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SUBJECT: RESPONSE TO THE INDEPENDENT REVIEW OF THE SARDI REPORT ENTITLED '*OCEANOGRAPHIC MONITORING AND FAR-FIELD MODELLING TO INFORM DESALINATION IN BOSTON BAY*' (SARDI PUBLICATION NO. F2022/000347-1) BY A/PROF. JOCHEN KAEMPF.

FROM: A/PROF. MARK DOUBELL AND DR CHARLES JAMES (SARDI AQUATIC AND LIVESTOCK SCIENCES)

CONTACT: PIRSA.SARDIEXECUTIVEOFFICE@SA.GOV.AU

DATE: 31 MARCH 2023

BACKGROUND

This document provides a response to the review of the SARDI report "*Oceanographic monitoring and far-field modelling to inform desalination in Boston Bay*" undertaken by Associate Professor Jochen Kaempf (hereafter the Reviewer) for Eyre Peninsula Seafoods Pty Ltd (hereafter EPS). SARDI became aware of the review after it was made publicly available on the 'ResearchGate' website on the 10th of March 2023.

Having been made aware of the review, and in recognition that the academic peer review process plays an important role in assessing and improving the quality of scientific publication, we have provided the following response to the 'critical questions to the SARDI authors' raised by the Reviewer. Most of the Reviewers criticisms align with the near-field modelling (which is a separated body of work yet to be completed and was not in the scope of the SARDI report), or concern site selection. The SARDI report was one of several reports commissioned by SA Water to provide the science to inform the decision-making process. Importantly, the report does not recommend a site. This appears to have been misunderstood by the Reviewer.

The modelling undertaken in the report was for a 5-year interval and a brine discharge (equivalent to 12GL/year) 50% above the proposed desalination plants maximum capacity (8GL/year). Brine was discharged into the bottom layer (~1m) of the model at sites nominated by SA Water. This provided an ultra-conservative approach to modelling the potential far-field and long-term impacts of brine outfalls as explained in the report.

It should be emphasised that the Reviewers assertion that the report was not peer reviewed is incorrect. The SARDI report was extensively reviewed externally by an independent Marine Science Review Panel (MSRP) as well as SARDI's internal review process. The MSRP consisted of national and international experts representing different disciplines of marine science including ecology, oceanography, and numerical modelling. The MSRP interacted closely with SA Water, the 'Site Selection Committee' and the SARDI authors to critically review the science, challenge its scientific rigor, and refine the language to improve its translation to a diverse stakeholder group and relevant decision-makers. The SARDI internal review process provided another layer of critical review, with an emphasis on whether stated objectives were met, and the interpretation of key results were adequately supported by robust science.

RESPONSE TO 'CRITICAL QUESTIONS TO THE SARDI AUTHORS'

1. Grid resolution: Why didn't you use a higher grid resolution to predict salinities at 100 m from the discharge structure, so that the salinity values can be compared with other desalination discharges? Do you agree that a higher grid resolution can yield higher salinity anomalies?

The authors do not agree that a higher grid resolution would result in higher salinity anomalies. This is because concentrations in the far-field model are defined in terms of mass per unit volume. The salinity anomaly is treated as the concentration difference and is therefore independent of the grid resolution. The Reviewer appears to have confused the report's objective of providing far-field modelling over the purpose of near-field modelling being undertaken by engineers to ensure brine discharges and salinity concentrations meet EPA mandated dilution standards and trigger values at a certain distance (e.g., 100 m) from the desalination diffusers. Near-field modellers do their own high resolution bathymetric surveys and use different models (e.g., CORMIX) to predict regulatory mixing zones and associated salinity concentrations. Our report clearly articulates the limitations of the far-field modelling to predict salinity concentrations at spatial resolutions less than the model grid resolution and the need for near-field modelling to fill this gap.

The purpose of this study was to develop a model to provide an understanding of the far-field and long-term capacity of Port Lincoln's surrounding embayments to flush brine discharges from several outfall locations proposed by SA Water. This was achieved using a model grid with a 300m horizontal resolution and 15 layers in the vertical. Salinity predictions were provided across a range of time intervals (hourly to seasonal averages) and spatial scales (at the injection cell and out to tens of kilometres from outfalls) to achieve this objective. The results provided a consistent picture of the relationship between brine dispersal and flushing consistent with flushing estimates derived from modelling studies (Herzfeld et al. 2008; Middleton et al. 2014).

The 300m model resolution chosen to meet these objectives was constrained by the bathymetric data available for the model grid development. This is a common challenge for ocean modellers. There is no benefit in developing a grid at a much higher resolution than that of the available bathymetric data. As detailed in the report, substantial effort was invested into improving the model grid using bathymetry data sourced from the Australian Hydrographic Office to improve predictions for the region. The resultant model grid bathymetry provided a significant improvement over previous grids used in South Australian regional models (Kaempf et al. 2009, 2010; Middleton et al. 2014, 2017). This includes the model grid previously used by the Reviewer to predict the potential "near-field" (~450 m resolution) and "far-field" (~3km resolution) flushing and dispersal of desalination brine discharges from upper Spencer Gulf (Kaempf et al. 2009).

2. Turbulent diffusion: Model assumptions altering turbulent diffusion strongly control the simulated dilution of desalination brine in the model. Given this, do you agree that your salinity predictions are highly uncertain and cannot be used to infer environmental impacts due to desalination discharges?

The authors do not agree that the salinity predictions are highly uncertain and cannot be used to infer impacts due to desalination discharges. Hydrodynamic models, such as the open-source ROMS model used by SARDI, or the COHERENS model previously used by the Reviewer (Kaempf et al. 2009), include a choice of turbulent closure schemes and other mixing parametrizations to account for sub-grid scale processes. The development, cross-comparison and validation of these mixing

parametrizations is a separate area of specialised research (e.g., Warner et al. 2005; Robertson and Dong, 2019). The internationally accepted approach to determining the appropriateness of the mixing parametrizations is through validation against observations of physical parameters (e.g., temperature, salinity, sea level and currents) which are influenced by turbulence and are reliably and readily measurable (Kaempf et al. 2009, 2010; McLeay et al. 2016; Middleton et al. 2014, Rogers et al., 2021).

For clarification, the mixing parametrisations applied to the model used in the report included a horizontal eddy viscosity of $5 \text{ m}^2/\text{s}$ (equivalent to that used in Kaempf et al. 2010) and a horizontal mixing coefficient for temperature and salt of $2 \text{ m}^2/\text{s}$. As per previous work by the Reviewer (Kaempf et al. 2009) a quadratic bottom stress formulation was assumed. Spencer Gulf models developed by SARDI over the last 10 years have shown acceptable levels of validation using different vertical turbulence closure schemes; k-epsilon (Middleton et al. 2014) and LMD (Middleton et al. 2017). In this report, the mixing parametrisations applied are identical to those currently used in the eSA-Marine Two-Gulf nowcast-forecast model (eSAmarine, Middleton et al. 2017). This model has undergone extensive development and testing over the last six-years by SARDI and the Bureau of Meteorology and is being used by multiple fisheries and aquaculture stakeholders to support their commercial operations (Middleton et al. 2017).

As discussed, a highly conservative approach was taken to predict the far-field dispersal of brine by injecting into the bottom model layer. The MSRP requested additional sensitivity studies (refer to Appendix 2 of the report) to account for a more realistic vertical dilution of brine discharges due to the turbulent mixing associated with potential diffuser designs. These studies demonstrated that turbulent mixing due to diffusers would further dilute brine discharges in the vertical resulting in lower salinity anomalies.

The validation of the model against field observations presented in the report indicates that the model was properly configured. All model limitations are appropriately detailed in the report. Given that the level of model validation is substantial and consistent with, or greater than, similar published peer-reviewed models (Kaempf et al. 2009, 2010; McLeay et al. 2016; Middleton et al. 2014; Rogers et al., 2021) – the authors reject the Reviewers unsupported assertion that variations in the model turbulence parameters would result in ‘much higher salinity anomalies’ or are ‘highly uncertain’.

3. Who defined the intake and outfall locations? Why didn't you consider offshore locations for intake structures? Why was the Sleaford West site no longer included in the discussion?

The report was commissioned by SA Water to understand the impacts of prescribed intake and outfall locations. As detailed in the report's Introduction, the Sleaford West site encountered substantial engineering issues due to geological conditions and was removed from further consideration by SA Water. As a result, this body of work was undertaken to examine the potential impacts and capacity of alternative sites located in and around Boston Bay to host a desalination plant.

4. Overall model performance: Do you agree that the model predictions of salinity and currents can still be significantly improved?

Ocean models are always constrained by a range of factors which influence their performance and validation. These constraints include bathymetric data limitations, parametrisations used to account for sub-grid scale processes, limitations in global atmospheric and oceanographic models used to drive the hydrodynamic models and

the availability of observations needed for model calibration. We acknowledge that improvements to any of these constraining factors can improve model performance. It was due to our understanding of existing lower-resolution 'whole-of-Spencer Gulf models' limitations (e.g., Kaempf et al. 2009; Tanner et al., 2020) that the monitoring and model development presented in the report was undertaken (i.e., to improve model performance in the shallow embayments surrounding Port Lincoln).

The report provided detailed comparisons of model predictions with direct observations of salinity, temperature, sea-level and currents taken at several sites over 12 months. The validation included a robust assessment of the model's predictive capability for both tidal and lower-frequency variations. The model was nested within, and receives information from, a larger (lower resolution) gulf scale model which has also been validated against concurrent measures of salinity, temperature, sea-level and currents at different locations throughout Spencer Gulf (McLeay et al. 2016; Middleton et al. 2017; Rogers et al., 2021; Tanner et al., 2020). The Boston Bay model presented in the report provides another step in the progression, and improvement, of ocean modelling in South Australian gulfs.

For this report, the level of model validation presented is equivalent to, or exceeds, any previous modelling undertaken in Spencer Gulf (Kaempf et al. 2009, 2010; McLeay et al. 2016; Middleton et al. 2013, 2014, 2017; Rogers et al., 2021). For example, the ocean model developed by Reviewer for the South Australian gulfs (Kaempf et al. 2009, 2010) was validated against available tidal sea level elevation and historical monthly temperature and salinity observations. Temperature and salinity predictions differed from the observations by up to 1°C and 1 PSU at two sites in Spencer Gulf, respectively. These errors are equal to, and for temperature exceed, those presented for the validation in our report. Additionally, the Reviewer provided no validation for currents or lower frequency variations associated with weather band forcing that is important to understand long-term dispersal and connectivity. Although the availability of observational data for validation was likely a factor constraining the model validation, this did not prevent the Reviewer from using the model to predict desalination brine increases (Kaempf et al. 2009) or undertake particle tracking studies (Kaempf et al. 2010).

Therefore, with the level of validation and within the limitations outlined in the SARDI report, the model represents the authors' best estimate of the ocean conditions, and the dynamics of the proposed brine discharges for the nominated sites.

5. After reading this review, do you agree that a model's ability to reproduce sea level, currents, and hydrographic properties (temperature and salinity) does not imply a model's predictive capability to predict the dispersal of a dissolved pollutant (such as desalination brine) or the dispersal of mussel larvae?

No, the authors do not accept this statement. The model validation is detailed in the response to Point 4. The level of model validation provided in the report is appropriate and the model provides the best available tool for predicting the regional (far-field) dispersal of brine discharge and connectivity of planktonic larvae in region. This view was supported by the independent MSRP.

6. Flushing: Do you agree that Proper Bay displays the weakest level of flushing of the entire region? Do you agree that a discharge at Billy Lights Point inshore has the biggest footprint on Proper Bay?

Yes. This is clearly demonstrated in the reported results.

7. Reliability of larvae predictions: Are you aware that wave-induced currents (Stokes and longshore drift) are fundamental processes of suspended particle transport (including mussel larvae) in the coastal zone? How reliable are your particle simulations without the inclusion of wave effects? Is it possible that a much higher percentage of mussel larvae can be affected by the intake due to wave effects than predicted in the report?

The Reviewer suggests that wave induced currents would lead to significantly higher levels of connectivity and rates of larval entrainment but provides no supporting evidence. As detailed in the report, there are many unknowns regarding the early life history of mussels which could influence their connectivity and dispersal. These include an understanding of their vertical behaviour and source/sink regions. For the reasons below the authors do not support the Reviewers assertion that a higher level of larval entertainment would result from the inclusion of wave induced surface drift.

Wave measurements undertaken by SARDI at the SAW1 mooring location near Bickers Isles during winter in 2021 (Figure 1) showed a median significant wave height of 30cm and indicate the regions embayments are not a high-energy wave environment. In the presence of smaller wind-waves, Stokes drift does not penetrate far below the surface and only influences the transport of positively buoyant material (including larvae) on the ocean surface layer (Tamtare et al. 2022). There is no evidence that mussel larvae are positively buoyant. If this were the case, connectivity with the bottom mounted intake would be negligible. Given the known limitations in understanding mussel spawning dynamics and its influence on transport and connectivity, Stokes drift would be only expected to impact the small percentage of particles that remain on the surface.

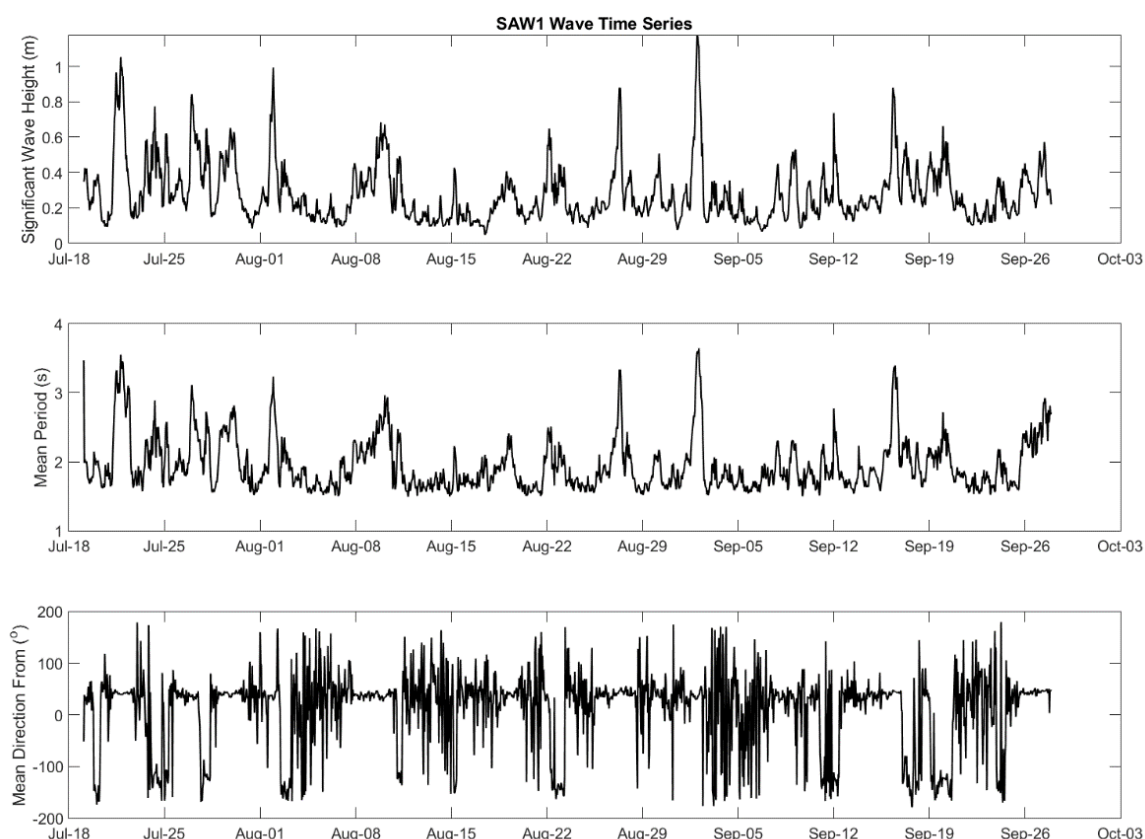


Figure 1: Wave observations taken at Site SAW1 in 2021.

Longshore drift is a nearshore process not resolved by the model and is not typically considered in far-field connectivity modelling. Given the low wave energy measured in the region we do not consider it would lead to significantly higher levels of connectivity.

In the absence of any information, the vertical behaviour of mussel larvae simulated in the report was assumed to be passive and the particles neutrally buoyant. The approach taken was consistent with previous particle tracking studies for blue mussel larvae (Coolen et al. 2020). As detailed and referenced in the report, we used the open-source LTRANS model to predict particle trajectories. LTRANS uses current predictions from the hydrodynamic model and includes a random displacement model to account for sub-grid scale turbulent motions (North et al. 2006, 2008). Previously published particle tracking work using LTRANS that did not include the effects of wave induced surface drift have been used to understand (McLeay et al. 2016) and validate (Rogers et al. 2021) larval connectivity in South Australia's gulfs for other important commercial species. Hence, the authors consider the results presented in the report provide the best available, and most reliable, estimates of mussel connectivity available for the Port Lincoln region.

For clarification, the Reviewers quote that the Executive Summary states "*The far-field connectivity modelling results indicated that less than 0.1% of the spawned biomass may be at risk of coming within a 25 m radius of intakes*" is not correct. The Executive Summary states that "*less than 0.1% of the particles released over the course of the mussel spawning season may be at risk*". This distinction is important. As mentioned in the report, particle tracking was undertaken to understand the far-field connectivity of spawning larvae with the proposed desalination intakes. Particle numbers released into the model are not proportional to larval concentrations (or biomass) which are unknown.

8. Entrainment of wastewater: How high is the risk that an intake near Billy Lights Point entrains wastewater discharged by the Port Lincoln WWTP near Billy Lights Point?

This issue was not within the scope of the report.

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