ALKIMOS DESALINATION PLANT DISCHARGE MODELLING: MODEL VALIDATION

REPORT OF INDEPENDENT PEER REVIEW PANEL

Prepared for
WATER CORPORATION

Prepared by
INDEPENDENT PEER REVIEW PANEL
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1. BACKGROUND

1.1 Introduction

The Water Corporation (WC) is undertaking investigations into the construction and operations of a desalination plant in Alkimos, Alkimos Seawater Desalination Plant (ASDP). ASDP will be developed in four 25 GL stages (ultimate production capacity 100GL/annum).

The WC has undertaken a comprehensive programme to assess the feasibility of the operation of the desalination plant. The first stage included the development of a hydrodynamic model for the coastal waters off Alkimos. Once calibrated the model was used to accurately depict the discharge of brine from the proposed ASDP as well as the discharge from the existing Alkimos wastewater treatment plant and their subsequent dilution, advection and dispersion. The model can also be used to optimise the location and design of marine infrastructure needed for a new seawater desalination plant

DHI was engaged to develop the model and undertake the modelling of the intake and discharge from the proposed ASDP.

The Water Corporation engaged the independent Peer Review Panel (PRP) to review the development of this model. The peer review panel (PRP) compromises:

- Prof. Chari Pattiaratchi (University of Western Australia)
- Mr Murray Burling (RPS)
- Dr Des Lord (Chair)

The PRP undertook a review of the following report;

- Alkimos Hydrodynamic Modelling – Calibration Report (January 2019)

The PRP was specifically requested to provide commentary on:

- Whether the model developed is fit for purpose as the basis for the EPA decision making.
- The appropriateness of the approach, methodology and data used to develop the model in light of current practices and knowledge
- The ability of the model to appropriately simulate the desalination discharge into the marine environment

Following the review of the validation report the PRP also provided comment on;

- Alkimos Hydrodynamic Modelling – Scenario Report (February 2019)

The terms of reference for the review of the scenario report was as follows;

- Whether the model developed was appropriate to simulate the discharge scenarios selected.

The PRP was not requested to provide comment on the individual scenarios selected for modelling however was required to provide comment on the outputs from the modelling results. The PRP also had no role in providing impact assessment commentary.

This document describes the review process undertaken and presents a summary of the main conclusions and recommendations made by the PRP.

1.2 Structure of the PRP process

The peer review process was undertaken in a rigorous and comprehensive manner. It commenced in June 2018 when the PRP was requested to review the first draft of the calibration report. The recommendations from this first review were incorporated into the model development by DHI and the second draft was provided to the PRP for final comment and accepted in November 2018.

The review of the Scenario Modelling report was completed in February 2019.

Throughout the iterative review process the PRP, the WC and DHI exchanged information, and resolved issues through a well-structured process of report reviews, workshops and written communication. This meant all technical issues raised were discussed and considered in detail, which resulted in the relevant modification of the final reports.

The PRP is of the view that this interactive process enhanced the structure and capacity of the model that was developed for this application as well as the analysis and interpretation of model results generated.

The WC retains the extensive record of all commentary and correspondence of the detailed review process.

2. PEER REVIEW - MODEL VALIDATION REPORT

DHI developed a local 3-D hydrodynamic model that combined input from

- DHI Regional 2D/3D Hydrodynamic model (developed from the HYCOM Global 3-D model and the DTU-Space Global Tidal Model); and
- DHI Local wave model (developed from the DHI Global Wave model

Model validation was undertaken with comparisons of measurements of various oceanographic features with model forecasts. The complex bathymetry of the area was noted as well as the presence on an existing treated wastewater outlet.

A summary of the main Conclusions and Recommendation from the PRP on the review of the model validation report is provided below. The detailed comments provided by the

PRP, the responses from DHI and the resolution of each of all matters raised during the review are presented in Appendix A of this report

Conclusion and Recommendations

1. The PRP advises that this is an appropriate suite of models for use in this location, where both wind and wave forcing as well as regional factors (such as coastal trapped waves and density gradients) are included. The models used are all recognised to be current state of the art and have been effectively applied in similar environments elsewhere

2. The PRP endorses the setting up of the model where
   - wind forcing is provided from the local wind field as measured at Whitford's
   - the model resolution of 50m is sufficient to resolve the complex flow patterns that occur between the reef lines, and
   - the inclusion of wave forcing of circulation only in the nearshore region east of the first reef line when the significant wave height is greater than 2m.

3. PEER REVIEW - SCENARIO MODELING REPORT

DHI undertook hydrodynamic modelling of the "preferred configuration" of the intake and outlet for the proposed ASDP, with the Intake located inshore of the first reef line and the outlet between the two reef lines and south of the existing WWTP discharge. Modelling was undertaken over a continuous 12-month period using maximum design flows for the ASDP in conjunction with the maximum potential discharge from the Alkimos WWTP.

Modelling showed that the brine discharge, (following dilution within the near field to a salinity of approximately 1.1ppt above ambient seawater salinity), descends perpendicularly downslope to the deep portion of the channel between the outer and second reef lines where the existing WWTP diffuser is located. Of significance is this behaviour is a near-permanent feature and is only minimally affected by the behaviour of the water column above it. The descending brine wastefield then bifurcates as it approaches the barrier of the outer reef line and spreads at reduced velocity parallel to the lines of reef (and the shore). It forms a semi-permanent feature near the sea bed of approximately a kilometre-in length within the channel. The brine layer shows variability from month to month depending on hydrographic conditions, but does not (within the year simulated) demonstrate major changes in dimensions by season.

A summary of the main Conclusions and Recommendation from the PRP on the review of the scenario modelling report is provided below. The detailed comments provided by the

PRP, the responses from DHI and the resolution of each of all matters raised during the review are presented in Appendix B of this report.

Conclusion and Recommendation

1. The PRP advises the WC that the results of the modelling undertaken represent a reliable depiction of the dilution, advection and dispersion of the higher density brine that is discharged. It is recognised that the reef lines provide a significant constraint on any lateral dispersion of brine.

2. The PRP wishes to provide comment on the scenarios that have been modelled and presented in the report. The report states that the "worst case" condition of discharge for the WWTP and intake and discharge for the ASDP were selected for modelling, namely, a discharge of 80ML/d from the WWTP and a capacity to produce 250ML/d (100GL/a) of desalinated water.

   The PRP is advised that the WWTP is licenced to the maximum (theoretical) discharge of 80ML/d which could be reached by the year 2060 (with appropriate expansion of treatment capacity on land). However the current discharge to sea from the WWTP is estimated at only 11ML/d with the plant operational since 2010. The WC is currently supporting the development of reuse options for the AWWTP discharge Hence there is a strong possibility that the rate of increase of discharge volume will be limited and the discharge design capacity may not be reached. Similarly, the ADSP has a final design capacity of 250ML/d, which will be implemented in 4 stages.

   Hence the PRP strongly recommends that the WC provide this context in its referral documents but also considers that modelling of realistic "intermediate" conditions is warranted.

   The WC has advised the PRP that the referral document will address this matter.

Appendix A: Alkimos Hydrodynamic Validation Report – PRP Review

PRP Review/Recommendation	Resolution	PRP Final acceptance/comment
The PRP advises that this is an appropriate suite of models for use in this location, where both wind and wave forcing as well as regional factors (such as coastal trapped waves and density gradients) are included. The models used are all recognised to be current state of the art and have been effectively applied in similar environments elsewhere		
Recommendation to provide a more comprehensive description of the coastal processes and their relative importance in terms of water circulation and exchange.		**Completed**
The current horizontal resolution of the model in the region of interest is 50m. Recommendation to provide further clarification in the report that the resolution is adequate to resolve the complex reef systems in the study region, particularly areas that are influenced by the proposed discharge.	A mesh resolution study was undertaken and presented to the PRP on the 23/11/2018. The validation report was updated to include the results of this study.	PRP confirmed the 50m resolution was appropriate based on the results of mesh resolution study presented in workshop 23/11/2018.
DHI to provide further clarification on the wind field selected for use in the Local 3-D hydrodynamic model including noting the performance in representing the major driving wind features of the area, which include winter/summer storms, calm periods and the summer sea breeze cycle.	Addressed as follows: • The local model is forced by BOM Ocean Reef data • The model calibration report will be updated based on this forcing, for the two calibration periods and two validation periods. Checks were conducted during the prior calibration to demonstrate that the impact of this wind selection was not material to the calibration, and a similar outcome was seen once applied.	The PRP agrees this approach is acceptable.

DHI to provide comment on the relevance of including heat fluxes (heating and cooling/evaporation) in the local model. The PRP believe that it is an important process that should be considered in the local model.	The process of heating and cooling/evaporation occurs throughout the year. Evaporation changes the salinity during the summer/autumn, they combine during late autumn and cooling is important throughout the winter into spring. The important process here is that nearshore waters are denser than the offshore waters resulting in a cross-shelf density gradient that drive gravity currents offshore. What occurs is that during storms there is significant cooling of the nearshore waters. The onshore component of winds creates a downwelling situation. Thus although we may expect that during storm events the water to be vertically mixed this is not the case – there is vertical stratification and two layer flow – surface water flowing onshore and bottom water flowing offshore. In particular capturing the flow through the reef systems is critical.	PRP notes that heat fluxes have been incorporated into the revised model. The PRP were provided a presentation of the influence of these terms in the simulations.
DHI to provide comment and comparison on the accuracy of the HYCOM sea level boundary conditions employed, with respect to magnitude and also alongshore gradient. Comparison of the HYCOM data with Hillarys Boat harbour is recommended.	A comparison which considered instantaneous measured and residual water level at Hillarys was undertaken, and compares the measured residual to that from HYCOM and the Regional 3D model at the Hillarys location. While there are certainly divergences (as would be reasonably expected), the three residual curves trend together (data, HYCOM, Regional 3D model). The Regional 3D model provides greater short-term detail than is present in HYCOM, which again would be expected, and generally follows the measured trends more closely than it follows HYCOM. The relevant tests and checks were considered to be best presented in the Scenario report.	

(a) The PRP noted that the local domain size is relatively small. The report should demonstrate this does not incur any adverse impacts within the domain in the area of interest due to the boundary effects. (b) Further the PRP noted that the (local) domain size should be assessed for suitable scale to contain any areas of affect that are to be assessed, including allowance for the scale of flow reversals from the boundaries at times where tracer return may not be adequately represented.	A significant amount of work was done to select these periods, and the periods selected address the requirements of the PRP.	The PRP will consider this recommendation in the review of the Scenario Report.
The PRP strongly supports the completion of the 12 month measurement programme being undertaken and the use of this information to inform the model of the main components forcing water movement at the site, as well as its use in the calibration and validation of the model under the range of conditions that will be experienced at the site throughout the year.	Calibration of the model to the periods as indicated in the calibration report (Apr-May 2005, and Apr-May 2017) was undertaken, and validation of the model against the periods to be used for scenarios (23 Jun – 22 Jul 2017, 17 Nov – 16 Dec 2017). The model will thus be calibrated/validated against all periods to be used for scenario simulation. The calibration report was updated to reflect the calibration period information.	PRP was provided relevant information

Model calibration and validation is required at all sites where there is the potential to locate intake and outlet structures.	While having validation data in the exact location at which modelled information is to be applied is the ideal, in many cases, models are constructed using available data, and those models are then used to site the infrastructure within the model domain. It is rare for the location of the infrastructure to be decided prior to the modelling exercise, and indeed prior to the deployment of measurement equipment. The existing measurements are located between 200m and 1000 m from the proposed intake/outfall sites. Given the location of measurements across the reef complex in 2017, and from two sites in 2005, it is our view that the broad characteristics at the scale of the plumes to be generated are captured by the existing measurement program, and that this program is sufficient to inform a model to be used for the purposes of contributing to intake and outfall location decisions.	PRP accepts the response. The Recommendation was made by the PRP upon learning that alternate sites for intake/outlet structures were being considered. As a measurement programme was underway it would be sensible to make these measurements at or close to sites of interest. The response confirms this is the case.

Appendix B – Alkimos Hydrodynamic - Scenario Report

PRP Review Comment	Resolution	PRP Response 25/02/2019
Model setup and vertical layering is sufficient, noting application of sigma grid. With reference to the simulation periods, with the manner of comparison used in Appendix A of the simulation modelling report, there would be benefit in providing additional clarification on how the simulation period fits within the range of typical or extreme for a season, given that assessment is likely to concentrate on an annual or shorter period. Was there intent to pick low mixing conditions for conservatism? It is noted that the period chosen for the Autumn conditions appears to have less calms than typical based on the wind roses presented. Please comment on the effect on the simulations and results for these periods.	Will modify text as suggested. Regarding simulation periods, more information will be provided in the revised report. The full analysis was done on a 12 month simulation, with the 3 1-month simulation used only for screening. The periods were deliberately chosen as being within the measurement and calibration period.	PRP notes and accepts response. As noted, context for the simulation period needs to be clearly stated in the report, as choosing to be within the measurement period and does not provide context in interannual trends, or how the simulation period represents the range of conditions expected over time. An example is the previous note regarding calms.

The PRP confirms the appropriateness of the process used to identify candidate intake and outlet sites for the ASDP. The PRP wishes to provide comment on the scenarios that have been modelled and presented in the report. The report states that the "worst case" condition of discharge for the WWTP and intake and discharge for the ASDP were selected for modelling, namely, a discharge of 80ML/d from the WWTP and a capacity to produce 250ML/d of desalinated water The PRP is advised that the WWTP is licenced to the maximum (theoretical) discharge of 80ML/d which could be reached by the year 2060 (with appropriate expansion of treatment capacity on land). However the current discharge to sea from the WWTP is estimated at 11ML/d with the plant operational since 2010. WC is currently supporting the development of reuse options for the AWWTP discharge. Hence there is a strong possibility that the rate of increase of discharge volume will be limited and the discharge design capacity may not be required. The ADSP has a final design capacity of 250ML/d, at an initial 125ML/d and with subsequent expansion, a capacity of 250ML/d Hence the PRP strongly recommends that the WC provide this context in its referral documents but also considers that modelling of realistic "intermediate" conditions is warranted.	WC Response: The referral documents will be updated to include further context regarding the ultimate capacity of the WWTP and potential staging however for the purposes of seeking approvals for the Desalination Plant it has been decided to only present the desalination plant discharge scenario based on the WWTP treating 80ML/day (aligned with the maximum capacity of the current WWTP ocean outlet). The Corporation is currently undertaking future planning for the WWTP including potential upgrades and the model developed will be utilised to run various discharge scenarios.	PRP accepts WC response and supports the intention to undertake additional modelling as operating conditions dictate.

Is the design level of a dilution factor of 30 a set minimum requirement, or did testing show variance around this? Not relevant to the modelling per se, but relevant to interpretation of the results. Was the background salinity curve used to set background salinity in the model/local scale boundary conditions?. The PRP is of the view that the use of a background salinity value that is 0.5ppt higher than any measured values is very conservative. A short discussion on the sensitivity of the model to this parameter is warranted. Was the ASP intake active in the model as a sink and coupled to the discharge, or was the discharge defined independently?	The actual dilution required to meet the LEPA targets is approximately 26 – a design target of 30 was selected to allow some level of conservatism (see Section 3.3). The background salinity curve was used to set background salinity in the model/local scale boundary conditions, as the local model was effectively uncalibrated to salinity. This reference curve was chosen for the sake of conservatism, and to avoid the scenario where ambient salinity may a) rise above the sparse survey data or b) recirculation is beyond that predicted. A 0.5 ppt increase in ambient salinity results in an increase in discharge salinity of 0.5*1.925 = 0.9625 ppt, which leads to an increase in ASDP plume salinity of 0.03 ppt after the design dilution of 1:30. This increase of ~3% in plume excess salinity will not materially alter the impact assessment, and largely de-risks variability in intake salinity with regard to permitting compliance. The ASP intake was not coupled to the discharge, it was defined independently. The intake was not active as a sink in the screening simulations to determine the preferred location, as the sink locations were themselves part of the screening process (ie we derived information from both candidate impacts from same simulations). This approach was maintained when moving to the 12 month simulation. Sensitivity tests have shown that the effects of an active intake sink being present is extremely small, and suggest that its omission is slightly conservative. We would expect no material changes should a sink be included.	The PRP accepts that the likely effect on the outcome is acknowledged as minor, however comments that best practice would be to include the intake in the model, and to also assess salinity excess and impact with pre and post simulations. As the plume behaviour and the hydrodynamics do depend on the predicted salinity, the performance of the model against expectations or some measurements as previously discussed could be demonstrated to strengthen the demonstration of quality. The PRP accepts this position from a technical perspective. But this matter of no impact of the WWTP plume on the ASP intake will require clear enunciation in any referral document.

The PRP requests further clarification on the sources for the discharge, can the description be expanded to explain how the source volume is split within the available source locations, how the dilution is managed, and how conservation of mass and volume is managed for the discharge flow and characteristics. Lastly, is the withdrawn water modelled at the intake location?	This section will be updated in the report.	The additional description is appreciated, and note re mass conservation of effluent is important. However, while the additional water volume added as a pre-dilution is noted, the potential effect on the simulation using this approach should be explained in more detail. Note: a 250x multiplier on flow from the WWTP inflow is a significant volume of water introduced in the model in a way that is not fully consistent with what happens in reality. The PRP recommends further explanation is needed to demonstrate that there are no adverse or artificial flows or outcomes introduced into the model by virtue of this method.
Please provide context/comment on the conservatism around the TTC and Enterococci source terms.	We believe this comment relates to the concentrations for the bacterial load provided in Table 3-1. These values were provided by the Water Corporation.	PRP accepts comment that the WC is the source of this information but regardless, this ,matter requires explanation in the report.
Section 4.1 indicates all intake/outlet options will be shown on plots. Why? As this report only presents simulations undertaken with Intake A and Outfall B. Perhaps 2nd sentence in 4.1 para 2 could read …the present report *only describes simulations* undertaken with the preferred intake/outfall options i.e.…with Figure	We will revise the plots and only include the preferred option in the final results.	PRP agrees and accepts

The description of how the excess salinity fields are determined could be enhanced. There is discussion of salinity but an inference then that the tracer has been used for that calculation. Please clarify and explain why the modelled salinity fields were not used for this purpose? It would be useful to get context of variability, peaks and also stability of the system once the discharge is active using time-series of salinity/salinity excess at various locations . Appendices C and D would benefit with information presented as vertical curtain and time series plots	As a result of the ambient salinity field being temporally and spatially variable, the direct reporting of excess salinity would require a differential analysis of post- and pre-development 3D salinity fields. As the excess salinity was derived from measurements rather than directly from the intake salinity, tracking the excess salinity as derived from dilution is equivalent to tracking the excess salinity directly (aside from differential precipitation and evaporative effects on the elevated salinity field, which is of no significance as the ASDP plume is on the bottom). Additional time series and curtain plots could be prepared for any set of circumstances and it is and it is agreed that they are required to round out the discussion	The PRP is of the view that comparison of the pre and post results using the model is best practice and this approach warrants a clear presentation. It should also be confirmed that boundary condition treatments for the tracer do not affect its use in this way. Time series plots at the discharge and intake locations, a key point in the feeder/connecting channel to the deeper zone, as well as alongshore in the "collecting" channel would be useful.
There is need for an explanation regarding the mixing schemes and coefficients applied in the model. These are important critical components for the accurate simulation of the temperature, salinity and tracer fields.	These details are provided in Table 4-1 of the calibration report and are repeated again in Table 2-2 of the scenarios report.	The PRP recommends that the rationale for selecting these factors be provided.

Extending the above, the dispersion performance of the model should be demonstrated through validation to field measurements of WWTP plumes. While the model performance in terms of circulation/advection is understood through the various comparisons made to measurements, the accuracy of the plume modelling is unclear without comparison to real data.	This is possible, but not straightforward given the extremely low flows active at the existing WWTP outfall. To achieve this, the exact capping arrangement of the existing diffuser is required, but has never been formally confirmed. As a result of the much smaller flow regime and length of active diffuser, the source arrangement applied to describe the existing outfall would need to differ substantially from that applied for the 80 ML/day WWTP scenario, which would impose an additional level of separation between the validation scenario and that applied for production. An interim step would be to attempt to validate the end of NFR dilutions and vertical plume distribution in the BMT monitoring using the Roberts formulation, as the model has shown to reproduce those Roberts-derived targets well. Another approach would be to validate the methodology against another Water Corporation WWTP diffuser of similar dimensions and character as the fully developed Alkimos facility – this would in some respects be a more direct validation, but obviously a far larger effort.	The PRP accepts this view inn light of the existing low flows from the WWTP diffuser (as well as uncertainty regarding its configuration) and the far higher flows envisaged at full capacity and which have been used for modelling. The PRP would regard that confidence in the model performance would be enhanced by a comparison of model vs measured of existing conditions