HR Wallingford
Working with water

# Cowes Harbour Model Review

## Flow modelling review

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# Executive Summary

Cowes Harbour Commission (CHC) is developing an improved set of hydrodynamic and sediment transport modelling tools to aid the management of Cowes Harbour and the surrounding areas. The tools are being developed by ABPmer. Cowes Harbour Commissioners (CHC) has requested HR Wallingford to undertake an independent review of the modelling studies. The purpose of the review is to provide confidence in the outcomes of the modelling which is being used to inform the management and development of the harbour.

In total three modelling activities require review:

- Regional tidal flow model
- Local tidal flow model
- Local sedimentation model.

This report focuses on the first two of these modelling activities: the regional and local tidal flow models. The objectives of this review are to identify any shortcoming of the regional and local tidal flow modelling and to make recommendations to address any identified shortcoming of the modelling.

### Regional model

The calibration and validation exercises undertaken for the regional model demonstrate that there are shortcomings in its ability to predict water levels and currents in general within the North Sea or English Channel but that it provides suitable boundary conditions for the currents and water levels in the Solent Region. It is the provision of boundary conditions for the Solent which is most relevant to the Cowes study, and therefore the most important objective of the regional model. It is judged that the regional model is suitable as a basis for modelling studies at Cowes. For locations outside the vicinity of the Solent, it is recommended that additional local calibration is undertaken before using the regional model as a basis for hydrodynamics predictions.

### Local model

The calibration and validation exercises undertaken for the local model indicate there is some over-prediction by the model of the currents into the Harbour from the east. This is likely to result in an over prediction of sediment transport from this direction into the estuary if these flow model results are used for modelling sediment transport. Otherwise the model is successful in reproducing the current patterns within and in the vicinity of Cowes Harbour. With respect to the prediction of water levels the local model in general is successful at predicting the variation in water levels within and in the vicinity of Cowes Harbour but has a tendency to under predict LW level and, less frequently, to significantly under predict HW level.

We recommend that the regional model be used for the study at Cowes but used for other modelling activities outside the Solent only after further calibration and validation. The local model is fit for purpose but the over prediction of currents into the harbour from the east and tendency to under prediction of LW level at Cowes should be borne in mind when interpreting any activities using the flow model results.

# Contents

# 1. Introduction

## 1.1. Background

Cowes Harbour Commission (CHC) is developing an improved set of hydrodynamic and sediment transport modelling tools to aid the management of Cowes Harbour and the surrounding areas. The tools are being developed by ABPmer. Cowes Harbour Commissioners (CHC) has requested HR Wallingford to undertake an independent review of the modelling studies. The purpose of the review is to provide confidence in the outcomes of the modelling which is being used to inform the management and development of the harbour.

In total three modelling activities require review:

- Regional tidal flow model
- Local tidal flow model
- Local sedimentation model.

This report will focus on the first two of these modelling activities: the regional and local tidal flow models.

## 1.2. Objectives

The objectives of this review are to:

- Identify any shortcoming of the regional  and local tidal flow modelling
- Make recommendations to address any identified shortcoming of the modelling.

## 1.3. Documents made available for review

The four  documents made available by ABPmer for this review are as follows:

- Cowes Harbour Commission, English Channel Regional Model Calibration, ABPmer Report R.2492, September 2015.
- Cowes Harbour Commission, Cowes Local Model Calibration, ABPmer Report R.2517, Version 1.0, 22 October 2015.
- Cowes Harbour Commission, Cowes Local Model Calibration, ABPmer Report R.2517, Version 2.0, 23 November 2015.

Cowes Harbour Commission, Cowes Local Model Calibration, ABPmer Report R.2517, Version 3.0, 9 December 2015.The previous version of this review considered Version 1.0 of the Cowes Local Model Calibration report (Dated 22 October, 2015) as well as the English Channel Regional Model Calibration report.  ABPmer have since issued two further revisions of the Cowes Local Model Calibration report.  This revised review has been updated to assess the latest version, Version 3.0, of the Cowes Local Model Calibration report (Dated 9 December, 2015).

## 1.4. Report structure

The remainder of this report comprises a further two sections. The regional flow model is reviewed in Section 2 and the local flow model is reviewed in Section 3. The conclusions of the report are presented in Section 4.

# 2. Review of the regional tidal flow model

## 2.1. Introduction

The review of the regional model was based upon ABPmer (2015a). It is worth noting that, rather than there being two separate models (a regional model providing boundary conditions for a local model), there is actually only one model which extends between the Lizard in Cornwall and Peterhead in Scotland and which is resolved in detail in the vicinity of the Medina Estuary. The separation of the reports into “Regional model calibration” and “Local model calibration” enables a separate focus of the performance of the model in the regional and local contexts – this not an unreasonable approach.

## 2.2. Software used

The software used for the modelling is the flexible mesh version of MIKE21. The MIKE21 software, developed by DHI, is well-respected and the flexible mesh version well-suited to this type of study, enabling coarser resolution away from the area of interest and detailed resolution in the area of interest.

## 2.3. Boundary conditions

To provide the water levels for the boundaries between France and Cornwall and between Scotland and Denmark the global tidal model DTU10 (Andersen and Knudsen, 2009) has been used. This model is similar in type to other global models, like TPXO (OSU, 2010), which are used for this purpose. TXPO is in our view generally better resolved and takes into account more tidal constituents but the DTU10 model ought to be adequate for the purpose.

Within the regional model assessment there is no freshwater input to the model, though it is planned to include the fluvial flow in the Medina in future modelling (see note in Section 2.3). The freshwater flow in the Medina itself is small (with a mean flow of 0.43 $m^3/s$ on average; ABPmer, 2015b). The importance of freshwater flow in the Medina is examined in the local model report (See Section 3). The absence of freshwater flow (around 24 $m^3/s$ on average in the winter; ABPmer, 2012) into Southampton Water may create a small effect in the wider Solent. In particular the freshwater will create longitudinal density gradients in Southampton Water, and to a lesser extent in the Solent, that may impact on calibration of a depth-averaged 2D flow model.

## 2.4. Bathymetry

The bathymetric data sources used in the study appear to be comprehensive. There is a potential cause for concern with respect to the bathymetry in the vicinity of the Isle of Wight in that there are large differences between the SA2 bathymetric data set (SA2 is the name given to the bathymetry data set used in the model for the Solent and the vicinity of the Isle of Wight) and the European Marine Observation and Data Network

(EMODnet) comparison. This does not necessarily mean that there is significant error in the SA2 data set but consideration needs to be given as to whether the magnitude of the differences between the two data sets is important for tidal propagation in the vicinity of the Isle of Wight. For instance there are extensive differences of up to 5 m between the SA2 and EMODnet data sets immediately east of the mouth of the Medina Estuary.

## 2.5. Friction

The friction in the flow model is represented through Manning's equation. The friction values chosen were varied within the English Channel (and Solent) on the basis of surficial sediment types from the European Marine Observation and Data Network (EMODnet) and selecting Manning friction values which corresponded to these surficial sediment types.

The choice of Manning friction value was selected based on three steps:

1. Identification of the EMODnet sediment types;
2. Identification of the reference drag coefficient ($C_{100}$) at 1 m above the bed (Soulsby, 1997) for different sediment types;
3. Identification of the Manning friction factor that corresponds to $C_{100}$ for each of the relevant sediment types.

1. Identification of the sediment types

The distribution of seabed sediment chosen for the English Channel appears to indicate a selection of friction values (M values of 44 or more) which are associated with muddier sediments rather than the coarse sandy gravel and gravels which abound in this region (Graham et al, 2001; DTI, 2007).

The seabed sediment within the Solent is similar to that shown in http://www.southampton.ac.uk/~imw/jpg-Wight/15IOW-West-Solent-Sediments-final-m.jpg, (which is based on BGS data but does not cover Southampton Water) but within Southampton Water the bed friction in the model is represented as low indicating very coarse material instead of muddy sediment. This is surprising given the extensive muddy intertidal flats, the ongoing maintenance dredging of muddy sediment from the dredged areas of Southampton Port, and doesn't match the literature (e.g. Velegrakis, 2000).

2. Identification of the reference drag coefficient for each sediment type

Table 1 of the report presents from $C_{100}$, drag coefficient values for different seabed sediments which are referenced to Soulsby (1997). However, the presented values in Table 1 (which range from 0.001 to 0.0017) bear no resemblance to the values presented in Soulsby (1997) (which range from 0.0016 to 0.0061). Furthermore the Soulsby values increase with particle size diameter while the values presented in Table 1 appear to reduce with large sized particles.

3. Identification of Manning friction factor that corresponds to $C_{100}$ for each of the relevant sediment types

Following steps 1 and 2 the selection of the Manning coefficient for each model node is based upon an equation (Equations 1b and 1a) relating the drag coefficient $C_D$ to the reference drag at 1 m $C_{100}$ and then relating the Manning friction to $C_D$. Equation 1b relating the drag coefficient $C_D$ to the reference drag at 1 m $C_{100}$ appears to be wrong.

The methodology for establishing friction values within the model (particularly the English Channel and Solent) therefore appears to be inconsistent. This is, however, not expected to be a major problem for trustworthiness of the model since bed friction is a model parameter which is often altered in order to achieve the required water levels and currents. It is therefore acceptable to consider the EMODnet data (and the drag coefficients shown by Soulsby (1997)) as starting points for the calibration procedure, rather than as an end in themselves. It is, however, suggested that the text be re-written to simply say that friction values were based around sediment types but were adjusted where necessary in the vicinity of the Isle of Wight to achieve the best calibration.

## 2.6. Calibration guidelines

The calibration guidelines originate from a 1998 Environment Agency report (EA, 1998). They are widely used in the UK and serve a useful starting point as a basis for calibration.

## 2.7. Calibration – general

The approach to calibration is comprehensive. Both calibration and validation have been undertaken and the criteria used to establish an acceptable model fit is very clear. There would be an added benefit to establishing model error statistics for the whole of the calibration and validation data set, rather than just at peak ebb/flood and HW/LW.

It is noted that the error statistic used appears to take an average of the difference between the model and data rather than working with the absolute (positive) value of the difference. In principle this means that if the model was sometimes greater and sometimes less than the data then the mean error could appear as zero. As use of this statistic will tend to under-estimate the real error in the model we would be keen to see a statistic (e.g. root mean square error) that counts all model/data differences as a positive contribution to the error.

The use of Total Tide for prediction of tidal water level variation is, in general, not successful for tides including significant magnitudes of higher tidal harmonics due to the simplified harmonic methodology used and the coarse time and height resolution used, but nevertheless provides a reasonable approximation to the tide. The use of Total Tide for estimating current magnitude and direction is based on the Admiralty Diamond tables shown on Admiralty navigation charts. In our experience Admiralty Diamonds are often old and can be out of date data in areas where the local morphology has changed so it would be greatly preferable to source local current measurements (for example by Acoustic Doppler Current Profiler (ADCP)) whenever possible.

## 2.8. Model calibration results – wide scale tidal distribution

The results of the model prediction of mean spring tide range throughout the English Channel and Southern North Sea are shown in Figure 13. A comparison of these predictions with data presented in the MAFF (1981) Atlas shows that the model is predicting the correct general distribution of patterns of tide range but in several places there is a difference of up to 0.5 m between the model prediction and the MAFF tidal atlas.

The model prediction of the co-phasing contours has more general problems, for instance the collapse of the co-phasing contour lines into a single line around the amphidromic point off East Anglia.

## 2.9. Model calibration and validation results – water level comparisons

The model predictions of water levels for a whole spring-neap cycle (in mid-December 2014) and for four consecutive spring tides and 4 consecutive neap tides within this period were compared to predicted variation in water levels (based on the tidal components only) from the National Tidal and Sea Level Facility for standard ports around the UK; Portsmouth, Lymington, Bournemouth, Weymouth, Newhaven, Devonport, Dover, Lowestoft and Whitby. These data were augmented by tide gauge data from Calshot and Dock Head (Southampton) provided by ABP.

The performance of the model in predicting water levels accurately was measured by deriving the mean error (absolute error and percentage when compared to the relevant spring or neap tidal range) in the prediction (over the period of interest) of:

- High Water Level;
- Low Water Level;
- Time of High Water;
- Time of Low Water.

The guidelines presented in EA (1998) are that the model error in predicted water level should be less than:

- Coastal sites - (taken to be Lymington, Bournemouth, Weymouth, Newhaven, Devonport, Dover, Lowestoft and Whitby) 0.1 m or 10% of spring tidal range or 15% of neap tidal range.
- Estuarine sites - (taken to be Calshot, Portsmouth and Dock Head) 0.1 m at mouth or 0.3 m at the head or 10% of spring tidal range or 15% of neap tidal range.

With respect to tidal phase the guidelines are that the model error in predicted time of water level should be less than:

- Coastal sites - (Lymington, Bournemouth, Weymouth, Newhaven, Devonport, Dover, Lowestoft and Whitby) 15 minutes.
- Estuarine sites - (Calshot, Portsmouth and Dock Head) 15 minutes at mouth or 25 minutes at the head.

Tables 4 to 6 of the report present the performance of the model in terms of calibration against the water level data. This data is summarised below (Table 2.1).

Table 2.1: Summary of results of regional model calibration for water levels – number of locations infringing calibration guidelines

| Spring-neap period | | Spring tide period | | Neap tide period | |
|---|---|---|---|---|---|
| Water level | Timing of HW/LW | Water level | Timing of HW/HW | Water level | Timing of HW/LW |
| 6 out of 11 | 6 out of 11 | 6 out of 11 | 8 out of 11 | 6 out of 11 | 8 out of 11 |

Notwithstanding the infringements of the calibration guidelines summarised above, the time series comparison of calibrated model and tidal gauge data in general shows the model to compare well with the data, although there are some exceptions: in particular the low water levels at Weymouth (Figure 19) which are up to 0.3 m too low, and the water levels around HW at Calshot (Figure 22) which are up to 0.6 m too low.

Tables 7 to 9 of the report present the performance of the model in terms of validation against the water level data. This data is summarised below (Table 2.2).

Table 2.2: Summary of results of regional model validation of water levels – number of locations infringing calibration guidelines

| Spring-neap period | | Spring tide period | | Neap tide period | |
|---|---|---|---|---|---|
| Water level | Timing of HW/LW | Water level | Timing of HW/HW | Water level | Timing of HW/LW |
| 6 out of 11 | 7 out of 11 | 5 out of 11 | 7 out of 11 | 10 out of 11 | 5 out of 11 |

Again, notwithstanding the infringements of the calibration guidelines summarised above the time series comparison of validated model and tidal gauge data in general shows the model to compare well with the data. As for the calibration phase, though, there are some exceptions – the tidal range at Dover is under-predicted (Figure 28). As for the calibration case water levels around LW at Weymouth (Figure 30) are not well reproduced (up to 0.4 m too low).

## 2.10. Model validation results – current speed, direction and phase

The model predictions of water levels for a period of nearly 2 months (in November 1 to December 23 2014) were compared to synthesised current predictions derived from the Total Tide package produced by the UK Hydrographic Office (UKHO). The performance of the model in predicting tidal currents accurately was assessed by deriving the mean error (absolute error and percentage when compared to the peak speed) in the prediction of:

- Peak speed during ebb tide;
- Peak speed during flood tide;
- Direction of peak ebb current speed;
- Direction of peak flood current speed;
- Time of peak ebb current speed;
- Time of peak flood current speed.

The synthesised current data was derived at coastal locations to the east and west of the Isle of Wight, at Dover and in the middle of the English Channel to the south of the Isle of Wight. The guidelines are that:

- The model error in predicted current speed at peak flood and at peak ebb should be less than 0.2 m/s or 10% of peak observed speeds;
- The model error in predicted current direction of peak flood and peak ebb should be less than 10º;
- The model error in the time of peak ebb and peak flood should be less than 20 minutes.

Table 10 of the report presents the performance of the model in terms of comparison with the synthesised current data. The results are summarised below (Table 2.3).

Table 2.3: Summary of results of regional model validation against for current speed, direction and phase – number of locations infringing calibration guidelines

| Current speed | Current Direction | Timing of peak current |
|---|---|---|
| 2 out of 4 | 0 out of 4 | 4 out of 4 |

The model prediction of currents east and west of the Isle of Wight seem to be well reproduced (it is notable that neither of these locations infringes the guidelines with respect to current speed or direction) but the model prediction of speeds at Dover is poor - speeds on early flood tide being under-predicted by as much as 44% - and at the “channel” location there are errors in the phasing of currents of more than 2 hours.

## 2.11. Summary of regional model performance

The calibration and validation exercises undertaken for the regional model demonstrate that there are shortcomings in the model’s ability to predict water levels and currents in general within the North Sea or English Channel but that it provides suitable boundary conditions for the currents and water levels in the Solent region. It is the provision of boundary conditions for the Solent which is most relevant to the Cowes study, and therefore the most important objective of the regional model. It is judged that the regional model is suitable as a basis for modelling studies at Cowes. For locations outside the vicinity of the Solent, it is suggested that additional local calibration is undertaken before using the regional model as a basis for hydrodynamics predictions.

# 3. Review of the local tidal flow model

## 3.1. Introduction

The local tidal flow model is essentially the same as the regional model and therefore the software, boundary conditions and distribution of friction values used for the local model are the same as those outlined in Section 2. Moreover the guidelines used for calibration are the same as those used for the regional model. The discussion of these is therefore not repeated in this section.

## 3.2. Model set up

The local model set up is essentially the same as the regional model except that freshwater flow into the Medina is included and further adjustment of friction in the region of Cowes Harbour was undertaken. The freshwater flow into the Medina is generally small (ABPmer give the median discharge as 0.28 $m^3/s$) and sensitivity tests using the model and a discharge of 1.34 $m^3/s$ (representing the freshwater discharge on a specific day within the field measurement period) indicated that any changes in current speed were confined to the Upper Estuary and did not extend as far downstream as Cowes. This concurs with evidence from measurements by the Medina Valley Centre (2015) which only identified evidence of stratified flow conditions in the Upper Estuary. An assessment of whether there are significant 3D effects in the Medina Estuary and the suitability of using a 2D model is provided in the local tidal flow model report and considered here in Section 3.11.

## 3.3. Data sources and uncertainty

Three types of measurements were undertaken:

- Fixed measurements of current speed and direction, using AWAC devices at locations outside the west and east entrances and at a location within the harbour around 220 m south of the breakwater;
- Transects of current speed and direction using vessel mounted ADCP – firstly forming a circuit along the axis of the Inner and Outer Fairway and then a circuit south of the breakwater; and,
- Measurements of water level, using a dedicated tide gauge established during the ADCP transect measurements.

The fixed measurements recorded data over a period of around 8 days (and thus included both spring and neap tides) in November/early December and a further 15 days in December. The ADCP transect measurements took place on consecutive days during spring tides during the November fixed point measurement campaign. The fixed AWAC and ADCP transect data was used for the purpose of model calibration while the December fixed point AWAC data was used for model validation.

Section 3.2 (and Tables 1 and 2) discuss the uncertainty in the measured depth-average current and relate this uncertainty to the variation in the measured depth-average current through the depth. It should be recognised, however, that the variation in the through-depth current speed is natural and expected and has little to do with uncertainty in the depth-averaged current speed. The relevant uncertainty comes from turbulent fluctuations in the currents (which cause currents to fluctuate over time scales which are of the order of seconds and smaller) and instrument error (such as mis-calibrating the internal compass). With well set up instruments which have been subject to appropriate levels of quality assurance the uncertainty from instrument error becomes small. Also if the measurements themselves are averaged over suitable time periods the uncertainty from turbulence is similarly reduced to small amounts.

There does seem to be instrument error in some of the measurements – in particular the measurements of current speed at locations 12 and 13 of the ADCP transect within the harbour, south of the breakwater as shown in Figures 20 to 26. These show measured current directions which are around 45º different to the model and to the general direction of flow. It is considered that these measurements of current direction should be disregarded. Excluding these measurements has implications for the comparison of predicted and measured current speed in Figures 11 and 12 which currently indicate a poor performance of the model in predicting current direction where actually the model prediction is much closer to the real (rather than measured) current direction.

Section 3.2 states that the dedicated gauge, set up for the ADCP survey period, highlighted errors in the CHC tide gauge and that therefore synthesised water levels from Total Tide were used for calibration/validation purposes at Cowes, instead of the CHC tide gauge. The additional water level data are plotted together with the Total Tide and predicted results in the water level comparisons for the 26 Nov[1] in Figure 30. Overall the dedicated survey tide gauge is similar to the Total Tide prediction except that the second (and lower) HW is predicted to be noticeably higher than that predicted by Total Tide. Elsewhere (Calshot, Portsmouth, Dock Head and Lymington) the water level data appears to be from tide gauges (including non-tidal influences).

## 3.4. Calibration and validation – general

The local model was therefore calibrated against the available data in the area of interest, building on the calibration and validation exercise of the regional model (ABPmer 2015a, discussed in Section 2). The guidelines for evaluating the standard of the model calibration remain the same (See Section 2).

For the calibration and validation of water levels tide gauge data was used (except for at Cowes where Total Tide predictions were used). The fixed AWAC current measurements and ADCP transect measurements from the November campaign were used for calibration of model current speed and direction while the data from the fixed AWAC deployment from the December campaign were used for validation purposes.

In addition to the formal assessment guidelines, time series of the predicted and measured current speed are presented in the report; both for the fixed AWAC and ADCP transect data. Lastly, the measured current

[1] There is a typo in the Spring tide comparison of Figure 30. The X-axis title should read “Hour of 26/11”.

velocity (in vector form) from the ADCP transects are plotted alongside the predicted current velocities from the model through a spring tide.

## 3.5. Model calibration results – current speed, direction and phase

The formal (as specified by the guidelines) model comparison is undertaken using the fixed AWAC current measurements. The mean difference (absolute and as a percentage of peak current speed) between the peak (depth-averaged) current speed at peak ebb and at peak flood is assessed, together with the mean difference in the direction of peak flood and peak ebb and the mean difference in the timing of peak flood and peak ebb. Assessments of model performance are made for the whole six day period of model comparison and for four consecutive spring tides and for four consecutive neap tides.

Table 3.1: Summary of results of local model calibration for current speed, direction and phase – number of locations infringing calibration guidelines

| Period of comparison | Current speed | Current direction | Timing of peak current |
|---|---|---|---|
| 6 day period of springs to neaps | 1 out of 3 | 0 out of 3 | 2 out of 3 |
| Spring tides | 1 out of 3 | 0 out of 3 | 2 out of 3 |
| Neap tides | 2 out of 3 | 0 out of 3 | 2 out of 3 |

The time series comparisons of the predicted current and direction with the measured data (Figures 5 to 10) show that in general the model does a good job of reproducing the observed data although westward directed flows at the east entrance of the harbour tend to be over-predicted and the model does not predict the change in current direction around LW well. This general performance is repeated with respect to the comparisons against the ADCP transect time series (Figures 11 to 16).

The current vector comparisons in Figures 17 to 29 provide helpful context in understanding the time-series but do not change the message outlined above. One or two of the plots illustrate the shortcomings in the model to predict times of change in current direction but otherwise the model predictions of current velocity appear satisfactory. The comparisons, however, do highlight the problems in the measurement of current direction at Locations 13 and 14 as noted in Section 3.2.

## 3.6. Model calibration results – water levels

Table 3.2 summarises the performance of the model with respect to the calibration guidelines for water levels.

Table 3.2: Summary of results of local model calibration for water levels – number of locations infringing calibration guidelines

| Spring-neap period | | Spring tide period | | Neap tide period | |
|---|---|---|---|---|---|
| Water level | Timing of HW/LW | Water level | Timing of HW/HW | Water level | Timing of HW/LW |
| 4 out of 5 | 5 out of 5 | 5 out of 5 | 5 out of 5 | 3 out of 5 | 4 out of 5 |

The infringements of the timing of HW/LW were all down to the timing of HW and result from the difficulty of reproducing the highest point of the double High Water stand. Around this time small changes in water level produce potentially large changes in the timing of HW.

Almost all of the infringements with regard to prediction of water level at HW/LW arose due to the model predicting LW to be too low.

However it should be noted that the time series comparison of calibrated model and tidal gauge data in general shows the model prediction of water levels to be good, notwithstanding the problems of timing of HW and LW level.

## 3.7. Model validation results – current speed, direction and phase

The formal (as specified by the EA (1998) guidelines) model comparison is undertaken (as in Section 3.5) using the fixed AWAC current measurements, but for the validation phase only measurements at the east and west entrances to the harbour were undertaken. The results are summarised in Table 3.3.

Table 3.3: Summary of results of local model validation for current speed, direction and phase – number of locations infringing calibration guidelines

| Period of comparison | Current speed | Current Direction | Timing of peak current |
|---|---|---|---|
| 6 day period of springs to neaps | 0 out of 2 | 0 out of 2 | 1 out of 2 |
| Spring tides | 1 out of 2 | 0 out of 2 | 0 out of 2 |
| Neap tides | 1 out of 2 | 0 out of 2 | 1 out of 2 |

Inspection of the time-series of model comparison (Figures 35 to 38) with measured current speed and direction indicates that the model is performing in a similar manner to that identified from the calibration procedure, with a tendency to over-predict currents into the harbour at the east entrance and to struggle to predict the change in current direction around LW. In addition, for this December data the model appears to under-predict the eastward (ebb) currents at the western entrance.

## 3.8. Model validation results – water levels

Table 3.4 summarises the performance of the model with respect to the EA (1998) guidelines for water levels.

Table 3.4: Summary of results of local model validation to water levels – number of locations infringing calibration guidelines

| Spring-neap period | | Spring tide period | | Neap tide period | |
|---|---|---|---|---|---|
| Water level | Timing of HW/LW | Water level | Timing of HW/HW | Water level | Timing of HW/LW |
| 3 out of 5 | 4 out of 5 | 3 out of 5 | 4 out of 5 | 3 out of 5 | 4 out of 5 |

For this December validation period, in the main the model performs as for the previous November calibration period confirming the calibration performance of the model is not a factor of the particular calibration period and that the model parameters are more generally applicable at the site. However in this December period, as well as a tendency to under-predict LW there is also a tendency, on occasion, to under-predict HW (with predictions up to 0.3 m too low at Cowes and up to 0.6 m too low at Calshot and Dockhead) as shown in the time-series Figures 39 to 43.

## 3.9. Summary of calibration and validation tests for local model

### Current speed and direction

Overall it seems that there is some over-prediction by the model of the currents into Cowes Harbour from the east. This is likely to result in an overall over-prediction of sediment transport from this direction into the estuary if these flow model results are used for modelling sediment transport. Otherwise the model is successful in reproducing the current patterns within and in the vicinity of Cowes Harbour.

### Water levels

The model in general successfully predicts the variation in water levels within and in the vicinity of Cowes Harbour but has a tendency to under-predict LW level and, less frequently, to significantly under-predict HW level.

## 3.10. Effect of local wind conditions

The local modelling report included an assessment of whether the predicted currents were sensitive to local wind action. The assessment demonstrated that the predicted currents could be sensitive to wind, but mainly under conditions of low tidal currents and there was no apparent correlation between error in the prediction of currents and wind speed and direction. However, no attempt was made to use the time series of the local wind speed and direction to drive the model which would be the clearest test of the significance of the wind effect.

## 3.11. Assessment of 3D modelling option

The local modelling report included an assessment of whether there are significant 3D features of the flow. This was undertaken by examining the measured data and by using an uncalibrated 3D model (albeit based on the validated 2D model above). The report concluded that no or limited 3D flow features can be clearly identified in the measured data. It is true that limited 3D flow features can be identified but there is definitely some 3D structure in the current direction around LW (which is the period when such features are most likely to become apparent) – particularly around late ebb and early flood at site Y (Figure 84) and on the early flood at Site Z (Figure 92).

The report (section 5.1.4) suggests the unimportance of salinity variation as vertical variation of salinity is not seen. However this ignores the potential importance of salinity gradients in the horizontal direction in the case that the salinity varies from place to place. Such horizontal gradients can be important (for example in the Mersey Narrows, although the vertical salinity variation is very small, the horizontal variation is not negligible and this contributes to a larger sediment load entering the estuary near the bed).

The 3D flow modelling did not reproduce the 3D features observed in the data at site Y and Z but the 3D flow model only contained 4 layers in the vertical which is very coarse and may not be sufficient to produce the necessary vertical flow structure to reproduce the observed behaviour. Because no freshwater was included in the 3D flow model it is not clear that salinity effects are unimportant in the near region of Cowes Harbour.

It is agreed that on the basis of the available field measurements, modelling in 2D represents an acceptable simplification. However, because the proposed works include deepening, which will potentially enhance the 3D structure within Cowes Harbour, it is advised that a further sensitivity test be undertaken using the 3D model to check whether near bed currents into the Harbour are increased as a result and hence investigate the possibility of this additional process resulting in additional sedimentation. However, this will only be relevant if freshwater flow is included in the 3D model.

# 4. Conclusions

The calibration and validation exercises undertaken for the regional model demonstrate that there are shortcomings in its ability to predict water levels and currents in general within the North Sea or English Channel but that it provides suitable boundary conditions for the currents and water levels in the Solent. It is the provision of boundary conditions for the Solent which is most relevant to the need for accurate modelling at Cowes, and is therefore the most important objective of the regional model. It is therefore judged that the regional model is suitable as a basis for the modelling undertaken at Cowes. For locations outside the vicinity of the Solent, it is suggested that additional local calibration against bespoke current and tidal measurements is undertaken before using the regional model as a basis for hydrodynamics predictions.

With respect to the local model there is some over-prediction by the model of the currents into Cowes Harbour from the east. This is likely to result in an overall over-prediction of sediment transport from this direction into the estuary if these flow model results are used for modelling sediment transport. Otherwise the model successfully reproduces the current patterns within and in the vicinity of Cowes Harbour. The local model in general predicts the variation in water levels within and in the vicinity of Cowes Harbour accurately but has a tendency to under-predict LW level and, less frequently, to significantly under-predict HW level.

We recommend that the regional model be used for the study at Cowes but used for other modelling activities outside the Solent only after further calibration and validation.

The local model is fit for purpose but the identified over-prediction of currents into the harbour from the east and tendency to under-prediction of LW level at Cowes should be borne in mind when interpreting any activities using the flow model results.

Although the field measurements indicate that any 3D structure in the current field is limited to around LW, it is advised that a further sensitivity test be undertaken using the uncalibrated 3D model with the proposed deepened harbour scenario to identify if near bed currents into the harbour are increased due to the deepening. This is a potential process with a risk of increased sedimentation which would not be captured by the 2D model applied.

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