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Expert review of modelling of water quality and local current flows at Mullaloo Beach

1. Introduction

I was engaged by the WA Department of Water and Environmental Regulation to undertake a review of the adequacy of the numerical modelling provided in the report "Independent Investigation into Water Quality and Local Current Flows at Mullaloo Beach", Revision 2, Report Number 24MET182 / R240416 dated 24 January 2025, by O2 Metocean.

2. Overview

In summary, the modelling tools used for the study are suitable and in accord with industry best practice. The modelling approach of nesting meshes from wider boundary conditions down to a local three-dimensional model is suitable for the study area where wind driven transport dominates.

The order of magnitude of the dilutions of effluent from the Beenyup Wastewater Treatment Plant Outfall (referred to henceforth as the outfall) are what I would expect. I agree with the premise that wind driven transport will dominate the currents, advection and dispersion in the study domain.

The model has been run for scenarios of ongoing, persistent wind directions and concludes that with and without the Ocean Reef Marina (referred to henceforth as the marina) the dispersion patterns from the outfall are reasonably unchanged. I agree with the approach of simulating a conservative constituent to infer the potential for changes to algae growth (rather than to simulate algae growth) however further analysis and simulation is required to support the study findings.

My recommendations for the updates to the modelling, analysis and reporting are summarised as follows and discussed further on within this letter.

Summary of Recommendations:

1. The modelling should include more vertical layers. I consider a 3 m thick surface layer too large to predict and represent the surface wind shear onto the water body. Consideration may be given to using fixed depth surface layers rather than sigma transformations.
2. Model verification should not be against depth averaged currents. Plots of ADCP data demonstrate that currents are regularly stratified. The model should be verified for its ability to reproduce the currents at various depths throughout the water column.
3. Current vectors at various depths (not depth averaged) and in particular at the surface (both with and without the outfall in place) should be plotted and analysed to determine whether there has been any change to the tendency for onshore transport under a greater range of wind directions and speeds.
4. Near field predictions in the report should be expanded to better consider where the near field outfall plume will end in the water column. Initial estimates that I have made indicated the plume will rise to the top 2 m of the water column under most conditions. This will have implications for the layering chosen and the values used for vertical dispersion.
5. Nearshore transport caused by longshore drift should be considered for inclusion in the modelling. At a minimum, presentation of calculations to demonstrate whether this transport is or is not significant, should be presented.
6. Scenarios of the conditions leading up to the known events (17 January and 25 April 2024) should be simulated as time varying conditions to assess for these specific conditions, would the dispersion be greater with or without the marina in place.
7. The modelling has not considered whether nutrient levels are sufficient in the far field to promote phytoplankton growth, but rather inferred that transport and dispersion are reasonably unchanged and hence the time available for algae growth has not changed.
8. As the events were characterised by a “brown surface scum”, modelling of a floatable or buoyant tracer should be undertaken. The conservative tracer (referred to in the model as a numerical signal) is a fully dissolved constituent which moves with the surrounding water. Consideration should be given to whether the phytoplankton being on the surface was behaving as a surface floatable constituent rather than a dissolved constituent.

1. Vertical mesh resolution

Wind shear is applied and acts upon the surface of the model. The model predicts the propagation of the effects of this surface shear down through the water column. Adequate layers are required to resolve the distribution and shear through the water column along with the parameterised vertical mixing process (vertical eddy viscosity). It is my experience when predicting three-dimensional circulations caused by winds in relatively shallow water bodies, that a surface layer in the order of 1 m is required. This allows for the surface currents to develop in the model without needing to “drag” water at depth. The accurate simulation of surface currents is especially significant for this modelling as the algal growth occurs on the surface of the water column.

I recommend that the model scenarios be run with more layers. The model would also benefit from simulating layers at fixed depth rather than sigma transformations (which change the thickness of the surface layer as the depth of the water column varies). A sensitivity analysis of the findings to the number of layers should be presented.

2. Verification should not be against depth averaged currents

The modelling is being used to assess potential changes in predominantly wind driven circulation and transport where the near field plume is residing at the surface. Therefore, this is a three-dimensional problem, so it is important the model be verified against currents at each depth and not the depth averaged conditions. Figures 10, 11 and 12 show different current directions in the surface and bed layers regularly occur.

For this study, variations in cross-shore (y) current directions between surface and bed are particularly important, as the potential for an onshore surface current with a near bed offshore current is an important condition to be considered when assessing the changes resulting from the construction of the marina. As such, it is important to demonstrate that the model is able to reproduce these conditions.

It is appreciated that the modellers and report authors may not have had full access to the ADCP data as indicated by the statement “No information on how the layers were defined nor the number of layers was received by O2Me”. My recommendation is that the full ADCP dataset be received, analysed and used for model verification.

3. Current vectors

Plotting of vectors at various depths (but in particular at the surface) for conditions with and without the marina would provide greater support for the conclusion that the marina is not having any impact on water quality and circulation. These plots could be provided in an appendix for all varying wind directions in order to assess whether any particular directions are impacted more or less than others. Such an analysis would expand the current hypothesis that, since current speeds are not significantly changed, water quality would not have changed.

Analysis of current vectors should concentrate on cross shore transport.

4. Near field predictions

The near field predictions used for determining a mesh resolution around the outfall indicated approximately 10 times dilution. I have quickly run some near field model scenarios flows, temperatures and potential stratification (using the model Jetlag or Visjet) and generally found that dilutions were in the order of 100 times. This order of magnitude supported the field data, indicating that nitrate/nitrite in the effluent was approximately 20 mg/L and sampling around the outfall was approximately 100 ug/L, indicating 200 times dilution.

Although the desktop analysis used has indicated a lower near field dilution, the far field model has resolved this by mixing vertically through the surface layer and the flux through this layer. However, the near field model predictions I undertook also indicated that the plume is generally in the top 2 m of the water column, with the dilutions resulting from entrainment of waters from the lower part of the water column into the initial momentum jet progressively transforming into a buoyant plume.

My recommendation is to keep the horizontal mesh resolution as is, but increase the vertical mesh resolution, and input the plume into the top layer(s) of the water column. I do not recommend coupling the near and far field models at this stage to include the transport of waters from the lower water column to the surface.

5. Longshore drift caused by waves

Longshore drift is a transport process which may potentially have been interrupted by the marina but which has not been included in the modelling. Desktop estimates of longshore currents resulting from breaking waves at the shoreline should be made for the typical water depths, wave heights and incident wave angles. This desktop analysis may be able to conclude that longshore drift is not relevant or important which would justify its exclusion. Alternatively, the longshore drift could be imposed on the model as a stress at the shoreline.

6. Simulation of conditions when events occurred

I agree that running scenarios forced with idealised wind conditions provides predictions of plume dispersion that can be interpreted for pre and post marina construction without simulating “all possible scenarios”. However, the events which occurred on 17 January and 25 April 2024 have not been simulated.

The premise of selecting scenarios has been to determine whether for a range of idealised, consistent conditions, the velocity fields and subsequent plume dispersion was significantly altered by the marina construction. This scenario addresses the hypothesis directly that for conditions when an event occurred, the same event would have occurred regardless of the construction of the marina.

As such, I recommend that scenarios be run simulating the conditions leading up to each of the events.

7. Analysis of algae growth and response to nutrient concentrations

Phytoplankton growth is generally modelled as a maximum growth rate which is limited by the available concentrations of nutrients (commonly nitrogen and phosphorous), temperature and sunlight. The report would benefit from some analysis of the specific phytoplankton of concern to assess whether subtle changes in nutrient concentrations may results in significant changes in growth rates. This would allow for better interpretation of the reduced currents about the marina (e.g. Figure 56) and whether the events may have resulted from (i) greater growth rate, (ii) longer residence time, or (iii) neither of these.

I agree with the overall predictions of far field dilutions being generally in the order of 500 times, so effluent concentrations are greatly reduced. I also agree with the approach of only simulating a conservative constituent to infer the potential for changes to algae growth (rather than to simulate algae growth). However, the above mentioned analysis of the reduced currents around the marina is required.

8. Consideration that algae was a floating constituent and not a dissolved constituent

A potential scenario for the events was that the “surface scum” was not acting as a dissolved constituent but rather floating. This would mean that it was affected more by the wind, and potentially able to accumulate near the shore. The modelling presented has not addressed this.

Should floating algae be considered important, the model should be able to predict the very near surface currents and potentially include a “floatable” constituent on the very surface. The conservative tracer (referred to in the model as a numerical signal) was a fully dissolved constituent which moves with the surrounding water. A constituent such as an oil or grease could be a suitable representation of a floating algae when being modelled as a numerical tracer.

If the winds were transporting water and algae onshore, this water would either travel along shore, or return offshore near the bed (downwelling). in the case of a floating algae, the algae would not necessarily return seaward with these waters but rather accumulate.

The study should investigate this potential process when considering the question "has the marina development changed circulation conditions". Desktop analysis (as minimum) or model scenarios should be assessed to indicate whether or under what conditions the marina development may have influenced the movement of "surface scum".

3. Conclusion

The study has concluded that "*No evidence has been found to support the claim that the marina redevelopment has substantially altered the distribution of the dispersed Beenyup effluent near the coastline, and therefore it is unlikely solely responsible for the alleged decline in marine water quality or high concentrations of Trichodesmium algae*".

However, the report also states that "*The influence of the redeveloped marina on current flows described in this study should be interpreted as a relative value rather than an absolute one. Whether the modelled reduction in current velocities is substantial enough to create an environment which exacerbates algal bloom events are yet to be confirmed, pending the assessment of other contributing factors, which was out of this scope of work*."

I have provided recommendations for updates to the modelling, analysis and reporting which are to improve model predictions for conditions which have not yet been assessed. However, it may be prudent to complete the assessment of other contributing factors that were outside of the scope of works to better conclude whether the already predicted changes in currents are indeed substantial enough (or not) to exacerbate algae blooms, before any changes or updates to the model are made.

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