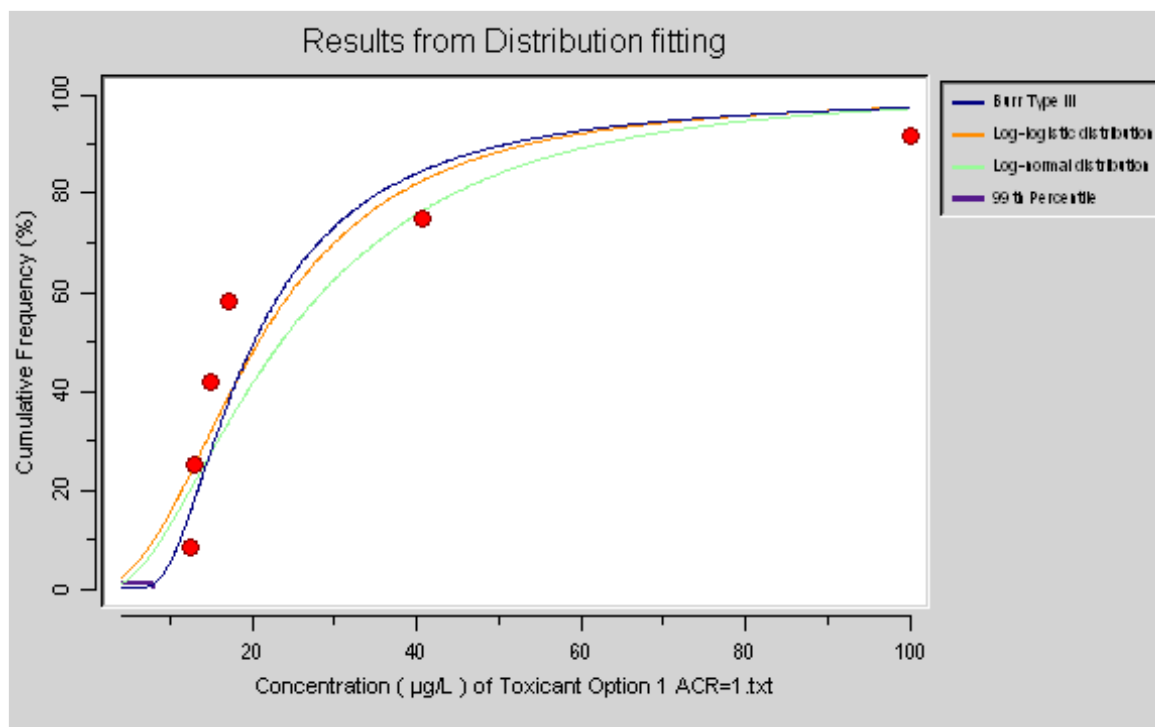


Figure 5-30 Species sensitivity distributions of EC10 values using an ACR of 1 for the round two Case 3 sample from the Perth Seawater Desalination Plant.

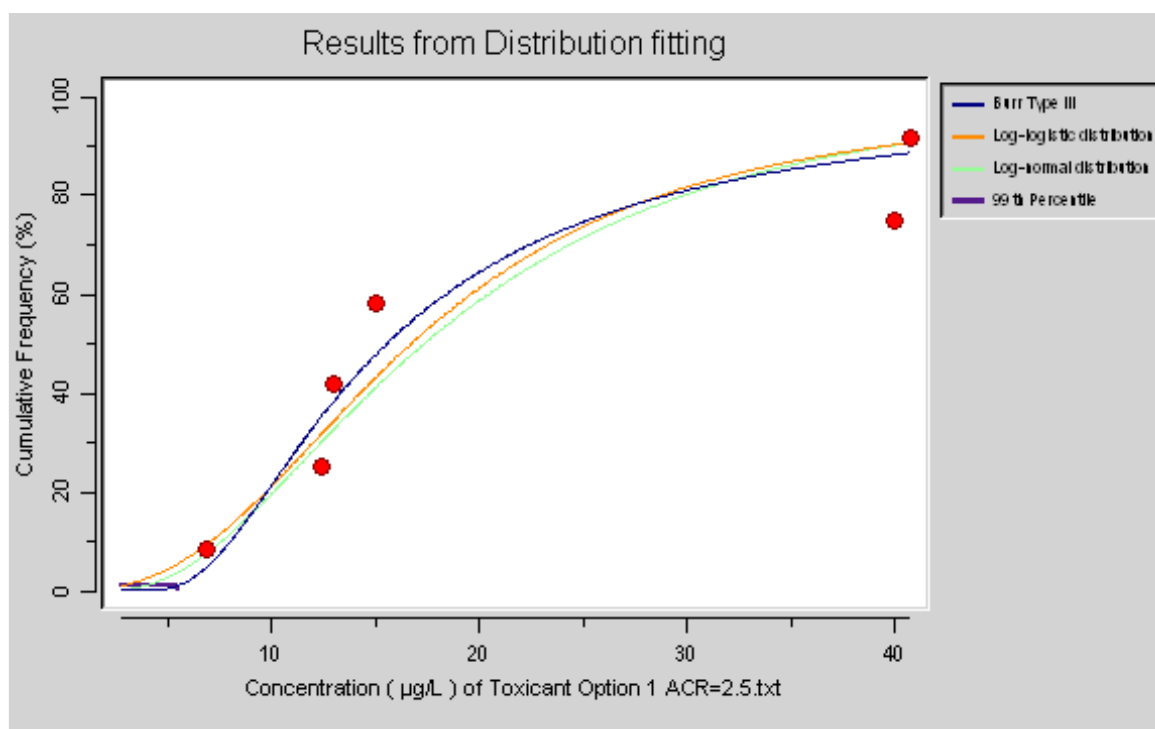


Figure 5-31 Species sensitivity distributions of EC10 values using an ACR of 2.5 for the round two Case 3 sample from the Perth Seawater Desalination Plant.

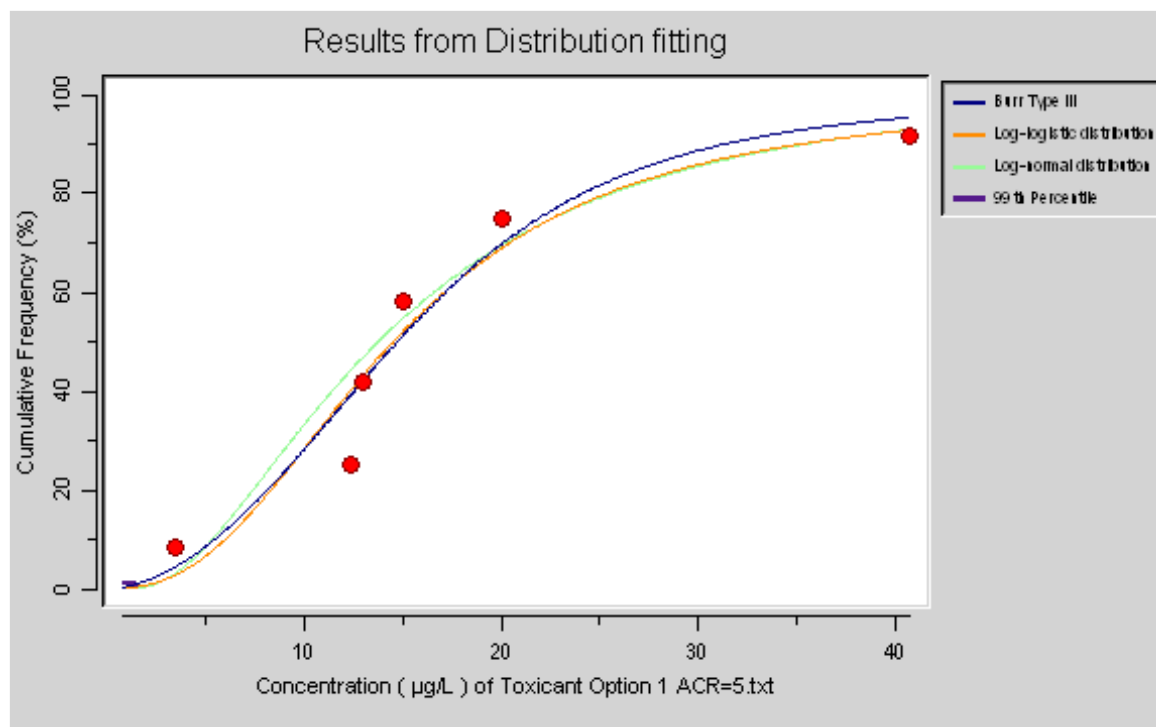


Figure 5-32 Species sensitivity distributions of EC10 values using an ACR of 5 for the round two Case 3 sample from the Perth Seawater Desalination Plant.

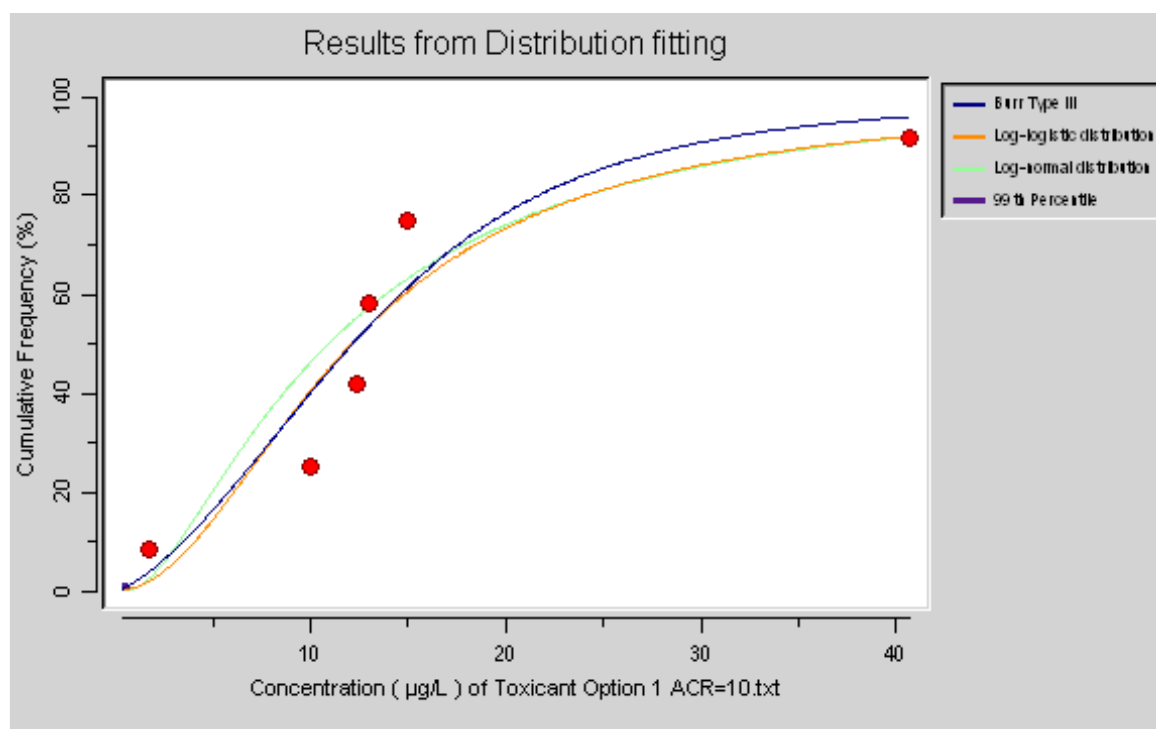


Figure 5-33 Species sensitivity distributions of EC10 values using an ACR of 10 for the round two Case 3 sample from the Perth Seawater Desalination Plant.

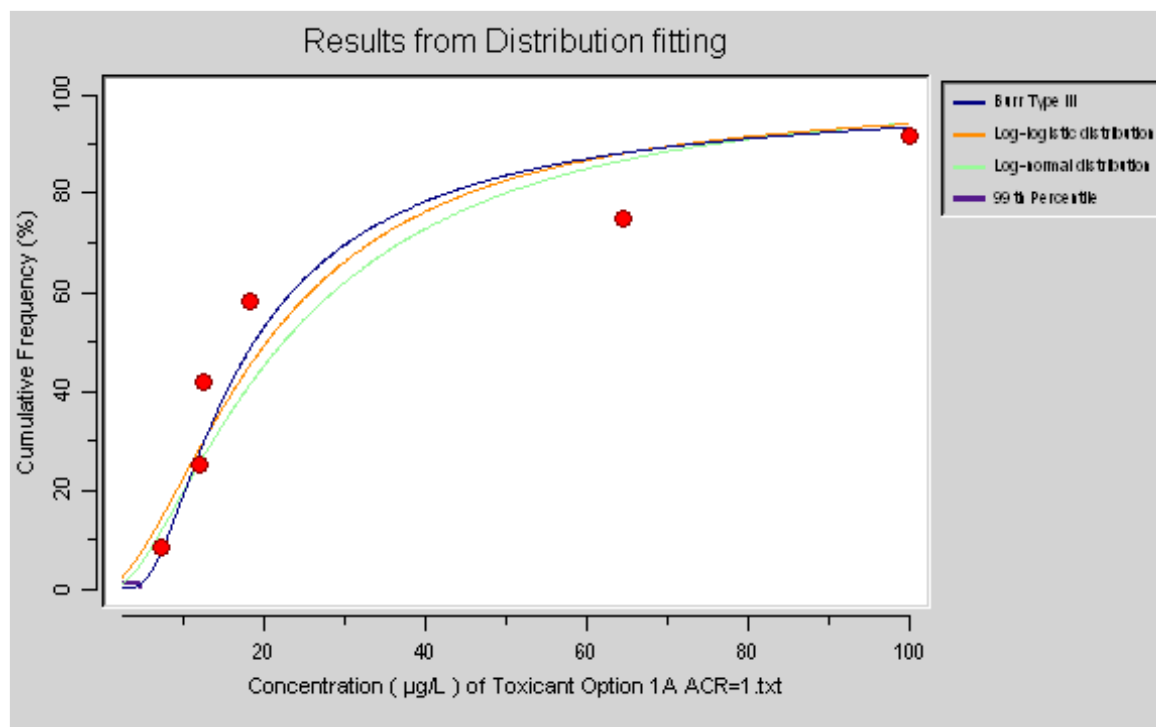


Figure 5-34 Species sensitivity distributions of EC10 values using an ACR of 1 for the round two Case 2 sample from the Perth Seawater Desalination Plant.

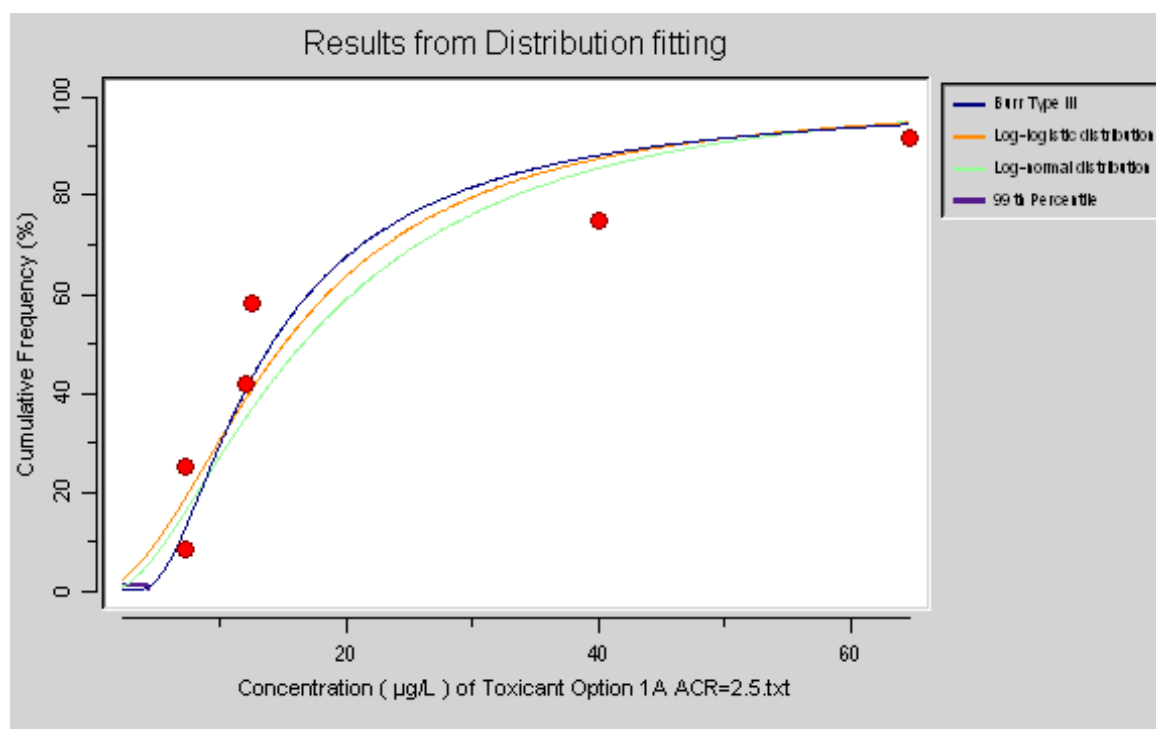


Figure 5-35 Species sensitivity distributions of EC10 values using an ACR of 2.5 for the round two Case 2 sample from the Perth Seawater Desalination Plant.

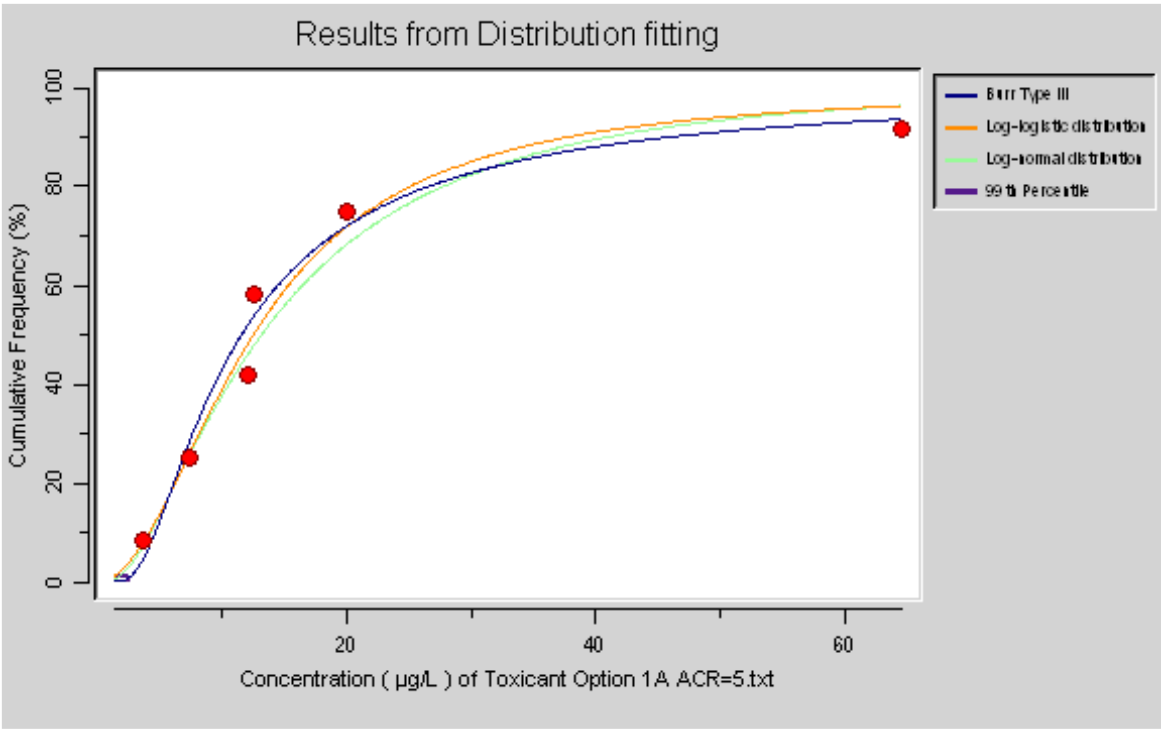


Figure 5-36 Species sensitivity distributions of EC10 values using an ACR of 5 for the round two Case 2 sample from the Perth Seawater Desalination Plant.

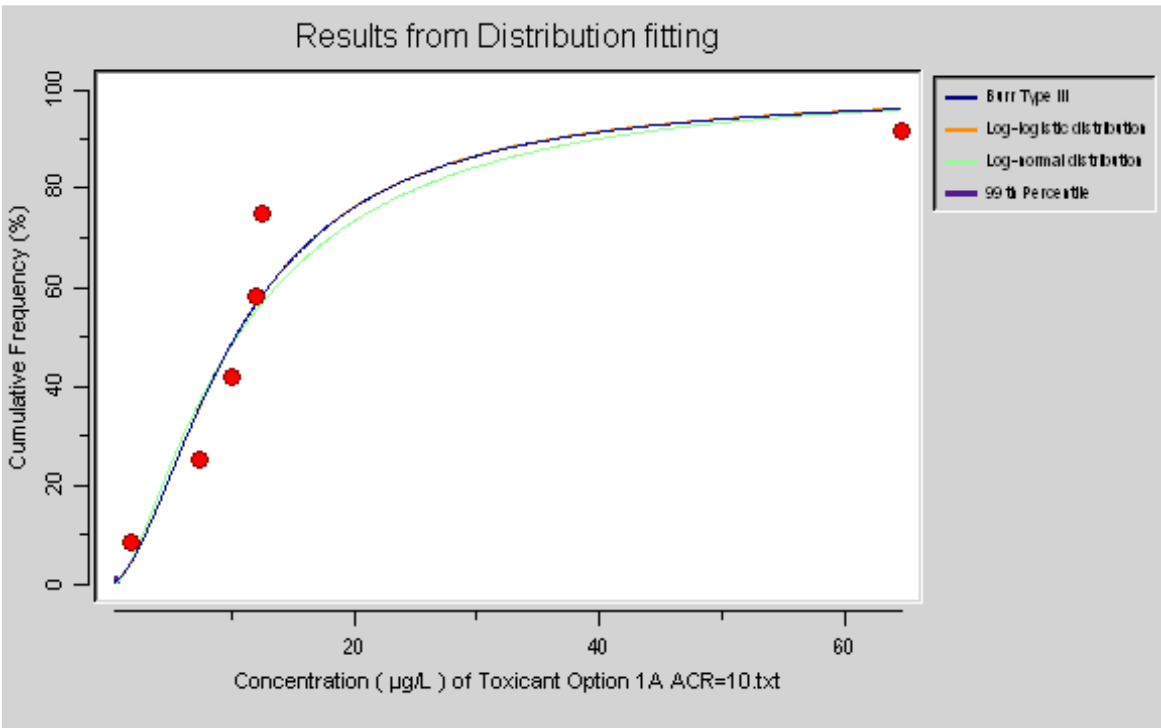


Figure 5-37 Species sensitivity distributions of EC10 values using an ACR of 10 for the round two Case 2 sample from the Perth Seawater Desalination Plant.

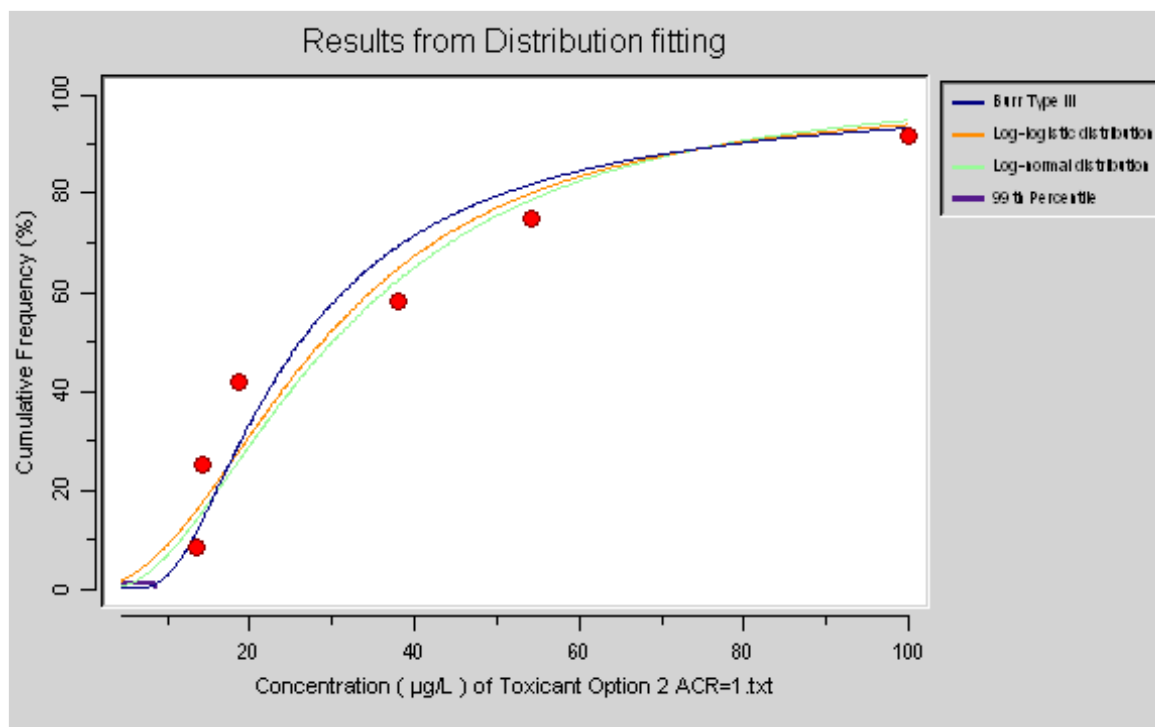


Figure 5-38 Species sensitivity distributions of EC10 values using an ACR of 1 for the round two Case 1 sample from the Perth Seawater Desalination Plant.

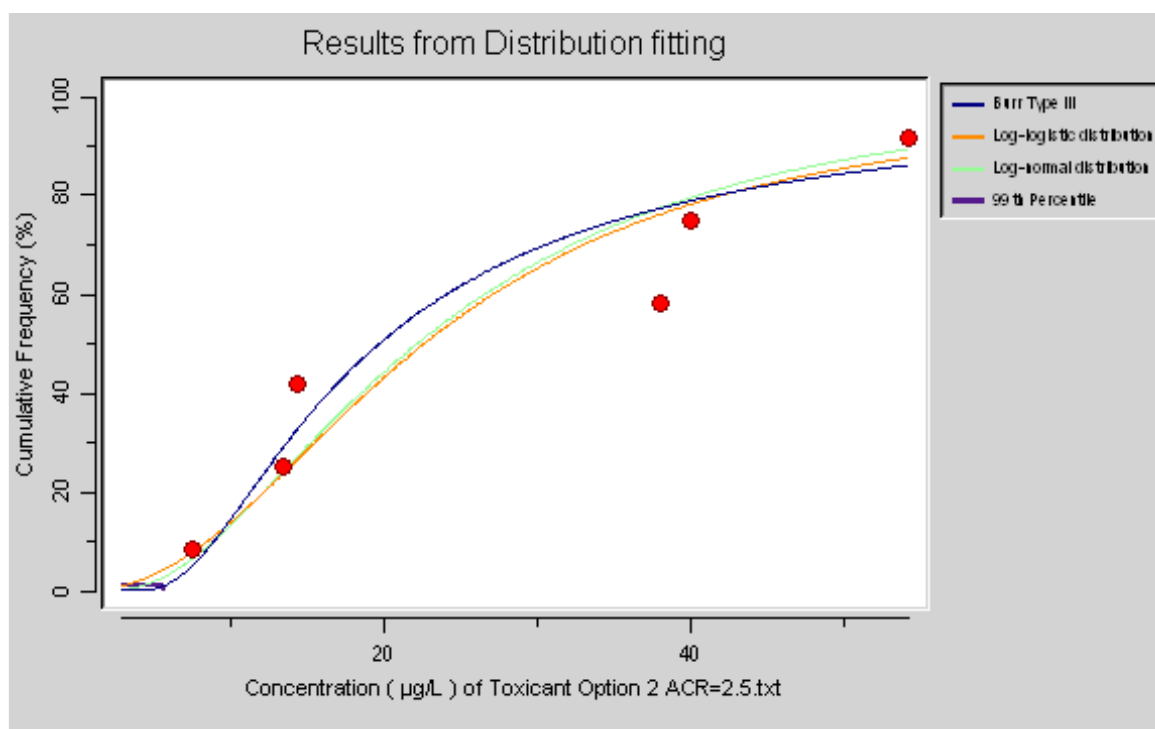


Figure 5-39 Species sensitivity distributions of EC10 values using an ACR of 2.5 for the round two Case 1 sample from the Perth Seawater Desalination Plant.

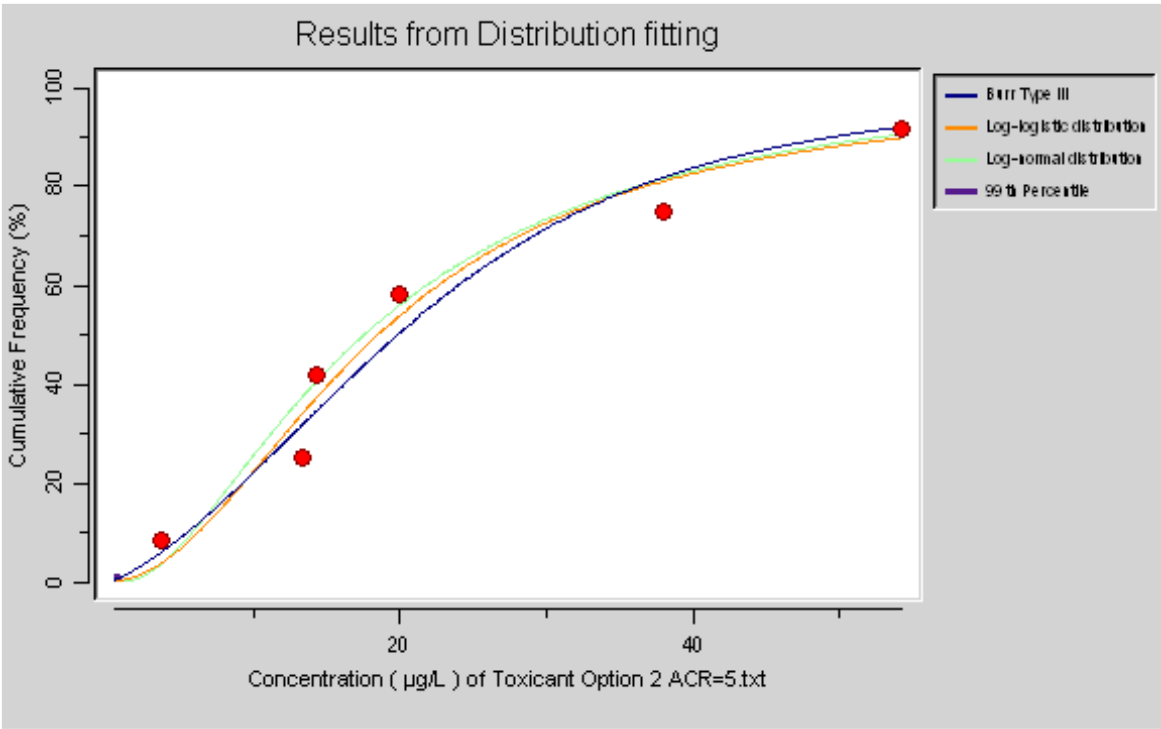


Figure 5-40 Species sensitivity distributions of EC10 values using an ACR of 5 for the round two Case 1 sample from the Perth Seawater Desalination Plant.

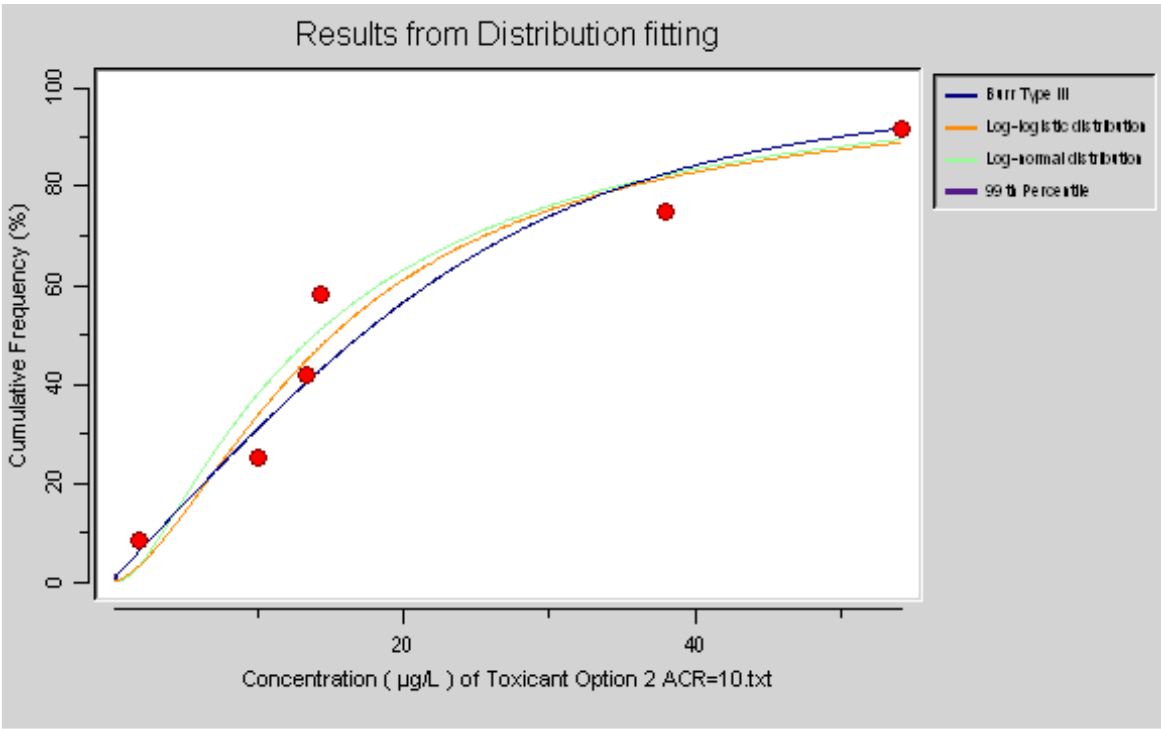


Figure 5-41 Species sensitivity distributions of EC10 values using an ACR of 10 for the round two Case 1 sample from the Perth Seawater Desalination Plant.

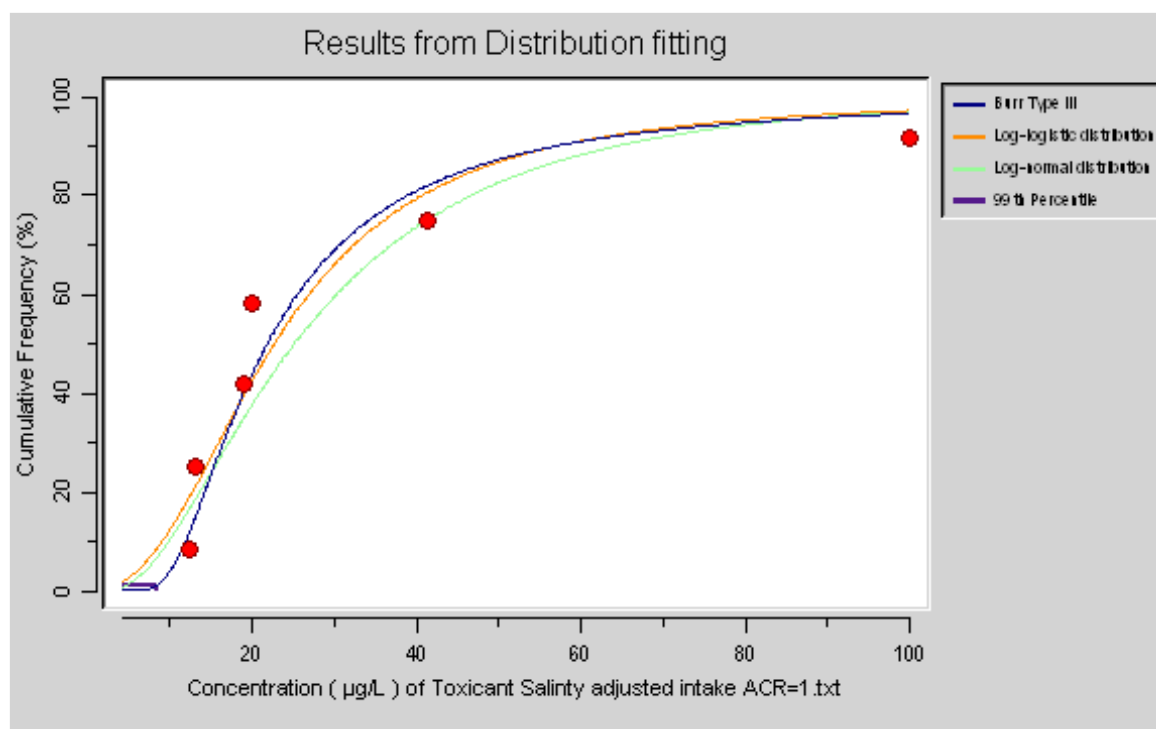


Figure 5-42 Species sensitivity distributions of EC10 values using an ACR of 1 for the round two salinity adjusted intake sample from the Perth Seawater Desalination Plant.

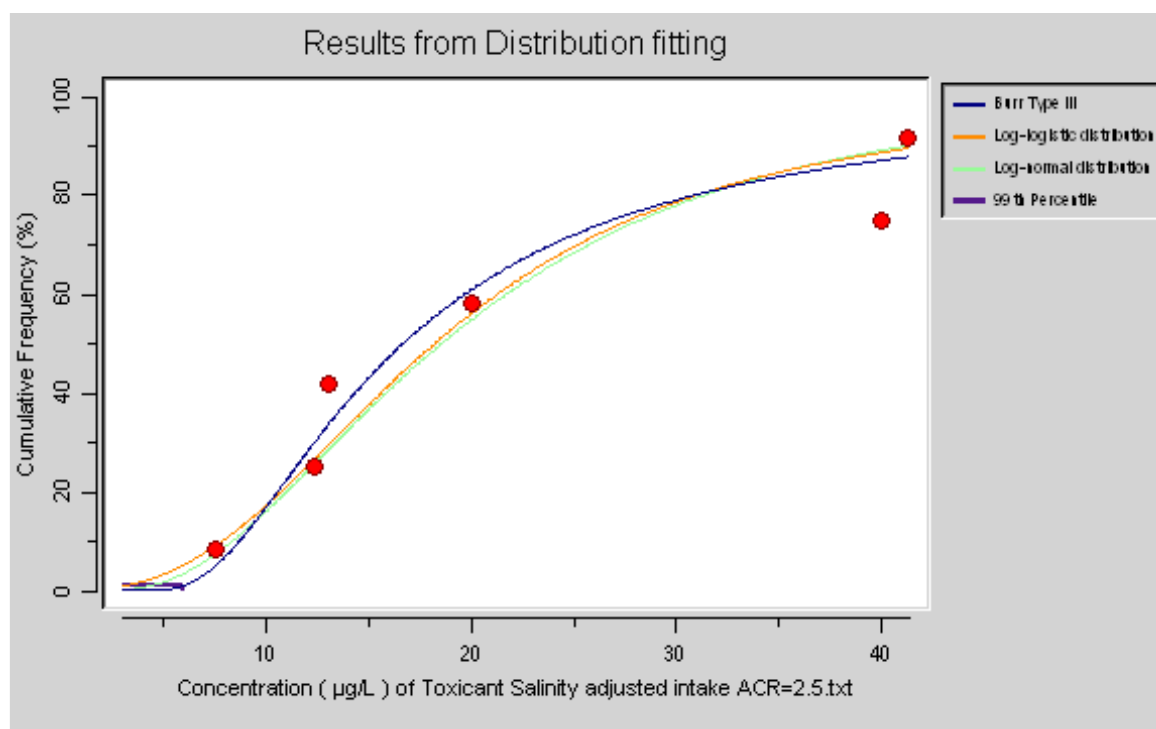


Figure 5-43 Species sensitivity distributions of EC10 values using an ACR of 2.5 for the round two salinity adjusted intake sample from the Perth Seawater Desalination Plant.

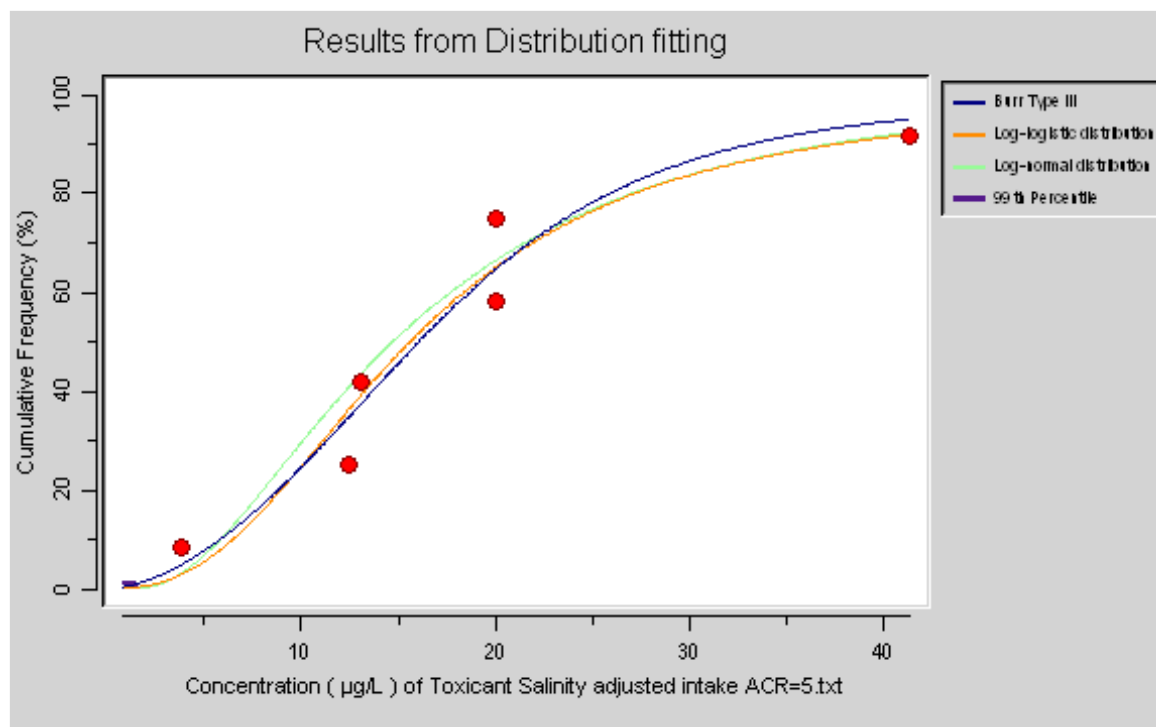


Figure 5-44 Species sensitivity distributions of EC10 values using an ACR of 5 for the round two salinity adjusted intake sample from the Perth Seawater Desalination Plant.

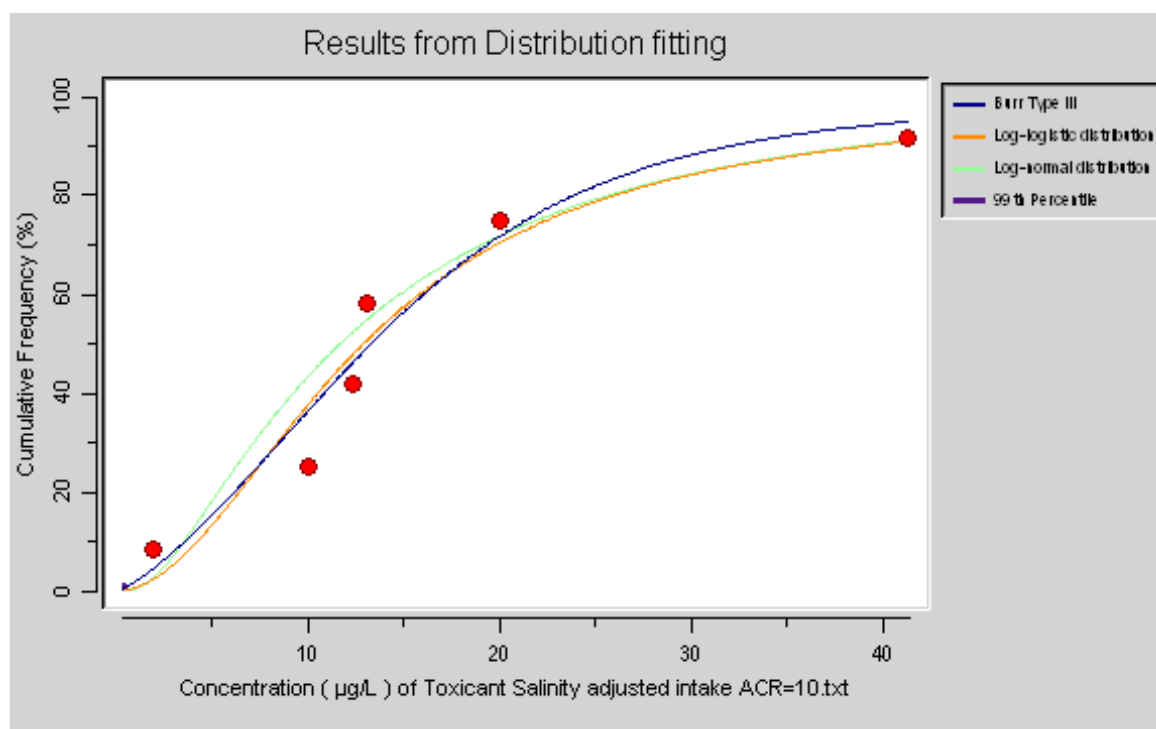


Figure 5-45 Species sensitivity distributions of EC10 values using an ACR of 10 for the round two salinity adjusted intake sample from the Perth Seawater Desalination Plant.

The fit of the Burr Type III distribution to each set of round two toxicity data was acceptable with the goodness of fit values ranging from 22.01 to 26.81. The higher the goodness of fit values the better

the fit. The values obtained for the above SSDs are similar to those obtained for trigger values in the Australian and New Zealand water quality guidelines (ANZECC and ARMCANZ, 2000) that are based on the same number of data.

The PC99 and corresponding safe dilution factors derived for the waste discharge option samples are presented in Table 5-46. As would be expected the size of the PC99 values decreases while the size of the safe dilution factors increases for each sample as the ACR values increase in size. The PC99 values for the various samples calculated using one ACR are all similar varying by no more than a factor of 2.7 (e.g. the PC99 values in column three). The safe dilution factors for the various samples calculated using one ACR are also similar, again varying by no more than a factor of 2.7. The safe dilution factors presented in Table 5-46 ranged from 11.6 (Case 1 with an ACR of 1) to 345 (Case 1 with an ACR of 10). The safe dilution factors calculated using the recommended ACR of 2.5 ranged from 16.7 to 22.6.

Table 5-46 The concentrations of the round two samples that should theoretically protect 99% of marine species (PC99) and the corresponding safe dilution factors calculated using EC10 data and a range of acute to chronic ratios.

Sample	Type of data generated	PC99 (% sample) and safe dilution factors			
		EC10 (ACR 1)	EC10 (ACR 2.5)	EC10 (ACR 5)	EC10 (ACR 10)
Case 1	PC 99	8.64	5.61	0.99	0.29
	Safe dilution factor	11.6	17.8	101	345
Case 2	PC 99	4.79	4.42	2.57	0.76
	Safe dilution factor	20.9	22.6	38.9	131.6
Case 3	PC 99	7.97	5.45	1.51	0.65
	Safe dilution factor	12.5	18.3	66.2	153.8
Salinity adjusted intake	PC 99	8.36	5.98	1.52	0.61
	Safe dilution factor	12	16.7	65.8	163.9

5.6 DIRECT TOXICITY ASSESSMENT OF LOW FLOW DISCHARGE - GCDP

Veolia commissioned Hydrobiology to investigate the potential for local marine organisms to suffer from acute toxicity after short-term exposure (i.e. less than 4h) to waste brines from the Gold Coast Desalination Plant (GCDP). This investigation was designed to address the potential risk associated with occasional short exposures to waste brines that may occur as a result of, for example, an emergency plant shut down during which low flow desalination effluent would be released through the diffuser.

Hydrobiology developed an adapted ecotoxicological testing method in conjunction with Ecotox Services Australasia for a direct toxicity assessment of short-duration pulse exposures of desalination brine to discharge area organisms. This was in response to unplanned shut downs of the desalination plant (power outages etc.) which caused a decrease in pressure at the outfall diffuser, resulting in short pulses of increased salinity brines reaching the receiving environment. The study identified the potential impact in terms of acute toxicity to the resident organisms in the outfall area.

The following three tests were selected for the pulse exposure testing as they were the most sensitive tests of the DTA suite previously tested for the GCDP:

- 72h marine algal growth test using *Nitzschia closterium* (based on Stauber et al. 1994)
- 48h bivalve larval development using the Sydney rock oyster *Saccostrea glomerata* (based on Krassoi et al. 1995, 1996 and APHA, 1998)
- 96h larval fish imbalance toxicity test using barramundi *Lates calcarifer* (based on USEPA 2002)

Test organisms were exposed to a 1h and 4-hour pulse concentrated effluent treatment after which the water was replaced with background seawater (i.e. reflecting typical conditions outside of the mixing zone when standard operation of the desalination plant occurs) and were maintained for the remainder of the test.

This new pulse-exposure DTA indicated that marine organisms tended to be less sensitive when exposed to elevated salinity for a few hours (up to 4 hours) compared with longer exposures. The following TVs were derived for pulse exposures such as those observed in low flow incidents:

- salinity concentration up to 42.0 ppt for an incident lasting less than one hour; and
- salinity concentration up to 41.9 ppt for an incident up to 4h.

5.7 SEAWATER DESALINATION ECOTOXICITY ASSESSMENT SUMMARY

The size and scale of each of the operational large seawater desalination plants in Australia and the dilution required to protect the receiving environment and the stated dilution achieved by each plants diffusers can be seen in Table 6-1. As can be seen, the required dilution ratio for all of these plants under normal operation is less than the proposed EDPD discharge dilution of 40:1, which can be considered very conservative in the context of the other operating plants. As discussed in Section 3, the toxicity associated with process and cleaning chemicals can be managed using standard procedures for their disposal into the waste stream at appropriate concentrations to ensure they have no effect on the receiving environment upon discharge.

6. RECOMMENDATIONS

Given the results from the ecotoxicity assessments of the ADP and ODDP where regionally relevant species were used for pre and post operational assessments, the EPDP will be considerably smaller (24 ML/day) than that of the ADP (250ML/day) and the discharge brine will be less saline due to a lower recovery rate, and that only ADP approved process chemicals and requirements for cleaning chemical disposal will be enforced for the EPDP, a full ecotoxicological assessment of the EPDP discharge is not deemed necessary. Where the disposal of CIP chemicals is considered in the waste stream, the required dilution will need to be achieved as per the ADP assessment. For alternative CIP chemicals, a full ecotoxicity assessment similar to that carried out as part of the ADP ecotoxicity assessment to derive a safe dilution will need to be completed.

It is recommended that a subset of regionally relevant organisms be used to do chronic pre-operational ecotoxicity testing of a pilot plant saline concentrate. The suggested species and tests should include:

- *N. closterium* 72h growth inhibition test.
- *M. gallaprovincialis* 14-day larval development test.
- *H. tuberculata* 72h larval development test.

The results of these tests can then be directly compared with the ADP results, but also supported by the results from the numerous tests undertaken on large seawater desalination plants around Australia for more toxicity context. The inclusion of the microalga is important to understand the potential additional toxicity of added anti-scalant above that seen for salinity alone. The pilot plant concentrate must be produced using water collected from the proposed feed water point and the proposed anti-scalant. Feed water should also be used as the ecotoxicity test diluent. These results should be within the bounds of that seen for the ADP assessment results considering the differences in the salinity of the discharge brine. This should indicate if the proposed 40:1 dilution to be achieved by the EPDP will be adequate to protect the receiving environment from any adverse effects from the brine discharge.

We also recommend that a post operational ecotoxicity assessment of the brine discharge be undertaken using the same subset of ecotoxicity tests as the plant is commissioned and brought up to

capacity, in a similar requirement to that placed upon the ADP (for example testing to be carried out at 50% of total production then 3 months and 6 months after full production has commenced).

Given the results of the ecotoxicological assessments for other large seawater desalination plants in Australia and the resultant discharge dilution ratios (Table 6-1), and the size and output volume of the proposed EPDP, the proposed 40:1 dilution rate that is to be achieved by the edge of the mixing zone should be adequate to protect the receiving environment. The recommended pre and post commissioning testing regime will ensure that this is achievable. The treatment of cleaning chemicals should be handled so that concentrations that enter the discharge stream are very low and present no risk to the receiving environment.

Table 6-1 Stated achievable dilution ratios and calculated dilutions ratios for selected large seawater desalination plants.

Plant	Max operation capacity (ML/day)	Stated achievable dilution ratio	Calculated required dilution ratio
Adelaide Desalination Plant	275	50:1	11:1 – 21:1 for 95% protection
Victoria Desalination Plant	410	30:1	29:1 for 99% protection
Sydney Desalination Plant	250	30:1	40:1 for 95% (Stream 2 as the most toxic)
Perth Desalination Plant	144	45:1	13:1 for 95% protection
Eyre Peninsula Desalination Plant	24	40:1	TBD

7. REFERENCES

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- Voutchkov, N. (2011). Overview of seawater concentrate disposal alternatives. *Desalination*, 273(1), 205–219. <https://doi.org/10.1016/j.desal.2010.10.018>
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